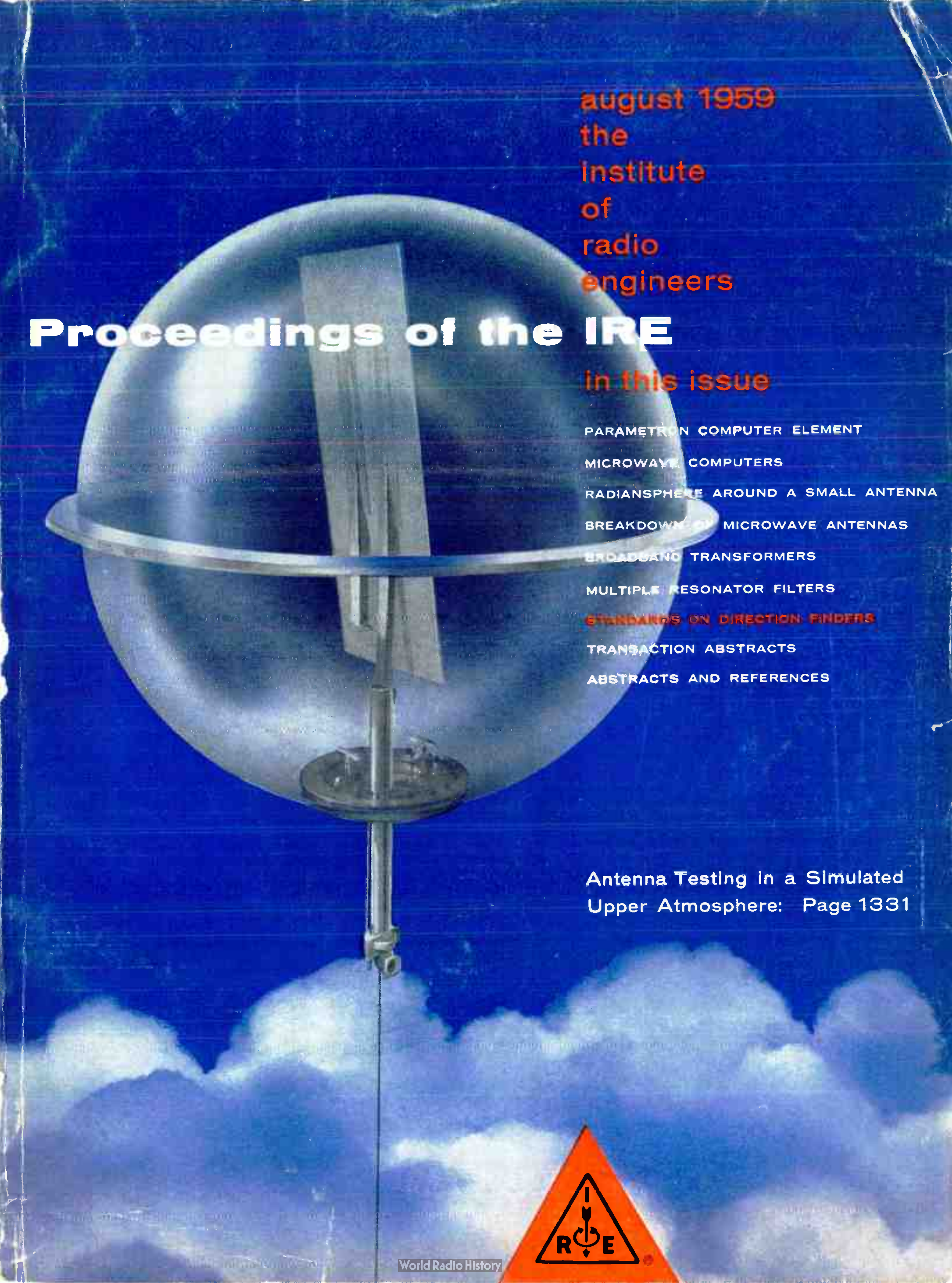
august 1959
the
institute
of
radio
engineers
Proceedings of the IRE
in this issue
PARAMETRON COMPUTER ELEMENT
MICROWAVE COMPUTERS
RADIANSPHERE AROUND A SMALL ANTENNA
BREAKDOWN OF MICROWAVE ANTENNAS
BROADBAND TRANSFORMERS
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ABSTRACTS AND REFERENCES
Antenna Testing in a Simulated
Upper Atmosphere: Page 1331
IRE

UTC NEW EXPANDED DO-T AND DI-T SERIES

Revolutionary transistor transformers hermetically sealed to MIL-T-27A Specifications.

UTC DO-T and DI-T transistor transformers provide unprecedented power handling capacity and reliability coupled with extremely small size. Comparative performance with other available products of similar size are shown in the curves (based on setting output power at 1 KC, then maintaining same input level over frequency range). The new expanded series of units cover virtually every transistor application.

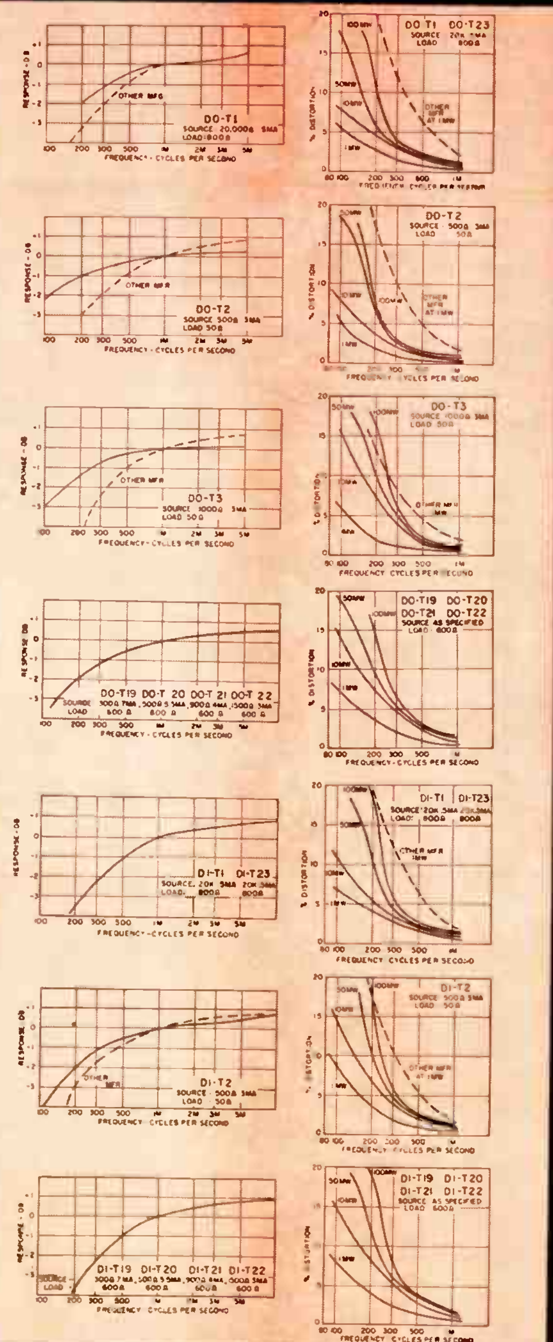
DO-T
ACTUAL SIZE

5/16 Dia. x 13/32, 1/10 Oz.

High Power Rating . . . up to 100 times greater.
Excellent Response . . . twice as good at low end.
Low Distortion . . . reduced 80%.
High Efficiency . . . up to 30% better.
Moisture Proof . . . hermetically sealed to MIL-T-27A.
Rugged . . . completely cased.
Anchored Leads . . . withstand 10 pound pull test.
Printed Circuit Use...plastic insulated leads.

DI-T
ACTUAL SIZE

5/16 Dia. x 1/4, 1/20 Oz.



DO-T No.	MIL Type	Application	Pri. Imp.	D.C. Ma.‡ in Pri.	Sec. Imp.	Pri. Res. DO-T	Pri. Res. DI-T	Level Mw.	DI-T No.
DO-T1	TF4RX13YY	Interstage	20,000 30,000	.5 .5	800 1200	850	815	50	DI-T1
DO-T2	TF4RX17YY	Output	500 600	3 3	50 60	60	65	100	DI-T2
DO-T3	TF4RX13YY	Output	1000 1200	3 3	50 60	115	110	100	DI-T3
DO-T4	TF4RX17YY	Output	600	3	3.2	60		100	
DO-T5	TF4RX13YY	Output	1200	2	3.2	115	110	100	DI-T5
DO-T6	TF4RX13YY	Output	10,000	1	3.2	790		100	
DO-T7	TF4RX16YY	Input	200,000	0	1000	8500		25	
DO-T8	TF4RX20YY	Reactor 3.5 Hys. @ 2 Ma. DC, 1 Hy. @ 5 Ma. DC				630			
	TF4RX20YY	Reactor 2.5 Hys. @ 2 Ma. DC, .9 Hy. @ 4 Ma. DC					630		DI-T8
DO-T9	TF4RX13YY	Output or driver	10,000 12,000	1 1	500 CT 600 CT	800	870	100	DI-19
DO-T10	TF4RX13YY	Driver	10,000 12,000	1 1	1200 CT 1500 CT	800	870	100	DI-T10
DO-T11	TF4RX13YY	Driver	10,000 12,000	1 1	2000 CT 2500 CT	800	870	100	DI-T11
DO-T12	TF4RX17YY	Single or PP output	150 CT 200 CT	10 10	12 16	11		500	
DO-T13	TF4RX17YY	Single or PP output	300 CT 400 CT	7 7	12 16	20		500	
DO-T14	TF4RX17YY	Single or PP output	600 CT 800 CT	5 5	12 16	43		500	
DO-T15	TF4RX17YY	Single or PP output	800 CT 1070 CT	4 4	12 16	51		500	
DO-T16	TF4RX13YY	Single or PP output	1000 CT 1330 CT	3.5 3.5	12 16	71		500	
DO-T17	TF4RX13YY	Single or PP output	1500 CT 2000 CT	3 3	12 16	108		500	
DO-T18	TF4RX13YY	Single or PP output	7500 CT 10,000 CT	1 1	12 16	505		500	
DO-T19	TF4RX17YY	Output to line	300 CT	7	600	19	20	500	DI-T19
DO-T20	TF4RX17YY	Output or line to line	500 CT	5.5	600	31	32	500	DI-T20
DO-T21	TF4RX17YY	Output to line	900 CT	4	600	53	53	500	DI-T21
DO-T22	TF4RX13YY	Output to line	1500 CT	3	600	86	87	500	DI-T22
DO-T23	TF4RX13YY	Interstage	20,000 CT 30,000 CT	.5 .5	800 CT 1200 CT	850	815	100	DI-T23
DO-T24	TF4RX16YY	Input (usable for chopper service)	200,000 CT	0	1000 CT	8500		25	
DO-T25	TF4RX13YY	Interstage	10,000 CT 12,000 CT	1 1	1500 CT 1800 CT	800	870	100	DI-T25
DO-T26	TF4RX20YY	Reactor 6 Hy. @ 2 Ma. DC, 1.5 Hy. @ 5 Ma. DC				2100			
	TF4RX20YY	Reactor 4.5 Hy. @ 2 Ma. DC, 1.2 Hy. @ 4 Ma. DC					2300		DI-T26
DO-T27	TF4RX20YY	Reactor 1.25 Hy. @ 2 Ma. DC, .5 Hy. @ 11 Ma. DC				100			
	TF4RX20YY	Reactor .9 Hy. @ 2 Ma. DC, .5 Hy. @ 6 Ma. DC					105		DI-T27
DO-T28	TF4RX20YY	Reactor .3 Hy. @ 4 Ma. DC, .15 Hy. @ 20 Ma. DC				25			
	TF4RX20YY	Reactor .1 Hy. @ 4 Ma. DC, .08 Hy. @ 10 Ma. DC					25		DI-T28
DO-T29	TF4RX17YY	Single or PP output	120 CT 150 CT	10 10	3.2 4	10		500	
DO-T30	TF4RX17YY	Single or PP output	320 CT 400 CT	7 7	3.2 4	20		500	
DO-T31	TF4RX17YY	Single or PP output	640 CT 800 CT	5 5	3.2 4	43		500	
DO-T32	TF4RX17YY	Single or PP output	800 CT 1,000 CT	4 4	3.2 4	51		500	
DO-T33	TF4RX13YY	Single or PP output	1,060 CT 1,330 CT	3.5 3.5	3.2 4	71		500	
DO-T34	TF4RX13YY	Single or PP output	1,600 CT 2,000 CT	3 3	3.2 4	109		500	
DO-T35	TF4RX13YY	Single or PP output	8,000 CT 10,000 CT	1 1	3.2 4	505		500	
DO-T36	TF4RX13YY	Isol. or Interstage	10,000 CT	1	10000 CT	950	970	500	DI-T36

DO-TSH Drawn Hipermalloy shield and cover for DO-T's, provides 25 to 30 db shielding, for DI-T's DI-TSH
‡DCMA shown is for single ended useage (under 5% distortion—100MW—1KC) . . . for push pull, DCMA can be any balanced value taken by .5W transistors (under 5% distortion—500MW—1KC)
*DO-T units have been designed for transistor application only . . . not for vacuum tube service. Pats. Pend.

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VOLUME 47, NUMBER 8

August, 1959

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

contents

AUGUST

published monthly by The Institute of Radio Engineers, Inc.

Proceedings of the IRE®

AUGUST

COVER

The advent of very-high-altitude vehicles has created a new design problem, that of voltage breakdown of antennas due to low atmospheric pressure. Important breakdown data is being gathered at Stanford Research Institute by testing antennas under reduced pressure inside a special 4-foot Plexiglass sphere, as described on page 1331 of this issue.

Proceedings of the IRE, published monthly by The Institute of Radio Engineers, Inc. at 1 East 79 Street, New York 21, N. Y. Manuscripts should be submitted in triplicate to the Editorial Department. Responsibility for contents of papers published rests upon the authors, and not the IRE or its members. All republication rights, including translations, are reserved by the IRE and granted only on request. Abstracting is permitted with mention of source.
Thirty days advance notice is required for change of address. Price per copy: members of the Institute of Radio Engineers, one additional copy $1.25; non-members $2.25. Yearly subscription price: to members $9.00, one additional subscription $13.50; to non-members in United States, Canada, and U. S. Possessions $18.00; to non-members in foreign countries $19.00. Second-class postage paid at Menasha, Wisconsin under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927. Printed in U.S.A.

Several years ago we ran into the oft-encountered problem of dividing an octave microwave frequency range into a number of adjacent channels. Stan Klug of our Reconnaissance Systems Department has prepared this "advertisement" which shows how the basic method has been developed into a compact, light-weight structure suitable for airborne or other applications.

Frequency Channels

Requirements of the Frequency Channelizers in addition to smallness and light-weight were low-loss, ease of development and tuning, good temperature stability and adaptability to frequencies from UHF to K-Band. The channels normally terminate in crystal video detectors but other terminations may be accommodated including a reciprocal unit used to recombine the channels. A few of the channelizers are illustrated. One unit (an octave, S-band, five channel device) was breadboarded and produced in final form in six weeks on a crash basis. Its weight, including several video components was 13.1 ounces and it measured 2 × 3 × 6 inches.

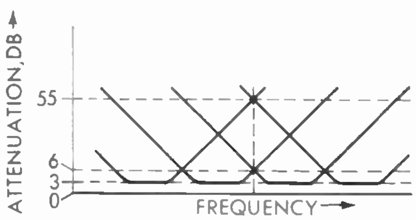

Figure 1—Idealized Channelizer Response

The basic channelizer consisted of filters periodically tapped along a "feedline." Three problems encountered were interaction between two filters at their cross-over (common cut-off frequency), interference from non-passing filters and performance of the feedline.

To smooth the over-all response, and particularly, the cross-over region, the feedline was terminated in a matched load resulting in 3 db of loss. In addition, since two filters absorb power at cross-over, the response should be at least 3 db below peak transmission. Good cross-over response was achieved by using filters such that one of a pair of filters at cross-over had a high admittance and the other low. The high admittance aborbed most of the power from the feedline termination (it was placed closest). As a result of a quarter-wave transformation (the filters were spaced by a quarter-wave on the feedline) the admittances of the filters became approximately equal and conjugate as seen by the power source. Hence, power split between channels.

Interference by non-passing filters was eliminated by using an L-C, "ell-section," pass-band matching network between a low admittance filter and a relatively high admittance feedline. The inductive shunt arm of the network was part of the filter input resonator (shunt, parallel) which is detuned and essentially short circuited in the filter stop-band. Hence, looking into the network from the feedline, the stop-band, input admittance was that of the network series arm, a low-capacitance, which, by itself did not produce appreciable feedline mismatch.

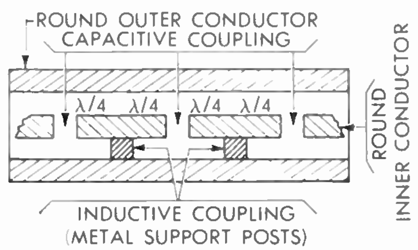

Figure 2—Four axially aligned resonators (cross-section)

A number of such stop-band filters on the feedline made it a low-pass structure. Because, near cut-off, the characteristic impedance varies rapidly, cut-off of this structure had to be kept well above the operating frequency of the feedline. Also, some matching needed to be done as the low frequency characteristic impedance of this structure differed from that of the unloaded feedline.

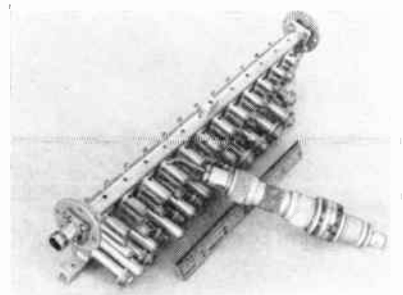

Figure 3—2-4 Kmc, 12 channels and tuning probe (12 × 3 × 2¼ inches, 2 lbs.-5 oz.)

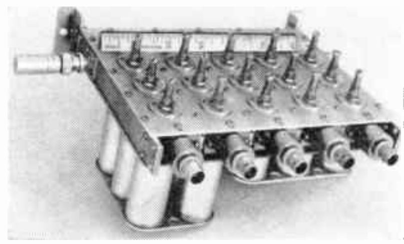

Figure 4—480-1000 Mc., 5 channels (5½ × 7⅜ × 3¾ inches, 2 lbs.)

At lower frequencies, physically parallel, quarter-wave, coaxial cavity resonators were foreshortened by the use of top-loading (capacitive tuning and inter-resonator coupling). Development of a method of axially aligning quarter-wave resonators minimized the coupling distance at higher frequencies. Since resonator lengths become short at higher frequencies, extremely small filters resulted even with axial alignment. Lightness and compactness resulted from a construction employing one-quarter inch diameter, thin-wall tubing. Unloaded Q's were sufficiently high to enable this construction to be used for low-loss filters having bandwidths down to three percent.

More detailed information on these filters and a short bibliography on filter design and tuning is given in the reference (see footnote).

W. J. Keane, A. Williams, S. H. Klug, "*Features of Two Novel Bandpass Filter Types Applicable to Frequency Channelizing*," National Conference Proceedings, Aeronautical Electronics (NAECON), 1959.

A complete bound set of our third series of articles is available on request. Write to Harold Hechtman at AIL for your set.

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"THE NATIVE HOLLANDER WEARS WOODEN SHOES."

A Bell Telephone Laboratories experiment in noise appraisal

"The native Hollander wears wooden shoes."

"Nebraska has no seacoast."

"The daisy is a common wildflower."

As these syllables, words and sentences come in over the telephones, stand-ins for millions of Bell System subscribers rate them for clarity of reception.

From these tests, Bell Telephone Laboratories engineers determine what is objectionable noise, and work to minimize it in telephone circuits. They begin by tape recording background noise associated with working telephone circuits. Test statements of appropriate length and content (such as those above) are read onto a second tape, and both are fed onto the test circuit under carefully controlled conditions. A third tape, of normal room noise, is played through a loudspeaker in the test lab.

Several hundred listeners, meeting in small groups several times a day for weeks at a time, are then asked to rate the effect of noise on transmission of the various simulated telephone calls.

For the Bell System, the results of the study will become part of the over-all transmission objectives. At Bell Laboratories, they will influence apparatus and systems development work.

Noise is a major distraction of modern day living. It is also an enemy of the Bell System. In a telephone receiver during a call, it might be power line hum, switching or thermal noise, or perhaps atmospheric static. Bell Laboratories spends a great deal of time, effort and money to keep this extraneous noise from becoming annoying and to assure you of a trouble-free connection.

BELL TELEPHONE LABORATORIES

World center of communications research and development

ENLARGED VIEW OF ONE CORNER REFLECTOR ELEMENT

LONG RANGE REMOTE CONTROL

ANDREW engineers regularly solve difficult antenna problems. An example is the 32-element array recently designed for The Trans-Arabian Pipe Line Company for long range communication and control.

REQUIREMENT: A 160 mc antenna system for use at four unattended radio-controlled gas-turbine pumping units located 60 to 100 miles away from the main pump stations along 754 miles of pipeline. Minimum forward gain of 20 db over a dipole and maximum VSWR of 1.5 across 156-174 mc band were required. Existing towers dictated that the design feature minimum weight and wind loading together with maximum mechanical stability.

SOLUTION: ANDREW engineers specified, designed, and produced a rectangular array of 32 aluminum corner reflectors that met all electrical and mechanical requirements of this system for telemetry, control, and voice communication.

Installations like this demonstrate our ability to handle difficult antenna assignments. ANDREW engineers are ready to apply their know-how to your antenna system problems.

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Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups which include exhibits.

August 18-21, 1959

WESCON, Western Electronic Show and Convention, Cow Palace, San Francisco, Calif.

Exhibits: Mr. Don Larson, WESCON, 1435 La Cienega Blvd., Los Angeles, Calif.

September 23-25, 1959

Special Technical Conference on Non-Linear Magnetics and Magnetic Amplifiers, Shoreham Hotel, Washington, D.C.

Exhibits: Mr. J. L. Whitlock, 6014 Ninth St. N., Arlington 5, Va.

September 28-30, 1959

National Symposium on Space Electronics and Telemetry, Civic Auditorium & Whitcomb Hotel, San Francisco, Calif.

Exhibits: Mr. Robert A. Grimm, Dymec, Inc., 395 Page Mill Road, Palo Alto, Calif.

October 5-7, 1959

Fifth National Communications Symposium, Hotel Utica, Utica, N.Y.

Exhibits: Mr. E. William Morris, 224 Fairway Drive, New Hartford, N.Y.

October 7-9, 1959

IRE Canadian Convention, Exhibition Park, Toronto, Ont., Canada

Exhibits: Mr. F. G. Heath, IRE Canadian Convention, 1819 Yonge St., Toronto 7, Ont., Canada.

October 12-14, 1959

National Electronics Conference, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Robert E. Bard, General Radio Co., 6605 W. North Ave., Oak Park, Ill.

October 26-28, 1959

East Coast Aeronautical & Navigational Electronics Conference, Lord Baltimore Hotel & 7th Regiment Armory, Baltimore, Md.

Exhibits: Mr. R. L. Pigeon, Westinghouse Electric Corp., Air Arm Div., P.O. Box 746, Baltimore, Md.

November 3-5, 1959

MAECON, Mid-America Electronics Convention, Municipal Auditorium, Kansas City, Mo.

Exhibits: Mr. John V. Parks, Bendix Aviation Corp., P.O. Box 1159, Kansas City 41, Mo.

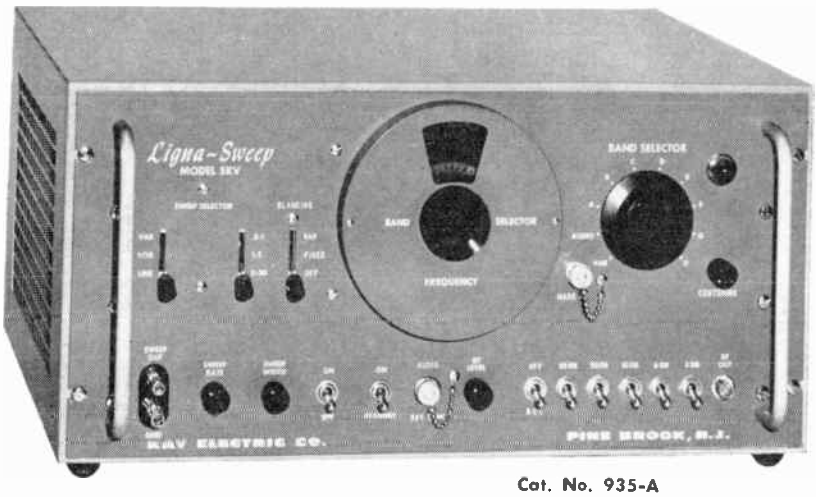
November 9-11, 1959

Fourth Instrumentation Conference, Atlanta, Ga.

Exhibits: Dr. B. J. Dasher, School of E.E., Georgia Institute of Technology, Atlanta 13, Ga.

(Continued on page 10A)

KAY *Ligna-Sweep* MODEL SKV



Cat. No. 935-A

NEW AUDIO-VIDEO ALL ELECTRONIC SWEEPING OSCILLATOR,

200 cps to 11 mc

- **Highly Stable Narrow Sweeps, at Customer Specified Frequencies: Widths from 20 kc to 12 mc on Variable Frequency Bands and from 2 kc to 20 kc on Fixed Frequency Bands**
- **High Output—1.0 V rms into 70 Ohms at Video AGC'd; 1.0 V rms into 600 Ohms at Audio**
- **Sweep Repetition Rates 0.2-60 cps**
- **Logarithmic Sweep at 30 cps Repetition Rate**
- **Continuously Variable Center Frequency and Sweep Width, on Variable Frequency Bands**

THE new Kay *Ligna-Sweep Model SKV* is an all-electronic low frequency sweeping oscillator covering a frequency range of 200 cps to 11.0 mc. It provides sweep widths from 20 kc to 10 mc on its variable sweep bands . . . from 2 kc to 20 kc on its fixed frequency bands.

The *Ligna-Sweep Model SKV* is designed for maximum stability in each of a wide choice of sweep widths. Four ranges of sweep width are provided utilizing four separate oscillator-and-sweep circuits, each designed for optimum performance in its particular application. A wide range of sweep repetition rates permits easy viewing of wide sweeps on conventional oscilloscope displays; the low repetition rates may be used with long persistence tubes for viewing the response of high Q-circuits and for observing the lower frequency limits of wide band circuits.

A front panel control selects any one of a series of customer-specified narrow band frequency sweeps to provide highly stable narrow band operation and to permit rapid switching to the frequencies of a series of narrow band circuits. Frequency markers to customer specifications can be supplied in companion *Vari-Marker* unit.

The sweeping oscillator is a beat frequency oscillator, carefully shielded and filtered to prevent spurious output signals. To eliminate phasing controls, a sawtooth voltage synchronized with the RF or audio output is available as a horizontal sweep voltage for the 'scope. The repetition rate of the sweep may be locked to the line voltage or varied. To provide an accurate zero voltage reference line on the 'scope, the output can be blanked during the retrace period.

SPECIFICATIONS

Frequency Range: 200 cycles to 11.0 mc.

Sweep Width, Band #1: 100 kc to 10 mc continuously variable; Sweep Widths 1 mc-10 mc, 200 kc-1 mc, 20 kc-200 kc.

Sweep Width, Band #2: 200 cps-20 kc; Sweep Width 2 kc-20 kc variable.

Sweep Width, Band #3-10: 50 kc—12 mc at 8 customer-specified ranges. Sweep Width 2 kc-20 kc variable.

Sweep Rate: 0.2-30 cps in three ranges, 30 cps, and line lock.

Logarithmic Sweep: The 30 cps rate provides a nominally logarithmic sweep frequency response.

Sweep Voltage: Approximately 5.0 volts at low impedance out.

RF Output: Approximately 1.0 volt rms into 70 ohms; AGC'd flat within ±5.0%.

Audio Output: Approximately 1.0 volt rms into 600 ohms.

Weight: 45 lbs.

Power Supply: 117 volts (±10%), 50-60 cps, 170 watts. B+ electronically regulated.

Price: $895.00, f.o.b. factory, including video and fixed-audio bands. Narrow fixed frequency bands to customer-specified frequencies—add $15 per band.

Ligna-Sweep CP VIDEO-RF

SWEEPING OSCILLATORS AND FREQUENCY MARKERS

Cat. No. 932-A: Variable bands between 100 kc and 215 mc. Price: $695.00 f.o.b. factory.
Cat. No. 932-B: Continuous coverage from 100 kc—150 mc. Price: $695.00 f.o.b. factory.

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Meetings with Exhibits

(Continued from page 8A)

November 10-12, 1959

Twelfth Annual Electrical Techniques in Medicine and Biology Conference, Sheraton Hotel, Philadelphia, Pa.

Exhibits: Mr. Lewis Winner, 152 West 42nd St., New York 36, N.Y.

November 16-19, 1959

Conference on Magnetism & Magnetic Materials, Sheraton-Cadillac Hotel, Detroit, Mich.

Exhibits: Mr. G. G. Scott, General Motors Co., Research Lab., Warren, Mich.

November 17-19, 1959

Northeast Electronics Research and Engineering Meeting (NEREM), Boston Commonwealth Armory, Boston, Mass.

Exhibits: Miss Shirley Whitcher, IRE Boston Office, 73 Tremont Street, Boston, Mass.

December 1-3, 1959

Eastern Joint Computer Conference, Hotel Statler, Boston, Mass.

Exhibits: John Leslie Whitlock Associates, 6044 Ninth St. North, Arlington 5, Va.

December 3-4, 1959

PGVC Annual Meeting, Colonial Inn & Desert Ranch, St. Petersburg, Fla.

Exhibits: Mr. A. W. Sullivan, Minneapolis-Honeywell Regulator Co., 13350 U. S. 19, St. Petersburg, Fla.

March 21-24, 1960

Radio Engineering Show and IRE National Convention, Waldorf-Astoria Hotel and New York Coliseum, New York, N.Y.

Exhibits: Mr. William C. Copp, Institute of Radio Engineers, 72 West 45th St., New York 36, N.Y.

April 20-22, 1960

SWIRECO, Southwestern IRE Regional Conference & Electronics Show, Shamrock-Hilton Hotel, Houston, Texas.

Exhibits: Mr. John McNeely, Southwestern Bell Telephone Co., 308 South Akard St., Dallas 1, Texas.

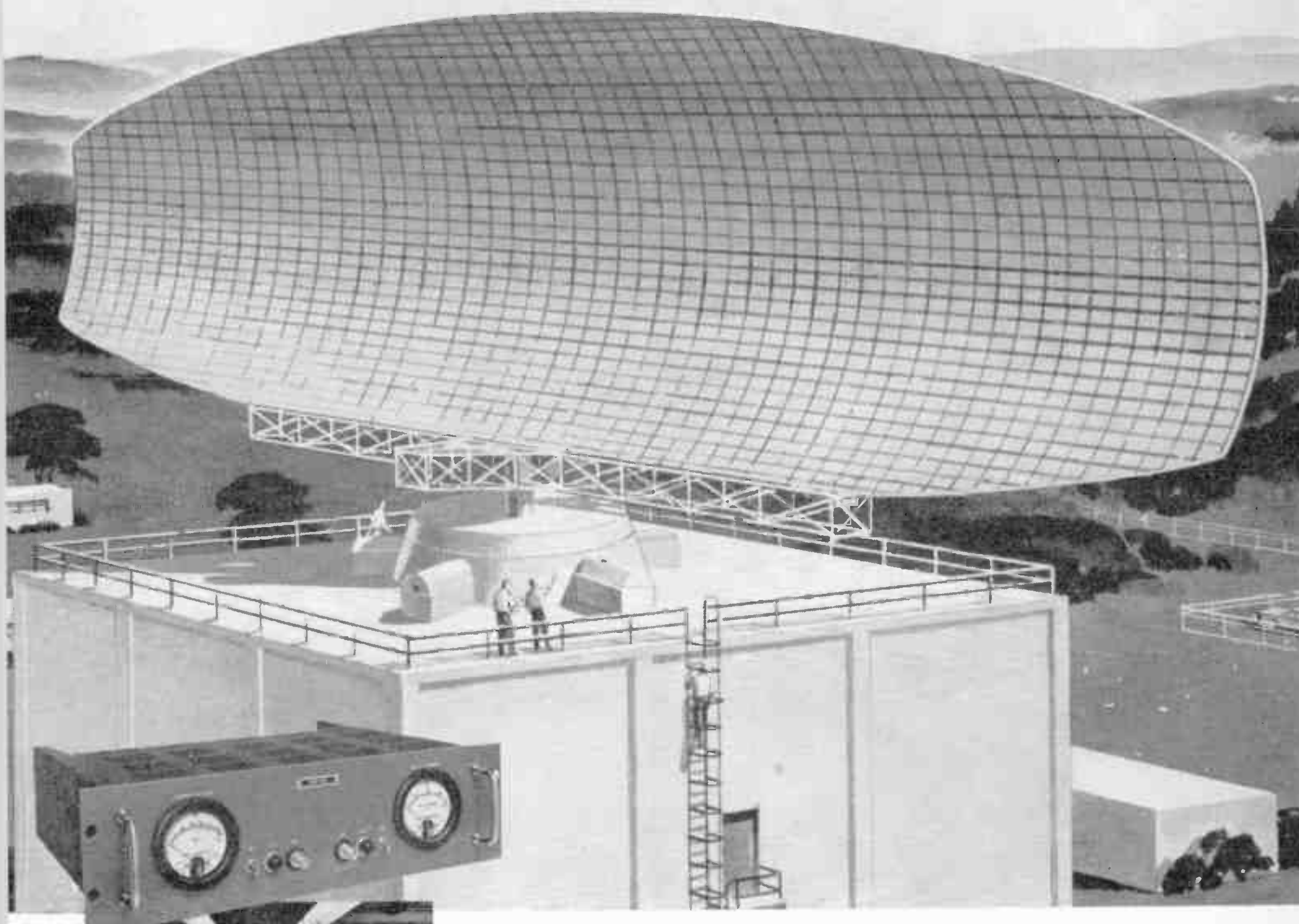
May 2-4, 1960

National Aeronautical Electronics Conference, Dayton Biltmore Hotel, Dayton, Ohio.

Exhibits: Mr. Edward M. Lisowski, General Precision Lab., Inc., Suite 452, 333 West First St., Dayton 2, Ohio.

Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

Lambda Power Supplies specified for newest radar installation



"Off-the-shelf" Lambda power supplies —modified only with special panels, MIL meters and tubes—will be part of the complex radar equipment housed in the 85-foot tower at Thomasville, Alabama, one of four identical installations.

Meet MIL-E 4158 environmental test requirements

Sperry Gyroscope Co., operating under the technical guidance of the Rome (N.Y.) Air Development Center, is producing the new SAGE radar equipment (AN/FPS-35). The power supplies employed to power transmitters and receivers must be able to pass stringent tests.

Sperry's choice: Lambda's COM-PAK,® already widely used as a component in many rocket and missile programs.

All Lambda stock industrial power supplies are made to MIL quality and *guaranteed for five years*. They are pictured and described in a new 32-page catalog. Write for your copy.

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GROUND SUPPORT EQUIPMENT

A Proven Kearfott Capability – Kearfott's prominence in the design and production of ground support equipment is a result of 15 years' experience in producing precision servo systems, computers, gyro reference systems and inertial guidance equipment. Kearfott test equipment is designed on modular principles which increase flexibility and economy and eliminate the obsolescence factor since modules can be readily modified or replaced. Modules are designed to be compatible with one another, thus providing test capabilities for a wide variety of applications.

Inertial Guidance System Test Console

IN-PLANT TEST EQUIPMENT: Rack-mounted modules comprise the necessary metering circuits, signal generators and power supplies, switching circuits and junction boxes to perform the following tests on inertial reference systems:
Voltage and phase • Current • Heating cycle checks • Verticality of platform in ground erection mode • First order erection time in ground erection mode • Measurements of platform roll and pitch output angles in ground erection mode • Measurements of free drift of platform in azimuth in ground erection mode • Measurement of azimuth gyro torquer scale factor in ground erection mode

FIELD-TYPE TEST EQUIPMENT: Modularized, self-contained unit that provides all power and signal voltages to operate, test or troubleshoot a gyro. All inputs to and outputs from the gyro are accessible at convenient jacks where connections to measuring equipment can be made, thereby enabling operator to evaluate gyro performance completely. Modules are slide-mounted for ready access if repair, modification or product improvement replacement are required. This portable equipment performs these basic tests:
Insulation resistance • Warm-up time • Torquer scale factor measurement Gyro transfer function • Free drift • Gimbal offset drift • Continuity Signal Generator Null • Phasing • Gyro drift • Fixed torque restraint

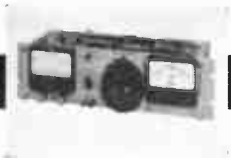
Floated Gyro Test Console

Scanalog 200-Scan
Alarm Logging System

GENERAL PURPOSE DATA PROCESSING: This data handling system provides a reliable, precise means of monitoring, logging and performing an alarm function of up to 200 separate temperature, pressure, liquid level or flow transmitters. Manual controls are provided for scanning rates, automatic or manual logging, data input relating to operator, time, day, run number and type of run. 200 numbered lights, corresponding to specific points being maintained, provide a visual "off normal" display for operator's warning. This system has growth built in and can be expanded in capacity to 1024 points and in scanning rate to 2000 points per second.

Write for complete information on Kearfott's ground support equipment.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.



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INHERENT STABILITY
Assured in a DALOHM RS Resistor

IN-HER-ENT, *adj.* Firmly infixed; esp., involved in the essential character of anything.

Stored on the shelf for months . . . or placed under continuous load . . . operating in severe environmental, shock, vibration and humidity conditions . . . Dalohm precision resistors retain their stability because it has been "firmly infixed" by Dalohm design and methods of manufacture.

For all applications demanding resistors that meet or surpass MIL specifications, you can depend on Dalohm.

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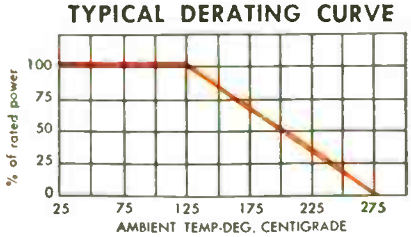
When space is at a premium, and precision and power are needed, specify DALOHM RS Type resistors.

Configurations: Type RS with radial leads and in most ratings and resistances shown; Type RLS with axial leads for printed circuits, and Type RSE for clip mounting.

TYPICAL DERATING CURVE



- Rated at 1, 2, 3, 5, 7, and 10 watts
- Resistance range from .05 ohm to 175K ohms, depending on type
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- Smallest in size, ranging from 3/32" by 13/32" to 3/8" by 1-25/32". Nine choices.
- Completely protected, impervious to moisture and salt spray
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IRE News and Radio Notes

Calendar of Coming Events and Authors' Deadlines*

1959

Natl. Ultrasonics Symp., Stanford Univ., Stanford, Calif., Aug. 17.

WESCON, San Francisco, Calif., Aug. 18–21.

Internatl. Conf. on Quantum Elec., Shawanga Lodge, Bloomingburg, N.Y., Sept. 14–16.

PGEWS Symp., Boston and Los Angeles, Sept. 17–18.

3rd Symp. on Antennas and Propagation, Sheraton Montrose Hotel, Cedar Rapids, Iowa, Sep. 18–19.

Biennial Communications Conf., Cedar Rapids Section, Cedar Rapids, Iowa, Sep. 18–19.

Special Tech. Conf. on Nonlinear Magnetics and Mag. Amplf., Shoreham Hotel, Washington, D.C., Sept. 23–25.

9th Annual PG on Broadcasting Symp., Willard Hotel, Washington, D.C., Sept. 25–26.

Natl. Symp. on Space Electronics and Telemetry, Civic Aud. & Whitcomb Hotel, San Francisco, Calif., Sept. 20–30.

Symp. on Indus., Elec., Mellon Inst., Pittsburgh, Pa., Sept. 30–Oct. 1.

5th Natl. Communications Symp. (formerly 5th Aero. Comm. Symp.), Hotel Utica, Utica, N.Y., Oct. 5–7.

Ann. Symp. on Interference Reduction, Museum of Sci. and Industry, Chicago, Ill., Oct. 6–8.

IRE Canadian Conv., Toronto, Can., Oct. 7–9

1959 Internatl. Systems Meeting of the SPA, Royal York Hotel, Toronto, Can., Oct. 12–14.

Natl. Elec. Conf., Sherman Hotel, Chicago, Ill., Oct. 12–14.

URSI-IRE Fall Meeting, El Cortez Hotel, Balboa Park, San Diego, Calif., Oct. 19–21.

Semiconductor Sym., Fall Meeting of the Electrochemical Society, Deshler-Hilton Hotel, Columbus, O., Oct. 19–22

East Coast Conf. on Aero. and Nav. Elec., Baltimore, Md., Oct. 26–28.

Electron Devices Mtg., Shoreham Hotel, Washington, D. C., Oct. 29–31. (DL*: Aug. 3, J. Hornbeck, Bell Tel. Labs., Murray Hill, N. J.

Mid. Amer. Elec. Conv., Kansas City, Mo., No. 3–4.

Natl. Conf. on Automatic Control, New Sheraton Hotel, Dallas, Tex., Nov. 4–6.

Radio Fall Mtg., Syracuse, N. Y., Nov. 9–11.

4th Instrumentation Conf., Atlanta Biltmore Hotel, Atlanta, Ga., Nov. 9–11.

12th Ann. Conf. on Elec. Tech. in Med. & Bio., Sheraton Hotel, Phila., Pa, Nov. 10–12.

5th Internatl. Automation Exp., N.Y. Trade Show Bldg., N.Y., N.Y., Nov. 16–20.

* DL = Deadline for submitting abstracts.

(Continued on page 154A)

Armour Foundation Plans Radio Interference Meeting

Armour Research Foundation has announced plans for the Fifth Conference of Radio-Interference Reduction, to be held in Chicago on October 6–8, 1959. It will be sponsored by the U. S. Army Signal Research and Development Laboratories and conducted in cooperation with the IRE Professional Group on Radio Frequency Interference.

Sessions are being planned to cover such areas as equipment design techniques, instrumentation and measurement techniques, practical interference reduction, etc. The program will be sufficiently diversified to be of interest to representatives from industrial and government activities both at the practical and more technical levels.

A feature of this year's conference will be a one-day session at which Classified papers will be presented.

For further information contact S. I. Cohn, Conference Chairman, Armour Research Foundation, Illinois Institute of Technology, 10 West 35 St., Chicago 16, Ill.

Australian IRE Elects New Officers

In May, 1959, the Australian Institution of Radio Engineers elected Graham G. Hall as president for the year 1959–1960. Mr. Hall, an executive of Ducon Condenser Ltd., Sydney, N.S.W., is a Fellow of the Institution. He is also a member of the IRE.

Other officers elected were F. W. J. Orr as deputy president, R. R. Mackay as senior vice-president, and R. D. Boadle as vice-president.

PGANE East Coast Meeting Includes Classified Topics

Advanced techniques in radar and data processing will be among the features of the Classified sessions scheduled for the sixth annual East Coast Conference of the IRE Professional Group on Aeronautical and Navigational Electronics to be held in Baltimore, Md., October 26–28, 1959.

The Classified sessions sponsored by the ARDC, and scheduled for the first two days of the Conference, will cover:

"Correlation Techniques of Data Processing," arranged by The Martin Co.

"Advanced Radar Techniques," arranged by the Air-Arm Div. of Westinghouse.

"Phased-Array Radars," arranged by the Bendix Aviation Corp.

"Airborne Radar Techniques and Test Equipment," arranged by Aircraft Armaments.

Details governing application for security clearance to attend the Classified sessions will be released in the near future. Correspondence concerning clearance may, in the meantime, be addressed to T. M. O'Connor, Security Coordinator, IRE ECCANE, Bendix Radio Corp., Baltimore 4, Md.

Unclassified sessions will be held concurrent with the Classified presentations and will extend through October 28.

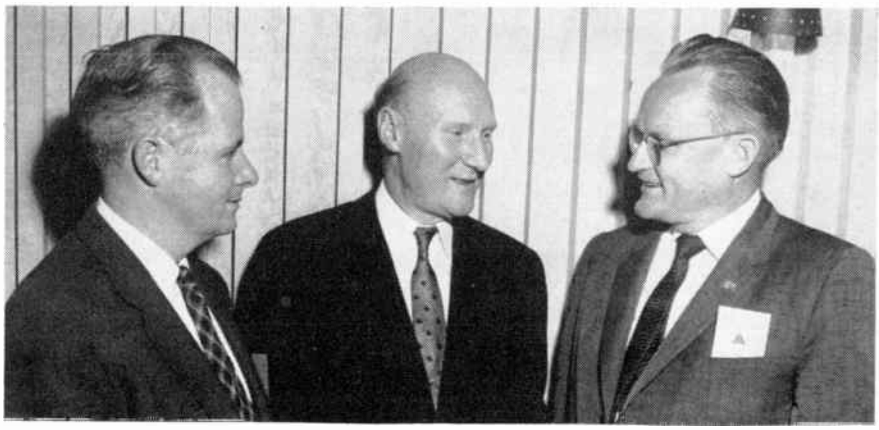
The Johns Hopkins University will act as host for the student session to be held on the afternoon of October 28. This session, to be held on the Homewood campus in Baltimore, will be devoted to a panel discussion concerning industry opportunities and job interviews. Mr. Gavin Pitt, vice-president of Hopkins, will be the panel chairman. Included on the panel will be W. Bender of The Martin Co., F. Hamburger, Jr., of Hopkins, W. E. Brown of Westinghouse, and C. W. King, ARDC.

In addition to the four technical sessions scheduled for each of the three days of the conference, a cocktail party will be held on the evening of October 26, and a banquet on October 27. There will be no exhibits this year.

SWIRECO Summary Available

The IRE Dallas Section has a quantity of the SWIRECO *Technical Summary of Papers* available at the cost of fifty cents per copy. The summary is an "in-between" device somewhat more complete than a listing of abstracts though not as extensive as a publication of the unabridged papers.

Copies are available from the Treasurer, Dallas Section of the IRE, 7118 Envoy Court, Dallas 35, Tex. Inquiries should be sent to the same address.



Los Angeles IRE members of the WESCON Board, Bruce Angwin (*left*) and Walter Peterson (*right*) discuss Convention plans with Dr. Ernst Weber, National IRE President, on his recent visit to the Los Angeles Section.

Call for Papers

1960 IRE National Convention

March 21–24, 1960

Waldorf-Astoria Hotel and New York Coliseum, New York, N. Y.

Prospective authors are requested to submit all of the following information by:

October 23, 1959

1. 100-word *abstract in triplicate*, title of paper, name and address
2. 500-word *summary in triplicate*, title of paper, name and address
3. An indication of the technical field in which the paper falls:

Aeronautical & Navigational Electronics	Engineering Writing & Speech
Antennas & Propagation	Human Factors in Electronics
Audio	Industrial Electronics
Automatic Control	Information Theory
Broadcast & Television Receivers	Instrumentation
Broadcasting	Medical Electronics
Circuit Theory	Microwave Theory & Techniques
Communications Systems	Military Electronics
Component Parts	Nuclear Science
Education	Production Techniques
Electron Devices	Radio Frequency Interference
Electronic Computers	Reliability & Quality Control
Engineering Management	Space Electronics & Telemetry
	Ultrasonics Engineering

Vehicular Communications

Note: Only considered are original papers not published or presented prior to the 1960 IRE National Convention; any necessary military or company clearance of paper must be granted prior to submittal.

Address all material to: Gordon K. Teal, Chairman
1960 Technical Program Committee
The Institute of Radio Engineers, Inc.
1 East 79 Street, New York 21, N. Y.

Calendar of Coming Events and Authors' Deadlines*

(Continued from page 14A)

5th Conf. on Magnetism and Magnetic Materials Sheraton-Cadillac Hotel, Detroit Mich. Nov. 16–19. (DL*: Aug. 25, J. E. Goldman, Sci. Lab., Ford Motor Co., P.O. Box 2053, Dearborn, Mich.

1959 NEREM (Northeast Electronics Res. & Engng. Meeting), Boston Commonwealth Armory, Boston, Mass., Nov. 17–19.

PGNS 6th Ann. Meeting, Commonwealth Armory, Boston, Mass., Nov. 19–20.

Eastern Joint Comp. Conf., Hotel Statler, Boston, Mass., Dec. 1–3. (DL*: Aug. 15, J. H. Felker, Bell Tel. Labs., Murray Hill, N. J.

4th Midwest Symp. on Circuit Theory, Brooks Mem. Union, Marquette Univ., Milwaukee, Wisc., Dec. 1–2.

PGVC Annual Meeting, St. Petersburg, Fla., Dec. 3–4 (DL*: Jun 30, J. R. Nubauer, RCA, Camden, N.J.)

4th Midwest Symp. on Circuit Theory, Marquette Univ., Milwaukee Wisc., Dec. 1–2.

1960

6th Natl. Symp. on Reliability and Quality Control, Statler-Hilton Hotel, Wash., D.C., Jan. 11–13.

1960 Solid State Circuits, Conf., Sheraton Hotel, Phila., Pa., Feb. 10–12. (DL*: Oct. 9, D. L. Finch, Bell Tel. Labs., Murray Hill, N. J.)

IRE National Conv., N. Y. Coliseum and Waldorf-Astoria Hotel, Mar. 21–24.

6th Nuclear Congress, N. Y. Coliseum, New York, N. Y., Apr. 4–8.

Conf. on Automatic Tech., Sheraton-Cleveland Hotel, Cleve., Ohio, Apr. 18–19.

SWIRECO (Southwestern Regional Conference), Houston, Texas, Apr. 20–22.

Natl. Aeronautical Electronics Conf., Dayton, Ohio, May 2–4.

Western Joint Computer Conf., San Francisco, Calif, May 2–6.

PGMTT Natl. Symp., San Diego, Calif., May 9–11.

7th Reg. Tech. Conf. & Trade Show, Olympic Hotel, Seattle, Wash., May 16–18.

Cong. Intl. Federation of Automatic Control, Moscow, USSR, June 25–July 9.

WESCON, Los Angeles Mem. Sports Arena, Los Angeles, Calif., Aug. 23–26.

Natl. Symp. on Telemetering, Washington, D. C., Sept.

Industrial Elec. Symp., Sept. 21–22.

Natl. Elec. Conf., Chicago, Ill., Oct. 10–12.

East Coast Conf. on Aero & Nav. Elec., Baltimore, Md., Oct. 24–26.

Electron Devices Mtg., Hotel Shoreham, Washington, D. C., Oct. 27–29.

Radio Fall Mtg., Hotel Syracuse, Syracuse, N.Y., Oct. 31, Nov. 1–2.

* DL = Deadline for submitting abstracts.

Transistor—Then and Now

On May 7, 1959, John A. Hornbeck, director of electron tube and transistor development at Bell Telephone Laboratories and Senior Member of the IRE, spoke at the Henry Ford Museum on "The Transistor, Then and Now." He also presented to the Museum examples of developments in transistors over the last eleven years. These will be placed on permanent display in the museum's communications section. Dr. Hornbeck's appearance for this lecture was sponsored by the Detroit Section of the IRE.

Bell Telephone Laboratories announced the invention of a semiconductor amplifier in 1948 and coined for it the name *transistor*. Since then, this invention has been hailed as one of the most significant milestones in the history of electronics.

Dr. Hornbeck joined Bell Labs in 1946 as a research physicist in the electronics department. In 1951 he transferred to the transistor research department. He headed groups specializing in semiconductor physics from 1943–1954, and in solid-state device development in 1955. He assumed his present position in October, 1958.

He is also a Fellow of the American Physical Society and a member of the American Association for the Advancement of Science.

Dr. John A. Hornbeck (*right*), director of Electron Tube and Transistor Development at Bell Telephone Laboratories, points to an early audion or vacuum tube developed by Dr. Lee De Forest and supplanted by the transistor. Dr. Hornbeck holds a case of four early transistors presented to Henry Ford Museum in Dearborn, Mich., for its communications collections in connection with a special meeting sponsored by the Detroit Section. A photograph of Dr. De Forest is in the case. Dr. L. J. Giacoletto, manager of the Electrical Department at the Ford Motor Company Scientific Laboratory and chairman of the Detroit Section, and Frank Caddy, director of Administration at the Henry Ford Museum, listen to Dr. Hornbeck's explanation.

Shown at a recent meeting in preparation for the 12th Annual Conference on Electrical Techniques in Medicine and Biology to be held in November, is the conference committee consisting of (*from left to right*) L. Winner, R. S. Gardner, Dr. R. L. Bowman, Dr. Otto H. Schmitt, Dr. D. A. Holaday, Dr. H. P. Schwan, chairman of the conference, Dr. L. E. Flory, C. Berkley, Dr. R. E. DeForrest, and J. Reid.

Mr. W. Lyle Donaldson (*left*), chairman of the Electrical Engineering Department, Southwest Research Institute; Mrs Ernst Weber; IRE President, Dr. Ernst Weber; and Dr. George Pish, manager of Chemical Physics Division, Physics Department, Southwest Research Institute, discuss paramagnetic resonance during the Webers' visit to Southwest Research Institute. This visit was a sidelight to Dr. and Mrs. Weber's visit with the San Antonio-Austin Section of the IRE.

ACM Conference Scheduled for September at M.I.T.

The 1959 ACM National Conference will be held at the Massachusetts Institute of Technology, Cambridge, Mass., on September 1–3, 1959. Technical papers will be presented covering numerical analysis, data processing, automatic programming, language translation, digital and analog devices, and various applications of computers.

In accordance with previous custom, there will be no exhibits presented during this conference.

The chairman of the local arrangements committee is Dr. Frank M. Verzuh, Computation Center, M.I.T., Cambridge, Mass.

Lack Receives EIA Medal of Honor

A highlight of the 35th Annual Convention of the Electronics Industries Association (EIA) in Chicago, May 20–22, 1959, was the presentation to Frederick R. Lack of the 1959 EIA Medal of Honor.

Mr. Lack is president of the Western Electric Company and former EIA vice-president and director representing the Military Products Division.

Mr. Lack, a native of Eastbourne, England, and a graduate of Harvard University, is a Fellow of the IRE. He has been an IRE Director (1940 and 1946–1947) and has served on numerous Institute Committees including Appointments, Awards, Board of Editors, Electronics, Executive, National Convention, Nuclear Studies, Office Practices, Papers, Special Publications Fund, and Tellers. He has also been IRE representative to the ASA Board of Directors and the RMA-IRE Coordinating Committee.

Eleven States Included in WEMA

The West Coast Electronic Manufacturers Association has officially taken a new name, the Western Electronic Manufacturers Association (WEMA). The association now includes member firms in eleven western states.

The 1959 WEMA Directory includes a comprehensive listing of the association's member firms in the 11 western states. Key personnel, plant facilities and product lines are incorporated under each company listing. The Directory also has a manufacturer and product cross reference index.

John A. Chartz, Dalmo Victor Co., San Carlos, Calif., is president of WEMA for 1959.

WEMA's main office is located in Los Angeles and a branch office is maintained in San Mateo, Calif. Both offices serve as clearing houses for general statistical and source data on the electronics industry.

Russian Solid-State Journal Available

An important new USSR Academy of Sciences journal, ***Fizika Tverdogo Tela***, made its initial appearance last January. Offering results of theoretical and experimental investigations in the physics of semiconductors, dielectrics, and on applied physics associated with these problems, this periodical publishes papers on electronic processes taking place in the interior and on the surface of solids.

In the belief that the journal is of immediate interest to a large segment of the Western physics community, the American Institute of Physics has added this monthly publication to the list of Russian physics periodicals now available in cover-to-cover translation. The English language version is titled *Soviet Physics—Solid State*.

The journal is a monthly, twelve issues containing approximately 2000 pages. Subscription prices are $55 domestic, $59 foreign, with special prices of $25 and $29, respectively, to libraries of degree-granting institutions. For a subscription, write the American Institute of Physics, 335 E. 45 St., New York 17, N. Y.

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NEREM Looks to Stars

NEREM—1959 (Northeast Electronics Research and Engineering Show), jointly sponsored by the Boston, Connecticut, and Western Massachusetts Sections of the IRE, will be held November 17-19, 1959, at the Commonwealth Armory in Boston, Mass. Richard B. Hackenberger has been named chairman of the convention.

Mr. Hackenberger, who has been associated with NEREM for a number of years said he was confident that NEREM—1959 will be the third largest electronics show in the United States. Attendance is expected to exceed 10,000; exhibits will number over 300.

Mr Hackenberger announced the theme for NEREM—1959 by saying, "Our theme encompasses each and every man's dream for the future whether it be the development of devices to simplify the complexities of the business world, the creation of labor-saving devices for the home, or the conquest of space and the military supremacy of our country. The 1959 theme will be 'Electronics—Man's Stairway to the Stars.' "

AIEE Elects New Officers

The election of J. H. Foote, of Jackson, Mich., as 1959–1960 President of the American Institute of Electrical Engineers was announced in June at the opening general session of the Institute's Summer and Pacific General Meeting in Seattle, Wash. Mr. Foote is chief engineer of Commonwealth Associates and has been active in national and Michigan affairs of AIEE for many years. He is also vice-president and director of engineering for Commonwealth Services Inc. at Jackson.

Mr. Foote, a member of the Institute since 1918, completed a term as vice-president in 1958. He has been a member of many AIEE technical and administrative committees and served as chairman of several. He is a graduate of Michigan State University and received an honorary degree of Doctor of Science in engineering from Wayne State University.

Mr. Foote is a member of the Engineering Society of Detroit and has served as president of the Michigan Engineering Society, chairman of the Michigan Board of Registration, and director of the Michigan Society of Professional Engineers. He is a director of the American Standards Association, a Fellow of the AIEE and of the American Association for the Advancement of Science.

Professional Group News

The following Chapters were approved by the IRE Executive Committee at its meeting held on June 30th: Joint Professional Group on **Antennas and Propagation and Microwave Theory and Techniques**—Columbus Section; and the PG on **Electronic Computers**—Omaha-Lincoln Section.

OBITUARIES

Donald A. Quarles (M'41–SM'43–F'54), Deputy Secretary of Defense in charge of missiles and satellite programs, died recently at the age of 64.

D. A. Quarles

Mr. Quarles, as Deputy Secretary of Defense, was one of the most influential officials at the Pentagon, particularly in the field of missiles and nuclear energy, and had been mentioned as the possible successor to Neil H. McElroy, Secretary of Defense. Mr. McElroy said that he was "extraordinarily qualified to assume the reins," and he cited Mr. Quarles' exceptional qualifications for administration, science, atomic energy and engineering, and also his tremendous appetite for work. "He worked harder than almost anyone I ever saw; days, nights, and weekends," Mr. McElroy said.

Mr. Quarles was born in Van Buren, Arkansas on July 30, 1894. He graduated from high school at the age of fifteen and then attended night courses at the University of Missouri. He later taught school in Van Buren. At 18 he entered Yale University where he majored in mathematics and physics. He was elected to Phi Beta Kappa and received the B.A. degree in 1917. He then enlisted in the Rainbow Division of the U. S. Army and served in France and Germany during World War I.

After the war he joined Western Electric Company (which later became Bell Telephone Laboratories). By 1940 he was the head of all BTL radar programs. During the Second World War he served as a member of the Joint Research and Development Board. In 1948 he was made a vice-president of Bell Telephone Labs. In March 1952, he became vice-president of Western Electric Company and president of Sandia Corporation, a subsidiary which still operates the atomic research weapons laboratories at White Sands, N. Mex.

In September, 1953 he was named Assistant Secretary of Defense in charge of missiles and satellite programs. He also served as a member of the National Security Council. In 1955 he was appointed Secretary of the Air Force, a position he held until he became Deputy Secretary of Defense.

Mr. Quarles was interested and active in civic politics in Engelwood, N. J., where he served on the Engelwood Common Council from 1940 until 1946 when he was elected Mayor. He also served on the Bergen County Sewer Commission. In December, 1958, the Engelwood Board of Education honored him by naming a new elementary school after him.

He was a Fellow of the IRE and a Director and past President of the American Institute of Electrical Engineers. He held honorary doctor's degrees in engineering from the University of Arkansas and New York University, in science from the Stevens Institute and Grinnell College and in law from Yale University.

Mr. Quarles was buried with military honors at the Arlington National Cemetery.

President Eisenhower gave him the following tribute:

"As Deputy Secretary of Defense and prior to that as Secretary of the Air Force, Mr. Quarles devoted his extraordinary talents to the service of his country. His contribution has inestimable value to the security not only of the United States but of that of the entire free world. I share with his associates in the Government a keen sense of personal loss."

Dr. Dudley A. Buck (M'56), assistant professor of electrical engineering at Massachusetts Institute of Technology, died recently. He was 32 years old.

D. A. Buck

Two years ago Dr. Buck, who was credited with several major developments in his field, developed the cryoton, a tiny computer component. He had been working on a project to shrink a computer from room size to the dimensions of a match box through the use of a "cross-film cryoton" only four-millionths of an inch in diameter.

Dr. Buck first disclosed the development of the cryoton, which represented one of the first important practical applications of the phenomenon of superconductivity, in a paper entitled "The cryoton—a superconductive computer component," published in the April, 1956 Proceedings of the IRE. The paper won for Dr. Buck the 1957 Browder J. Thompson Memorial Prize of the IRE for the best paper written by an author under 30 years old.

Dr. Buck was born in San Francisco, Calif., on April 25, 1927. He received the B.S. degree in electrical engineering from the University of Washington in 1948. After two years as a communication officer with the U. S. Navy, he became a research assistant in the M.I.T. Servomechanisms Laboratory where he worked on Project Whirlwind. He received the M.S. degree in electrical engineering in 1952.

William J. Morlock (A'43–SM'46–F'57), a consultant to the vice-president and general manager of the Industrial Electronics Division of the General Electric Company, died recently at the age of 50.

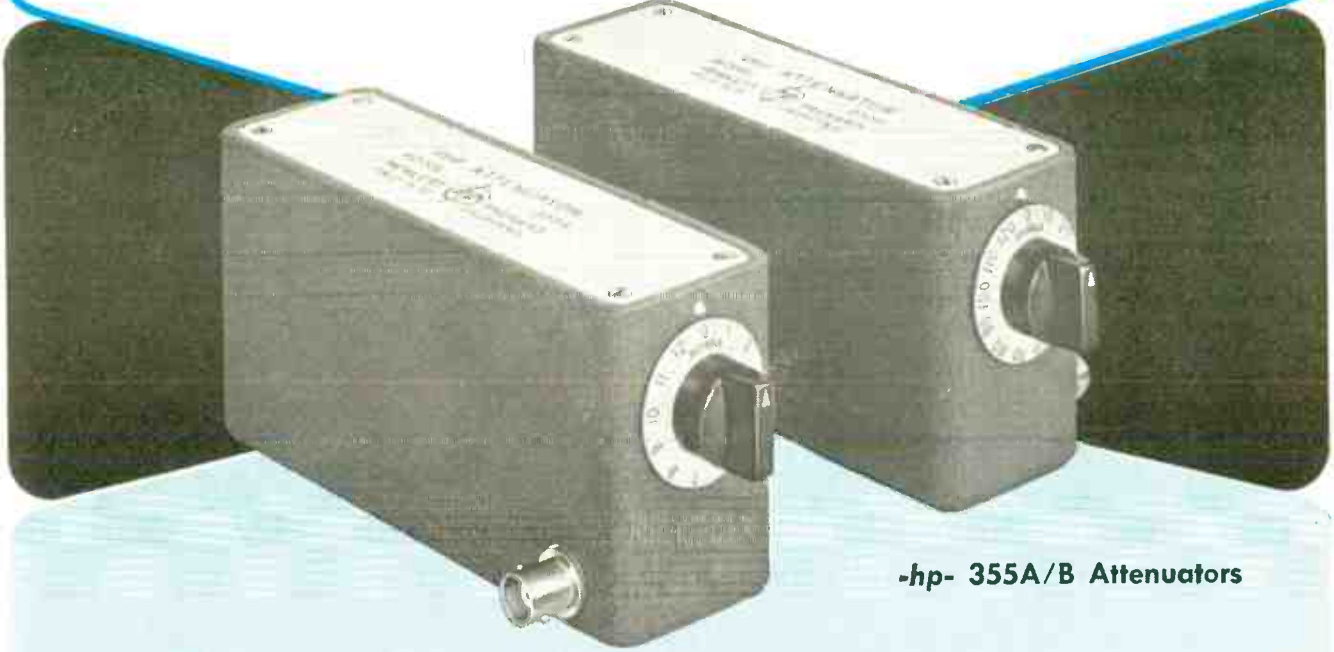
W. J. Morlock

Mr. Morlock was born in McKeesport, Pa. in July, 1908. In 1926 he was awarded a National Westinghouse Memorial Scholarship to attend Ohio State University. He was graduated in 1930 and received the B.E.E. degree in electrical engineering.

For seventeen years he was with the Radio Corporation of America in Camden, N. J. and Indianapolis, Ind., where he was

New design 50 ohm attenuator

0 to 132 db in 1 db steps— DC to 500 MC



-hp- 355A/B Attenuators

¼ db accuracy full range for low attenuation values. Maximum error at full attenuation 2 db. "One-knob" control. Super compact design—size approximately 2½" x 2½" x 6".

These are characteristics of the new, rugged, simple -*hp*- 355A/B attenuators.

-*hp*- 355A provides 0 to 12 db in 1 db steps. -*hp*- 355B provides 0 to 120 db in decade steps. Together, 132 db of attenuation from DC to 500 MC is available, with simplest possible controls, premium accuracy, and no complex setup. A solid-shield 50 ohm connector may be used to interconnect the two attenuators.

These new -*hp*- attenuators have balanced capacities and completely shielded sections. They are enclosed in a sturdy metal case, yet weigh only 1½ pounds.

Ask your -*hp*- representative to show you these practical, minimum-space attenuators this week.

SPECIFICATIONS

Attenuation: -*hp*- 355A, 12 db in 1 db steps. -*hp*- 355B, 120 db in 10 db steps

Frequency Range: DC to 500 MC

Overall Accuracy: -*hp*- 355A, ±0.25 db, DC to 500 MC. -*hp*- 355B, ±1 db, DC to 250 MC, ±2 db, 250 to 500 MC

Nominal Impedance: 50 ohms

Maximum SWR: 1.2 to 250 MC, 1.5 to 500 MC

Max. Insertion Loss: 0 at DC, 0.4 db at 60 MC, 1 db at 250 MC, 1.5 db at 500 MC

Power Dissipation: 0.5 watt average; 350 v peak

Connectors: BNC

Size: 2-3/16" wide, 2-5/8" high, 6" long. Net weight 1½ pounds

Price: -*hp*- 355A, $125.00. -*hp*- 355B, $125.00

Data subject to change without notice. Prices f.o.b. factory

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For over ten years he was engaged in development and design of interior communication and sound equipment used by the U. S. Navy and other Government agencies. During World War II he was a committee member of the Government's Office of Scientific Research and Development.

He joined General Electric Co. in 1947 as a division engineer of the former Specialty Division. After serving in various engineering and managerial positions he was named general manager of the Technical Products Division, a position which he held until recently.

Mr. Morlock was made a Fellow of the IRE in 1957 for his contributions to sound systems and to engineering management. He served as a member of the Professional Groups Committee in 1957. From 1948–1951 he was IRE representative to the ASA Subcommittee on Magnetic Recording.

He served as chairman of the Electronics Industries Association Technical Products Division and was a member of the National Stereophonic Radio Committee of the EIA. He was a member of the board of directors of the Onondaga County Chapter of the American Cancer Society, a member of the Society of Motion Picture Engineers, Pi Tau Pi Sigma, Theta Kappa Phi, the Radio Old Timers Association, and the American Ordnance Association.

Mr. Morlock's sister is Mrs. Martha Kinzie, who has served as secretary of The National Television System Committee and as secretary to W. R. G. Baker.

Dr. Louis N. Ridenour, Jr. (SM'52–F'55), vice-president of Lockheed Aircraft Corporation and prominent in the fields of physics and electronics, died recently at the age of 47.

L. N. Ridenour

Dr. Ridenour, born in November, 1911, in Montclair, N. J., received the B.S. degree from the University of Chicago in 1932 and the Ph.D. degree in physics from the California Institute of Technology in 1936.

During World War II he was Assistant Director of the Massachusetts Institute of Technology Radiation Laboratory where he worked on the development of airborne radar and radar bombing systems. For this work he was given the President's Medal for Merit. While there he also served as editor-in-chief of the 28-volume Radiation Lab. Series summarizing World War II achievements in radar and electronics, which is still a standard reference work in the field.

After the war he taught at Princeton University and the University of Pennsylvania. He then went to the University of Illinois where he was made professor of physics and dean of the Graduate College.

In 1950–1951 he served as first chief scientist for the Air Force and headed a special USAF Scientific Advisory Board committee that surveyed the Air Force's research and development organization.

The resulting "Ridenour Report" urged the development of space age weapons and led to the establishment of the Air Force Research and Development Command.

Dr. Ridenour joined Lockheed's Missile and Space Division in 1955 as director of research. He later became the division's assistant general manager and chief scientist. In March, 1959, he was elected a vice-president of the corporation and was made general manager of the newly formed Electronics and Avionics Division.

He was a member of the American Physical Society, the American Association for the Advancement of Science, the American Rocket Society and a Fellow of the IRE. In 1946 he served on the IRE Board of Editors Committee.

He was the author of several scientific books including "Modern Physics for the Engineer," as well as many technical papers. In addition to the President's Medal for Merit he was the recipient of the Bronze Star in 1946 and the Citation of Honor Award of the Air Force Association in 1951.

National Ultrasonics Symposium

Stanford University, Stanford, Calif., August 17, 1959

The IRE Professional Group on Ultrasonics Engineering has planned this symposium together with a session at WESCON in San Francisco, Calif. on August 18, 1959 (see next page) to provide a two-day program on ultrasonics.

The chairman of the Symposium Committee, Dr. Vincent Salmon of the Stanford Research Institute, has arranged a program of 15 papers to be presented in two sessions on August 17.

Also included in the plans are a cocktail hour and a banquet.

Registration, which will be held in the lobby of Memorial Auditorium starting at 8:00 A.M., will be $3.00. Banquet tickets will be $5.00 and cocktail hour prices will be $0.70 per cocktail. No advance registration is required.

Monday Morning, August 17

"The Specification of Multiply-Tapped Delay Lines," *R. M. Lerner, M.I.T. Lincoln Labs.*

"Low Temperature Coefficient Ultrasonic Delay Lines," *W. H. Jenkins, Corning Glass Works.*

"Ultrasonic Strip Delay Lines," *A. H. Meitzler, Bell Tel. Labs.*

"Wire Type Dispersive Ultrasonic Delay Lines," *J. E. May, Jr., Bell Tel. Labs.*

"Dispersive Ultrasonic Delay Lines Using the First Longitudinal Mode in a Strip," *T. R. Meeker, Bell Tel. Labs.*

"An Improved Deep Water Sonar Transducer," *D. G. McAnally, Texas Instruments, Inc.*

"A Compact Electromagnetic Band-Pass Filter for Frequencies Below 20 KC," *W. P. Mason and R. N. Thurston, Bell Tel. Labs.*

Monday Afternoon

"Lamb Waves at Ultrasonic Frequencies," *D. C. Worlton, Testing Methods Operation, Hanford Atomic Products Operation, Gen. Elec. Corp.*

"The Reduction of Static Friction by Sonic Vibrations," *H. D. Fridman and P. Levesque, Res. Div., Raytheon Mfg. Co.*

"Application of Ultrasonic Light Modulation to Signal Recording, Display, Analysis, and Computation," *A. H. Rosenthal, Fairchild Camera and Instrument Corp.*

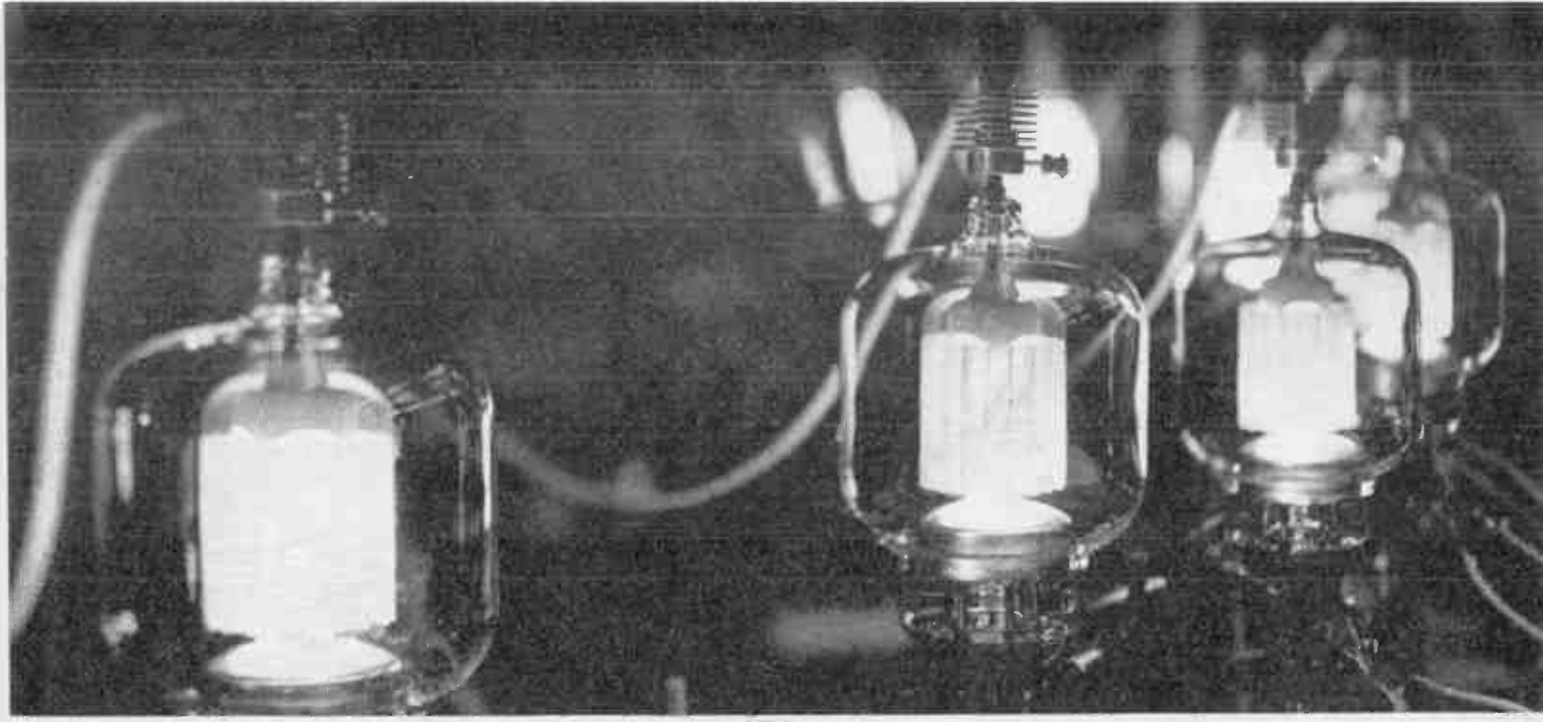
"Ultrasonic Diffraction of a Narrow Light Beam and its Relation to Ultrasonic Pressure Measurements and Ultrasonic Stroboscopes," *K. L. Zankel and E. A. Hiedeman, Dept. of Physics, Michigan State Univ.*

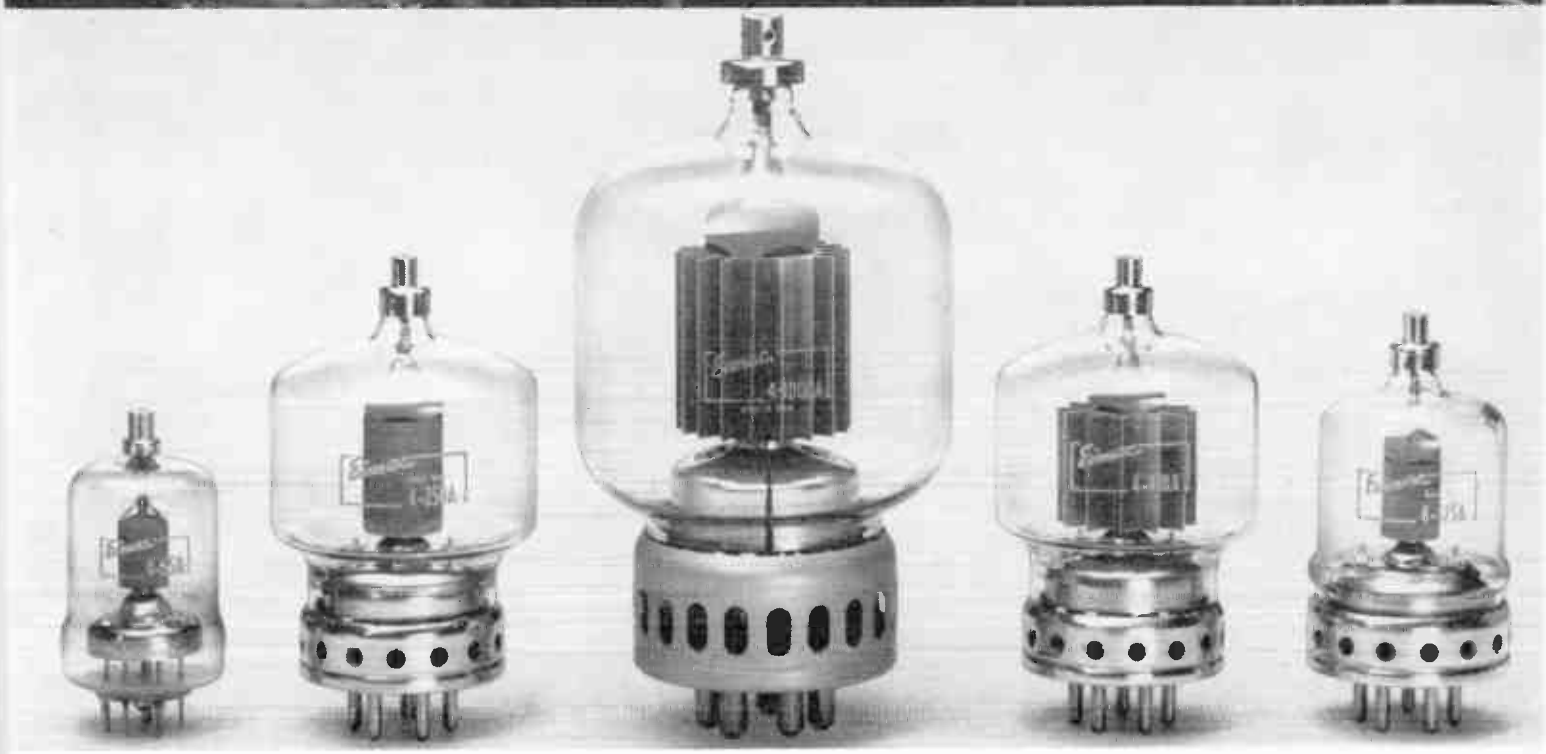
"Ultrasonic Doppler for Distance Measurement," *M. H. Wachspress, Arma Div., American Bosch Arma Corp.*

"A High Efficiency Transducer for Transmission to Air," *J. Kritz, Arma Div., American Bosch Arma Corp.*

"An Analytic Study of the Vibrating Free Disk," *R. N. House, Jr., and J. Kritz, Arma Div., American Bosch Arma Corp.*

"Ultrasonic Doppler Measurement of Human Body Motion in Three Dimensions," *D. K. Ross, Clayton, Mo.*





EIMAC PIONEERED INTERNAL-ANODE TETRODES— PERFORMANCE LEADERS FOR OVER A DECADE

Developed and introduced to the industry in the mid 1940's, Eimac's line of internal-anode radial-beam tetrodes immediately received widespread and enthusiastic acceptance. Well over a million have been sold since that time. These tubes, quality leaders from the very start, still maintain that position through advanced processing techniques, inherently sound design and continuing concern with production refinements.

Clean electrode design, for example, and the exceptionally hard vacuums achieved on Eimac-developed rotary vacuum pumps, result in consistently reliable tubes with an exceptional ability to withstand high momentary overloads and peak powers. Rugged filament design with high reserve emission contributes greatly to their reliability and long life.

Stable operation at high frequencies is assured by low inter-electrode capacitances and low lead inductances. Driver requirements and associated circuitry are simplified by the high power gain and low driving power requirements of these tube types.

These features, plus other Eimac design innovations such as the Pyrovac* plate and non-emitting grids make Eimac internal-anode tetrodes your logical choice for new equipment designs, as well as tube replacements, when exceptional performance and reliability are required. Most types available for immediate delivery.

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1959 Western Electronics Show and Convention

Cow Palace, San Francisco, Calif., August 18–21, 1959

The 1959 Western Electronics Show and Convention (WESCON) will be held at the famous Cow Palace in San Francisco, Calif., from August 18 through 21, 1959.

In addition to the scheduled technical conferences listed below, there will be five field trips to various Bay Area electronic manufacturing establishments and laboratories. The tours are a feature of WESCON's "New Look" policy for this year which also includes the establishment of an annual competition for exhibits. All items chosen for exhibit will receive a "WESCON Award of Merit for Industrial Design," and those judged to be particularly outstanding will receive the "WESCON Award of Excellence for Industrial Design."

Another feature will be the Future Engineers' Show, initiated in 1957, in which secondary school students of the West participate.

This year the WESCON Convention Record will be available at the Conference.

A ladies program is being planned for the wives of conference attendees.

Tuesday Morning, August 18

Session 1—Ultrasonics

Chairman: *V. Salmon, Stanford Res. Inst.* Sponsored by PGUE.

"An Ultrasonic Method for the Determination of Stress," *R. W. Benson, Armour Res. Found., Chicago, Ill.*

"A New Type Directive Sound Source for Long Range Sonar," *D. R. Church, Acoustics Assoc., Inc., Mineola, N. Y.*

"Nondestructive Measurement of Tensile and Compressive Stresses," *R. Shahbender, RCA, David Sarnoff Res. Ctr., Princeton, N. J.*

Session 2—Reliability 1: Reliability Analysis

Chairman: *R. A. Davis, Philco Western Dev. Lab.*, Sponsored by PGRQC.

"Electronic Design: Reliability vs Manufacturing Cost," *N. L. Kreuder, Electro Data Div., Burroughs Corp., Pasadena, Calif.*

"The Statistical Dynamics of Preventive Replacements," *D. M. Brender, IBM Watson Lab., N. Y., N. Y.*

"Some Aspects of Disposal at Failure Maintenance of Military Airborne Electronic Equipment," *R. O. Stone, Natl. Bur. of Stand., Washington, D. C.*

Session 3—Space Antenna Problems

Chairman: *E. A. Blasi, Lockheed Missile and Space Div., Sunnyvale, Calif.* Sponsored by PGAP.

"Electromagnetic Effects Associated with Hypersonic Re-entry Vehicles," *R. F. Whitmer, Sylvania Elec. Prods., Inc., Microwave Physics Lab., Mt. View, Calif.*

"Estimating Voltage Breakdown Performance of High-Altitude Antennas," *W. J. Linder and H. L. Steele, Boeing Airplane Co., Seattle, Wash.*

"Interferometer Phasing Problems at Microwave Frequencies," *G. Swarup and K. S. Yang, Stanford Univ., Radio Propagation Lab., Stanford, Calif.*

Session 4—Computers 1

Chairman: *John P. Nash, Lockheed Missiles Systems Div., Palo Alto, Calif.* Sponsored by PGEC.

"Transistor Circuit Techniques for a Core Memory with 500 Millimicrosecond Cycle Time," *V. J. Sferrino, M.I.T., Lincoln Lab., Lexington, Mass.*

"A Versatile Character Generator with Digital Input," *E. D. Jones, Stanford Res. Inst., Video Systems Lab., Menlo Park, Calif.*

"An Error Correcting Encoder and Decoder for Phone Line Data," *K. E. Perry, M.I.T. Lincoln Lab., Lexington, Mass.*

Session 5—Semiconductor Devices 1

Chairman: *R. N. Noyce, Fairchild Semiconductor Corp., Palo Alto, Calif.* Sponsored by PGED.

"Tunnel Diodes for Low Noise Amplification," *K. K. N. Chang, H. Nelson, R. Steinhoff, P. Schnitzler, and H. S. Sommers, Jr., RCA Labs., Princeton, N. J.*

"Germanium and Silicon Tunnel Diodes-Design, Operation and Application," *M. W. Aarons, N. Holonyak, Jr., V. S. Davidsohn, and I. A. Lesk, Gen. Elec. Co., Syracuse, N. Y.*

"Variable Capacitor with Large Capacity Change," *J. L. Moll, Electronics Research Lab., Stanford Univ., Stanford, Calif.*

Tuesday Afternoon

Session 6—Audio

Chairman: *R. Long, Stanford Res. Inst., Menlo Park, Calif.* Sponsored by PGA.

"A New Stereophonic Projection Console," *B. B. Bauer, G. W. Sioles, CBS Labs., Stamford, Conn.*

"Novel Compression-Expansion Method for Audio and Video Use," *W. R. Aiken, Radio Corp., Los Altos, Calif. and C. Susskind, Dept. of Elec. Eng., Univ. of Calif. at Berkeley.*

"A Resonance-Vocoder and Base-Band Complement: A Hybrid System for Speech Transmission," *J. L. Flanagan, Bell Telephone Labs., Murray Hill, N. J.*

Session 7—Engineering Management

Chairman: *S. A. Ferguson, Sylvania Elec. Prod. Co., Mountain View, Calif.* Sponsored by PGEM.

"An Industrial Dynamic Management Approach to Research and Development," *A. Katz, Eng. Dept., Electronic Data Processing Div., RCA, Camden, N. J.*

"Leadership: Man and Function," *A. Bavelas, Stanford Univ., Stanford, Calif.*

"Getting Started in the Electronics Business," *J. V. N. Granger, Granger Assoc., Palo Alto, Calif.*

Session 8—Microwave Antennas

Chairman: *R. S. Elliott, Rantec Corp., Calabasas, Calif.* Sponsored by PGAP.

"Electronically Scanned Microwave Arrays Employing Synchronous Ferrite Phase Shifters," *A. Clavin, L. A. Kurtz, and S. A. Rosen, Rantec Corp., Calabasas, Calif.*

"Logical Pattern Synthesis," *A. Ksienski, G. G. Comisar, and O. R. Price, Hughes Aircraft Co., Culver City, Calif.*

"The Effects of Wide-Band Signals on Radar Antenna Design," *Lt. L. R. Dausin, Lt. K. E. Niebuhr,* and *Lt. N. J. Nilsson, Rome Air Dev. Ctr., Griffis AFB, N. Y.*

Session 9—Computers 2

Chairman: *J. D. Noe, Stanford Res. Inst., Menlo Park, Calif.* Sponsored by PGEC.

"Megacycle Magnetic Rod Logic," *D. A. Meier, B. Kaufman, and D. W. Rock, Natl. Cash Register Co., Hawthorne, Calif.*

"Evaporated Films and Digital Computers," *D. W. Moore, Servomechanisms, Inc., Goleta, Calif.*

"BIAX High Speed Magnetic Computer Element," *C. L. Wanless, Digital Computer Eng., Computer Div., Aeronutronic Systems, Inc., Santa Ana, Calif.*

Session 10—Semiconductor Devices 2

Chairman: *J. L. Moll, Stanford Univ., Stanford, Calif.* Sponsored by PGED.

"A Stepping Transistor Element," *L. A. D'Asaro, Bell Telephone Labs., Murray Hill, N. J.*

"Recovery Time of PNPN Diodes," *A. N. Baker, J. M. Goldey, and I. M. Ross, Bell Telephone Labs., Murray Hill, N. J.*

"Silicon Mesa Transistors for Use as Saturating Switches," *V. H. Grinich and R. N. Noyce, Fairchild Semiconductor Corp., Palo Alto, Calif.*

Wednesday Morning, August 19

Session 11—Circuit Theory 1: Network Theory and Application

Chairman: *C. Desoer, Univ. of Calif., Berkeley, Calif.* Sponsored by PGCT.

"The Relation Between Kron's Method and Classical Methods of Network Analysis," *F. H. Branin, Jr., IBM Prod. Dev. Lab., Poughkeepsie, N. Y.*

"Practical Applications of Time Domain Theory," *J. T. Banger, Bell Telephone Labs., Murray Hill, N. J.*

"Synthesis Techniques for Gain Bandwidth Optimization in Passive Transducers," *H. J. Carlin, E. E. Dept., Brooklyn Polytechnic Inst., N. Y.*

Session 12—Production Techniques

Chairman: *A. Kromer, Ampex Corp., Redwood City, Calif.* Sponsored by PGPT.

"Lenkurt Automatic Wiring Process," *J. M. Coffin, Lenkurt Elec. Co., San Carlos, Calif.*

"Thermal Evaporated Thin Film," *F. Ura, Hewlett Packard Co., Palo Alto, Calif.*

"Investigation of Printed Circuit Board Solder Joints," *S. Levine and Assoc., Melpar Inc., Va.*

Power your TWTs and BWOs with the ALFRED 250

ALFRED's versatile Model 250 will operate more low-powered and low noise TW tubes than any other commercially available power supply. It operates most medium-powered traveling wave tubes as well. High regulation, low ripple and low drift make the Model 250 an ideal standard for testing and evaluating tubes, backward wave oscillators and carcinatrons.

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Alfred's design protects both operator and tube. A "helix over-current relay" trips at full scale at any range and shuts off all high voltage supplies. All meters are isolated from panel for operator safety.

Aligning a backward wave oscillator with the Alfred Model 250 Traveling Wave Tube Power Supply. The 250 features four anodes and grid supply, plus helix and collector supply. Note each supply is individually metered.

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HELIX SUPPLY	
Voltage	90 to 3500 v, range switch and 10 turn vernier
Current	0 to 5 ma to helix 0 to 60 ma to collector
External Modulation	Direct or capacitively coupled
PROTECTION	Overcurrent relay shuts off all high voltage supplies
COLLECTOR SUPPLY	
Voltage	0, +150, +250 v, relative to helix
Current	0 to 60 ma
GRID SUPPLY	(relative to cathode)
Voltage	0 to —150 v
Current	.1 ma average
External Modulation	Direct or capacitively coupled

ANODE SUPPLIES (relative to cathode)		
	#1	#2
Voltage	0 to + 450 v	0 to + 300 v
Current	0 to 20 ma	0 to 1 ma
	#3	#4
Voltage	0 to +750 v	0 to 2500 v
Current	0 to 1 ma	0 to 1 ma
HEATER SUPPLY		
Voltage	0 to 10 v ac	
Power	20 va maximum	
SOLENOID SUPPLY		
Voltage	0 to 100 v	
Current	0 to 7 amperes	
BLOWER SUPPLY		
Voltage	115 v ac or 28 v dc	
Current	0 to 1 ampere ac or dc	
PRICE	$1990 F.O.B. Palo Alto	

Session 13—Radio Wave Propagation

Chairman: *A. T. Waterman, Jr., Stanford Univ., Stanford, Calif.* Sponsored by PGAP.

"Optimum Transmission Rate for Low Power Meteor Burst Propagation," *B. M. Sifford, Stanford Res. Inst., Menlo Park, Calif.*

"Radio Propagation Measurements in the 100 to 118 KMC Spectrum," *A. W. Straiton and C. W. Tolbert, Elec. Eng. Res. Lab., Univ. of Texas, Austin, Tex*

"L-Band Multipath Propagation in an Airborne Pulse System," *G. E. Hart and H. M. Lamb, Hazeltine Corp., Little Neck, L. I., N. Y.*

Session 14—Vacuum Tubes 1

Chairman: *H. R. Johnson, Watkins-Johnson Corp., Palo Alto, Calif.* Sponsored by PGED.

"Measurements of Internal Reflections in TWT's Using Millimicrosecond Pulse Radar," *H. T. Classon and D. O. Melroy, Bell Telephone Labs., Murray Hill, N. J.*

"Fast Longitudinal Space Charge Wave Parametric Amplifiers," *J. S. Cook and W. Louisell, Bell Telephone Labs., Murray Hill, N. J.*

"Miniaturized Low-Noise Traveling Wave Tubes for Airborne Application," *C. L. Cuccia, H. J. Wolkstein, and J. J. Napoleon, RCA Electron Tube Div, Harrison, N. J.*

Session 15—Semiconductor Devices 3

Chairman: *J. Peterson, Pacific Semiconductors, Inc., Culver City, Calif.* Sponsored by PGED.

"Molten Dot Technique for Alloy Junction Fabrication," *R. C. Ingraham and R. E. Hunt, Sylvania Elec. Prod., Inc., Semiconductor Div., Woburn, Mass.*

"Three Layer Compensated Avalanche Diodes," *G. S. Horsley, Shockley Transistor Corp., Palo Alto, Calif.*

"The Annealing of Neutron Damage in Silicon Mesa Transistors," *C. S. Roberts and V. H. Grinich, Fairchild Semiconductor Corp., Palo Alto, Calif.*

Wednesday Afternoon, August 19

Session 16—Microcircuitry

Chairman: *C. Eldon, Hewlett Packard Co., Palo Alto, Calif.* Sponsored by PGCP and PGPT.

"Dynamic Testing of Microfilm Circuits," *W. D. Fuller, Lockheed Missile and Space Div., Palo Alto, Calif.*

"Microcircuitry with Refractory Metals," *D. A. McLean, Bell Telephone Labs., Murray Hill, N. J.*

"Micro-Miniature Electronic Circuitry for Space Guidance," *E. Keonjian, American Bosch Arma Corp., Garden City, N. Y.*

Session 17—Circuit Theory 2: Active Networks

Chairman: *D. O. Pederson, Univ. of Calif., Berkeley, Calif.*

"A Network Synthesis Approach to Wide-Band Amplifiers," *N. DeClaris, School of E. E., Cornell Univ., Ithaca, N. Y.*

"Synthesis of Driving-point Impedances Using Active RC Networks, *B. K. Kinariwala, Bell Telephone Labs., Murray Hill, N. J.*

"Transistor—RC Network Synthesis," *B. R. Myers, E. E. Dept., Univ. of Illinois, Urbana, Ill.*

Session 18—Reliability 2: Reliability Engineering

Chairman: *C. S. Bartholomew, Lockheed Missile and Space Div., Sunnyvale, Calif.* Sponsored by PGRQC.

"Electronic Circuit Tolerances," *K. S. Packard, Airborne Inst. Lab., Mineola, N. Y.*

"Meeting AGREE Reliability Requirements for Airborne Tacan Equipment," *H. G. Romig and A. L. Floyd, Hoffman Labs. Div., Hoffman Electronics, Los Angeles, Calif.*

"De-Rating: Its Meaning and Limitations," *J. R. Isken, Internatl. Resistance Co., Philadelphia, Pa.*

Session 19—Vacuum Tubes 2

Chairman: *S. E. Webber, Gen. Elec. Microwave Lab., Palo Alto, Calif.* Sponsored by PGED.

"Design Theory and Characteristics of the Helitron, A New Microwave Oscillator," *G. Wada, Watkins-Johnson Co., Palo Alto, Calif. and R. Pantell, Microwave Lab., Stanford, Calif.*

"Broadband High-Power Klystrons," *W. L. Beaver, G. Caryotakis, A. Straparans, R. S. Symons, Varian Assoc., Palo Alto, Calif.*

"Studies on the Magnetron Type Hollow Beam Electron Gun," *G. R. Brewer and E. G. Todd, Hughes Aircraft Co., Culver City, Calif.*

Session 20—Professional Group on Military Electronics 1

Chairman: *L. A. G. terVeen, Lockheed Missile and Space Div., Palo Alto, Calif.,* Sponsored by PGME.

"A Two-Way Air-Ground Digital Data Link for use with Meteor Burst Propagation," *A. C. Lytle, Jr., Hughes Aircraft Co., Los Angeles, Calif.*

"An Application of Digital Computation to a Problem of Army Tactics," *J. H. Brick, W. L. Maxon Corp., N. Y., N. Y.*

"An Optimum Maintenance Procedure for Airborne Electronic Equipment," *Maj. D. F. Mileson, U. S. Marine Corps, Washington, D. C.*

Wednesday Evening

Session 21—Special Session

Chairman: *L. V. Berkner, President of the Associated Universities, Inc.*

"The International Geophysical Year in Retrospect."

Thursday Morning, August 20

Session 22—Self Adaptive Systems

Chairman: *W. H. Kautz, Stanford Res. Inst., Menlo Park, Calif.* Sponsored by PGEC and PGIT.

"Plastic Neurons as Memory Elements," *D. G. Willis, Lockheed Missile and Space Div., Palo Alto, Calif.*

"A Class of Machines which Determines the Statistical Structure of a Sequence of Inputs," *J. D. Foulkes, Bell Telephone Labs., Murray Hill, N. J.*

"Adaptive Sampled-Data Systems—A Statistical Theory of Adaptation," *B. Widrow, M.I.T. Cambridge, Mass.*

Session 23—Stereophonic Broadcasting

Chairman: *R. A. Isberg, Consulting Engineer, Palo Alto, Calif.* Sponsored by PGB and PGBTR.

"An Optimized Compatible AM Stereo Broadcast System," *D. T. Webb, and H. B. Collins, Philco Corp., Philadelphia, Pa.*

"A Stereophonic System for AM Stations," *L. R. Kahn, Kahn Res. Labs., Inc.. Freeport, N. Y.*

"FM Multiplex Stereo Receiver," *H. Parker, Calbest Engineering and Electronics Co., Los Angeles, Calif.*

Session 24—Circuit Theory 3: Parametric Amplifier Circuit Theory

Chairman: *H. Rowe, Bell Telephone Labs., Holmdel, N. J.* Sponsored by PGCT.

"Circuit Considerations in Traveling-Wave Parametric Amplifiers," *C. V. Bell, and G. Wade, Electronics Res. Labs., Stanford Univ., Stanford, Calif.*

"Circuit Aspects of Parametric Amplifiers," *G. F. Hermann and H. Seidal, Bell Telephone Labs, Murray Hill, N. J.*

"Four-Terminal Equivalent Circuits of Parametric Diodes," *C. S. Kim, Electronics Lab., Gen. Elec. Co., Syracuse, N. Y.*

Session 25—Space Electronics and Telemetry

Chairman: *J. W. Muehlner, Lockheed Missile & Space Div., Palo Alto, Calif.* Sponsored by PGTRC.

"Delta Modulation for Cheap and Simple Telemetering," *F. K. Bowers, Univ. of British Columbia, Vancouver, Canada.*

"Interplanetary Telemetry," *G. E. Mueller, Space Technology Labs., Los Angeles, Calif.*

"The Tracking of Pioneer IV; The Elements of Deep Space Tracking System," *L. R. Richter, Jr. and R. Stevens, Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena, Calif.*

Session 26—Military Electronics II: Data Processing for Military Uses

Chairman: *A. S. Brown, Stanford Res. Inst., Menlo Park, Calif.* Sponsored by PGME.

"Automatic Data Transmission to Multiple Receivers within the Missile Monitor System," *L. H. Kurkjian, Hughes Aircraft Co., Fullerton, Calif.*

"A New Airborne Data Recorder," *P. N. A. Veenhuyzen, North American Aviation, Downey, Calif.*

"Some New Techniques in Airborne Data Acquisition," *E. P. Brandeis and M. E. Harrison, Ampex Corp., Redwood City, Calif.*

Thursday Afternoon, August 20

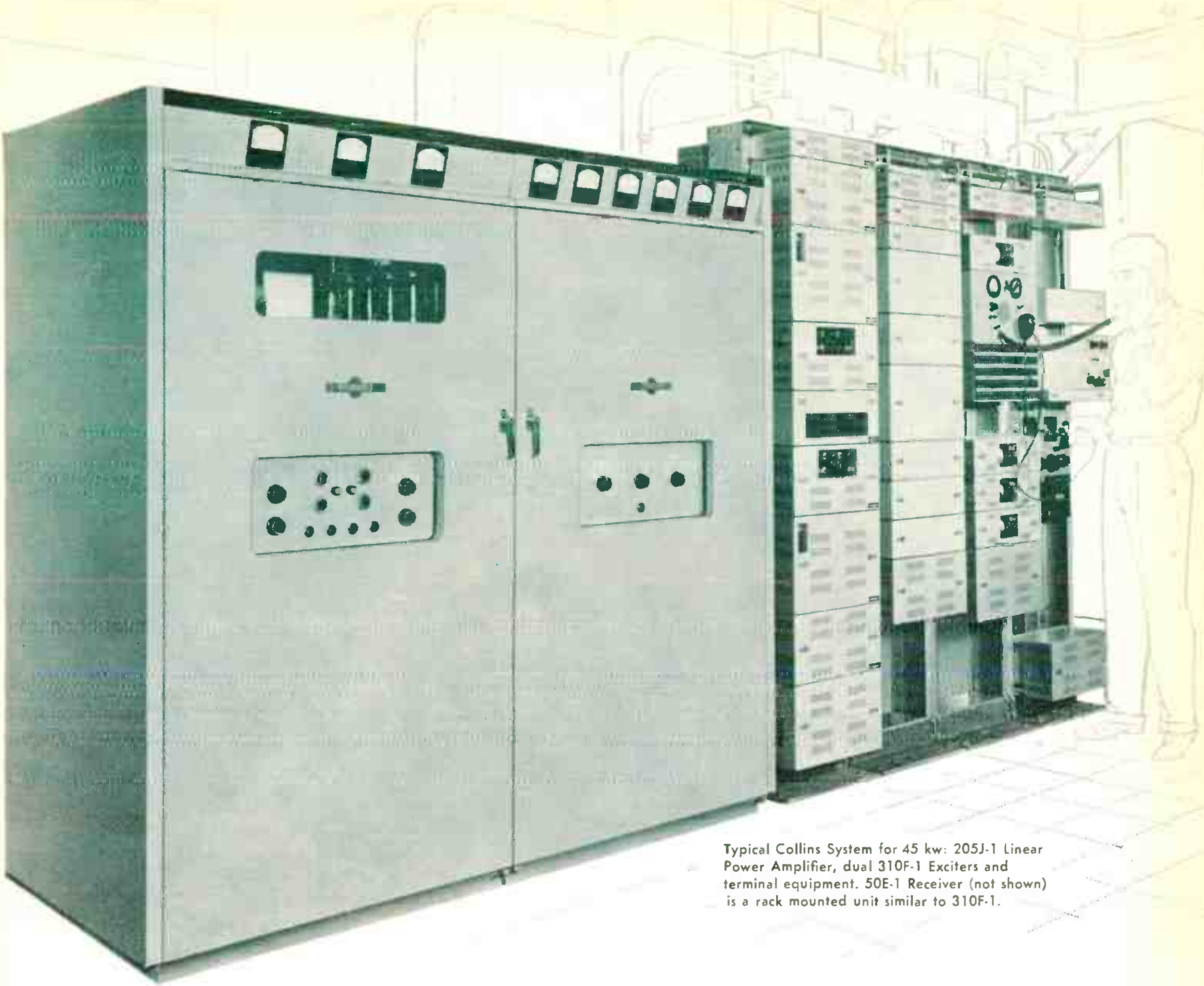
Session 27—Information Theory

Chairman: *L. A. Zadeh, Univ. of Calif., Berkeley, Calif.* Sponsored by PGIT.

"Linear Estimation of Deterministic Signals," *S. Zahl, Hdq. Air Force Cambridge Res. Ctr., ARDC, Bedford, Mass.*

"Some New Results for the Prediction of Derivatives of Polynomial Signals in Additive Stationary Noise," *I. Kanter, RCA, Moorestown, N. J.*

"A Non-Parametric Technique for the Detection of a Constant Signal in Additive



Typical Collins System for 45 kw: 205J-1 Linear Power Amplifier, dual 310F-1 Exciters and terminal equipment. 50E-1 Receiver (not shown) is a rack mounted unit similar to 310F-1.

automatic tuning for 45 kw communication stations COLLINS SSB

Stemming from a common heritage of design concepts and engineering standards, Collins single sideband systems range in function from low power, fixed tuned facilities to this automatic 45 kw station. Any frequency in 1 kc steps in the 2 to 29.999 mc range may be selected on a direct reading counter dial. Switching matrices enable local or remote selection of antennas as well.

Nucleus for this station is the 205J-1, a fully automatic 45 kw PEP linear power amplifier. Tuning is completed automatically by servo systems actuated by an error signal derived from phase comparison of input and output signals.

The automatically tuned 310F-1 Exciter generates the sideband signal with a balanced modulator and Mechanical Filter, heterodynes it to the operating frequency and amplifies it to the desired excitation level, using receiving type tubes throughout.

Closely related to the exciter is the 50E-1 Receiver. It uses a Mechanical Filter for narrow bandwidth and sharp skirt attenuation. Frequencies are synthesized by a stabilized master oscillator which is phase locked to an internal frequency standard imparting a stability of 1 part in 10^{6} per month. Frequency standards with a stability of 1 part in 10^{8} per day are available.

The equipment described is part of the complete Collins line of SSB equipment and accessories. Other equipment can provide from 100 watts to 45 kilowatts output with manual or automatic servo tuning.

Write for literature or consult your Collins representative for additional technical information.

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Gaussian Noise," *J. Capon, Columbia Univ., Dept. of E. E., N. Y., N. Y.*

Session 28—Human Factors

Panel Discussion: "The Role of Human Factors in Electronics," Sponsored by PGHF.

Moderator: *O. B. Moan, Lockheed Missile and Space Div., Palo Alto, Calif.*

Panel: *S. N. Roscoe, Hughes Aircraft Co., Culver City, Calif., L. J. Fogel, Convair, San Diego, Calif., G. Long, Boeing Aircraft Co., Seattle, Wash.*

Session 29—Circuit Theory 4: Transistor Analysis and Applications

Chairman: *J. Linvill, Stanford Univ., Stanford, Calif.* Sponsored by PGCT.

"Semiconductor Comparator Circuits," *G. L. Hoehn, Jr., Magnolia Petroleum Co., Dallas, Tex.*

"An Evaluation of Transistor Low Pass Broadbanding Techniques," *D. O. Pederson and R. S. Pepper, E. E. Dept., Univ. of Calif. at Berkeley.*

"Stored Charge Analysis of Transistors," *J. M. Early, Bell Telephone Labs., Murray, Hill, N. J.*

Session 30—Automatic Control

Chairman: *G. Franklin, Stanford Univ., Stanford, Calif.* Sponsored by PGAC.

"A Parameter Tracking Servo for Adaptive Control Systems," *M. Margolis and C. T. Leondes, Univ. of Calif. at Los Angeles.*

"Maximum Effort Control for an Oscillatory Element," *H. K. Knudsen, Univ. of Calif. at Berkeley.*

"Identification and Command Problems in Adaptive Systems," *E. Mishkin and R. A. Haddad, Microwave Res. Inst., Brooklyn Polytechnic Inst., N. Y.*

Session 31—Microwave Theory and Techniques 1: Microwave Variable Reactance Amplifiers

Chairman: *S. B. Cohn, Stanford, Res. Inst., Menlo Park, Calif.* Sponsored by PGMTT.

"Low-Noise Microwave Reactance Amplifiers with Large Gain-Bandwidth Products," *P. P. Lombardo and W. E. Sard, Airborne, Instr. Lab., Mineola, N. Y.*

"A Low Noise Up-Converter Parametric Amplifier," *E. M. T. Jones and J. S. Honda, Stanford Res. Inst., Menlo Park, Calif.*

"Parametric Amplifiers and Superregenerative Detectors," *J. J. Younger, A. G. Little, H. Heffner and G. Wade, Electronics Res. Lab., Stanford Univ., Stanford, Calif.*

Thursday Evening

Session 32—Medical Electronics

Chairman: *J. P. Swanson, Levinthal Electronics Prod. Inc., Palo Alto, Calif.* Sponsored by PGME.

"New Techniques in Physiological Recording Under Dynamic Conditions," *H. M. Hanish, Bio Technical Systems, Los Angeles, Calif.*

"Unitary Transistorized Artificial Larynx," *H. L. Barney, Bell Telephone Labs., Murray Hill, N. J.*

"A Rapidly Convergent Orthogonal Representation for EEG Time Series and a Special Electronic Analyzer for Measuring the Series Parameters," *B. Saltzberg and N. R. Burch, Ramo-Wooldridge Corp., Los Angeles, Calif.*

Friday Morning, August 21

Session 33—Component Parts

Chairman: *C. B. Clark, Stanford Res. Inst., Menlo Park, Calif.,* Sponsored by PGCP.

"New Ceramoplastic Insulating Material for 500°C Component Applications," *A. S. Backus and P. S. Hessinger, Mycalex Corp. of America, N. Y., N. Y.*

"An Ultra Stable Diffused Subminiature Voltage Reference Diode," *W. Hunter, Transitron Electronic Corp., Wakefield, Mass.*

"Microlamp," *D. J. Belknap, Diamond Ordnance Fuse Labs., Washington 25, D. C.*

Session 34—Aeronautical and Navigational Electronics

Chairman: *H. P. Blanchard, Stanford Res. Inst., Menlo Park, Calif.* Sponsored by PGANE.

"Landing Aids for Aircraft," *J. Holahan, Space Aeronautics Magazine, N. Y., N. Y.*

"Analysis of a New Glide-Slope System for Landing Fixed-Wing Aircraft," *A. Tatz and F. H. Battle, Airborne Instruments Lab., Mineola, L.I., N. Y.*

"A Frequency Domain Approach to Sub-Clutter Visibility Limitations Due to Statistic and Non-Statistic Phenomena as Encountered in Coherent M.T.I. Operation," *F. S. Rees and G. F. Thomas, Electronics Div., Westinghouse Elec. Corp., Baltimore, Md.*

Session 35—Instrumentation

Chairman: *L. Cutler, Hewlett Packard Co., Palo Alto, Calif.* Sponsored by PGI.

"Sampling Oscillography," *R. Carlson et al. Hewlett Packard Co., Palo Alto, Calif.*

"Faint Signal Limitations of Radiometers," *R. S. Colvin, Radio Propagation Lab., Stanford Univ., Stanford, Calif.*

"Spectrum Analysis with Delay Line Filters," *H. J. Bickel, Federal Scientific Corp., N. Y., N. Y.*

Session 36—Automatic Control 2

Chairman: *A. R. Bergen, Univ. of Calif. at Berkeley.* Sponsored by PGAC.

"Evaluating Residues and Coefficients of High Order Poles," *D. Hazony and J. Riley, Electromeasurements, Portland, Ore.*

"Improved Optical Analog Computer," *E. N. Leith, L. J. Cutrona, and L. J. Porcello, Univ. of Mich., Willow Run Labs., Ann Arbor, Mich.*

"Pole Determination with Complex Zero Inputs," *J. A. Brussolo, Dept. of E. E. Univ. of Calif. at Berkeley.*

Session 37—Microwave Theory and Techniques 2: Microwave Components and Systems

Chairman: *K. Tomiyasu, Gen. Elec. Microwave Lab., Palo Alto, Calif.* Sponsored by PGMTT.

"Harmonic Suppression by Leaky Wall Waveguide Filters," *V. C. Price and R. H. Stone, Gen. Elec. Microwave Lab., Palo Alto, Calif.*

"Application of a Solid-State Ruby Maser to an X-Band Radar System," *R. L. Forward, F. E. Goodwin, and J. E. Kiefer, Hughes Aircraft Co., Culver City, Calif.*

"An Automatic RF Matching Device," *R. G. Martin, L. Young, D. S. Friedman, and G. Runke, Electronics Div., Westinghouse Elec. Corp., Baltimore, Md.*

Friday Afternoon, August 21

Session 38—Nuclear Science

Chairman: *W. M. Brobeck, W. M. Brobeck and Assoc. Oakland, Calif.* Sponsored by PGNS.

"An Electronic Positional Assist for Film Readers," *R. N. Lewis, Argonne Natl. Lab., Lemont, Ill.*

"Radiation Effects on Electron Tube Materials," *E. R. Johnson, Stevens Inst. of Tech., Hoboken, N. J.*

"Oscilloscopes and Detectors used for Measurement of Nuclear Detonations," *R. C. Epps, Lawrence Radiation Lab., Livermore, Calif.*

Session 39—Communication Systems

Chairman: *Martin Grushkin, Lenkurt Electric Co., San Carlos, Calif.* Sponsored by PGCS.

"The Design of Wideband Scatter Links," *M. O. Felix, Gen. Communications Eng. Dept., Electronics Div., Canadian Westinghouse Co., Ltd., Hamilton, Ontario, Canada.*

"Evaluating Total Noise in a Multi-Trunk Communications System," *N. W. Feldman, U. S. Army Signal Res. & Dev. Lab., Fort Monmouth, N. J.*

"A Miniature Underwater Cable System," *B. G. King, L. R. Wrathall, L. O. Schott, and G. Raisbeck, Bell Telephone Labs., Murray Hill, N. J.*

Session 40—Industrial Electronics

Chairman: *R. DeLiban, Barrett Electronics Corp., Menlo Park, Calif.* Sponsored by PGIE.

"Silicon Controlled Rectifier—Triggering and Turn-off Circuitry for Inverter Applications," *D. V. Jones, Smeiconductor Prods. Dept., Gen. Elec. Co., N. Y.*

"An Intermittent-Action Camera with Absolute Time Calibration," *R. H. Doherty, G. Hefley, and E. L. Berger Propagation Lab., Natl. Bur. of Stand., Boulder, Colo.*

"Thermoelectric Spot Cooling Applications," *R. S. Lackey, Westinghouse Elec. Corp., Pittsburgh, Pa.*

Session 41—Automatic Control 3

Chairman: *Mac Hopkins*, Sponsored by PGAC.

"Random Noise with Bias Signals in Nonlinear Devices," *G. S. Axelby, Westinghouse Air Arm Div., Baltimore, Md.*

"Nongyroscopic Inertial Reference," *J. J. Klein, Lockheed Missile & Space Div., Sunnyvale, Calif.*

"Sampled-Data Design by Log Gain Diagrams," *M. P. Pastel and G. V. Thaler, U. S. Naval Postgrad. School, Monterey, Calif.*

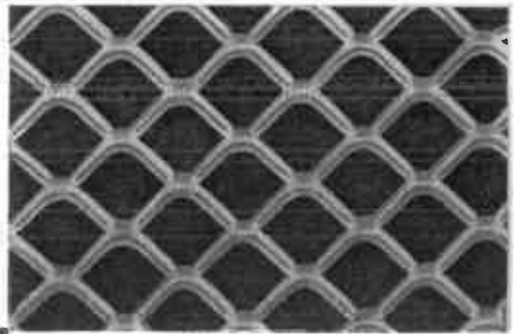
Session 42—Microwave Theory and Techniques 3: Microwave Magnetic-Resonance Applications

Chairman: *J. L. Melchor, Microwave Eng., Labs., Inc., Palo Alto, Calif.* Sponsored by PGMTT.

"Microwave Applications of Thin Films," *P. E. Tannenwald, M.I.T. Lincoln Lab., Lexington, Mass.*

"Cavity and Traveling-Wave Masers Using Ruby at S-Band," *W. S. C. Chang, J. Cromack, and A. E. Siegman, Electronics Res. Lab., Stanford Univ., Stanford, Calif.*

"An S-Band Traveling Wave Maser," *H. Tenney and P. Vartanian, Microwave Eng. Labs., Inc., Palo Alto, Calif.*



To Venus and back in 5 minutes with the help of Penmetal Squarex

Here is the 84-foot diameter space antenna used to establish contact with the planet Venus – some 28 million miles distant. Built by D. S. Kennedy & Co., it is installed at MIT's Lincoln Laboratory at Westford, Massachusetts. Microwaves beamed from the upturned reflector made the round trip in about five minutes.

Within the periphery of the dish is *Penmetal Squarex**, an expanded aluminum mesh having square openings instead of the usual oblong diamonds. The most versatile reflecting surface yet developed for radio, radar and telemetry reception, it provides constant response for radio energy regardless of polarization. In addition, this mesh is extremely strong, yet light in weight. The pattern was evolved through the joint efforts of D. S. Kennedy & Co. and Penn Metal Company.

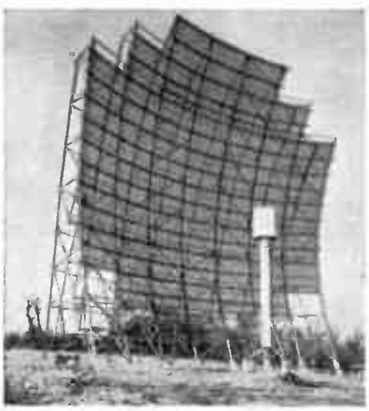
Squarex is available in a range of mesh sizes from 1/4" to 2 3/8", to cover frequencies from less than 100 megacycles to more than 10,000 megacycles. It is made in either aluminum or steel.

Squarex is only one example of many unique products developed by Penn Metal Company in cooperation with industrial designers during the last 90 years. This experience is available to you for the development of special meshes to meet your individual requirements. Write for further details.

PENN METAL COMPANY, INC.

General Sales Office: 40 Central Street, Boston 9, Mass.
Plant: Parkersburg, W. Va.
District Sales Offices: Boston, New York, Philadelphia, Pittsburgh, Chicago, Detroit, Dallas, Little Rock, Seattle, San Francisco, Los Angeles, Parkersburg, St. Louis

This 120-foot antenna was designed and built by D. S. Kennedy & Co., of Cohasset, Mass., for long-distance radio communication. Here, too, the reflecting surface is *Penmetal Squarex.*



PENN METAL COMPANY INC. 90th YEAR 1869 – 1959

PM-219

*Trade mark registered; patent applied for.

Dual National Symposia IRE Professional Group on Engineering Writing and Speech

Boston and Los Angeles, September 17 and 18, 1959

This year the annual national symposium of the IRE Professional Group on Engineering Writing and Speech will be held in two simultaneous sessions on September 17 and 18 at Boston, Mass. and Los Angeles, Calif.

The objective of the annual symposia is to offer information on professional writing and speaking techniques for engineers and on the writer-reader communications problem. The programs include both invited and contributed papers. The theme of the conference is "More Effective Communication of Scientific and Engineering Information."

The Boston session will be held at the Sheraton-Plaza Hotel and the Los Angeles session at the Ambassador Hotel. There will be luncheons on both days of the symposia and also a cocktail party.

The chairmen of the sessions are: *Boston*, A. H. Cross, Raytheon Mfg. Co., Wayland, Mass.; *Los Angeles*, J. M. Cryden, Litton Industries, 336 N. Foothill Rd., Beverly Hills. Calif. The National Symposium Chairman is T. T. Patterson, Radio Corporation of America, Bldg. 13-2, Camden, N. J.

The registration fees are as follows:

Los Angeles

General registration fee—$10.00 (covers all activities: 4 technical sessions, 2 luncheons, and cocktail party).

Fees for individual events:

4 technical sessions—$4.00 for IRE members and PGEWS affiliates; $5.00 for nonmembers.
Luncheons—$4.00 each.
Cocktail party—$3.00 each.

Send advance registration by September 8 to David Wersen, 3561 Military Ave., Los Angeles 34, Calif. Make payment payable to IRE Professional Group on Engineering Writing and Speech.

Boston

Fee for technical sessions:

Advance registration for IRE members and PGEWS affiliates—$4.00.
Nonmembers and at-the-door registration—$5.00
Luncheons—$4.25 each.
Cocktail Party $3.50.

Send advance registration by September 8 to Frederick T. Van Veen, General Radio Co., West Concord, Mass.

Boston Sessions

Thursday, September 17

Communication in Modern Society

Moderator: *Joseph Chapline.*

"Background to Scientific Communication" (Keynote Speech), *Dr. M. M. Kessler, Lincoln Lab., Lexington, Mass.*

"Advances in Human Communication," *H. F. Arader, Gen. Elec. Co., Schenectady, N. Y.*

"Design as a Means of Corporate Communication," *W. Burton, Visual Res. & Design Consultant, N. Y., N. Y.*

Thursday Afternoon

Problems in Communication

Moderator: *Eleanor McElwee.*

"Engineers as Communicators," *I. A. Getting, Raytheon Mfg. Co.*

"Some Legal Considerations in Presenting Technical Information" *R. R. Rines, Attorney, Boston, Mass.*

"Space Technology: Reporting the New Dimension," *R. E. Hohmann, IBM Corp., Kingston, N. Y.*

Friday Morning, September 18

How to Communicate Effectively

Moderator: *Charlie DeVore.*

"What the Military Expects in Engineering Proposals," *U. S. Navy Panel: Chairman—Capt. E. M. Fagan, USN.*

"What Technical People Can Learn From Advertising Techniques," Representatives of Bomac Div. of Varian Assoc. and Sigma Instruments, Inc.

"Scientific Report Writing," *G. Pope, Jackson and Moreland Co., Boston, Mass.*

Friday Afternoon

How to Deliver Technical Information

Moderator: *Prof. Thomas Farrell.*

"Language as an Engineering Tool," *J. R. Gould, Rensselaer Polytechnic Inst., Troy, N. Y.*

"How to Write for Engineering Journals," *J. Girdwood, Electronics, New York, N. Y.*

"Visual Aids," L. K. Hamilton, *Technifax Corp., Holyoke, Mass.*

Los Angeles Sessions

Thursday Morning

Welcome: *J. Cryden, IRE Administrative Committee, PGEWS, Litton Industries, Los Angeles.*

Keynote Speaker: *Dr. Van Atta, IRE Fellow: Chairman, IRE Los Angeles Section; Hughes Aircraft Co.*

Defense Requires Better Engineering Writing and Speech

Moderator: *Adm. C. V. Horne, USN (Ret.), vice-president and gen. man., Convair, Pomona.*

"Improved Communication. Research and Development Requirement," *Speaker to be announced.*

"Better Engineering Writing and Speech Results In More Reliable Systems," *Lt. Col. F. Hnapper, Chief, Field Service Div., Army Rocket and Guided Missile Agency, Redstone Arsenal.*

"An Improved System of Government Reports," *Prof. C. Susskind, Univ. of Calif. at Berkeley.*

"Improved Communication—Strategic Requirement," *Speaker to be announced.*

Thursday Afternoon

State of the Art—A Report on Significant Developments

Moderator: *to be announced.*

"Technical Information Developments in the Soviet Union," *M. J. Ruggles, vice-president, Council on Library Resources, Washington, D. C.*

"Developments in Dessimination in the United States," *Speaker to be announced.*

"The International Geophysical Year—Case Study in Communications," *Dr. W. Kellogg, The Rand Corp.*

Friday Morning

Education for Better Engineering, Writing and Speech

Moderator: *To be announced.*

"Training Engineers to Communicate Effectively—The Role of the Engineering School," *Dr. R. W. Winchell, Univ. of Southern Calif.*

"The Role of the Engineering Department in Training Engineers to Write," *Dr. P. Zoll, Director, Communication Res. Center, Los Angeles State College.*

"Communications, Art or Science?" *Dr. G. F. Paskusz, Univ. of Calif. at Los Angeles.*

Note: A series of panels will convene at the end of the session for the purpose of reviewing the presentation in preparing questions to be submitted to the speakers who will reply. This will assist in the active participation of the engineering profession in helping education determine the proper course or courses, to follow in the development of educational programs.

"The Technical Press Looks At The Problems of Better Engineering Writing and Speech," *Speaker to be announced.*

Friday Afternoon

Techniques for Better Engineering Writing and Speech

Moderator: *J. Harrison, Staff Director, Joint Congressional Committee on Printing.*

"How The Graphic Arts Can Help The Engineer To Communicate More Effectively," *A. N. Spence, Director of Publications, Dept. of the Navy.*

"Motion Pictures, The Vertical Medium for Technical Communications," *I. Seligsohn, Corp. for Economic & Industrial Res.*

"Effective Writing—How Westinghouse Does It," *W. C. Haas, Supervising Eng., Aviation Gas Turbine Div., Westinghouse Elec. Corp.*

Note: A panel discussion similar to the one for the educational session will follow this session.

To Assure You Safe, Trouble-Free Electrical Protection

every BUSS Fuse is electronically tested!

Before a BUSS or FUSETRON fuse ever leaves the plant, it must meet our high quality control standards.

Each fuse is tested in a sensitive electronic device that automatically rejects any fuse not correctly calibrated, properly constructed and right in all physical dimensions.

Thus . . . by specifying BUSS and FUSETRON fuses you have one more way to help safeguard the reputation of your equipment for service and reliability.

Complete Line For All Your Fuse Needs

Single-element fuses for circuits where quick-blowing is needed.

Single-element fuses for normal circuit protection.

Dual-element, slow-blowing fuses for circuits where harmless current surges occur.

Indicating fuses where signals must be given when fuses open.

BUSS fuses range in size from 1/500 amperes up — and there's a companion BUSS line of fuse clips, blocks and holders.

If You Have A Special Protection Problem

The BUSS fuse research laboratory, world's largest, plus experience gained by solving all types of electrical protection problems for over 44 years — is on call to you at all times. BUSS fuse experts will work with your engineers to help you find the best, yet most economical solution.

For more information, write for BUSS bulletin SFB.

BUSSMANN MFG. DIVISION,
McGraw-Edison Co.
University at Jefferson, St. Louis 7, Mo.

859

BUSS fuses are made to protect - not to blow, needlessly.

BUSS makes a complete line of fuses for home, farm, commercial, electronic, electrical, automotive and industrial use.

FUSETRON
TRUSTWORTHY NAMES IN ELECTRICAL PROTECTION
BUSS

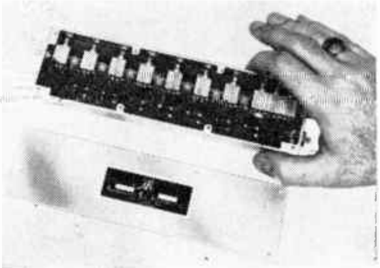
McGRAW EDISON

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

IF Amplifiers

The IFI T-300 series of transistorized IF amplifiers were designed by **Instruments for Industry, Inc.,** 101 New South Road, Hicksville, N. Y.



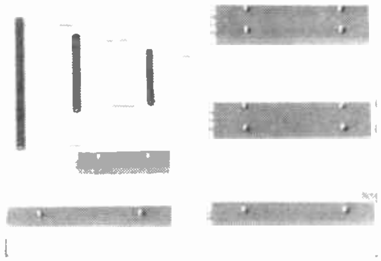
Specifications

	T-330A	*T-330B*
Gain	85 db(min)	100 db(min)
Center Frequency	30 mc	30 mc
Bandwidth	10 mc	3 mc
Source Impedance	50 ohms	50 ohms
Output Impedance	50 ohms	50 ohms
Noise Figure	10 db	9 db
Maximum Output	−10 dbm(min)	+10 dbm(min)
Mean Stage Gain	12.5 db	14 db
Circuitry	Stagger-tuned	Synchronously-tuned

The operating temperature is −55 to +85°C. Power requirements are (±20 v at 10 ma) 0.4 watt. Dimensions are $9\frac{1}{2}\times2\frac{1}{2}\times1$ inch. Gain control is provided.

Distributed Constant Delay Lines

The development of a new series of distributed constant delay lines, the 25J series, having a delay period of 0.6 microseconds per inch of winding, has just been announced by **Technitrol Engineering Co.,** 1952 E. Allegheny Ave., Philadelphia 34, Pa.



The 25J Series is available in a variety of standard case styles including hermetically-sealed metal cans and epoxy encapsulated sticks for pig-tail mounting. Maximum delay per six inches of winding stick is 3.0 μs. Several windings having the same or different delay time may be cascaded in the standard metal cans to produce longer delay periods if desired. Available impedances for the 25J Series include 3900, 5600, or 7500 ohms with rise times (per 3.0 μs delay) of 0.33, 0.48 and 0.53 μs respectively.

Allegheny Electronic Chemicals Begins Production of Silicon

A new firm, **Allegheny Electronic Chemicals Co.,** has been formed for the production of silicon in all forms for the semiconductor industry, according to a joint announcement by Norman J. Egli, manager of sales and Thayer Rudd, plant manager, for the firm. Production has started at the firm's Bradford, Pa., plant, and deliveries to customers are currently being made. Silicon will be available in a wide variety of forms including needles, densified chunks, densified rods, single crystals (both Czochralski and float zoned), rough cut and lapped single crystal slices, seeds and master doping alloys.

The bulk polycrystalline silicon produced by the chemical portion of the plant is of exceptional uniformity, in the range of 100 to 300 ohm-centimeter resistivity.

Size 8 Control Transformer

New manufacturing techniques have enabled **Clifton Precision Products Co., Inc.,** 9014 West Chester Pike, Upper Darby, Pa., to add a new 400 cps high impedance control transformer to their line of size 8 synchros. This control transformer, identified as the CTC-8-A-6, has impedance levels comparable to those found in size 10 and 11 synchros.

Impedances are as follows: Zro = 2625, ∠72.2°, Zso = 465, ∠75°, Zrss = 970, ∠17°. Maximum error is 7′ of arc. Unit is standard 11.8 volt input control transformer. Power input is as low as 0.058 watt.

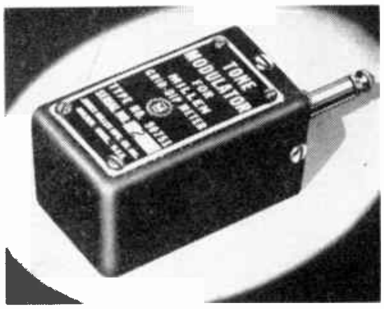
For complete electrical characteristics and outline drawing, write to the firm.

Systems Brochure

A revised edition of a 32-page, three-color brochure entitled "Sylvania Electronic Systems for National Defense" has been made available by **Sylvania Electronic Systems,** a division of **Sylvania Electric Products, Inc.,** 63 Second Ave., Waltham, Mass. Sylvania Electric is a wholly-owned subsidiary of General Telephone & Electronics Corp.

The brochure outlines the company's capabilities in the field of electronic warfare systems, defensive missile systems, intelligence and reconnaissance systems, data processing systems, and related subsystems and equipment in communications, navigational aids, radar, countermeasures, counter-countermeasures, and computers. It also lists and describes the 16 plants and laboratories that comprise the division's facilities.

Transistor Tone Modulator



A new transistor Tone Modulator, No. 90751, for modulating grid dip meters is announced by **The James Millen Mfg. Co., Inc.,** 150 Exchange St., Malden, Mass. A small package containing a transistor oscillator and its mercury battery, plugs into the 'phone jack of a grip dip meter to modulate the signal at approximately 800 cps for applications requiring a modulated signal. Modulator is automatically turned on when plugged into a grip dip meter.

Oscillogram Processor

Details of the new Type 23-109A Oscillogram Processor are described in an illustrated two-color brochure published by **Consolidated Electrodynamics Corp., Electro Mechanical Instrument Div.,** 360

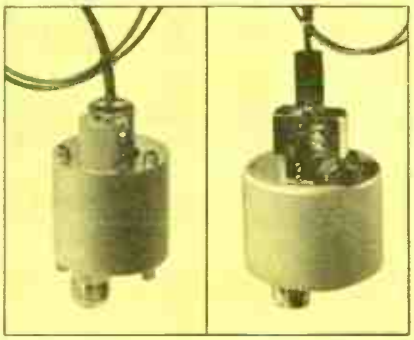
(Continued on page 32A)

Creative Microwave Technology

Published by MICROWAVE AND POWER TUBE DIVISION, RAYTHEON COMPANY, WALTHAM 54, MASS., Vol. 1, No. 5

NEW RAYTHEON MICROWAVE TUBE DEVELOPMENTS

Miniature pulsed magnetrons for missile beacon applications are ruggedly constructed with integral magnets. The RK-7461 is tunable from 9,300 to 9,500 mc and has minimum peak power output of 60 watts. It is 1¼" in diameter and 2½" long, and weighs only 6 ounces.

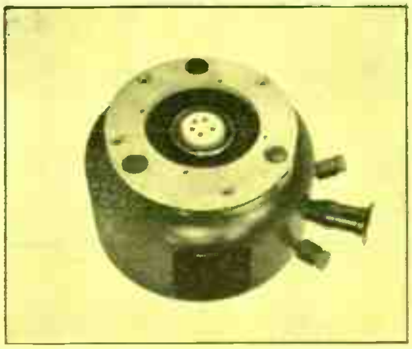


RK-7461 QK-735

The QK-735 is tunable from 5,400 to 5,900 mc with minimum peak power output of 400 watts. 1½" in diameter and 3¼" long, it weighs 8 ounces.

* * *

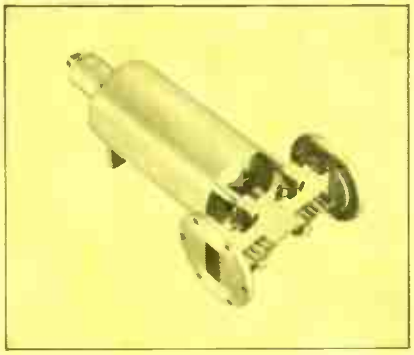
Designed for electronic countermeasures and FM/CW operations, the QK-625 BWO provides a minimum CW power output of 180 watts and a nominal CW power output of 250 to 350 watts over the 2,500 to 3,000 mc band. The tube is voltage tunable over the entire range with tuning sensitivity of approximately 0.4 mc/volt. Liquid-cooled, the QK-625 BWO is equipped with an integral



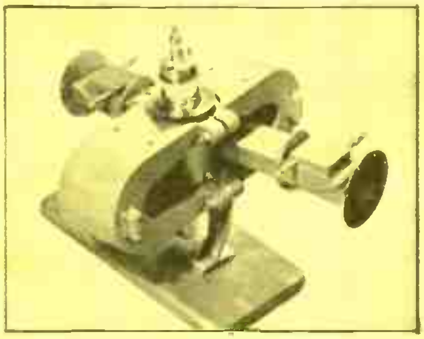
permanent magnet, and can be mounted in any position.

* * *

Small-signal gain of up to 35 db in microwave relay links is achieved by means of a new compact traveling wave tube amplifier -- the QK-542. This permanent-magnet focused CW tube has nominal saturated power output of 5 watts over 5,900 to 7,400 mc. An integral UG 344/U waveguide-type flange is supplied as standard. With an optional coaxial output coupler the QK-542 covers 4,000 to 8,000 mc.



Ideal for linear accelerators and high-power radar systems. The QK-783 and QK-622 Amplitrons operate over the 2,700-2,900 mc and 2,900-3,100 mc bands, respectively, at a peak power of 3 megawatts and a typical efficiency of 75%. Because no heater is required, these tubes are capable of exceptionally long life. RF gain is 8 db under rated conditions, and as high as 12 db at lower peak power outputs. Phase pushing figure is less than 0.5 degrees for a 1% variation of anode current.



* * *

Compiled as a Raytheon service to the field, new Consolidated Data Booklet contains comprehensive information about principal unclassified magnetrons, klystrons, backward wave oscillators and special purpose tubes manufactured by Raytheon. Characteristics presented include maximum ratings, typical operating values, band or frequency ranges and other essential data for microwave engineers and purchasing departments.

A Leader in Creative Microwave Technology RAYTHEON

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 30A)

Sierra Madre Villa, Pasadena, Calif.

The self-contained, motorized unit is designed for daylight processing of paper records, reducing the interval between recording and interpretation of data. New features incorporated in the processor are a thermistor drum temperature control, variable bath temperature, a speed-control contact shoe that makes it possible to process two narrow rolls and facilities for easy record removal. Request Bulletin 1537.

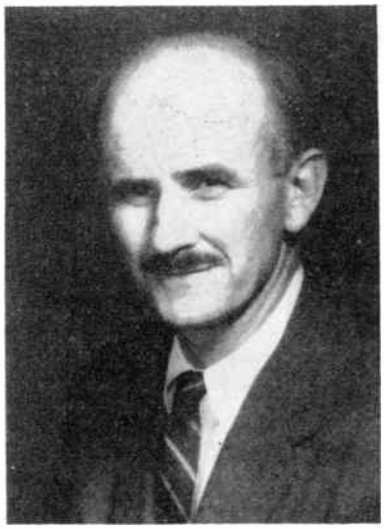
Transformer Design Notes

A new four-page bulletin from **CBS-Electronics, Inc.,** gives formulae for designing transformers for use in transistorized power supplies. It offers a handy guide to selecting the proper transistors, choosing operating frequencies, and determining the values of biasing resistors.

The bulletin, written by Robert Tomer, can be obtained by writing to CBS-Electronics Advertising Service, Parker St., Newburyport, Mass., and asking for Bulletin E-285.

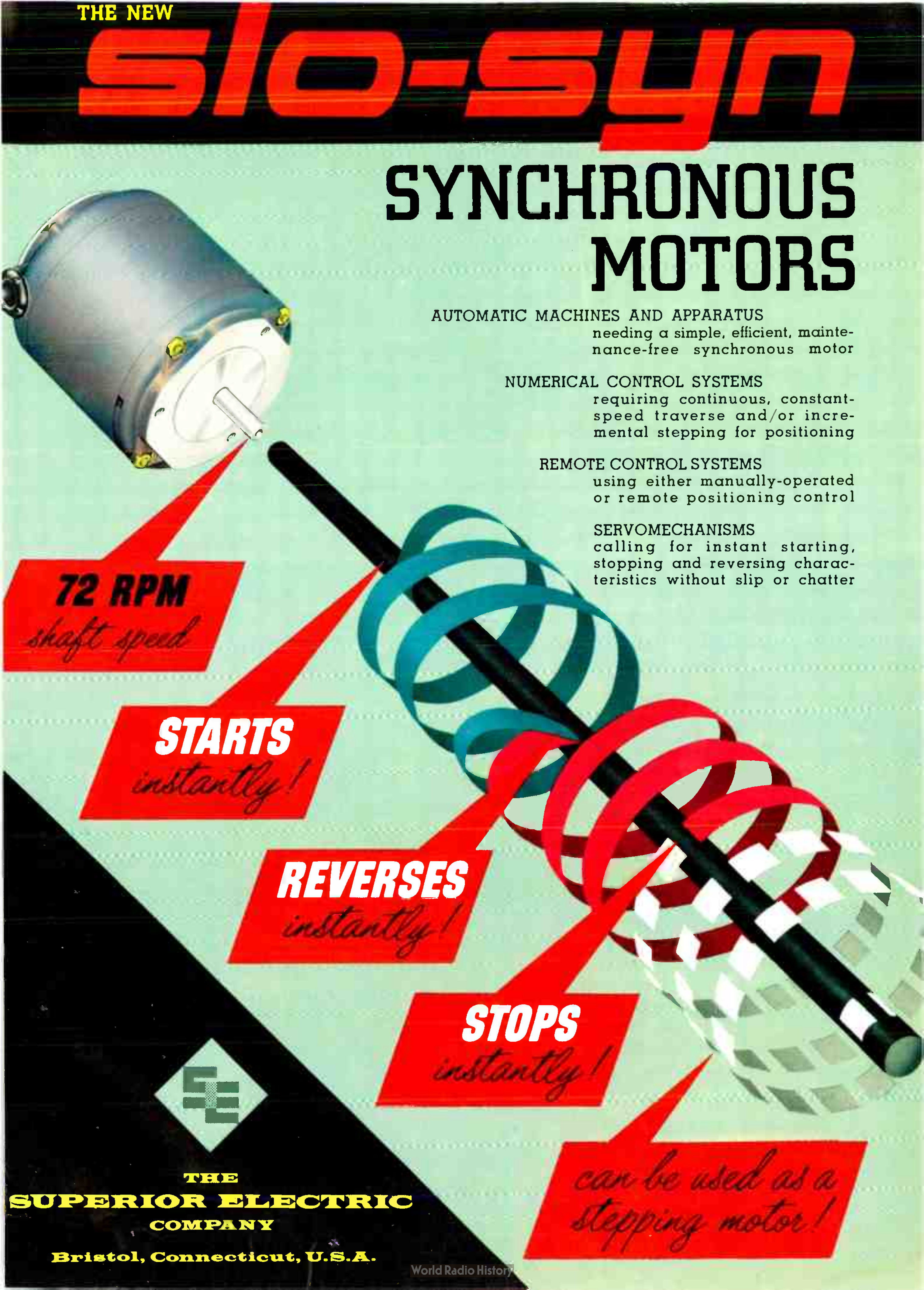
Hermes Electronics Is New Name for Hycon Eastern

Effective May 1, 1959, the new name for Hycon Eastern, Inc., of Cambridge, Mass. is **Hermes Electronics Co.**



"Our fields of interest" stated Malcolm M. Hubbard, President of Hermes Electronics, "will continue as before: Telecommunications; Antennas and Propagation; Advanced Data-handling Subsystems; Timing Systems for Missile and Satellite Tracking and Telemetry; Crystal Filters and Frequency Selective Devices; Ultra-stable Oscillators; Frequency Translators."

(Continued on page 172A)


THE NEW
slo-syn
SYNCHRONOUS MOTORS
AUTOMATIC MACHINES AND APPARATUS
needing a simple, efficient, maintenance-free synchronous motor
NUMERICAL CONTROL SYSTEMS
requiring continuous, constant-speed traverse and/or incremental stepping for positioning
REMOTE CONTROL SYSTEMS
using either manually-operated or remote positioning control
SERVOMECHANISMS
calling for instant starting, stopping and reversing characteristics without slip or chatter
72 RPM shaft speed
STARTS instantly!
REVERSES instantly!
STOPS instantly!
can be used as a stepping motor!
THE SUPERIOR ELECTRIC COMPANY
Bristol, Connecticut, U.S.A.

slo-syn SYNCHRONOUS MOTORS

*A SLO-SYN is an enclosed, permanent magnet type a-c motor **with a slow basic shaft speed of 72 RPM.** A single-pole, three-position switch can give complete forward, reverse and "off" control because the motor has three leads only. The SLO-SYN Motor **will start or stop in less than 0.025 seconds** or approximately 1.5 cycles. **No need for electrical or mechanical braking** because the motor will stop in less than 5° of shaft rotation. Maximum moment of inertia of a load rigidly attached to the shaft is 1.5 pound-inches². Loads with higher inertia can be started by using a coupling method which allows 5° freedom. Types having specially-designed planetary gear assemblies are available to provide speeds of 3.323, 0.665, 0.133 or 0.027 RPM. Torque on all planetary gear types is 2500 ounce-inches.*

TYPE SS150

AS A D-C STEPPING MOTOR

The SLO-SYN Synchronous Motor can be adapted for use as an incremental stepping device by the use of a d-c power source and a suitable switching arrangement. When used as a control system stepping or "inching" motor, d-c electrical impulses are converted into either 200 or 400 precise increments of one revolution of the motor shaft. The motor will maintain its rated torque for any stepping position. Each step is made instantly without slip or clatter because no ratchets are used.

▼ Available with speed reducing planetary gears

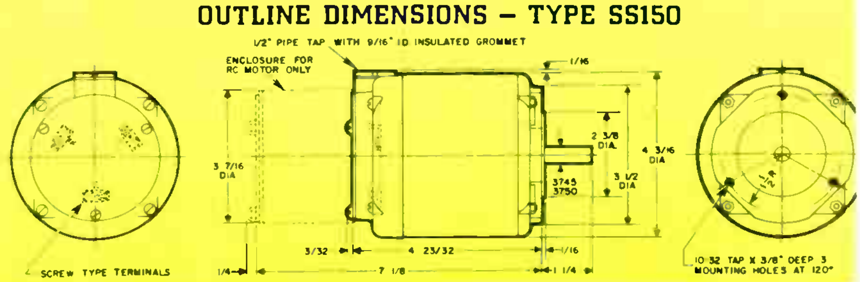
▼ Available with enclosed capacitor and resistor

▼ Available with both enclosed capacitor and resistor and planetary gears

RATINGS AND SPECIFICATIONS

INPUT	120 volts, 40/70 cycles, 1 phase
OUTPUT SPEED	72 RPM at 60 cycles
MAX. CURRENT	0.3 ampere at 60 cycles
TORQUE	150 ounce-inches
WEIGHT	6.5 pounds

OUTLINE DIMENSIONS — TYPE SS150



THE SUPERIOR ELECTRIC COMPANY, Bristol, Connecticut

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name

company

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Request SLO-SYN Bulletin giving full technical information, ratings and specifications.

THE SUPERIOR ELECTRIC COMPANY
Bristol, Connecticut, U.S.A.

WITH ARC's NEW TYPE T-25A 360 CHANNEL TRANSMITTER

As air traffic becomes heavier, pilots are busier with more frequent ground communications. To meet this growing need in traffic control, ARC designed the Type T-25A 360 Channel Transmitter with the widest range of frequencies — more than adequate for today or years to come. Weighing only 7.7 pounds including shock mounting, the T-25A provides complete coverage of 360 channels at 50 kc spacing between 118.00-135.95 megacycles. It is a 6-10 watt unit (nominal 8 watts), providing ample range for planning approaches in congested air traffic areas. Power consumption of only 2.0 amperes during transmission on the 28 volt model, plus the 2.0 amps input to the receiver dynamotor that supplies high voltage. This means little added power drain on the electrical system.

This transmitter is recommended for use with ARC's line of tunable receivers, (R-13B and R-19) for a primary communication system on small aircraft or as a "back-up" to ARC Type 210 Transmitter-Receiver on larger aircraft.

Certified to CAA TSO C-37 Category A and FCC Requirements

Engineers: Investigate Career Opportunities at ARC

Aircraft Radio Corporation BOONTON, N. J.

Dependable Airborne Electronic Equipment Since 1928

OMNI/LOC RECEIVERS • MINIATURIZED AUTOMATIC DIRECTION FINDERS • COURSE DIRECTORS • LF RECEIVERS AND LOOP DIRECTION FINDERS
UHF AND VHF RECEIVERS AND TRANSMITTERS (5 TO 360 CHANNELS) • INTERPHONE AMPLIFIERS • HIGH POWERED CABIN AUDIO AMPLIFIERS
10-CHANNEL ISOLATION AMPLIFIERS • OMNIRANGE SIGNAL GENERATORS AND STANDARD COURSE CHECKERS • 900-2100 MC SIGNAL GENERATORS

IRE People

Corrections:

On page 110A of the June, 1959 issue of PROCEEDINGS the photograph identified as G. W. Sioles is really Dr. Bernard R. Linden. (For an article on Dr. Linden see page 58A of this issue.)

On page 78A of the June, 1959 issue of PROCEEDINGS Mr. Albert Preisman's IRE membership progression should read (M'38–SM'43–F'53).

Dr. L. J. Castriota (S'47–M'52) has been appointed a consultant to the Research & Development Division of Polytechnic Research & Dev. Co., Inc. Brooklyn, N. Y.

L. J. CASTRIOTA

Dr. Castriota will be involved in all phases of operation with the company, which designs and manufactures precision microwave and electronic test equipment and components for the military and industry.

Since 1952 Dr. Castriota has been a member of the staff of the Microwave Research Institute of the Polytechnic Institute of Brooklyn as a section leader involved with countermeasures, radar systems, and microwave network theory. Prior to that, Dr. Castriota had been associated with the Rome Air Development Center, heading a section in communication interference reduction research.

Graduated from New York University in 1947 with a B.E.E. degree, he received his Master's degree in electrical engineering from Harvard in 1948 and his Doctorate from the Polytechnic Institute of Brooklyn in 1958. Dr. Castriota is a member of the society of Sigma Xi and RESA.

Herman N. Chait (A'55), microwave scientist and engineer, has been appointed chief scientist of the Cascade Research Division of Monogram Precision Industries. He will supervise the company's work in the microwave antenna-systems field.

H. N. CHAIT

Prior to joining Monogram he was an electronic scientist and solid-state physicist with the Naval Research Laboratory in Washington, D. C. Earlier this year he was presented with an Award of Merit from the Department of the Navy for his important contributions to the microwave art.

Other awards received by Mr. Chait include the first Microwave Prize of the Professional Group on Microwave Theory and Techniques (PGMTT) of the IRE. He has had published more than 20 papers in various technical journals.

He graduated from Tufts College, Medford, Mass., with the B.S. degree in electrical engineering. He also attended the University of Maryland for graduate study of electromagnetic theory.

Mr. Chait is a member of Research Engineering Society of America (RESA), the non-metallic magnetic materials and microwave ferrite group of the American Society for Testing Materials (ASTM), and and the PGMTT of the IRE.

H. J. Doane (M'49), of Space Technology Laboratories, Inc., has been appointed associate head of STL's Thor Project Office, Flight Test Operations, at Cape Canaveral, Florida.

Mr. Doane has been engaged in missile flight testing in the Cape Canaveral area for the past eight years. Prior to joining STL in 1956, he was associated with the Missile Test Facility at Northrop Aircraft, Inc. During 1953, he was engaged in missile recovery operations at the Cape and Grand Bahama Island and, from 1951 to 1953, he was with the Air Force Missile Test Center in range operations.

From 1946 to 1951, he was associated with Watson Laboratories, the former Air Force development laboratory, at Red Bank, N. J.

Mr. Doane received his B.S. degree in electrical engineering from the University of Tennessee.

Albert D. Emurian (A'42–M'44–SM'46) has joined Hoffman Laboratories Division of the Hoffman Electronics Corporation, as East Coast manager of Hoffman's phase of the Air Force's global communications complex, Air Com. This system, also known as Project 480L, is designed to improve and modernize the Air Force's global communications network. Contract for the system was awarded earlier this year to a four-company team headed by International Telephone & Telegraph Corp. as senior member, and including RCA, Hughes Aircraft Co., and Hoffman as team members.

Mr. Emurian was previously engineering manager, Data Transmission Systems, Government & Industrial Division, Philco Corporation, where he managed the overall engineering program for the Spread Eagle data transmission system. During his 17 years with Philco he also participated in that company's activities in TACAN, drone reconnaissance systems, Dew Line, and the Tall Tom electronic reconnaissance system. For several years he was employed at the U. S. Army Signal Corps Engineering Laboratories, Ft. Monmouth, N. J., serving as senior staff engi-

(Continued on page 40A)

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Low in cost...

easiest to program and operate...

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Optimizes electronic component and system design

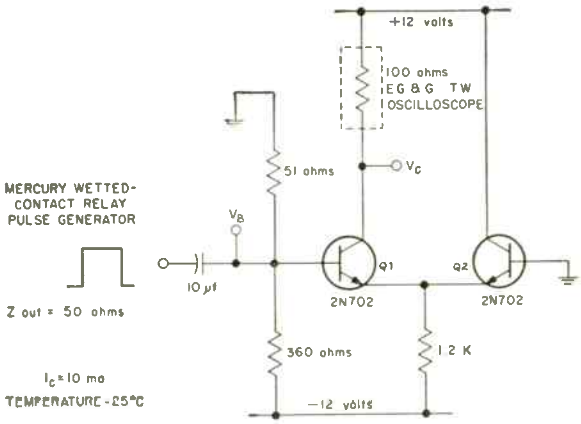
Operating from any convenient wall outlet, the LGP-30 is used right at your desk . . . helps you increase your productivity by taking the tedium out of detailed mathematical analyses. Facilitating the optimum design of electronic tubes and circuitry, servo systems, radar and antennae–the LGP-30 also serves as an important Research and Development tool in magnetic field applications, microwave and semi-conductor studies.

Because you operate the LGP-30 yourself, there's no waiting in line for the answers you need. Solutions are printed out in any desired alphanumeric format – require no deciphering. Result: you optimize designs faster and easier . . . free yourself for other important creative work.

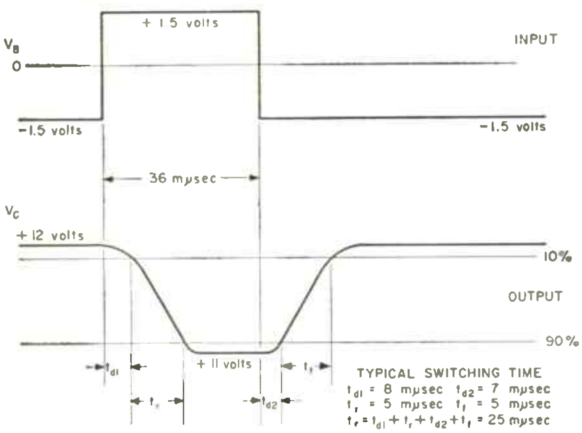
The lowest-priced complete computer your company can buy, the LGP-30 gives you memory (4096 words) and capacity comparable to computers many times its size and cost – yet it is by far the easiest to program in basic machine language. No expensive installation or air-conditioning is required. Auxiliary high-speed input-output equipment is available for system expansion.

Backed by 20 years of electronics experience, LGP-30 sales and service are available through Royal McBee offices coast-to-coast. Customer training is free. An extensive library of programs and sub-routines is available–as well as membership in an active users organization. For further information and specifications, write Royal McBee Corporation, Data Processing Division, Port Chester, N. Y. In Canada: The McBee Company, Ltd., 179 Bartley Drive, Toronto 16.

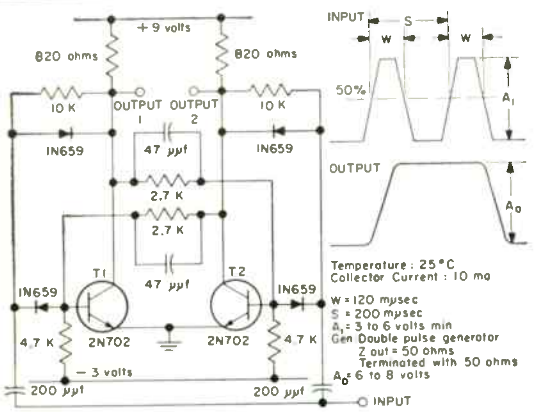
· data processing division



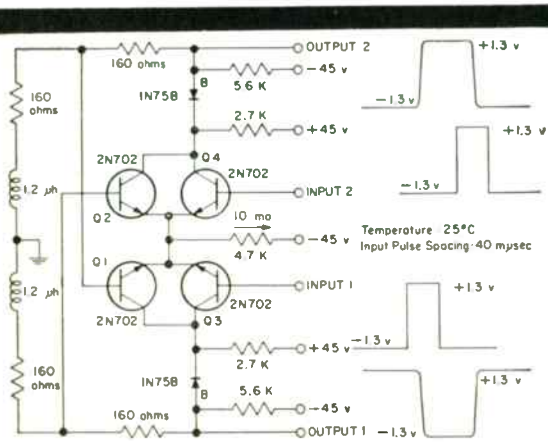
TYPICAL NON-SATURATED LOGIC SWITCHING CIRCUIT



TOTAL SWITCHING TIME NON-SATURATED CIRCUIT



TYPICAL CIRCUITRY FOR OBTAINING 5-MC REP RATE IN SATURATED FLIP-FLOP



TYPICAL CIRCUITRY FOR OBTAINING 25-MC REP RATE IN NON-SATURATED FLIP-FLOP

NEW SILICON

TO-18 PACKAGED DIFFUSED-BASE 'MESA' TRANSISTORS

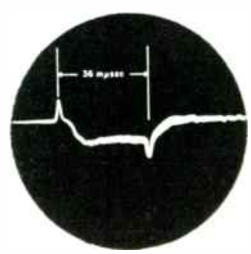
ACTUAL SIZE

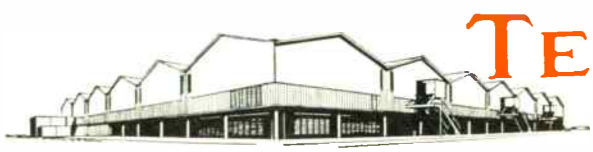
Now available for your evaluation, the subminiature 2N702 is built specifically for your 5-20 ma transistor logic switching applications.

This newest addition to TI's line of diffused-base 'mesa' transistors features . . .

- **Guaranteed dc beta of 15 to 45**
- **50 mc minimum unity beta frequency (f_t)**
- **Maximum 12 μμf output capacitance**
- **Subminiature TO-18 package**

As do all other TI semiconductors, the 2N702 carries a *full-year guarantee* to published specifications. Check the specs at right and contact your nearest authorized TI distributor or your TI sales office for detailed information.



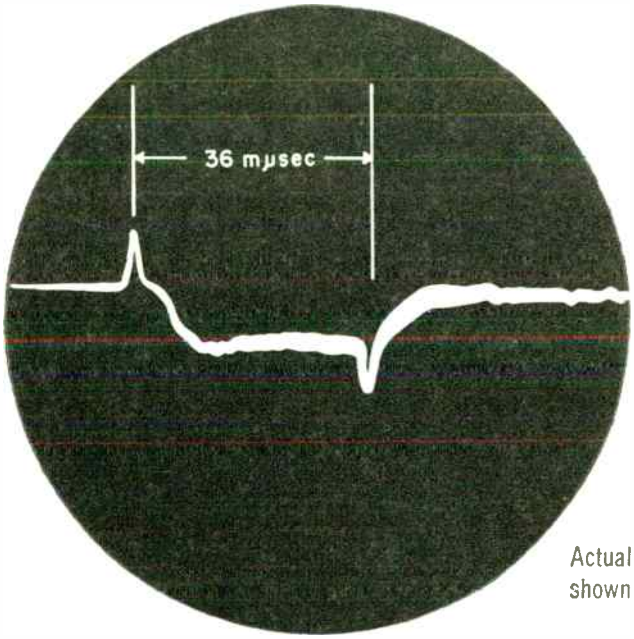


TEXAS

FROM THE WORLD'S LARGEST SEMICONDUCTOR PLANT

25 mμsec

SWITCHERS FROM TI



Actual photo of collector wave form as shown on traveling-wave oscilloscope

absolute maximum ratings (25°C)

Collector Voltage Referred to Base	20 v
Collector Voltage Referred to Emitter	15 v
Emitter Voltage Referred to Base	5 v
Collector Current	50 ma
Dissipation (100°C Free Air, Derate 0.5°C/mw)	150 mw

design characteristics at 25°C (except as indicated)

Symbol	Characteristic	Test Conditions	Min	Typ	Max	Unit
I_{CBO}	Collector Cutoff Current	$V_{CB} = 10$ v, $I_E = 0$			0.5	μa
I_{CBO}	" " " @ 150°C	$V_{CB} = 10$ v, $I_E = 0$			50	μa
BV_{CBO}	Breakdown Voltage	$I_{CBO} = 10$ μa, $I_E = 0$	20			v
BV_{CEO}	Breakdown Voltage	$I_{CEO} = 10$ μa, $I_B = 0$	15			v
BV_{EBO}	Breakdown Voltage	$I_E = 10$ μa, $I_C = 0$	5			v
h_{FE}*	DC Beta	$V_{CE} = 5$ v, $I_C = 10$ ma	15		45	
V_{BE}*	Input Voltage	$V_{CE} = 5$ v, $I_C = 10$ ma	0.7		1.2	v
C_{ob}	Output Capacitance	$V_{CB} = 5$ v, $I_E = 0$, f = 1 mc		7	12	μμf
f_T	Frequency at which h_{fe} is unity	$V_{CE} = 5$ v, $I_E = 10$ ma	50	100		mc
V_{CE} (Sat*)	Saturation Voltage	$I_C = 10$ ma, $I_B = 2$ ma			0.6	v

* Tested using pulse measurement.

NOTE: These units meet JEDEC outline TO-18 dimensions.

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Write on your company letterhead describing your application for specific details on TI products.

IRE People

(Continued from page [illegible])

neer, and also was assigned as chief of the Weather Radar Section, Evans Signal Laboratory.

Mr. Emurian, a graduate of the University of Pennsylvania, has had several papers published on meteorological electronics and color TV studio equipment, and holds four patents on radiosonde transmitters, weather radar and air navigation devices.

❖

Dr. James B. Fisk (SM'52–F'55), president of Bell Telephone Laboratories, received the honorary degree of Doctor of Science on Thursday evening, June 4, at the 43rd commencement exercises of Newark College of Engineering. He is the ninth person to have received the degree since the college first granted honorary doctorates in 1919.

A native of West Warwick, R. I., Dr. Fisk attended local public schools before entering Massachusetts Institute of Technology, where he received his B.S. degree in 1931, and his Ph.D. in 1935.

From 1932 to 1934 he was a Proctor traveling fellow at Cambridge University (England), and from 1936 to 1938 was a junior fellow in the Society of Fellows at Harvard University. He also served during this period as associate professor of Physics at the University of North Carolina.

Dr. Fisk joined the technical staff of Bell Laboratories in 1939. During World War II he headed the group at Bell Laboratories developing microwave magnetrons for high-frequency radar. After the war he was appointed to the Laboratories' work in electronics and solid-state physics.

He was director of the Division of Research of the Atomic Energy Commission, from 1947 to 1948, and Gordon McKay Professor of Applied Physics at Harvard University from 1948 to 1949. He also served for six years on the AEC's General Advisory Committee.

In 1949 when he returned to the Laboratories from the Atomic Energy Commission and Harvard, he was placed in charge of research in the physical sciences. He became vice-president in charge of research in March, 1954, executive vice-president in June, 1955, and president of the Laboratories in January, 1959.

In the summer of 1958, Dr. Fisk served as chairman of the Western delegation at the Geneva Conference to study the possibility of detecting violations of a possible agreement on the suspension of nuclear tests.

In addition to the NCE degree, Dr. Fisk holds honorary doctorates from Carnegie Institute of Technology (1956) and Williams College (1958). He is a member of the National Academy of Sciences, a fellow of the American Physical Society, and the American Academy of Arts and Sciences. He was formerly a senior fellow of the Society of Fellows at Harvard, and is a member of a number of other scientific and professional groups.

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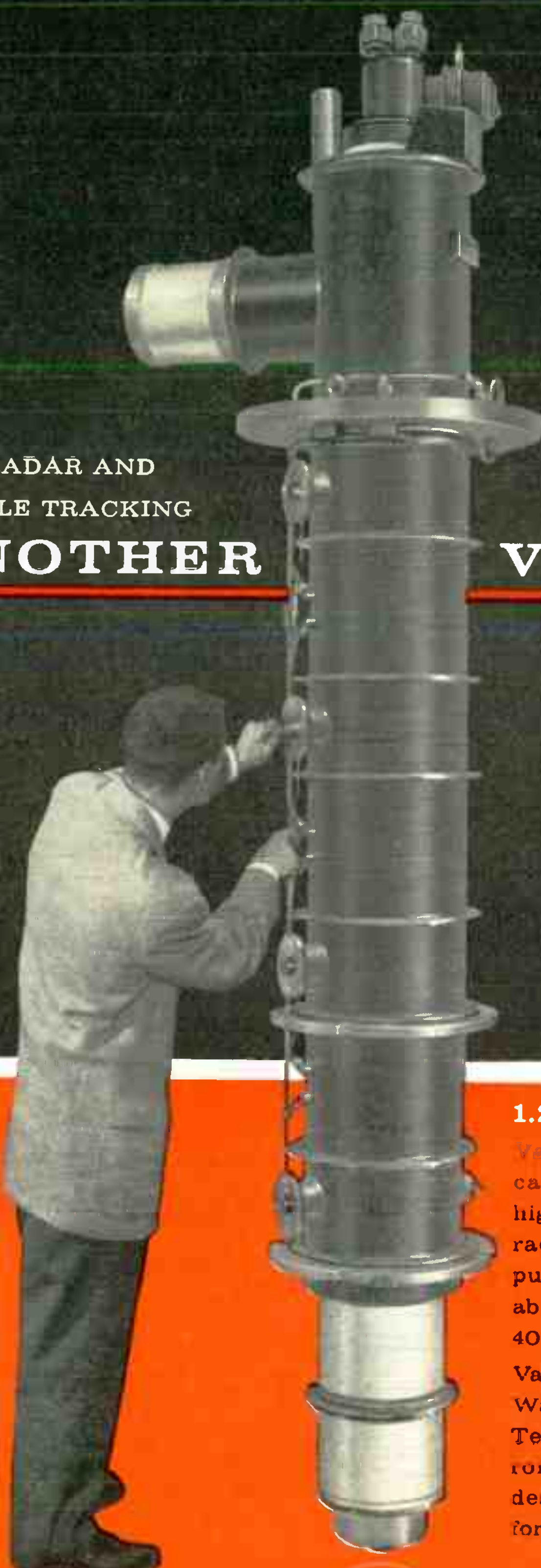

FOR RADAR AND
MISSILE TRACKING

ANOTHER VARIAN FIRST

INTERNAL CAVITY PULSE AMPLIFIER KLYSTRON with 75 KILOWATTS average output

- RUGGED
- NON CRITICAL
- HIGH PERFORMANCE
- SINGLE PUSH-BUTTON OPERATION

1.25 MEGAWATTS PEAK POWER

Varian's VA-842 is the world's largest internal cavity Klystron. It produces the tremendously high average power of 75 kilowatts for long pulse radar and missile tracking. Features include a pulse duration time of 2000 microseconds, tunable frequency range of 400 to 450 megacycles, 40 db stable RF power gain.

Varian makes a wide variety of Klystrons and Wave Tubes for use in Radar, Communications, Test and Instrumentation, and for Severe Environmental Service Applications. Over 100 are described and pictured in our new catalog. Write for your copy—address Tube Division.

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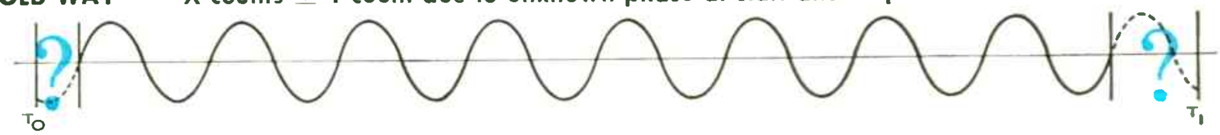
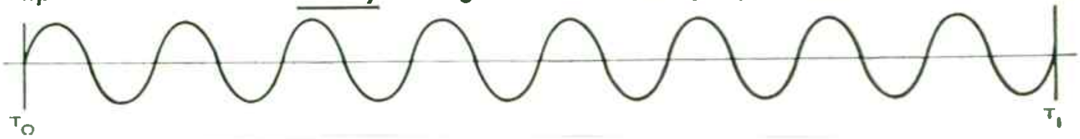
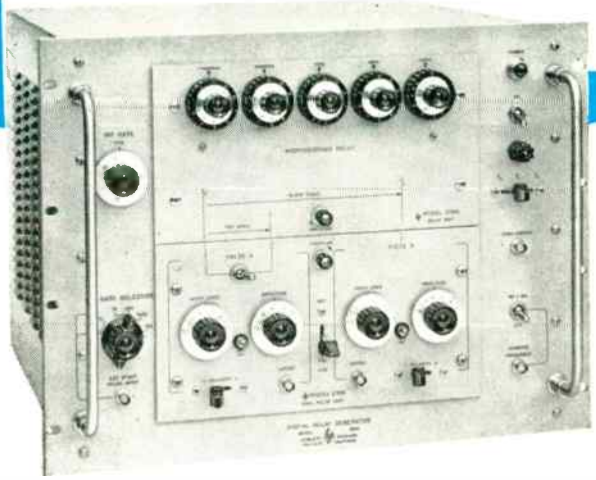
± 1 COUNT AMBIGUITY ELIMINATED!

OLD WAY X counts ± 1 count due to unknown phase at start and stop.



NEW -*hp*- 218A X counts exactly—timing wave starts with sync pulse and only full cycles counted!





New ease, for precision

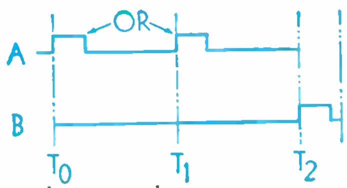
Time measurement and pulse simulation in radar, loran, Tacan, DME, oscilloscopes, computers, fast gates, pulse code systems —almost any fast circuit double pulse measurement with any kind of delay may now be made quickly and accurately with the new -*hp*- 218A Digital Delay Generator.

Constructed along rigid military standards, the -*hp*- 218A is basically a pulsed crystal oscillator synchronizable *in constant phase* with an initial trigger pulse (zero time) and two positionable terminating pulses. Time is counted with a 1 MC preset counter, and two independent output pulses (T_1 and T_2) are available in any relationship. For utmost present and future versatility, output pulses are generated through -*hp*- 219A series plug-in units.

Model 218A is a direct slave to an external trigger, 0 cps to 10 KC, or may be triggered internally over a 10 cps to 10 KC range. A push-button manual trigger is also provided. The two delay pulses are *separately and digitally adjustable* from 1 to 10,000 μsec with interpolation 0 to 1 μsec. Timing accuracy is ± 0.1 μsec ± 0.001%; time interval and pulse characteristics are directly selected on front panel controls.

Brief specifications appear alongside; for complete details see your -*hp*- representative or write direct. Also request -*hp*- Journal, Vol. 9, No. 8.

-hp- 219A Dual Trigger Unit contains two blocking oscillators supplying positive polarity trigger pulses to control auxiliary equipment. Pulse A available at T_0 or T_1; pulse B at T_2. Pulse characteristics identical to sync output pulse of -*hp*- 218A. (See "Specifications") $100.00.



-hp- 219B Dual Pulse Unit contains two pulse generators providing digitally delayed, fast rise time, high power pulses. Positive or negative polarity, amplitude variable 0 to 50 v, pulse width variable 0.2 to 5 μsec, rise time 0.06 μsec. Pulse A available at T_0 to T_1, pulse B at T_2. Internal impedance is 50 ohms. $450.00.

hp offers the world's most complete

This new -hp- 218A Digital Delay Generator produces pulses accurately spaced in time, with spacing controlled by a crystal oscillator. The 218A is a perfect slave to any beginning or synchronizing pulse, even though random, and locks in constant phase during each counting period.

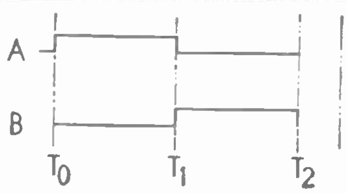
speed and 0.1 μsec accuracy time measurements

SPECIFICATIONS

-hp- 218A DIGITAL DELAY GENERATOR
(Plug-in necessary to operate)

Time Interval Range: 1 to 10,000 μsec, T_0 to T_1 and T_1 to T_2. Accuracy: ± 0.1 μsec ± 0.001% of time interval selected.
Digital Adjustment: 1 μsec steps, 1 to 10,000 μsec.
Interpolation: Continuously variable, 0 to 1 μsec.
Input Trigger: *Internal,* 10 cps to 10 KC, 3 decade ranges. *External,* 0 to 10 KC. Pos. or neg. pulses 2 to 40 v peak. Delay between external trigger and T_0 is 0.25 μsec ± 0.05 μsec.
Jitter: 0.02 μsec or less.
Recovery Time: 50 μsec or 10% of selected interval, whichever is larger.
Sync Output: 50 v pos. pulse, 0.1 μsec rise time (from 50 ohm source). Available at T_0, T_1 or T_2.
1 MC Output: 2 volt 1 MC pulses (from 500 ohm source) available at panel connector when counting on internal 1 MC oscillator.
Power: 115/230 v ± 10%, 50/60 cps, 525 watts.
Size: 14" high, 19" wide, 24" deep. Weight 75 lbs.
Price: *-hp-* 218A (cabinet) or *-hp-* 218AR (rack mount), $2,000.00.

Data subject to change without notice. Prices f.o.b. factory.



***-hp-* 219C Digital Pulse Duration Unit** produces a high power pulse with digitally controlled delay and duration. Pulse duration either T_0 to T_1, or T_1 to T_2. Both polarities available simultaneously; amplitude variable 0 to 20 v (from 90 ohms impedance) or 100 v (from 500 ohms). Rise or decay time 0.03 μsec (90 ohms). $350.00.

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Cable "HEWPACK" • DAvenport 5-4451
Field representatives in all principal areas

selection of precision electronic counters

IRE People

(Continued from page 40A)

In conferring the degree, Dr. Edward F. Weston, chairman of the NCE Board of Trustees, cited Dr. Fisk as a physicist, industrial leader, and government adviser, saying that "Newark College of Engineering is honored to bestow upon you, inspirer of others, esteemed scientist and citizen, the degree of Doctor of Science."

❖

At commencement exercises in Greenville, South Carolina, the honorary degree of Doctor of Laws was awarded by Furman University to **Dr. Thomas T. Goldsmith, Jr.** (A'38–SM'46–F'49), vice-president for research and engineering at Allen B. Du Mont Laboratories, Inc.

The citation conferring the degree termed Dr. Goldsmith "an unselfish, tireless research specialist and a noted inventor, who is making his life work an experience of joyous adventure for himself and a source of pleasure and benefit to mankind."

Dr. Goldsmith has been associated with Du Mont Laboratories since 1936. Considered one of the country's leading electronic scientists, he has been responsible for direction of the company's research and development programs in the fields of cathode-ray tubes, television systems, broadcasting apparatus, oscilloscopes and other scientific instruments, medical, industrial, and military electronics.

In addition to his position as vice-president at Du Mont Laboratories, Dr. Goldsmith is a member of the Board of Directors and is president of Du Mont Television and Electronics, Ltd., of Canada.

A graduate of Furman University, he received his Ph.D. from Cornell. He is a fellow of the Institute of Radio Engineers and the Society of Motion Picture and Television Engineers, and is a member of numerous other professional associations and societies. Dr. Goldsmith holds a number of U. S. patents.

❖

Gibson Electric Company, electrical contacts manufacturers, has named **Childress B. Gwyn, Jr.** (SM'57) as special projects engineer. He will be responsible for technical liaison with engineering, manufacturing, and sales at the company's home plant in Delmont, Pa.

Prior to joining Gibson, Mr. Gwyn was a product specialist and technical advisor with the General Plate Division of Metals and Controls Corp. in Attleboro, Mass. He also held engineering and management positions with H. A. Wilson Co., Union, N. J.; Fansteel Metallurgical Corp., North Chicago, Ill.; and P. R. Mallory & Co., Indianapolis, Ind.

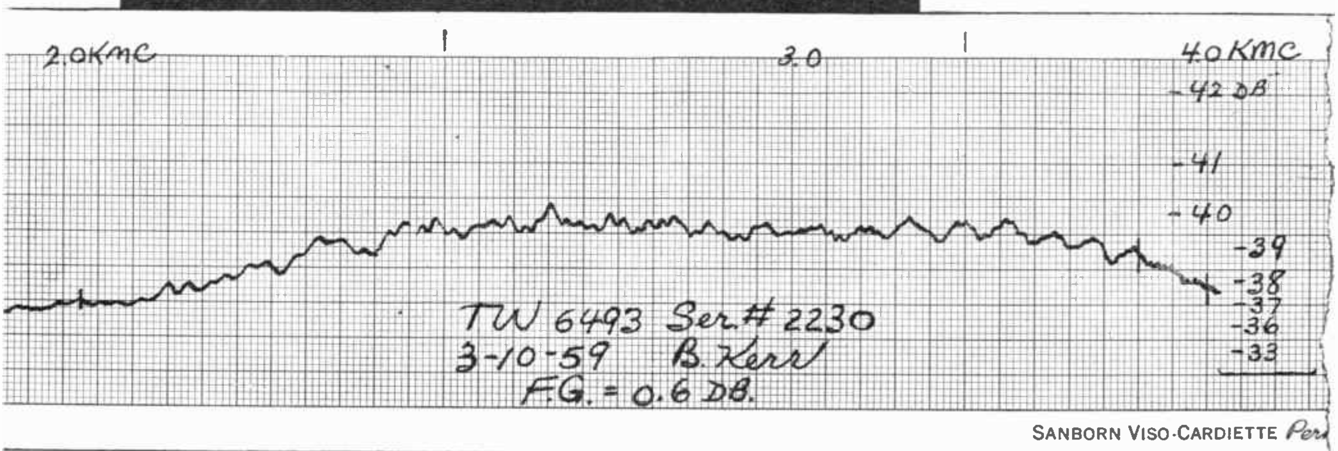
A member of the American Institute of Electrical Engineers, he is the holder of over 40 patents.

❖

(Continued on page 48A)

Microwave Component News
from SYLVANIA

Now available—a wide range of traveling wave tubes



▲

Actual strip chart recording of test on a production tube shows the uniform gain characteristics of this Sylvania tube over the 2.0 KMC to 4.0 KMC spectrum

ONLY SYLVANIA CAN OFFER YOU

AVAILABILITY— now in production, 16 types of traveling wave tubes covering the microwave spectrum from 1 to 11 kmc, and milliwatts to kilowatts. Backward wave oscillators are also available. Modifications and new designs for your special requirements are part of Sylvania's service.

HIGHEST GAIN—Sylvania's traveling wave tubes deliver 2 to 5 times the gain of competitive types. For example, TW-4002 delivers a minimum gain of 37 db over its full 2 to 4 kmc band.

GUARANTEED UNIFORMITY— Sylvania guarantees gain variations one-half those of other tubes; i.e. 2 to 3 db narrower limits. Other test limits are correspondingly more rigid.

PROVEN RUGGED DEPENDABILITY— Sylvania traveling wave tubes have proved their performance by meeting tough military standards and by being specified and used in modern supersonic aircraft.

For more information
write your nearest Sylvania tube sales office or
Sylvania Electric Products Inc.,
Special Tube Operations,
500 Evelyn Ave., Mountain View, Calif.

SYLVANIA
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

IRE People

(Continued from page 11A)

In a recent re-alignment of executive responsibilities at the Burroughs Corporation Research Center, **John H. Howard** (SM'50), manager of the research and development division, has been appointed manager of the Paoli, Pa. laboratory. He will be responsible for line technical management of research and development programs assigned to that laboratory with prime responsibility in the commercial product areas.

J. H. Howard

Mr. Howard, a graduate of both Kansas State University and Massachusetts Institute of Technology, joined Burroughs in 1950 as a senior research engineer. He has since served as associate director at the center, manager of the development division, and manager of engineering services.

A U. S. Navy veteran, Mr. Howard is a member of Sigma Xi, the American Institute of Electrical Engineers, and the Main Line Chamber of Commerce.

❖

The appointment of **David Y. Keim** (A'36–VA'39–M'55) as chief engineer of military products of the Electronics Division of Stromberg-Carlson has been announced.

Mr. Keim previously served as engineering department head for Microwave and Electronic Equipment for the Sperry Gyroscope Company. He was responsible for planning and managing projects for the development and production of checkout equipment for weapons systems. He also directed advanced research work in ferrites, microwave spectrometers and special microwave circuits. Before joining Sperry Mr. Keim was employed by Sylvania Products Company.

Mr. Keim received his B.S.E.E. degree from Pennsylvania State University in 1936. He is a member of the American Institute of Electrical Engineers, and American Ordnance Association, and is a former member of the Joint IRE-AIEE Committee on High Frequency Measurements. He has written a number of articles and technical papers on weapons support equipment and related subjects.

❖

Dr. Herbert Kroemer (M'56), from Hamburg, Germany, has joined the Central Research team organized by Varian Associates in Palo Alto, Calif. He brings to his job of senior research scientist for Varian, nine years experience in the semiconductor field both in the United States and abroad.

He received his "diploma" in physics as well as his Ph.D. degree from the Uni-

(Continued on page 50A)

.005 µsec. to 5,000 µsec.

ESC DELAY LINES TAKE GIANT STEPS!

From the smallest to the largest—.005 µsec. to 5,000 µsec.—ESC's research staff has custom-designed delay lines for virtually every military and commercial application! And with every delay line prototype comes a comprehensive laboratory report, which includes submitted electrical requirements, photo-oscillograms (which indicate input and output pulse shape and output rise-time), the test equipment used, and an evaluation of the electrical characteristics of the prototype.

In addition, an extensive factory rep organization spans the nation, ready to provide on-the-spot assistance in specification and installation.

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IRE People

(Continued from page 48A)

versity of Gottengen in Germany. After graduation, he spent several years as a research physicist in the semiconductor group at RCA Laboratories, Princeton, N. J. He returned to Hamburg in 1957 to head the semiconductor group of the German branch of Philips Laboratory.

Dr. Kroemer is a member of the Deutsche Physikalische Gesellschaft, the American Physical Society, and Sigma Xi. He is the author of more than a dozen published papers.

❖

Charles Kruse (S'50–A'52–M'57) has been appointed a supervisor of the California Technical Industries (CTI), Division of Textron, Inc. He will head development activity of microwave instrumentation, including radome and antenna testing systems.

Mr. Kruse has been with CTI for over six years, and as project engineer he has contributed greatly to the work that he will now supervise.

❖

The appointment of **Meyer Leifer** (A'46–M'48–SM'50–F'55) as general manager of Special Tube Operations for Sylvania Electronic Systems, a major division of Sylvania Electric Products Inc., has been announced.

Mr. Leifer, who formerly served as manager of this organization, will continue to make his headquarters in Mountain View. He is responsible for directing an expanding program of research, development and production in the microwave field. Included in his organization are production facilities at Williamsport, Pa., the Mountain View Component Laboratories and Mountain View Tube Plant.

He joined Sylvania in 1946 as an engineer in the Physics Laboratory in Bayside, N. Y., becoming manager of the systems and circuits branch in 1951. He was instrumental in establishing the Electronic Defense Laboratory, becoming engineering manager of the laboratory, and in 1956, assistant director. He was named manager of the Microwave Tube Laboratory in 1957 and manager of Special Tube Operations in 1958.

During World War II, he served as a physicist with the United States Navy, specializing in degaussing, a technique of treating ships electrically to protect them from magnetic mines. From 1944 to 1946 he served as a Naval officer in the Pacific Theater.

A graduate of Brooklyn College with a B.S. degree in mathematics, Mr. Leifer also holds a master's degree in physics from Columbia University and has completed all course requirements for a doctorate from New York University. He is past chairman of the IRE San Francisco Section. He is past president of the Sequoia branch of the Research Society of America, and is a member of the American Physical

(Continued on page 54A)

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GENERAL SALES MANAGER

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Over four years of development, design and improvement of manufacturing methods in the Sola labs and plant have finally resulted in two advances in the voltage regulating field:

> A new "standard" Sola Constant Voltage Transformer provides famous Sola $\pm 1\%$ regulation, along with SINUSOIDAL OUTPUT AT NO PRICE PREMIUM OVER OTHER MAKES OF STATIC-MAGNETIC REGULATORS.
>
> Many "normal-harmonic" types of the Sola CV have been REDUCED IN PRICE, thus opening to you the benefits of supply voltage regulation in new fields where cost has heretofore been a deterrent.

The new Sola Standard Sinusoidal Constant Voltage Transformer affords all the proved benefits of a static-magnetic regulator. It provides output voltage regulation of $\pm 1\%$ for line voltage variation as great as $\pm 15\%$. It provides completely automatic and continuous regulation, with output having less than 3% rms harmonic content.

In addition to the improved output wave form, the new design is substantially smaller and lighter than previous models. Because of design and production innovations, it is relatively compact compared to other equipment for comparable ac voltage regulation. It costs about the same as previous models which did not have sinusoidal output. This sine wave output feature at such a low cost permits use in many applications requiring harmonic-free input where previously the cost was prohibitive.

The sinusoidal output feature contributes to ease of selection and ordering. The buyer merely selects the stock unit whose output capacity equals or exceeds the desired equipment input. Formulae based on sinusoidal wave shape may be used in designing related load

... please turn page

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circuitry. The Sola Standard Sinusoidal CV Transformer is available in nine stock output ratings from 60va to 7500va.

The "Normal-Harmonic Type" -- the familiar "Sola CV" -- had become the "standard of the industry" for static-magnetic voltage regulation by virtue of its outstanding performance for over fifteen years. Now it, too, has been given a comprehensive re-design treatment which has yielded the same kind of weight and size reduction secured in the new sinusoidal type -- and without sacrificing the performance for which it was widely recognized.

Cost savings from this four-year program of refinement are NOW PASSED ON TO YOU in the form of appreciable price reductions on many of the most popular ratings. You can now consider the benefits of closely-regulated supply voltage for your equipment at less cost than ever.

With electrical control systems and components continuing to increase in number and complexity, and imposing more rigid reliability requirements, these new Sola Constant Voltage Transformers provide many advantages and virtually unlimited application. They are ideal where utmost reliability is required, with no transformer maintenance.

We would welcome the opportunity to provide you with more detailed information. Please write for Sola Product Bulletins for data on our stock models. Or write or call for full information on custom units for specific requirements, available in production quantities. Your request will be promptly handled.

Sincerely,

SOLA ELECTRIC CO.

Nelson P. Marshall

Nelson P. Marshall
General Sales Manager

IRE People

(Continued from page 50A)

Society, Pi Mu Epsilon, Sigma Pi Sigma, and Sigma Xi. His articles have appeared of the PROCEEDINGS of the IRE and in the *Sylvania Technologist.*

❖

Robert C. Sprague (SM'53), chairman of the board and treasurer of the Sprague Electric Co., North Adams, Mass., received an honorary doctor of science degree from the Lowell Technological Institute. The degree was presented at the annual commencement exercises by M. J. Lydon, president, who cited Mr. Sprague as "industrialist, leader, humanitarian. . . . Pioneer in the field of electronics, his has been a significant force in developing a challenging industry of incalculable size and importance. Dedicated to the advancement of his fellowman, he is the epitome of the American way of life."

As commencement speaker, Mr. Sprague termed this "the age of research" and projected some economic dimensions of 10 years hence: a fantastic 40-million population increase in a single decade; a doubling of our present annual rate of spending for new manufacturing plant and equipment; greatly increased manufacturing productivity and total output through automation and new techniques; the gross national product soaring from $469 billion to well over $700 billion, with comparable rises in wages, personal income and disposable income. He discussed the attendant problems which will be incurred with 1969's dramatic progress through research and advised that along with our material progress we must find a way of whetting the edge of the human conscience.

❖

Arthur B. Mayer (A'58) has joined Electra Manufacturing Company in Kansas City, Mo., as sales manager of the company's Capacitor Division. Mr. Mayer formerly was sales manager of the Condenser Research Corporation and prior to that was associated with the P. R. Mallory & Company organization. Altogether he has had 10 years direct experience in the capacitor field.

❖

Basil R. Myers (S'51–A'52–M'56–SM'58), assistant professor of electrical engineering in the Circuit Theory Research Group at the University of Illinois, Urbana, Ill., has been appointed professor and head of the dept. of electrical engineering at the University of Waterloo, Waterloo, Ontario, Canada, effective September 1, 1959.

B. R. MYERS

Dr. Myers has been at the University of Illinois since 1956, and was also there for the academic year 1950–51. He has been most recently engaged in active network synthesis research. From 1951 to 1956 he was with Bell Telephone Laboratories, Inc., Murray Hill, N. J., engaged in time-assignment speech interpolation studies and bandwidth compression techniques.

He did his undergraduate work at Oxford and Birmingham Universities in England, and graduate work at the University of Illinois, where he received the Ph.D. degree in electrical engineering in February, 1959.

He is a member of the British IEE, Tau Beta Pi, Eta Kappa Nu and Sigma Xi.

❖

Emo D. Porro (M'58) has been appointed vice-president of Broadview Research Corporation, and will be responsible for development and expansion of the organization's programs of research services to government and industry.

He was formerly executive vice-president and general manager of Thermo Materials, Inc., and before that for 10 years headed research activities in chemical and metallurgical engineering at Stanford Research Institute.

He began his professional career after graduation from the University of Cali-

(Continued on page 58A)

New Precision in Stereo Control

We have developed a new approach to a one-knob control for dual stereo amplifiers. It gives far greater precision of match and track than you may have thought possible. On typical systems we have developed control packages based on a db or voltage conception which deliver matching and tracking coinciding in volts throughout the useable range of the control.

This is equivalent to approximately 5% resistance match and track. In contrast, "standard" 20% tolerance controls when ganged may be 40% out of track between match points, while the matching and tracking of the Mallory units is tailored to the individual requirements.

We welcome the opportunity to discuss this new idea . . . to engineer a control package for your system . . . to develop new match and track specifications with you.

P.R. MALLORY & CO. Inc.

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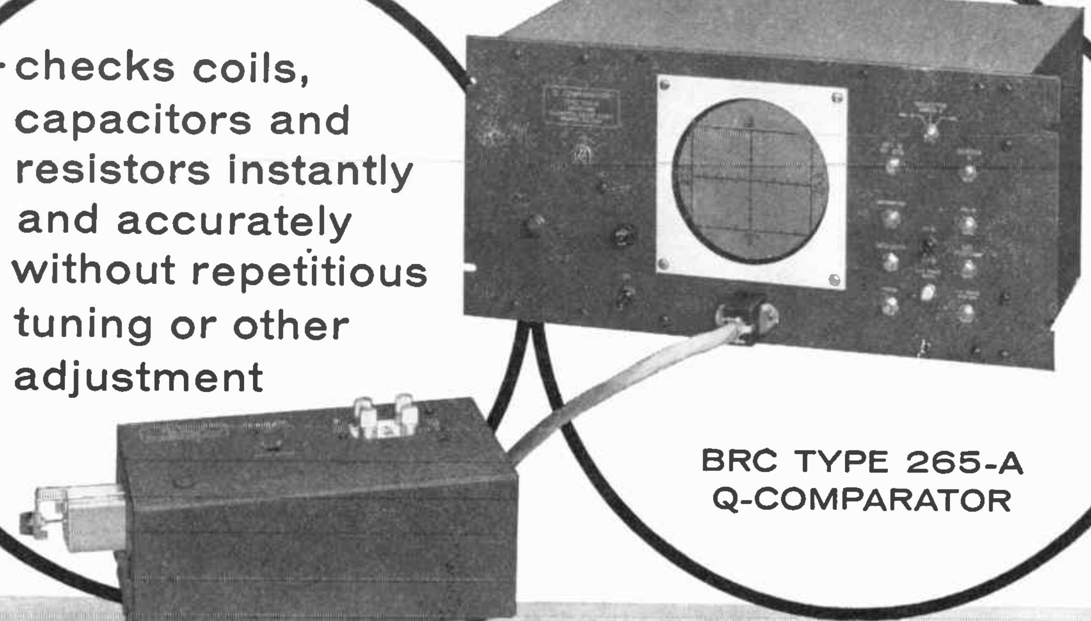
Mallory Controls Company
Frankfort, Indiana

The Perfect Answer to

High Production Q Testing

– checks coils, capacitors and resistors instantly and accurately without repetitious tuning or other adjustment



BRC TYPE 265-A
Q-COMPARATOR

- INSTANT SIMULTANEOUS CRT READOUT OF Q AND L-C
- READS DIRECTLY ON CRT IN % DEVIATION FROM STANDARD
- NO ADJUSTMENTS OR TUNING AFTER INITIAL SET-UP
- EXTREMELY RAPID, SIMPLE—MINIMUM OPERATOR TRAINING
- WIDE FREQUENCY RANGE—FROM 200KC TO 70MC

SPECIFICATIONS

Radio Frequency Characteristics
RF RANGE: 200KC to 70MC*
RF ACCURACY: to ±0.5% against external standard
*Through use of 8 Type 520-A Oscillator Inductors

Q Measurement Characteristics
Q-RANGE: 30 to 500
% Q-RANGE: ±25% of standard
% Q-ACCURACY: ±5% on 25% range
% Q-CALIBRATION: increments of 5%

L-C Measurement Characteristics
L RANGE: 0.15 μh to 15 mh*
C RANGE: 5 μμf to 0.01 μf*
R RANGE: 500 ohms to 20 Megohm*
*Actual range depends upon test frequency
% L-C RANGE: ±5% or ±20% of standard, full scale
% L-C ACCURACY: Direct reading to ±20% of % L-C range*
*For L between 1 μh and 15 mh and C between 500 μμf and 0.01 μf
Comparison to ±10% of limit standards*
*For L between 0.15 μh and 15 mh and C between 5 μμf and 0.01 μf
% L-C CALIBRATION:
1% increments on ± 5% range
5% increments on ±20% range

BRC Type 265-A Q-Comparator is a rapid, versatile and easy to use production tool. It provides instant CRT presentation of % Q on the calibrated vertical axis and % L-C on the calibrated horizontal axis. In operation the instrument is first calibrated against a known standard component. After initial calibration, production components are successively connected to the test terminals without further tuning or adjustment. The instantaneous readout on the CRT is in % deviation from the standard component. Except for initial set-up, practically no operator skill is required.

Price $795.00* F.O.B. Boonton, N. J. *Includes choice of any one (1) Type 520-A Oscillator Inductors. Additional Inductors available at $25.75 each.

Coil Number	Range Desig.	Frequency Range
520-A1	Range A	50-70 mc
520-A2	Range A	30-50 mc
520-A3	Range A	15-30 mc
520-A4	Range A	8-16 mc
520-A5	Range A Range B	4- 8 mc 2- 4 mc
520-A6	Range A Range B	1- 2 mc .55- 1 mc
520-A7	Range B	300-550 kc
520-A8	Range B	200-300 kc

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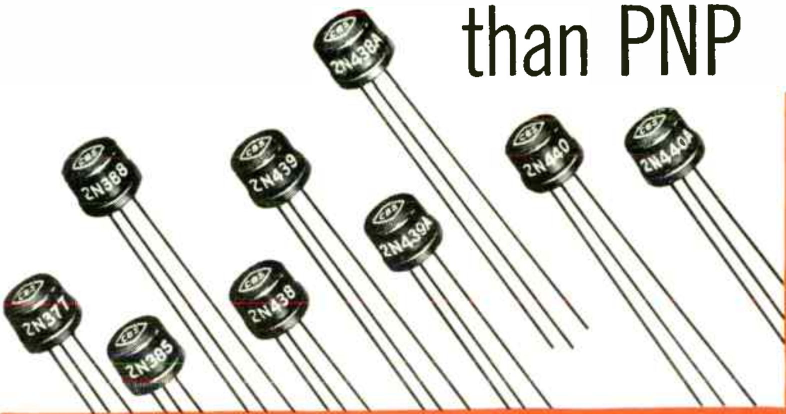
VISIT BOOTHS 1823-1825

25th ANNIVERSARY *Precision Electronic Instruments since 1934*

BOONTON RADIO CORPORATION

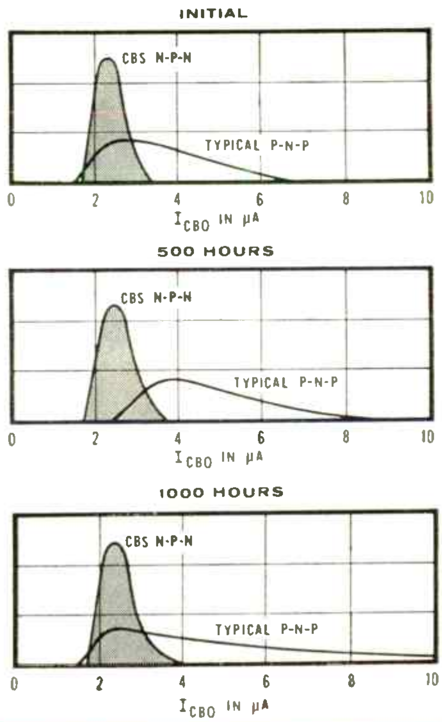
BOONTON, NEW JERSEY, U.S.A.

NPN switching transistors PROVE MORE RELIABLE than PNP



Some design engineers specify PNP switching transistors because they consider them inherently more reliable. Actually NPN transistors can give you superior reliability along with their well-known higher speed. Life tests covering hundreds of thousands of CBS NPN alloy-junction germanium switching transistors proved this during the past year. See graphs comparing these transistors with typical military-approved PNP transistors.

Comparative Life Tests
NPN vs. PNP Switching Transistors.



CBS NPN Switching Transistors

Type	Minimum BV_{CBO} (Volts)	Dissipation @ 25°C (Milliwatts)	Minimum h_{FE} @ I_c (Ma)		Typical $f_{\alpha b}$ (Megacycles)	Application
2N306	20	50	16*	1	1	Audio Driver
2N312	15	75	25	10	2	Switching
2N356	20	100	20	100	3	Core Driver
2N357	20	100	20	200	6	Core Driver
2N358	20	100	20	300	9	Core Driver
2N377	25	150	20	200	5	Core Driver
2N385	25	150	20	200	6	Core Driver
2N388	25	150	30	200	8	Core Driver
2N438	30	100	20	50	4	Logic Circuit
2N438A	30	150	20	50	4	Logic Circuit
2N439	30	100	30	50	8	Logic Circuit
2N439A	30	150	30	50	8	Logic Circuit
2N440	30	100	40	50	12	Logic Circuit
2N440A	30	150	40	50	12	Logic Circuit
2N444	15	100	10*	1	1	Switching
2N445	15	100	20*	1	3	Switching
2N446	15	100	30*	1	8	Switching
2N447	15	100	50*	1	10	Switching
2N556	25	100	15	10	1	Core Driver
2N558	15	100	20	10	3	Core Driver
2N634	20	150	15	200	8	Switching
2N635	20	150	25	200	12	Switching
2N636	20	150	35	200	17	Switching
2N1000	40	150	25	100	9	Core Driver
2N1012	40	150	40	100	5	Core Driver

*h_{fe} (a.c. gain)
Operating and storage temperature, $T_j = -65$ to $+85$°C

The superiority of CBS NPN transistors is achieved by special processing: For example, advanced surface chemistry techniques seal out moisture and contamination. Precise control of alloying produces high back voltages. Thorough bake-out stabilizes gain. The result is reliable NPN computer-type switching transistors featuring fast switching . . . high voltage . . . low cutoff current . . . and low saturation resistance . . . in a welded JETEC TO-9 package

A comprehensive line of these reliable CBS NPN high-speed switching transistors is available now in production quantities. Check the table. Order types you need . . . or write for Bulletin E-353 giving complete data . . . today.

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IRE People

(Continued from page 54A)

fornia at Berkeley with various industrial interests of Henry J. Kaiser. During World War II he served as a Naval officer in the South Pacific.

A registered professional engineer in the State of California, Mr. Porro holds a number of patents for metallurgical processes.

❖

John H. Rubel (A'44–M'55) has been appointed assistant director of research and engineering for strategic weapons of the Department of Defense. He has been granted a leave of absence to accept the government position from Hughes Aircraft Company where he has been director of airborne systems laboratories.

J. H. Rubel

An electrical engineering graduate of California Institute of Technology, Mr. Rubel has had 16 years' experience in the electronics industry. In 1946 he joined the Hughes company, where he contributed to work on automatic celestial navigation, the Falcon series of air-to-air guided missiles, and the airborne armament control systems used in U. S. Air Force all-weather jet interceptors.

He is the author of papers on video delay lines, a wide band spectrum analyzer, landing gear stability, and engineering management. He is a member of Tau Beta Pi and the American Society for Engineering Education.

❖

Sol Schneiderman (S'48–A'53–M'58) has been appointed manager of customer engineering of Adler Electronics, Inc., New Rochelle, N. Y. Prior to joining Adler, he was with Instruments For Industry, Inc. and Radio Receptor Company.

Mr. Schneiderman holds a B.S. degree in electrical engineering from Polytechnic Institute of Brooklyn and is a licensed professional engineer.

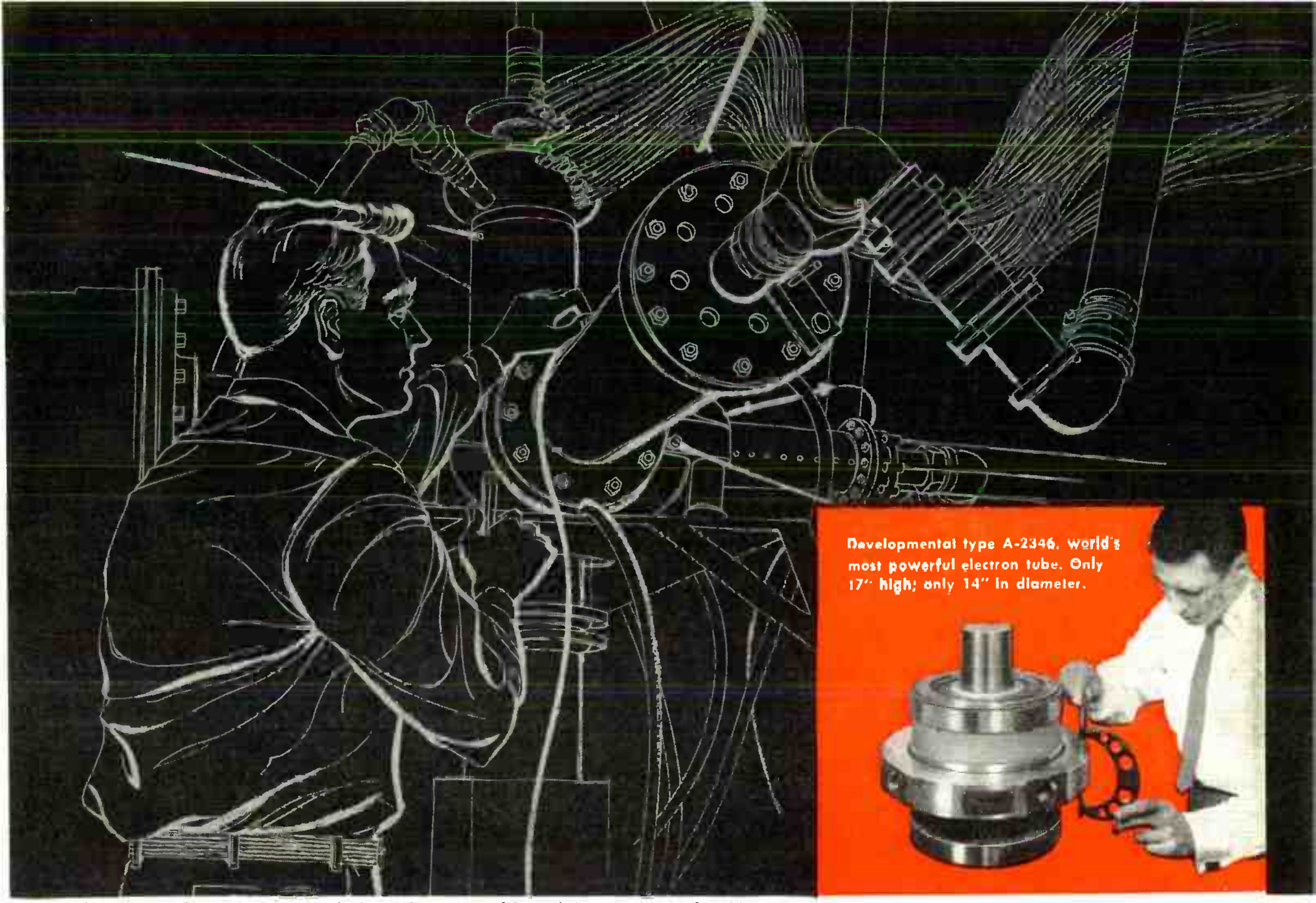
❖

Dr. Bernard R. Linden (A'25) in April, 1959 was appointed Assistant Manager of the Vacuum Tube Physics Department of the CBS Laboratories. Prior to joining CBS in 1958 he was manager of the Photosensitive Devices Engineering Department of the Allen B. DuMont Labs.

B. R. Linden

Dr. Linden is a graduate of Cornell University and received his masters and doctorate degrees from Ohio State University and later

(Continued on page 62A)



Adjusting an A-2346 Super-Power Tube in an rf power amplifier utilizing experimental cavities.

5 MEGAWATTS OF LONG-PULSE POWER

–at 450 Megacycles

Revolutionary new RCA developmental Super-Power Tube delivers tremendous RF Power with a pulse duration of 2000 microseconds and a duty factor of 0.06

Innovator in super-power tube development and manufacture for almost two decades, RCA takes another bold step into high-power rf generation with the new developmental type A-2346—*the most powerful UHF electron tube on earth.*

Here, within the geometry of a single tube no bigger than a nail keg, lies the potential ability to generate the rf power it takes for outer-space communications ...scatter transmission on a global scale...super-range radar and missile guidance ...industrial rf applications on a mass-production basis.

Developmental type A-2346 is just one among a number of RCA Super-Power types now available to research, industry, and the military. RCA Super-Power Tubes have been serving in major projects and are being incorporated in other major defense projects.

For more information on both commercial and developmental types of RCA Super-Power Tubes—and application assistance—talk to your RCA Field Representative.

Typical data on RCA Super-Power Tubes in plate-pulsed service

TYPE	USEFUL POWER OUTPUT (Kw)■	DUTY FACTOR	FREQ. (Mc)	MAX. FREQ. FOR FULL INPUT (Mc)	UPPER USEFUL FREQ. (Mc)‡
RCA-2041	300	0.003	450	600	1500
	250	0.05	250	600	1500
A-15049*	1100	0.003	500	1000	1250
	500	0.06	500	1000	1250
RCA-2039	1500	0.06	200	200	250
RCA-6952	2000	0.0018	425	600	1000
A-2344*	5000	0.003	1000	1000	1250
A-2349*	8000	0.003	200	200	250
A-2346*	10000	0.01	450	450	600
	5000	0.06	450	450	600
A-15025*	27500	0.003	425	600	600

*RCA Developmental Type ‡For Prototype Design
■At Peak of Pulse

Typical data on RCA Super-Power Tubes in hard-tube pulse-modulator service

TYPE	MAX. SWITCHED POWER (Kw)	DUTY FACTOR
A-15030*	22,000	0.05
A-15034*	11,000	0.05

*RCA Developmental Type

RADIO CORPORATION OF AMERICA
Electron Tube Division *Harrison, N. J.*

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AC

NEW!

-hp- 403A Transistor ac Voltmeter—1 cps to 1 MC

Battery-operated, weighing less than 5 pounds and small enough to hold in your hand—this new transistor ac voltmeter measures 100 μv to 300 v (max. full scale sensitivity 1 mv) over frequencies 1 cps to 1 MC! Twelve voltage ranges; also reads direct in db from —12 to +2 db. 400 hour battery life equals 6 months of average use; battery voltage may be checked by front panel switch. Noise less than 50 μv. Completely isolated from power line or ground interference. Average reading meter minimizes turnover and waveform errors. Accuracy $\pm$3% to 500 KC, $\pm$5% to 1 MC. Input impedance 2 megohms; generous 600 v overload capacity on higher ranges, 25 v maximum on lower ranges. $250.00.

All of these widely useful -hp- instruments are available in rack-mounted
-hp- voltmeter accessories—voltage dividers, coaxial connectors, voltage

DC

NEW!

-hp- 405AR Digital Voltmeter
Automatic range, polarity

Here's true "touch-and-read" measuring simplicity. Automatic range, polarity selection; covers 0.001 v to 1,000 v. (Accuracy $\pm$0.2% of reading $\pm$ 1 count). New, unique circuitry provides a stability of readings virtually eliminating fatiguing jitter in the last digit. Floating input, multi-electronic code output for use with digital recorders. Uses electronic computing circuits to insure low maintenance, trouble-free operation. Just 7" high! $825.00.

Complete array of ac and dc measuring equipment

versatile, precision OHMMETERS you need. multi-purpose!

(hp) 400D
10 cps to 4 MC

Regarded by many as finest ac VTVM ever built. Covers all frequencies 10 cps to 4 MC, extremely sensitive, wide range, accurate within 2% to 1 MC. Measures 0.1 mv to 300 v (max. full scale sensitivity 1 mv), 12 ranges. Direct reading in v, db. 10 megohm input impedance with 15 $\mu\mu f$ shunt insures negligible loading to circuits under test. $225.00.

(hp) 400L
Log VTVM—10 cps to 4 MC

Covering 10 cps to 4 MC, this new hp VTVM features a true logarithmic scale 5" long plus a 12 db linear scale. The log voltage scale plus long scale length provides a voltmeter of maximum readability, with accuracy a constant percentage of the reading. Accuracy is ±2% of reading or ±1% of full scale, whichever is more accurate, to 500 KC, ±5% full range. Range 0.3 mv to 300 v, 12 steps, (max. full scale sensitivity 1 mv). $325.00.

(hp) 400H
1% accuracy VTVM

Here's extreme accuracy of 1% in a precision VTVM covering 10 cps to 4 MC. Big 5" meter has exact-reading mirror-scale, measures voltages 0.1 mv to 300 v (max. full scale sensitivity 1 mv). 10 megohm resistance with 15 $\mu\mu f$ shunt minimizes circuit loading. Amplifier with 56 db feedback insures lasting stability. $325.00.

(hp) 410B
ac to 700 MC, also dc

Time-tested standard all-purpose voltmeter. Covers 20 cps to 700 MC, full scale readings 1 to 300 v. Input capacity 1.5 $\mu\mu f$, input resistance 10 megohms. Also serves as dc VTVM with 122 megohms input impedance, or ohmmeter for measurements 0.2 ohms to 500 megohms. $245.00.

models! Also, inquire about multipliers and shunt resistors.

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Cable "HEWPACK" • DAvenport 5-4451
Field representatives in all principal areas

NEW!

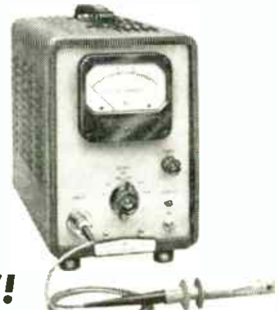
(hp) 412A Precision Volt-Ohm-Ammeter

At last a true, precision multi-purpose instrument. Measures dc voltage 100 μv to 1,000 v (max. full scale sensitivity 1 mv), 1% accuracy full scale. Measure currents 1 μa to 1 amp with ±2% accuracy full scale. 13 ranges. As ohmmeter measures 0.02 ohms to 5,000 megohms. Extremely low noise, drift. Recorder output provides 1 v full scale. $350.00.

NEW!

(hp) 425A Microvolt-Micromicroammeter

New, high sensitivity, high stability instrument reading end scale voltages of 10 μv to 1 v in 11 ranges, or currents of 10 $\mu\mu a$ to 3 ma in 18 step, 1-3-10 sequence. Accuracy ±3% on all ranges. Drift less than 2 μv under all conditions; very much less under lab conditions. Input impedance 1 megohm ±3% on all ranges. Also usable as 100 db amplifier with up to 1 v output from signals as small as 10 μv. $500.00.



NEW!

(hp) 428A Clip-On Milliammeter

Employs radical new approach to current measurement which eliminates breaking leads, soldering connections or loading of circuit under test. Revolutionary "current sensing" probe clips around wire under test, measures the magnetic field around the lead. Easily measures dc current in presence of strong ac. Covers 0.3 ma to 1 amp in 6 steps; full scale sensitivity 3 ma. Accuracy ±3%, probe inductance less than 0.5 μh. $475.00.

—unique value, traditional -hp- dependability

IRE People

(Continued from page 58A)

was the recipient of a Fulbright Fellowship at the University of Amsterdam.

He is a member of the American Physical Society, and serves on the IRE Committee on Camera Tubes and the EIA Committee on Photosensitive Devices.

❖

Dr. Earl L. Steele (A'55–SM'57), a physicist expert in semiconductor devices, has been appointed assistant manager of the development laboratory for the semiconductor division of Hughes Aircraft Company's Products Group.

Dr. Steele, formerly research chief for Motorola, Inc., is the author of many technical papers on diodes, transistors and rectifiers, and serves as editor of the IRE Transactions on Electron Devices.

He was graduated in 1945 from the University of Utah with the B.S. degree, and received his Ph.D. degree in physics from Cornell University in 1952. He is a member of the American Physical Society and Sigma Xi.

❖

On June 15, 1959, **Dr. Julius A. Stratton** (M'42–SM'43–F'45) was inaugurated as the eleventh president of the Massachusetts Institute of Technology.

Dr. Stratton had been acting president for thirteen months while his predecessor, Dr. James R. Killian, was serving as Special Assistant for Science and Technology to President Eisenhower.

Dr. Stratton holds the B.S. degree and the M.S. degree from Massachusetts Institute of Technology; the D.Sc. degree from Technische Hochschule; the D.Eng. (Honorary) degree from New York University; D.Sc. (Honorary) from St. Xavier University; and LL.D. (Honorary) from Northeastern University.

He has served as an IRE Director from 1948–1951 and in the year 1954. He has been a member of numerous Institute Committees, including Annual Review, Appointments, Board of Editors, Education, IRE-IEE International Liaison, Membership, Policy Development, Professional Groups, and Standards Committees. He was chairman of the Committee on Radio Wave Propagation and Utilization.

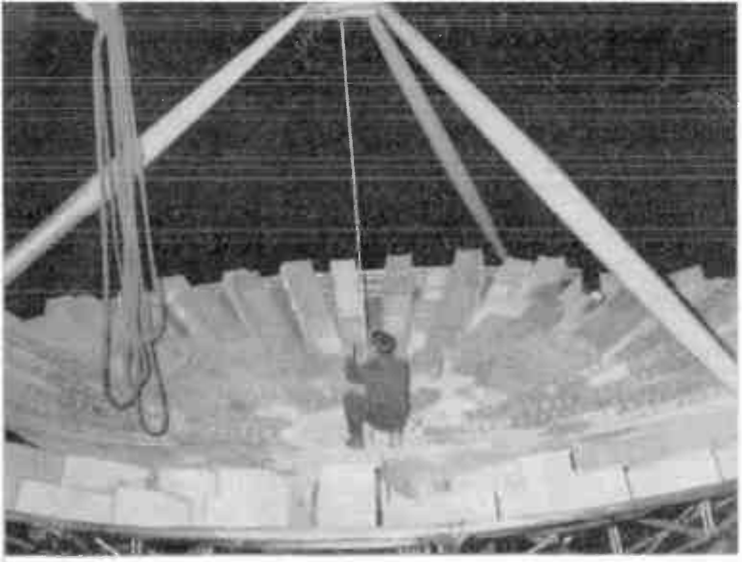
In 1946, Dr. Stratton was awarded the Presidential Medal for Merit. He was given the IRE Medal of Honor in 1957.

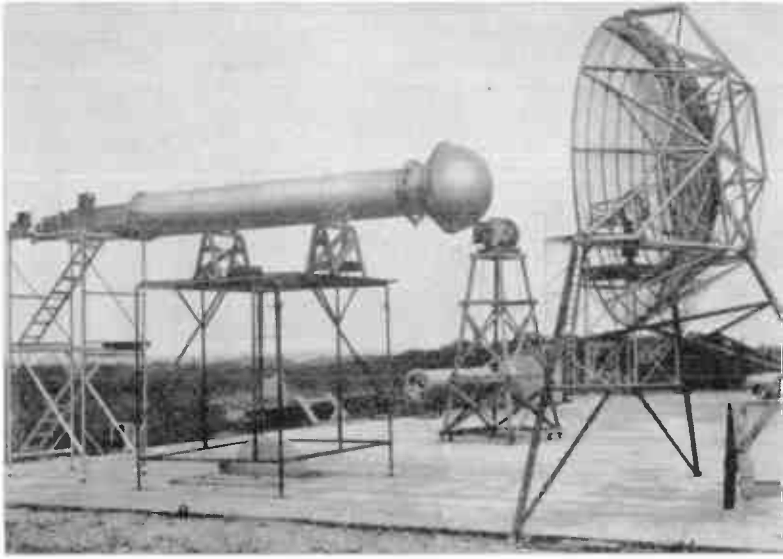
❖

Richard L. Taylor (A'56) has been advanced to staff engineer in the IBM Advanced Systems Development Division in Poughkeepsie, New York. He is a key member of a General Development group and is directly involved in the advanced development of analog to digital conversion equipment.

He joined the company in 1957 as an associate engineer in the Special Engineering Products Division where he made significant contributions to the development

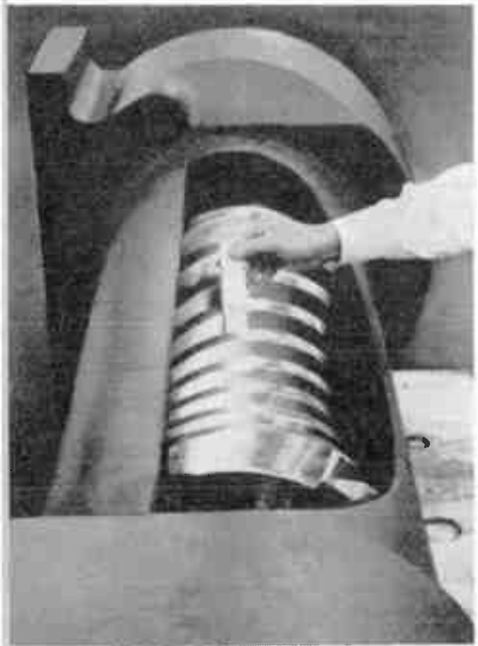
(Continued on page 66A)

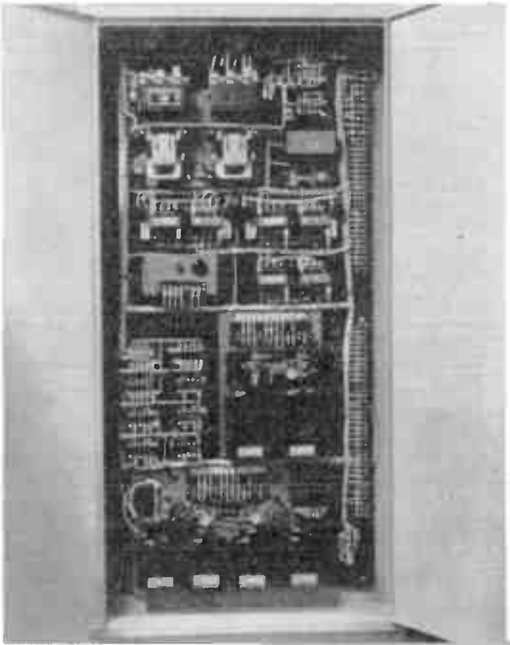




In antenna systems

KENNEDY capability is total capability





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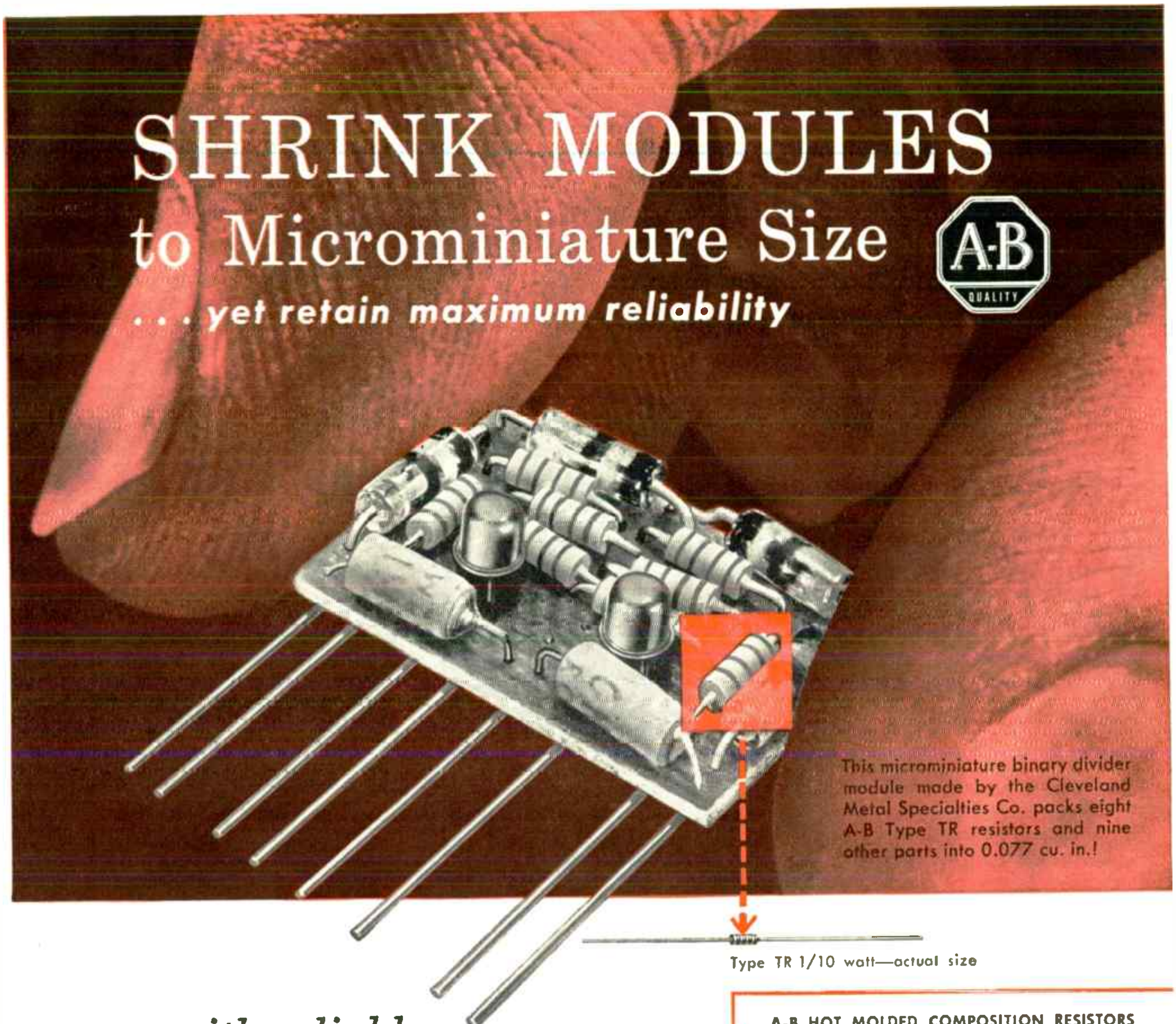

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. . . yet retain maximum reliability

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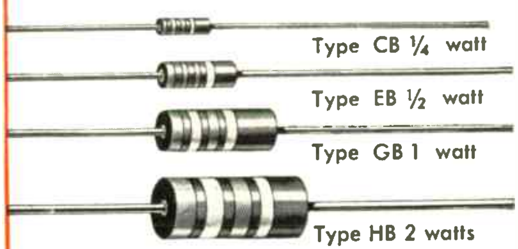
A-B HOT MOLDED COMPOSITION RESISTORS



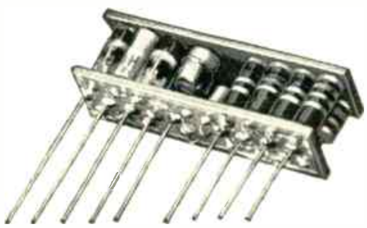
Type CB ¼ watt

Type EB ½ watt

Type GB 1 watt

Type HB 2 watts

Actual Size



This shows still another type module packaging which uses A-B Type CB ¼ watt composition resistors.

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(Continued from page 62A)

of the paper-to-magnetic tape converter.

Mr. Taylor graduated from the Massachusetts Institute of Technology with the B.S. and M.S. degrees in electrical engineering in 1955. He is a member of Eta Kappa Nu.

❖

H. C. Tittle (A'27–M'55) has been named general manager for divisional operations of Sylvania Electronic Systems Buffalo, N. Y. Operations.

Mr. Tittle has been connected with Sylvania for more than 20 years. He joined the Colonial Radio Corporation, a predecessor company of Sylvania, as chief engineer in 1935. In 1948, following Colonial's acquisition, he became chief engineer of the then Home Set Division, and two years later was assistant chief engineer for the then Radio and Television Division. In 1952, he became manager of the Boston, Mass. Engineering Labs., and in 1955 became manager of Buffalo Operations.

Born in Rapid City, S. Dak., he holds the B.S. and B.E.E. degrees from South Dakota State School of Mines and Technology.

He is a member of the Association of the U. S. Army and the Buffalo Chamber of Commerce.

❖

The appointment of **Dr. J. Earl Thomas, Jr.** (SM'53), eminent solid-state physicist, to the newly created post of director of research and engineering for the Semiconductor Division of Sylvania Electric Products Inc. has been announced.

Dr. Thomas joined the Sylvania organization on an advisory basis in January, completing the academic year at Wayne State University, Detroit, where he headed the Physics Dept. In his new assignment he will be responsible for all of the Division's product research and engineering activities.

Dr. Thomas, who served as assistant professor of electrical engineering at Massachusetts Institute of Technology from 1947 to 1955, has lectured extensively on transistor physics and semiconductor applications. His published works include articles on the physical phenomena affecting semiconductor reliability, point-contact transistors, magnetic microwave oscillators, and nuclear particle accelerators.

During World War II, Dr. Thomas headed a group of military and civilian engineers at the California Institute of Technology in Pasadena, Calif., in a project designed to test the effect of rockets on various types of targets. He was also a group leader at the Atomic Energy Project in Los Alamos, New Mexico.

From 1948 to 1950, while at M.I.T., he acted as a consultant to Sylvania in the solid-state field. Dr. Thomas participated in the development of one of the world's first hermetically sealed semiconductor devices, a glass-encased crystal diode, introduced by Sylvania in 1949. He later served as a member of the technical staff of Bell Telephone Laboratories.

(Continued on page 72A)

10 Mc COUNTER

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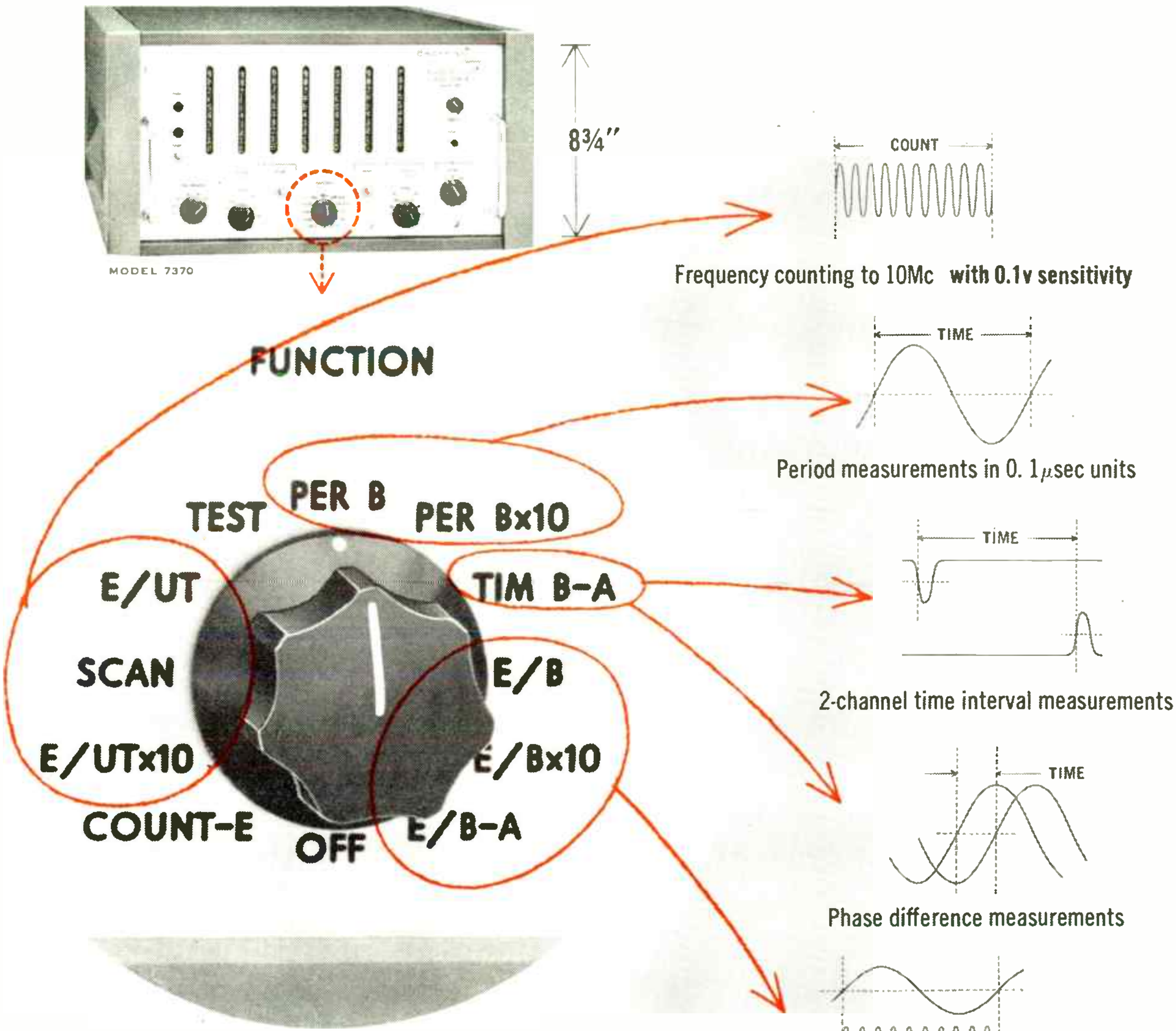
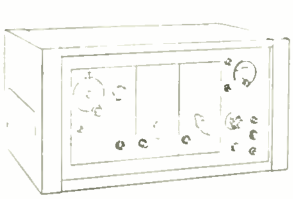
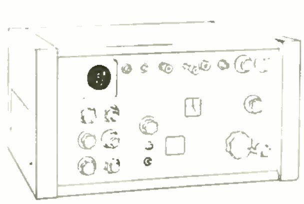




Add this heterodyne unit (Model 7570 Series) to measure frequencies up to 1000Mc.



Or add this computing transfer oscillator (Model 7580) to get a counter display of frequencies up to 15,000Mc.

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I_{co} (V_{ec} 2 volts) Typical 25°C.	65	65	65	65	65 μa.
HFE (3 amp.)	–	60-150	30-75	30-75	–
HFE (5 amp.)	–	–	–	–	20-50
AC Power Gain (I_c = 0.6 amp.)	37 DB	–	–	–	–
V_{ceo} (I_c = 1 amp.)	40 typical	50 typical	60 min.	60 min.	60 volts min.
Thermal Gradient max.	1.5	1.5	1.2	1.2	1.2° c/w

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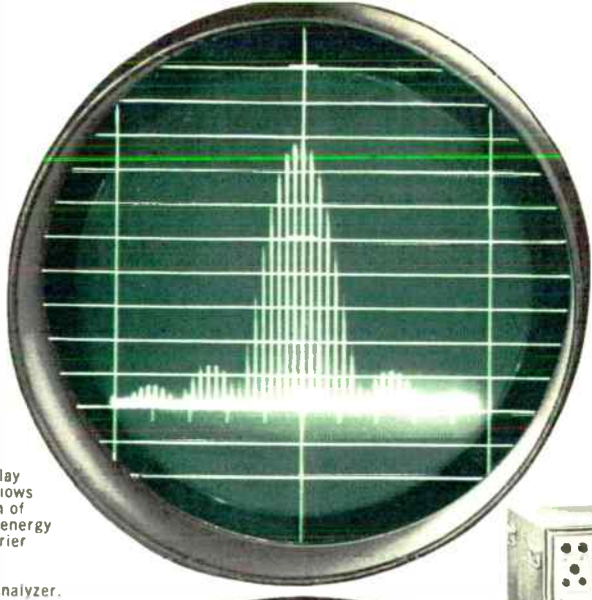
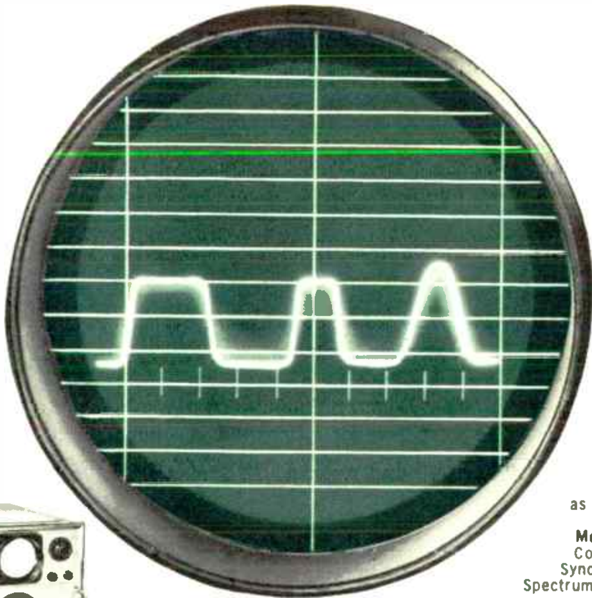
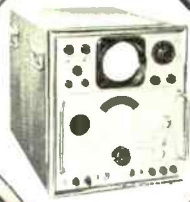
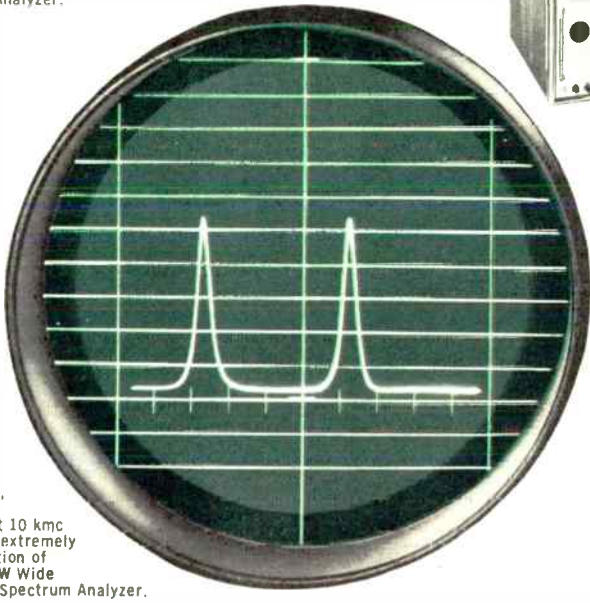


Visual display instantly shows distribution of microwave energy around carrier frequency. **Model TSA** Spectrum Analyzer.

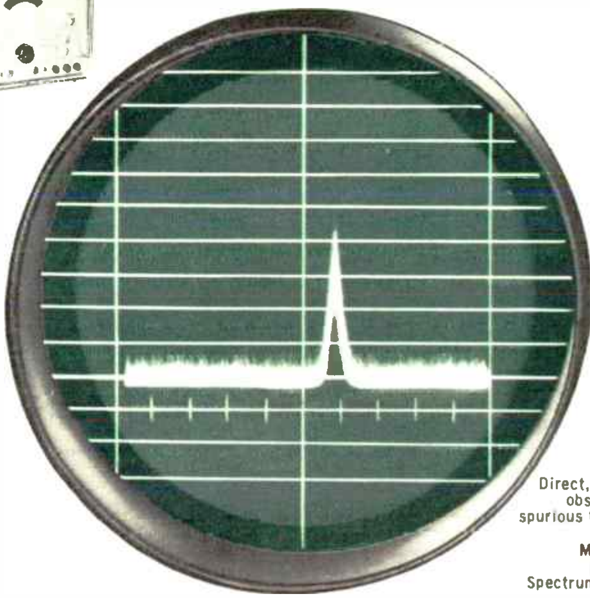


Pulsed signal displayed as a function of time. **Model TSA-S** Combination Synchroscope-Spectrum Analyzer.





Rapid signal comparison, accurate to .00025% at 10 kmc because of extremely fine resolution of **Model TSA-W** Wide Dispersion Spectrum Analyzer.



Direct, immediate observation of spurious transmitter radiation. **Model SA-84** Multi-Band Spectrum Analyzer.

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4 microwave analyzers cover every application, 10–44,000 mc

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Polarad spectrum analyzers are basic "scopes" for all microwave work. They display instantaneously such parameters as attenuation, insertion loss and gain, bandwidth characteristics, SWR, frequency, power, etc. In addition they detect and display modulator and transmitter malfunctions such as double moding, misfiring, pushing and pulling by a magnetron, and frequency drift.

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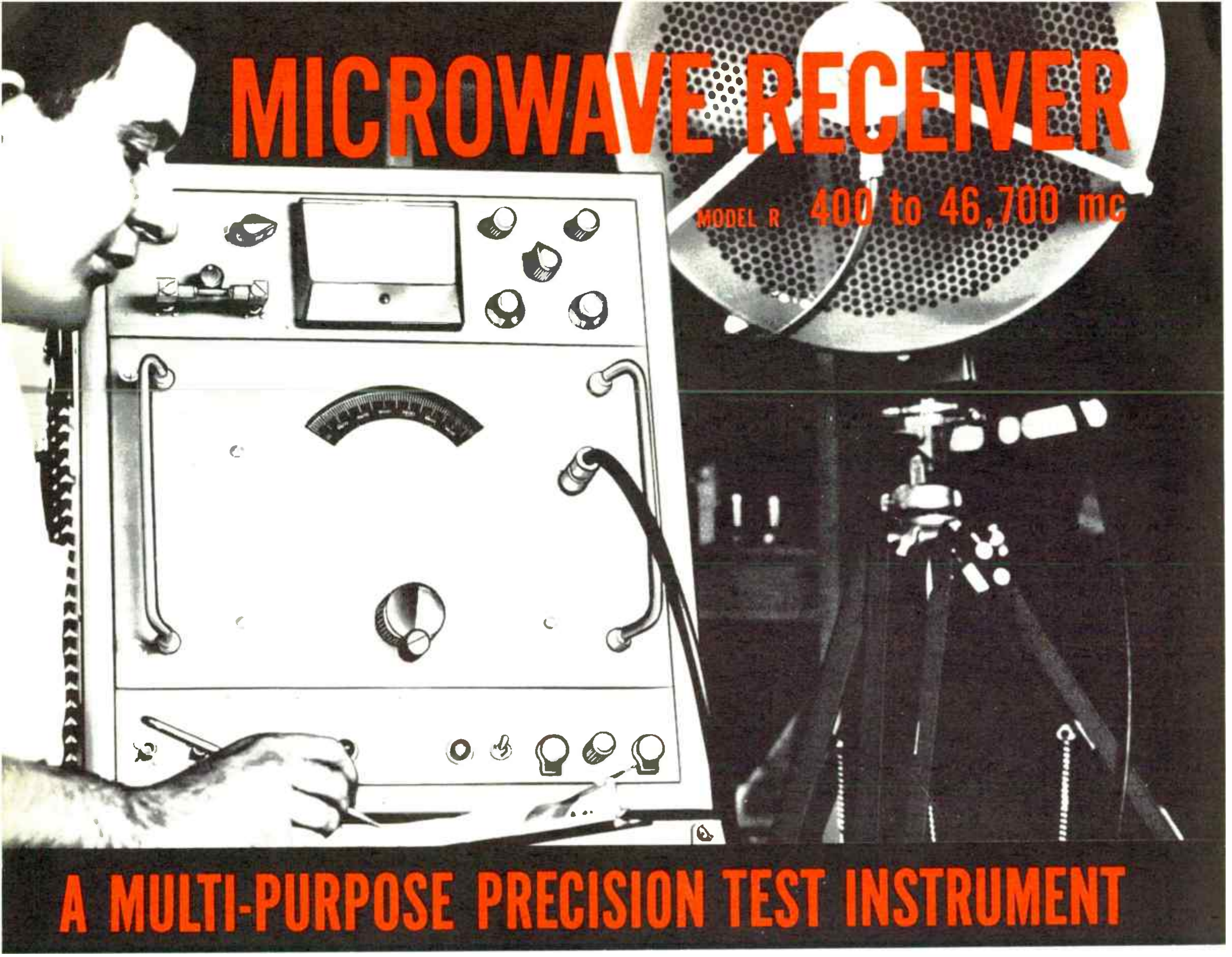

DETECTS AND MEASURES:

- Antenna patterns
- Field intensity
- R-F power
- R-F noise figure
- Leakage and interference
- Filter characteristics
- Bandwidth of microwave cavities
- Attenuation
- Insertion gain and loss
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It permits all standard forms of signal monitoring: special output jacks for audio and video; trigger output to reproduce pulse width and repetition rate; recorder output to transcribe signals through commercial recording equipment.

Model R is simple to operate, extremely sensitive, highly accurate, and is designed for quick, easy inspection and servicing. It provides AFC, AGC, and continuous UNI-DIAL tuning. Eight interchangeable tuning units cover the entire frequency range.

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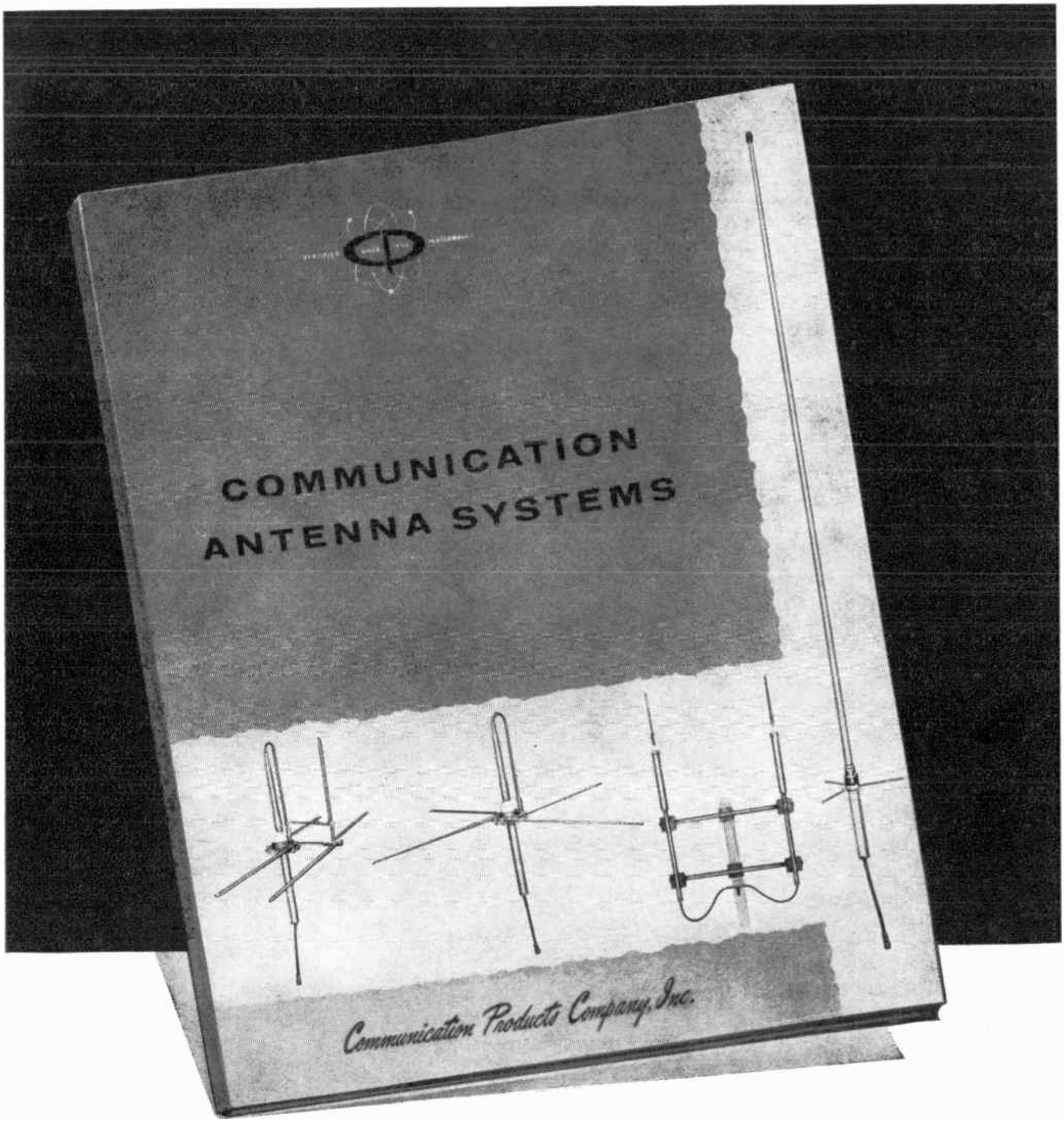

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(Continued from page 66A)

A native of Philadelphia, Dr. Thomas attended Johns Hopkins University, where he received a B.A. degree in physics and mathematics in 1939. In 1943, he received a Ph.D. degree from the California Institute of Technology at Pasadena.

He is a member of Phi Beta Kappa, Tau Beta Pi, and Sigma Xi, and the American Physical Society.

❖

Dr. Herbert Trotter, Jr. (SM'46) has been elected a senior vice-president of Sylvania Electric Products Inc.

H. Trotter

Dr. Trotter, a physicist, has been designated senior vice-president for engineering and research, with over all responsibility for the engineering program as it relates to the entire scope of Sylvania's activities, and for the operations of Sylvania Research Laboratories, a major division of the company. His headquarters will be at Sylvania's executive offices in New York City.

Previously a member of the Sylvania organization in the World War II years 1942 to 1945, Dr. Trotter has been executive vice-president of the Sharples Company, Philadelphia, Pa., since 1956. Sharples is a large manufacturer of process and centrifugal equipment for the chemical, food, and other industries.

After a period as a development physicist at Johns Hopkins University's Applied Physics Laboratory, Dr. Trotter joined Sylvania in 1942 and served for three years as manager of engineering and development of the company's V-T, or "proximity," fuze program.

He joined Eastman Kodak Company in 1945, serving over an 11-year period as assistant director of the Navy Ordnance Division and the New Apparatus Division.

A native of Woodstock, Va., Dr. Trotter was graduated from Hampden-Sydney College, and received a doctor of philosophy degree in Physics from the University of Virginia. In 1935–1936, he held the Du Pont research fellowship at the University of Virginia, and from 1936 to 1941 was associate professor of physics at Washington and Lee University.

Dr. Trotter is a member of the American Physical Society, the Institute of Radio Engineers, and Sigma Xi, national scientific fraternity. He was awarded a Presidential Certificate of Merit for his work on the V-T fuze during World War II.

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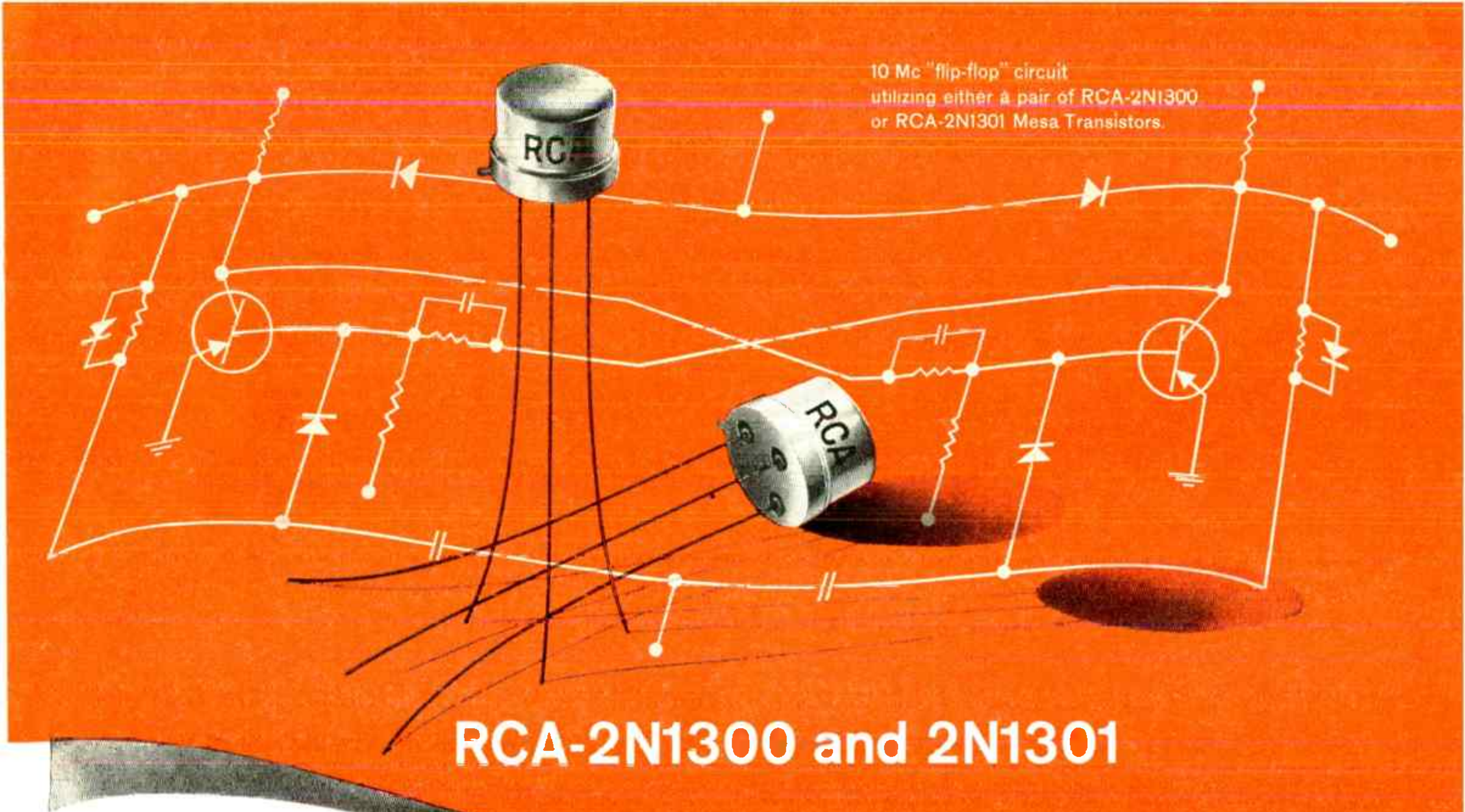
(Continued on page 74A)



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RCA-2N1300 and 2N1301 Germanium P-N-P Mesa Transistors offer these 10 major benefits to designers of switching circuits. And they're ready for you now!

- rugged Mesa structure—permits extremely small base width to insure top performance at high frequencies
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- rugged overall design—units have unusual capabilities to withstand severe drop tests and electrical overloads
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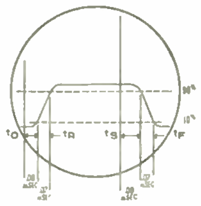
RCA TYPE	Maximum Ratings* Absolute-Maximum Values						Characteristics: Common-Emitter Circuit, Base Input Ambient Temperature of 25°C		
	Collector-to-Base Volts	Emitter-to-Base Volts	Collector Milli-amperes	Transistor Dissipation—mw			Minimum DC Current Gain		Gain Bandwidth Product• Mc
				at 25°C	at 55°C	at 71°C	at collector ma = −10	at collector ma = −40	
2N1300	−13	−1	−100	150	75	35	30	–	40
2N1301	−13	−4	−100	150	75	35	30	40	60

*Maximum collector-to-emitter voltage rating = −12 volts

• For collector ma = −10 and collector-to-emitter volts = −3.



Oscilloscope wave form shows typical delay, rise, storage, and fall times achieved with 10-ma inverter circuit utilizing the RCA-2N1301 MESA TRANSISTOR.

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(Continued from page 72A)

The promotion of **Francis X. Urrico** (M'59) as section head in charge of the electronic equipment development department of the Semiconductor Division of Sylvania Electric Products Inc., has been announced. Mr. Urrico has been a senior engineer in the department since 1957.

He joined Sylvania as an electronic design engineer at division headquarters in Woburn, Mass., in 1956. Prior to that Mr. Urrico was with the Naval Research Laboratory in Washington, D. C., and with the U. S. Army, at the Electronic Proving Ground in Ft. Huachuca, in Arizona.

A native of Woonsocket, R. I., Mr. Urrico attended the University of Rhode Island, where he received a B.S. degree in electrical engineering in 1951.

❖

The appointment of **Frank E. Vaccaro** (S'47–A'49–M'55), as manager, Microwave Advanced Development, RCA Electron Tube Division, has been announced.

A native of Memphis, Tennessee, Mr. Vaccaro is a graduate of the University of Tennessee and the Stevens Institute of Technology. He joined RCA in 1949 as a specialized engineer trainee, later being assigned as an engineer in the Microwave Tube Development activity. In 1956 he was promoted to engineering leader and was transferred to the newly established Microwave Advanced Development group of the Electron Tube Division located at the David Sarnoff Research Center, Princeton, N. J.

Among Mr. Vaccaro's accomplishments was his role in the development of a new tuning concept for wide-frequency range, high-power tunable magnetrons currently used in the most modern weapon systems. He also worked with electrostatically-focused traveling wave tubes, leading to the development of the Estiatron.

He is the author of several technical papers on microwave tubes and holds many patents on microwave devices. His memberships include Tau Beta Pi and Eta Kappa Nu.

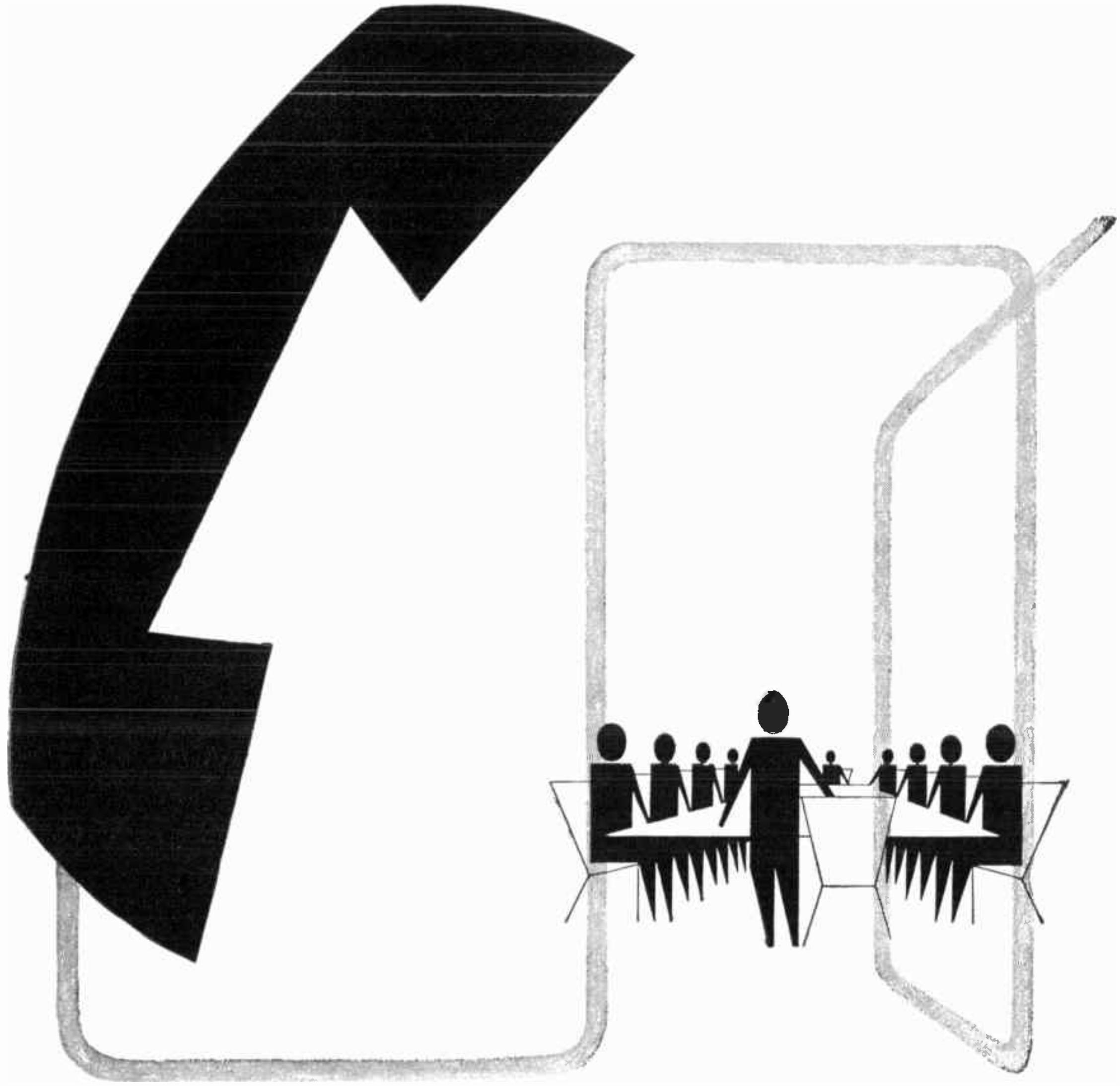
❖

The appointment of **Louis R. Wanner** (M'45) to the newly created post of chief engineer of the Parts Division of Sylvania Electric Products Inc., has been announced.

Mr. Wanner has been manufacturing manager in charge of metal base and plastics operations for the division since 1957. He will continue to have his offices at division headquarters in Warren. In his new assignment he will be responsible for all new product engineering, new process engineering and equipment development.

Mr. Wanner joined the Sylvania organization in 1948, as a senior engineer. In

(Continued on page 78A)



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They talk together, exchange ideas, reach decisions — *without leaving their desks!*

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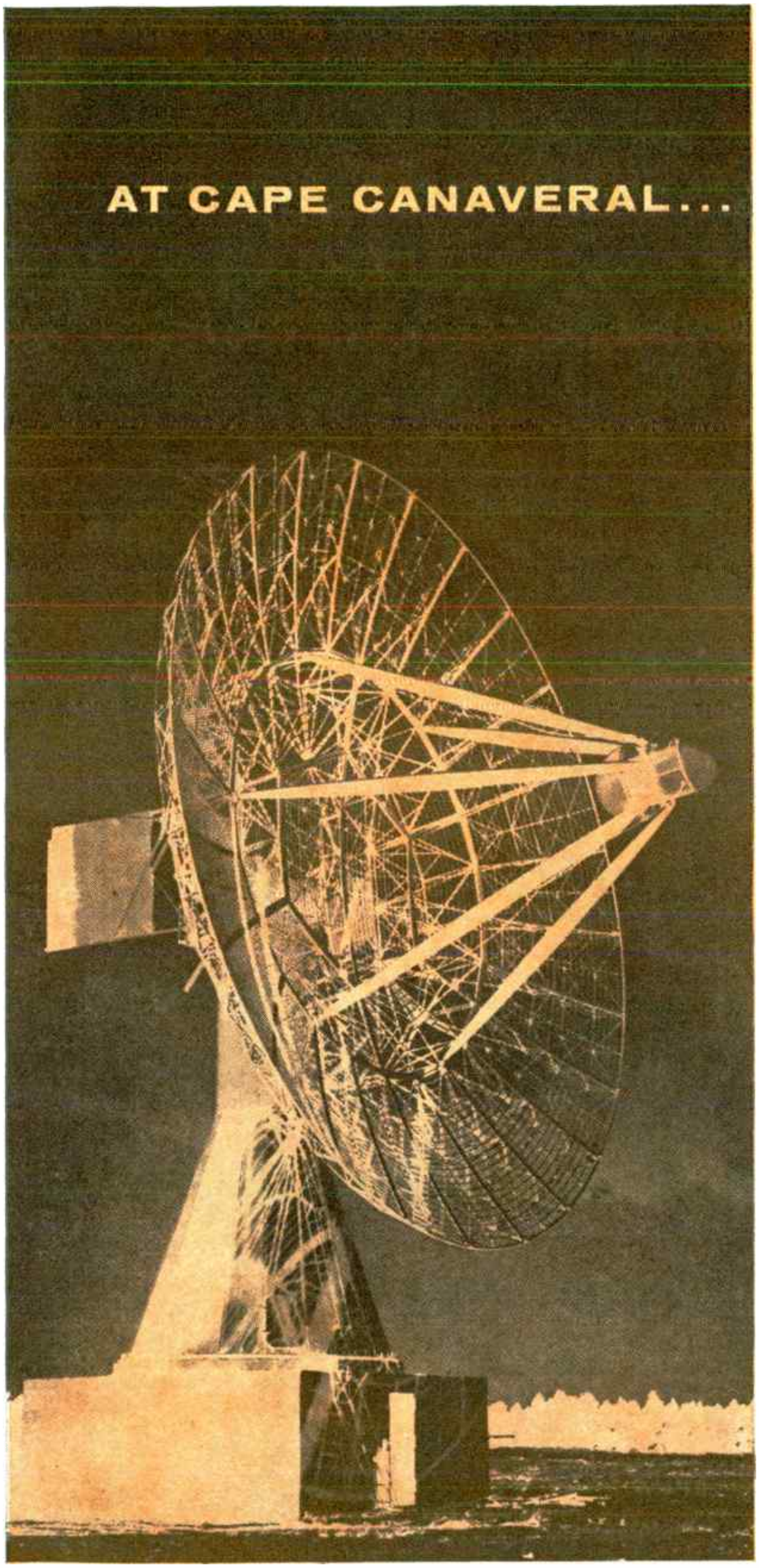

Styroflex® Coaxial Cable

is a vital part of the Air Force Automatic-Tracking Antenna System!

The powerful TLM-18 telemetry antenna now in service at the Air Force Missile Center, Cape Canaveral, Fla., is used for the automatic tracking of missiles and earth satellites. This huge "mechanical ear," specifically designed by Radiation, Inc., Melbourne, Fla., has an effective data reception range of over 1000 miles.

One of the key parts of this highly sensitive device is the ⅞", 50 ohm, aluminum sheathed Styroflex® coaxial cable that links the 60-foot parabolic reflector to the receivers. The task of carrying missile-to-earth signals from the antenna to the control building demands a low-loss, high frequency cable with a high signal to noise ratio.

The remarkable characteristics of Styroflex® cable not only meet these rigid specifications but also have extra operational advantages, including long operating life under severe conditions and stable electrical properties during wide temperature variations.

Styroflex® coaxial cable has earned an outstanding record for these qualities in a variety of industrial, mass communication and telemetering applications. Perhaps this cable can answer your particular high frequency cable problem. We invite your inquiry.

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CORPORATION

300 Park Avenue, New York 22, N.Y.

IRE People

(Continued from page 74A)

1950, he was appointed plant manager of plastics operations, a position he held until 1957.

A native of Germantown, Pa., Mr. Wanner attended Lehigh University in Bethlehem, Pa., where he received a B.S. degree in electrical engineering. He has also done graduate work at the University of Pennsylvania in Philadelphia.

Author of several articles on the plastics industry, Mr. Wanner has spoken extensively on the manufacturing processes involved in the molding of plastic components for the radio and television industries. He is a member of the American Institute of Electrical Engineers, Society of Plastics Engineers, Society of Plastics Industries, and the O8C Socket Committee of the Radio-Electronics-Television Manufacturers Association.

❖

Appointments to two key positions in the Military-Industrial Division of Dynamic Electronics-New York, Inc. have been announced. **Dr. Joseph H. Vogelman** (M'46–SM'46), has been appointed director of research and development; and **Irving Mirman** (S'41–A'44–SM'52), has been named director of technical planning and operations.

(Continued on page 82A)

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actual size

Raytheon *Diffused Junction* Silicon Rectifiers provide the precise junction gradient necessary for many applications. Operating temperature range is from minus 65° C to plus 165° C.

Available in stud and wire-in types having a wide range of characteristics, meeting MIL specifications.

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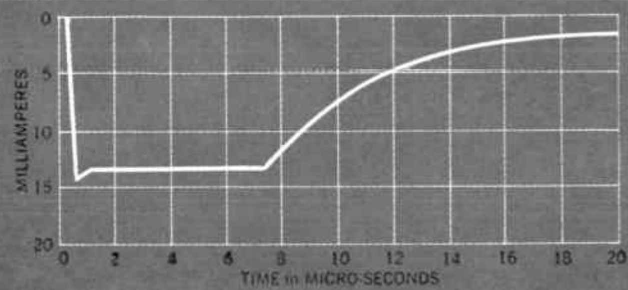
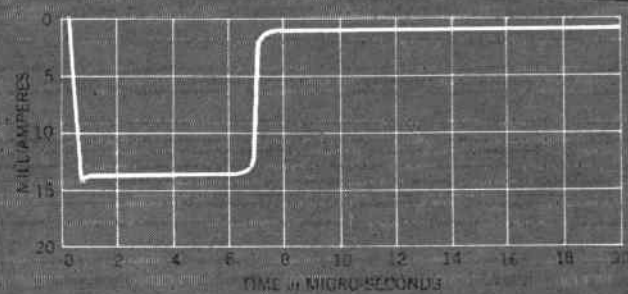
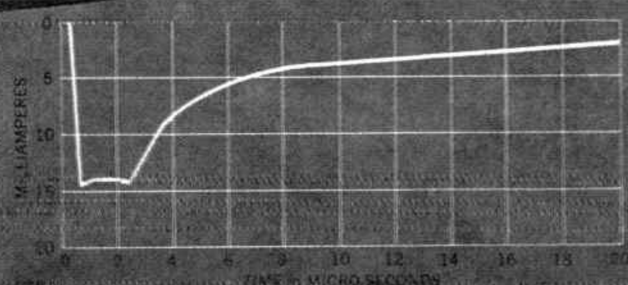


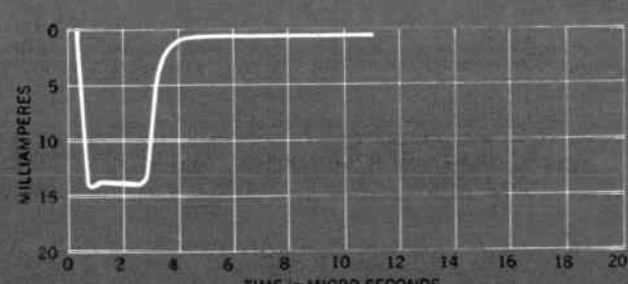
SOME silicon rectifiers give you slow start — slow rise



SOME silicon rectifiers give you slow start — fast rise



SOME silicon rectifiers give you fast start — slow rise



BUT RAYTHEON Reliable SILICON RECTIFIERS give you fast start — fast rise

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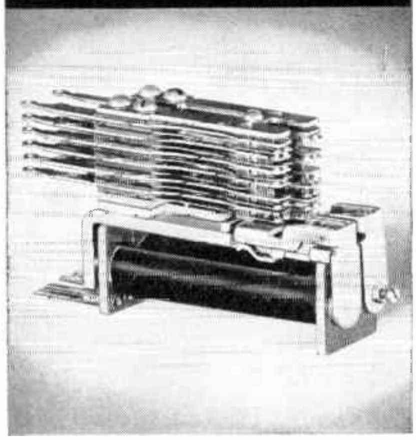
"TELEPHONE QUALITY"

Relays



. . . available immediately for any part of your operation that depends on electromechanical switching.

Proven by many years of meeting the exacting requirements of the telephone industry, these twin-contact relays of unsurpassed reliability are available in many types. The following are representative:

Type A: general-purpose relay with up to 20 Form "A" spring combinations. This relay is excellent for switching operations.

Type B: a gang-type relay with up to 60 Form "A" spring combinations. **Type BB** relay accommodates up to 100 Form "A" springs.

Type C (illustrated): two relays on the same frame. A "must" where space is at a premium.

Type E: has the characteristics of Type A relay, plus universal mounting arrangement. Interchangeable with many other makes.

Complete details and specifications on all Stromberg-Carlson relays are contained in our *new relay catalog*. Contents include: spring combinations, table of equivalents, contact data, variations and special features, plus complete mounting and cover information.

The catalog is available on request.

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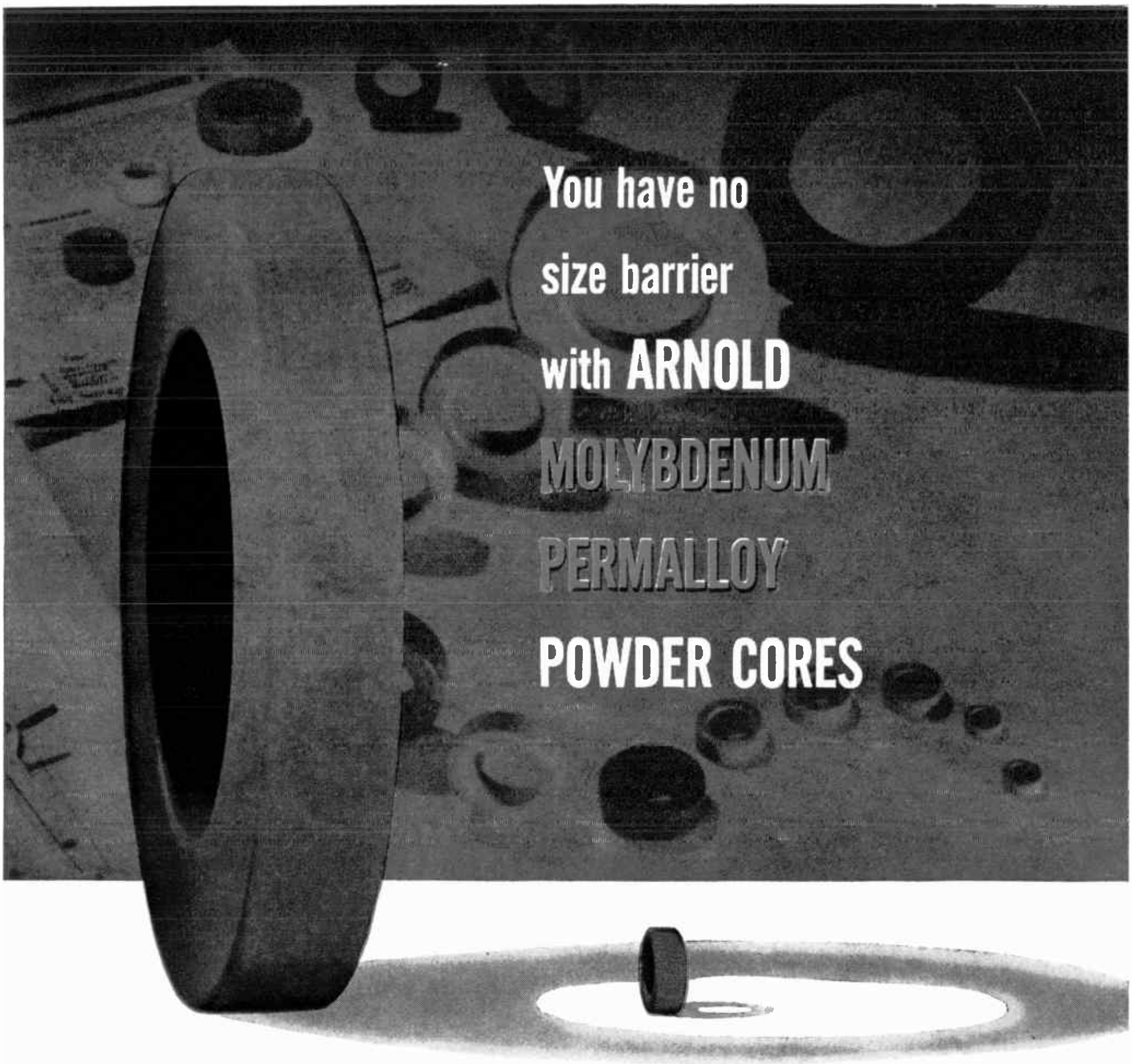

From the smallest to the largest on the market, Arnold leads the way in offering you a full range of Molybdenum Permalloy powder cores for greater design flexibility . . . from 0.260″ O.D. to 5.218″ O.D.

As long ago as 1953, Arnold pioneered and developed for production use the small "Cheerio" core illustrated above. Today, hundreds of thousands of Arnold "Cheerio" cores are filling the requirement for miniaturization in circuit design in industrial and military applications. Even smaller sizes have been developed by Arnold's continuing research and are now available.

Arnold also is the exclusive producer of the largest 125 Mu core commercially available. A huge 2,000 ton press is required for its manufacture and insures its uniform physical and magnetic properties. This big core is also offered in the other three standard permeabilities of 60, 26 and 14 Mu.

Most core sizes can be furnished with a controlled temperature coefficient of inductance in the range of 30° F to 130° F. Many can be supplied temperature stabilized over the wide range covered by the MIL-T-27 specification of −55° C to +85° C . . . another of the special features that only Arnold provides.

Graded cores are available upon special request, and all popular sizes of Arnold Mo-Permalloy powder cores are of course produced to an inductance tolerance of + or −8%.

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IRE People

(Continued from page 78A)

J. H. Vogelman

I. Mirman

Dr. Vogelman's professional background includes nearly 20 years of experience in various phases of electronics—communications, radar, microwave techniques, electronic warfare. Prior to joining Dynamic, he was technical director of the Directorate of Communications at the U. S. Air Force's Rome Air Development Center, where he directed activities in research, engineering, and evaluation of ground communications systems for the Air Force. He was also a technical advisor to the Department of Defense, USAF, on matters relating to communications systems.

A graduate of the City College of New York where he received the B.S. degree and the Polytechnic Institute of Brooklyn where he received the M.E.E. and Ph.D. degrees, Dr. Vogelman is a noted author and inventor in the field of electronics. He has written more than 30 technical papers and has been granted or has in process 13 patents. He has served as Chairman or Member of numerous Government and Professional committees on electronics.

Mr. Mirman comes to Dynamic from the USAF Rome Air Development Center, where he served as technical director of Technical Services. In that capacity, he was responsible for the management of electronic research and development programs; budget control, long range planning, contract administration, manpower and priority allocations, and advisory service to the USAF Air Research and Development Command.

A recognized authority on R&D program management, Mr. Mirman has often served on professional panels and advisory boards dealing with his subject. He holds the B.E.E. degree from New York University and the M.E.E. degree from Polytechnic Institute of Brooklyn. He also completed a Radar Graduate Program at Harvard-M.I.T. and the Special Weapons Program at the USAF Air University. His numerous technical and management papers include a study of management and organization of a 20 year plan for electronics, prepared for the Air Research and Development Command.

❖

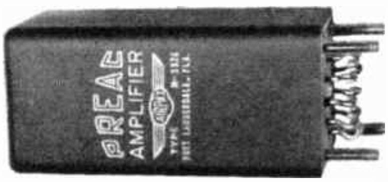
Dr. Ernst Weber (M'51–SM'43–F'51), President of the IRE and president of the Polytechnic Institute of Brooklyn, re-

(Continued on page 86A)

AIRPAX ...for proven performance and reliability

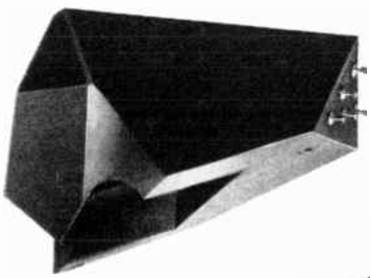
2300-1 LOW NOISE CHOPPER
Developed for use where low level signals in low impedance circuits would be lost in background noise.

6025 TRANSISTOR CHOPPER
Drive transformer and transistor chopper combined in a miniature chopper enclosure. Hermetically sealed, it is provided with a 7 pin header.



PREAC MAGNETIC AMPLIFIERS
Available in both 60 and 400 CPS types, these amplifiers deliver linear output with power gains above 50db.

CIRCUIT BREAKER SERIES 500
Miniature electro-magnetic inverse time delay breaker provides positive protection for electrical and electronic equipment. Types for DC, 60 and 400 CPS supplied in standard or special ratings.



AMPLIFIERS
Airpax also produces magnetic amplifiers with unique electrical, mechanical and space configurations. For special or standard types, call on Airpax for quality products.

ELECTRONIC TACHOMETERS SERIES 7000
Semi-conductors and a saturating transformer provide a high degree of reliability and long life. Accuracy is better than one percent.

The illustrations show only a few of the components produced by Airpax, undisputed leader in the manufacture of precision choppers. Other products are equally noted for excellence of design and performance reliability. Chopper types, both standard and custom with mounting and header variants, number well over 250. Transistor chopper types were added to the line after operational and reliability tests proved their acceptability.

The miniature circuit breaker, designed to rigid government specifications, has found widespread use in industry. Its protective features and availability in AC and DC types, make it invaluable in critical electrical and electronic circuits where costly equipment demands the ultimate in protection.

Pulse, audio and power transformers . . . custom designed or standard types . . . are an important part of Airpax production. Our transformer engineering staff will design transformers meeting your most exacting requirements.

Airpax maintains a Western Sales-Engineering office to expedite service to the ever expanding electronic industry on the West Coast. The office, located at 2550 East Foothill Blvd., Pasadena, is staffed with graduate engineers competent to assist in the solution of complex problems. Teletype facilities to Airpax plants ensure rapid communication and speedy delivery of your requirements.

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HICKORY BRAND
Electronic Wires and Cables

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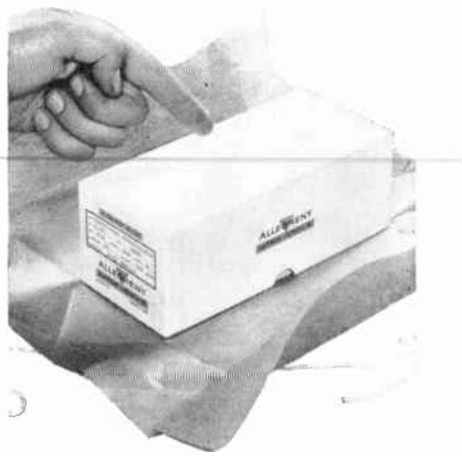
This package can end your worries about silicon processing . . .



Inside this box you'll find doped silicon single crystal slices from Allegheny.

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If you wish to *increase* production without tying up capital in facilities for slicing, lapping, etching and such.

If you'd like to *avoid* being dependent on just one source of supply.

You solve either (or both) of these problems with Allegheny's new service because you get single crystal slices that are *ready for use.*

These slices from vertically pulled or float zoned crystals are doped to range with 99.999% group III and/or V elements. Standard thicknesses from .005″ to .020″ and diameters from ¼ to 1½ inches.

As for lapping, this we do to your specification. If you wish, we prepare one or both sides for diffusion. Otherwise slices are etched, cleaned and dried before being delivered to you.

Details? We'll provide answers to your questions, promptly.

NOTE: You'll find that Allegheny devotes its efforts exclusively to producing ultra-pure silicon in every form. You might also be interested in more facts about bulk, billets, rods, doping alloys, seeds or special forms.

If so, write, wire or phone:

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ALLEGHENY
ELECTRONIC CHEMICALS CO.

Producers of semiconducting materials for the electronics industry.

IRE People

(Continued from page 82A)

ceived the honorary degree of Doctor of Engineering on Thursday evening, June 4, at the 43rd commencement exercises of Newark College of Engineering. He is the twelfth person to have received the degree since the college first granted honorary doctorates in 1919.

E. WEBER

Born in Vienna, Austria, September 6, 1901, Dr. Weber developed during the years of his youth a dual interest in philosophy and engineering which led him to pursue a double course of studies in his native city at the two separate institutions of the Technical University of Vienna and the University of Vienna.

Following receipt of the diploma in electrical engineering, he joined the Austrian Siemens-Schucket Company as research engineer, and in 1927, on the basis of his studies and publication on field theory as applied to machinery, was awarded the D.Sc. degree from the Technical University in Vienna.

During the same years, he maintained his other studies in philosophy, physics and mathematics at the University of Vienna, and received his Ph.D. from that institution in 1926.

In 1929, Dr. Weber was transferred to the Siemens-Schucket offices in Berlin, and was also appointed lecturer at Berlin's Technical University. In the fall of 1930 he accepted an invitation to serve as a visiting professor at the Polytechnic Institute of Brooklyn, and began his long record of service to the Institute which culminated, in December 1957, in his being elected its president.

In 1931 he was named a permanent research professor of electrical engineering in charge of graduate study. From 1942 to 1945 he was professor of graduate electrical engineering and head of graduate study and research in that field.

Early in the second World War, Dr. Weber organized a microwave research group which developed among other things the precision microwave attenuator, sorely needed for the accurate calibration of radar. In recognition of the contributions of the research group, he was awarded the Presidential Certificate of Merit. Out of this wartime research grew the Microwave Research Institute and the Polytechnic Research and Development Corporation, owned by the Polytechnic Institute of Brooklyn.

In 1945 Dr. Weber was appointed head of the department of electrical engineering and director of the Microwave Research Institute.

Creation of a vice-presidency for research was called for in 1957 by the

(Continued on page 90A)

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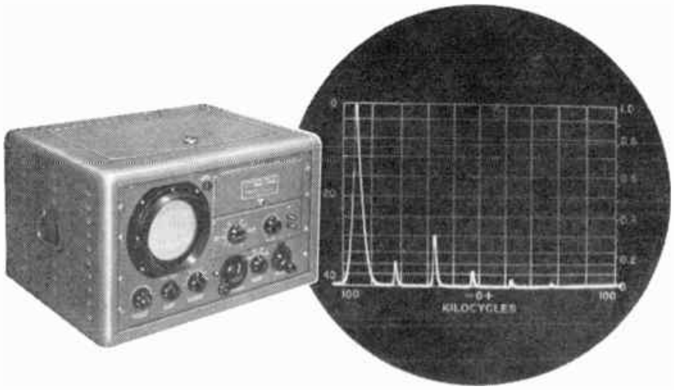
BOOTHS 204-301



HOW TO SOLVE SPECTRUM ANALYSIS PROBLEMS in the 0.5 cps. to 25 mc range

...LOOK TO PANORAMIC BROADBAND ANALYZERS

This series of repetitive scanning heterodyne receivers provides *automatic* measurement of the frequency and amplitude of input signal components—and provides a *calibrated* X-Y plot on either a CR Tube, or inked paper chart, or both.

PANORAMIC Spectrum Analyzers are easy to operate, versatile, compact and reliable. They handle both discrete and noise-type signals. They are widely used for vibration and noise analysis, cross-modulation measurements, general Fourier analysis, monitoring of transmissions, geophysical investigations, medical work, and many other purposes. Their utility can be extended greatly for other applications by the use of available accessory equipment.

Most models feature a choice of scanning width ranges for a quick overall look at the spectrum or a finely resolved analysis of magnified narrow spectrum segments. A wide variety of sweep rates is also provided, to obtain desired degrees of resolution at the different sweep widths and sweep rates, and for handling various types of input signals—either random or discrete.

This series of spectrum analyzers eliminates tuning heads thus minimizing the risk of spurious response or ambiguous calibrations. All are characterized by high sensitivity, low residual distortion, extensive dynamic range, and calibrated linear and log amplitude scales. Their high input impedance permits direct use of most transducers.

MODEL LF-2a SUBSONIC
0.5 cps to 2250 cps

Extremely stable. Resolution range 0.1 cps to 20 cps. Sweep rate: 10 seconds, 1, 2, 4, 8, 16 minutes, and by hours if desired. Inked chart readout.

MODEL LP-1a SONIC
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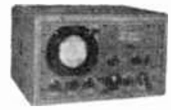

Pre-set sweepwidths for narrow linear frequency analysis in one second between 20 cps and 22.5 kc. Features "quick look" log sweep from 40 cps-20 kc. Automatic optimized resolution on log and linear sweeps. Variable resolution 10 cps to 1 kc optional. Residual spurious down more than 60 db.

MODEL SB-7bz ULTRASONIC
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Versatile, with discriminator linearized sweep. Sweepwidth variable 200 kc to 0 kc. Resolution capability of 100 cps through 2 kc variable. Residual distortion —50 db. Sweep repetition 6.7 sweeps/second.

MODEL SB-15 ULTRASONIC
0.1 kc to 525 kc

Complete, compact analyzer only 8¾" high. Includes many advanced features. Sweepwidth variable 200 kc to 0 kc. Resolution capability 100 cps through 4 kc (variable). Residual distortion —55db. Sweep repetition 1 to 60 sweeps/second.

MODEL SPA-3 WIDE RANGE
200 cps to 15 mc

MODEL SPA-3/25
200 cps to 25 mc

Very broad coverage in one versatile instrument. Continuously adjustable center frequency, sweep width, sweep rate, and IF bandwidth. Resolution capability, variable—200 cps through 30 kc. Sweepwidth variable 3 mc to 0 kc. Residual distortion, —46db.

Where two different models cover similar frequency areas, the two instruments are not necessarily equally effective in meeting a certain need. Other factors and performance ratings should be evaluated in considering an Analyzer for a specific purpose.

PANORAMIC Engineers will be glad to aid you in choosing a Broadband Analyzer for your requirements. For this assistance, or further information about the PANORAMIC line—phone, wire, or write TODAY.

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IRE People

(Continued from page 86A)

marked growth of research projects. Dr. Weber was the first person named to that position.

Following the death on June 6, 1957, of Dr. Harry S. Rogers, the Institute's fifth president, he was appointed acting president. On December 20, 1957, Preston R. Bassett, chairman of the Institute's governing body, announced the unanimous election of Dr. Weber as president.

A pioneer in high frequency electronic research, Dr. Weber holds more than 50 American, Canadian and British patents in the field of microwave techniques. His published works include many scientific papers on electromagnetic fields, linear and nonlinear circuits, and microwave measurements. He has contributed to several books and has published "Mapping of Fields" and "Linear Transient Analysis."

In conferring the degree, Dr. Edward F. Weston, chairman of the NCE Board of Trustees, cited Dr. Weber as a research scientist, electrical engineer, and educator and teacher, saying that "your development of graduate study and your devotion to the enrichment of engineering education are rivaled only by your ability to guide seekers of knowledge along the tortuous path to true learning. Your election as President of the Polytechnic Institute of Brooklyn attests the trust and admiration which you command."

❖

Dr. William M. Webster (A'48–SM'54) has been appointed administrative engineer on the staff of the vice-president, RCA Laboratories, Radio Corporation of America.

A former member of the RCA Laboratories technical staff, Dr. Webster has been for the past five years manager of Advanced Development for the RCA Semiconductor and Materials Division at Somerville, N. J. In his new position, he will have his office at the David Sarnoff Research Center in Princeton and will handle special assignments relating to various aspects of the over-all RCA research program.

A native of Warsaw, N. Y., Dr. Webster was graduated in 1945 from Union College in Schenectady, N. Y., and received his Ph.D. degree from Princeton University in 1954. He joined the RCA Laboratories staff in 1946 as a specialist in vacuum and solid-state electronics, making numerous contributions to tube and transistor developments. In 1954, he was transferred to the RCA Electron Tube Division and subsequently to the newly-formed RCA Semiconductor and Materials Division at Somerville, where he was placed in charge of advanced development relating to transistors and other semiconductor devices.

Dr. Webster holds a number of patents relating to semiconductor devices. He is presently Chairman of the IRE Professional Group on Electron Devices.

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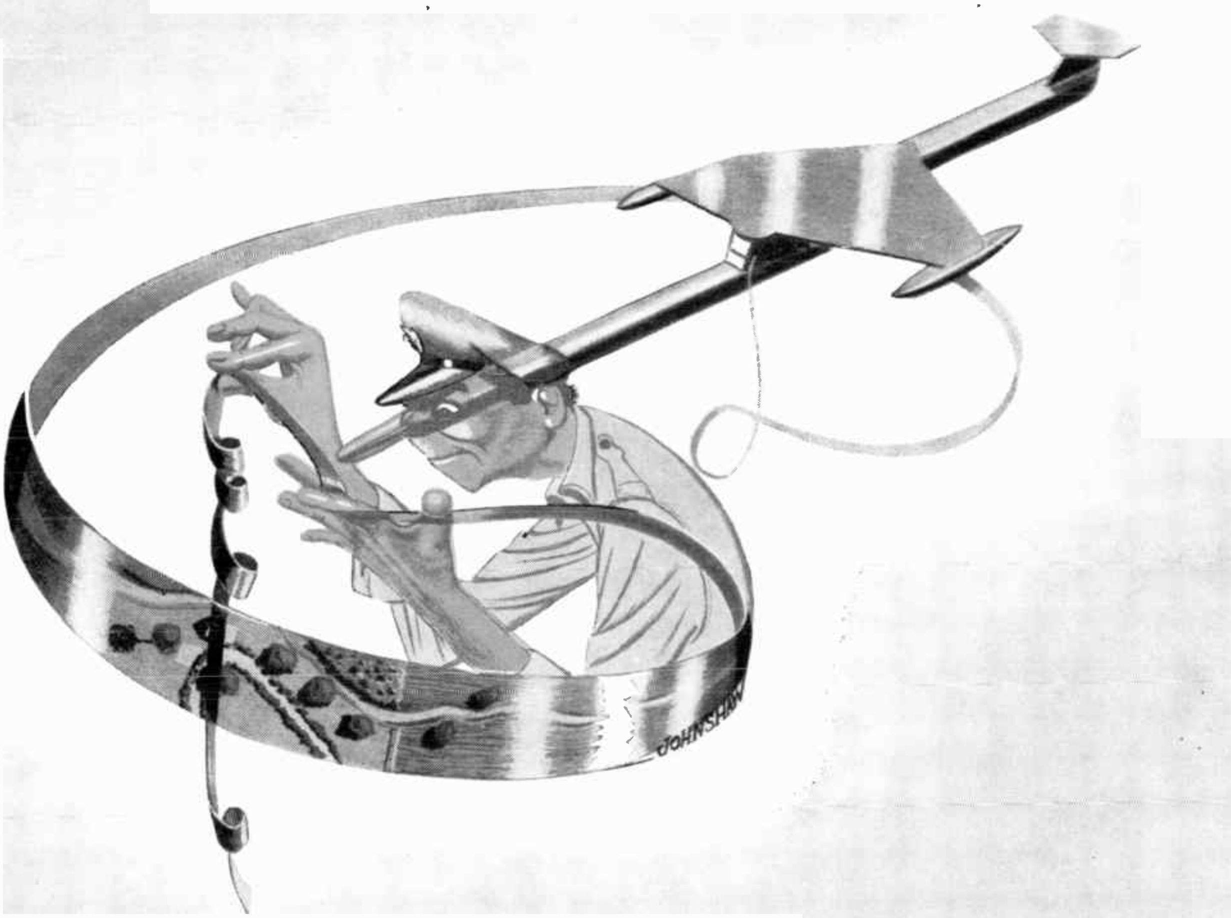

T/I combat surveillance

Stay 'home' and see more

Aggressor terrain and positions are open secrets to TI-equipped recon drones and snooper aircraft. Field commanders can now reconnoiter "in person" far behind aggressor lines *without leaving field HQ.* Instant, accurate, continuous data on thousands of sq mi of hidden territory can flow into headquarters *in the time one foot patrol could complete its mission.* Hundreds of targets can be spotted, evaluated and brought under fire in the same time interval . . . most of them within seconds after detection.

This capability exists now at Texas Instruments. For detailed discussion, military and industrial personnel with need to know please write or call: SERVICE ENGINEERING DEPARTMENT.

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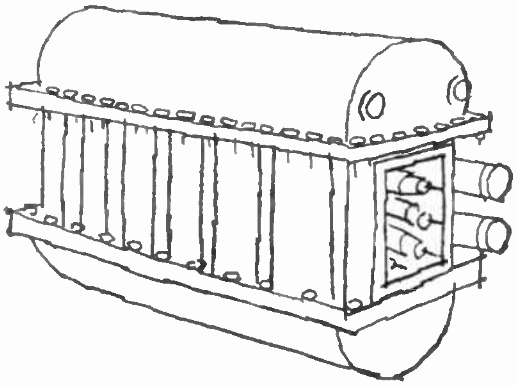
A PROBLEM OF UTMOST GRAVITY



RAYTHEON-DESIGNED, HIGH VOLTAGE DC MAGNETRON POWER SUPPLY

Weight, in one form or another, seems to be a concern of most of us today. While astronauts contend with the problem of "none at all", designers of electronic components continually face the problem of "too much".

An aircraft manufacturer recently called on Raytheon to design a 10,000-volt, 60-kva, 400-cycle, filtered DC magnetron power supply for high-temperature airborne-radar application. Several designs were available, but their weight -- more than 1,800 pounds -- put them in the lead balloon class.

Our engineers, thoroughly experienced in the field of fluorochemical transformer design, were able to get the "lead" out, about 1,300 pounds of it, and to come up with a unit (shown above) weighing less than 500 pounds.

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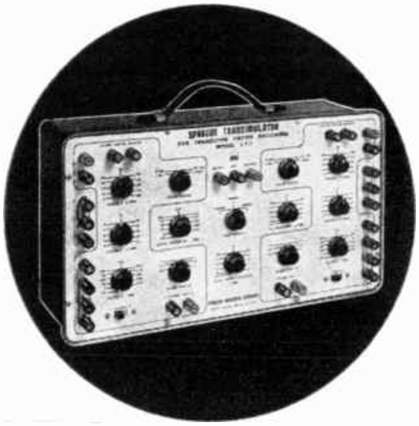

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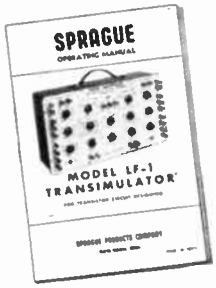

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IRE People

(Continued from page 90A)

Dr. Max T. Weiss (S'43–A'45–M'55–SM'57), authority in microwave physics, has joined Hughes Aircraft Company as senior staff physicist of the microwave laboratory's electronics research department.

M. T. Weiss

Dr. Weiss, who comes to Hughes after nine years with Bell Telephone Laboratories, will specialize in solid-state microwave physics, including research in ferromagnetics and ferrite amplifiers.

He is a 1943 electrical engineering graduate of City College of New York. After several years with the U. S. Naval Ordnance Laboratory designing underwater electronic mines, he became a research associate at Massachusetts Institute of Technology where he received master's and doctor's degrees in physics.

Dr. Weiss holds four patents on microwave ferrite devices and has published technical papers on microwave ferrites and microwave spectroscopy. He is a member of Sigma Xi, Eta Kappa Nu, and the American Physical Society.

(Continued on page 96A)

3.5-millimicrosecond risetime

with these TWO NEW OSCILLOSCOPES

TYPE 581

The Tektronix Type 581 is a new laboratory oscilloscope with many of the capabilities needed in the current rapid advancement of the electronic art. Its 3.5-mμsec risetime, 0.1-v/cm sensitivity, and 0.01-μsec/cm sweep time are excellent features for modern high-speed pulse applications. In addition to these unique features, the Type 581 also has the slow sweeps, versatile triggering, and dc-coupled vertical-deflection system needed for most general-purpose laboratory work. A new series of Tektronix plug-in preamplifiers promises outstanding signal-handling versatility for an oscilloscope with a vertical passband of dc to approximately 100 mc.

With the Type 80 Plug-In Preamplifier and Type P80 Probe the basic vertical-deflection factor is 0.1 v/cm with input impedance of 10 μμf paralleled by 100 kilohms. Five snap-on probe attenuator heads provide deflection factors of 0.2, 0.5, 1, 2, and 5 v/cm at input impedances ranging up to 1.5 μμf paralleled by 5 megohms. A fixed balanced delay line is incorporated in the main vertical amplifier. The cathode-ray tube is a lumped-constant traveling-wave type with 10-kv accelerating potential.

The wide sweep range of the Type 581 includes sweeps fast enough to take advantage of its risetime capabilities. Calibrated range is 0.05 μsec/cm to 2 sec/cm in 24 steps, with 5-x magnifier to increase calibrated range to 0.01 μsec/cm. Sweep time is continuously adjustable between steps. Versatile triggering includes amplitude-level control, and preset stability for operating convenience. Lockout-reset circuitry provides for one-shot sweep operation.

TYPE 585

The Tektronix Type 585 has, in addition to the identical general specifications of the Type 581, a second time base generator. This time-base generator, designated TIME BASE B, acts as a delay generator, providing a wide range of calibrated sweep delay. Two modes of sweep delay are available—triggered (delayed sweep is started after the delay period by the signal under observation), and conventional (delayed sweep is started at the end of the delay period by the delayed trigger). Calibrated sweep delay is continuously variable over the range of 1 μsec to 10 sec. Color-correlated controls eliminate confusion, making this new high-performance oscilloscope easy to operate.

TYPE 581, without plug-in units	**$1375**
TYPE 585, without plug-in units	**1675**
TYPE 80 Plug-In Preamplifier	**50**
TYPE P80 Probe, with 5 attenuator heads .	**100**

(Both Preamplifier and Probe are needed to operate the Type 581 and Type 585.)

Other Plug-In Preamplifiers are currently in development.

Prices f.o.b. factory.

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Tektronix is represented in 20 overseas countries by qualified engineering organizations.

SEE THIS AND OTHER NEW TEKTRONIX INSTRUMENTS AT WESCON, BOOTHS 1801 AND 1802

IRE People

(*Continued from page 94A*)

Kent J. Worthen (S'49–A'50–M'52), manager of product planning for General Electric point-to-point communication systems, has been appointed manager of mobile radio equipment sales for the Communication Products Department at Lynchburg, Va.

Mr. Worthen joined General Electric in 1949 after receiving the B.S. degree in electrical engineering from the University of Utah. From 1951 to 1956 he was district sales manager for General Electric mobile radio at Los Ange es, Calif., where he was chairman of the Los Angeles Chapter of the IRE Professional Group on Vehicular Communications.

In 1956, Worthen was named market development manager for General Electric two-way radio with headquarters at Syracuse, N. Y., and was appointed manager of microwave product planning a year later. Later he became manager of product planning for point-to-point communication, which included responsibility for product development on power line carrier devices, microwave relay, terminal communication products and allied products of a systems nature.

❖

Makoto Yoshida (M'56) has joined the technical staff of the Ramo-Wooldridge Division of Thompson Ramo Wooldridge Inc.

Prior to joining R-W, he worked for Amelco, Inc. as an electrical engineer for one year. He also held electrical engineering positions with Bendix Aviation from 1956 to 1957, and with the Westinghouse Electric Division from 1952 to 1956.

A native of Santa Monica, Calif., Yoshida received his B.E. degree in electrical engineering from Ohio State University in 1952. He is a member of the American Institute of Electrical Engineers.

❖

Membership

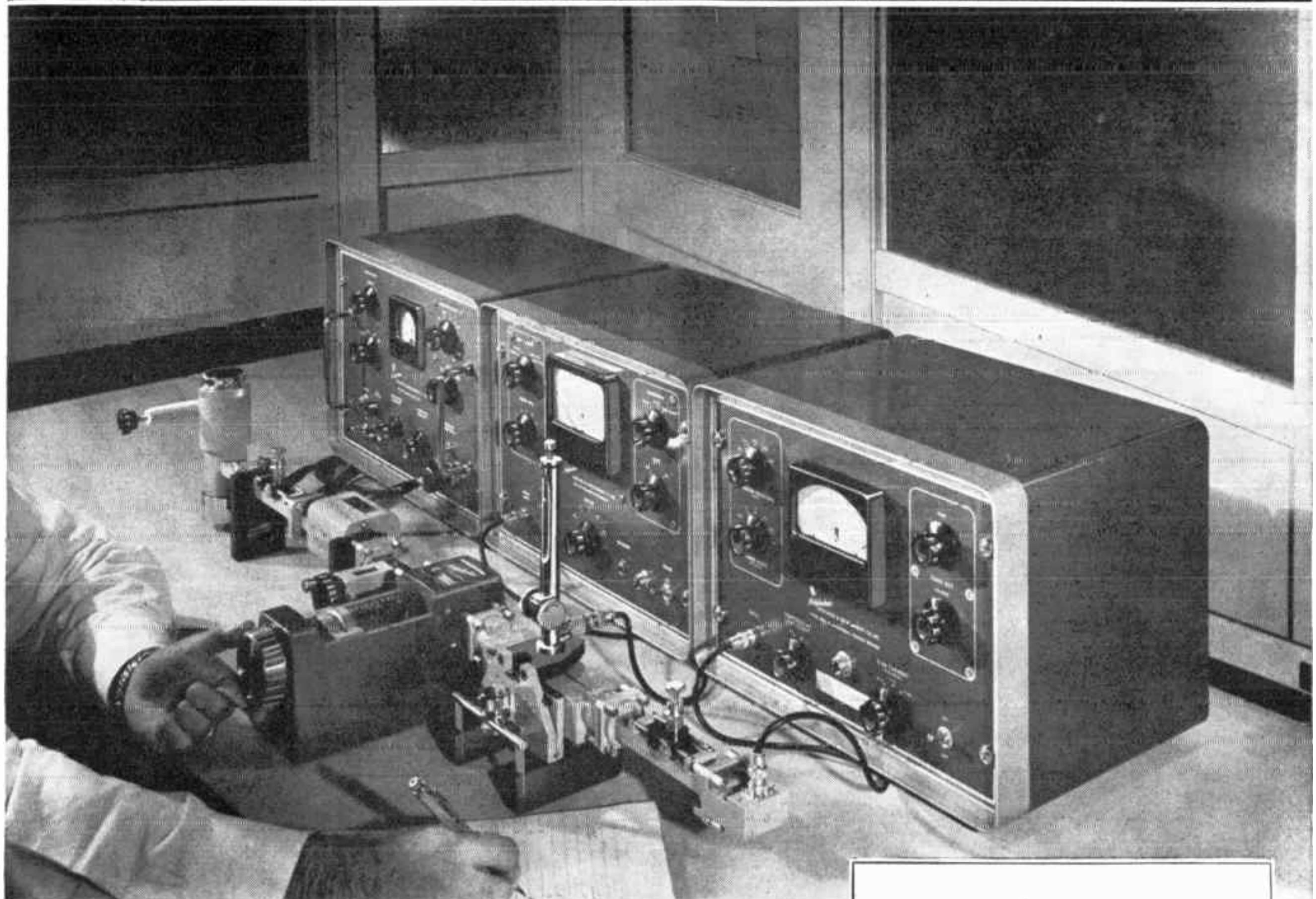
The following transfers and admissions have been approved and are now effective:

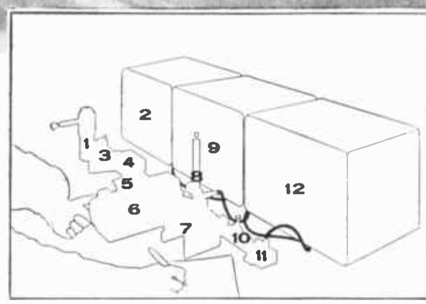
Transfer to Senior Member

Acker, R. E., Spring Lake Heights, N. J.
Aisberg, E., Paris, France
Babbitz, H. B., San Diego, Calif.
Barrow, B. B., The Hague, Netherlands
Bates, J. F., Alexandria, Va.
Bell, D. E., Corona, Calif.
Blake, J. T., Patrick AFB, Fla.
Blikken, W. A., Ypsilanti, Mich.
Chaber, R. K., Hicksville, L. I., N. Y.
Chaney, W. G., New York, N. Y.
Clute, D. G., Dayton, Ohio
Cullen, F. P., Bethpage, L. I., N. Y.

(*Continued on page 98A*)

HOW TO MEASURE POWER





This microwave bench set-up is for the measurement of power by the Self-Balancing Bolometer Bridge method. Other systems, including PRD's more accurate Calorimetric Instrumentation could have been shown, but the Bridge represents the most universally used technique.

The operating procedure is quite simple. First adjust the PRD 650-B Universal Power Bridge for the thermistor or bolometer available. Next tune and match the transmission line for a minimum VSWR indicated on the PRD 277-A Standing Wave Amplifier. Then record the reading of the PRD 650-B Self-Balancing Bridge (directly in milliwatts) and you're ready for your next microwave measurement.

Easy, isn't it? Even more important it's accurate. The PRD 650-B Bridge has guaranteed accuracy of ±5% full scale. The use of the PRD 303-A Slide Screw Tuner eliminates the slightest mismatch of the 643 Thermistor Mount. The importance of fine matching can best be shown by example: a mismatch VSWR of only 1.2 would result in a power error of 1%.

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For technical details and specifications covering products shown write:

TEST INSTRUMENTS USED IN THIS X-BAND POWER BENCH

1—703 Shielded Tube Mount, catalog page F-8
2—809 Klystron Power Supply, catalog page F-10
3—303-A Slide Screw Tuner, catalog page B-14
4—1203 Isolator, catalog page A-21
5—159-A Level Set Attenuator, catalog page A-17
6—535 Frequency Meter, catalog page D-12
7—203-D Slotted Section, catalog page B-11
8—250-A Broadband Probe, catalog page B-12
9—277-A Standing Wave Amplifier, catalog page E-7
10—303-A Slide Screw Tuner, catalog page B-14
11—643 Broadband Thermistor Mount, catalog page E-9
12—650-B Universal Power Bridge, catalog page E-13

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(Continued from page 96A)

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Domingue, J. C., Ft. Huachuca, Ariz.
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Douma, T., Haddonfield, N. J.
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Moorman, F. W., Fort Huachuca, Ariz.
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(Continued on page 100A)

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(Continued from page 98A)

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(Continued on page 102A)

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Kline, S. R., Northridge, Calif.
Korolenko, A. V., Syracuse, N. Y.
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Manlove, W. R., Inglewood, Calif.
Mann, M. E., Jr., Eau Gallie, Fla.
Markey, J. T., Providence, R. I.

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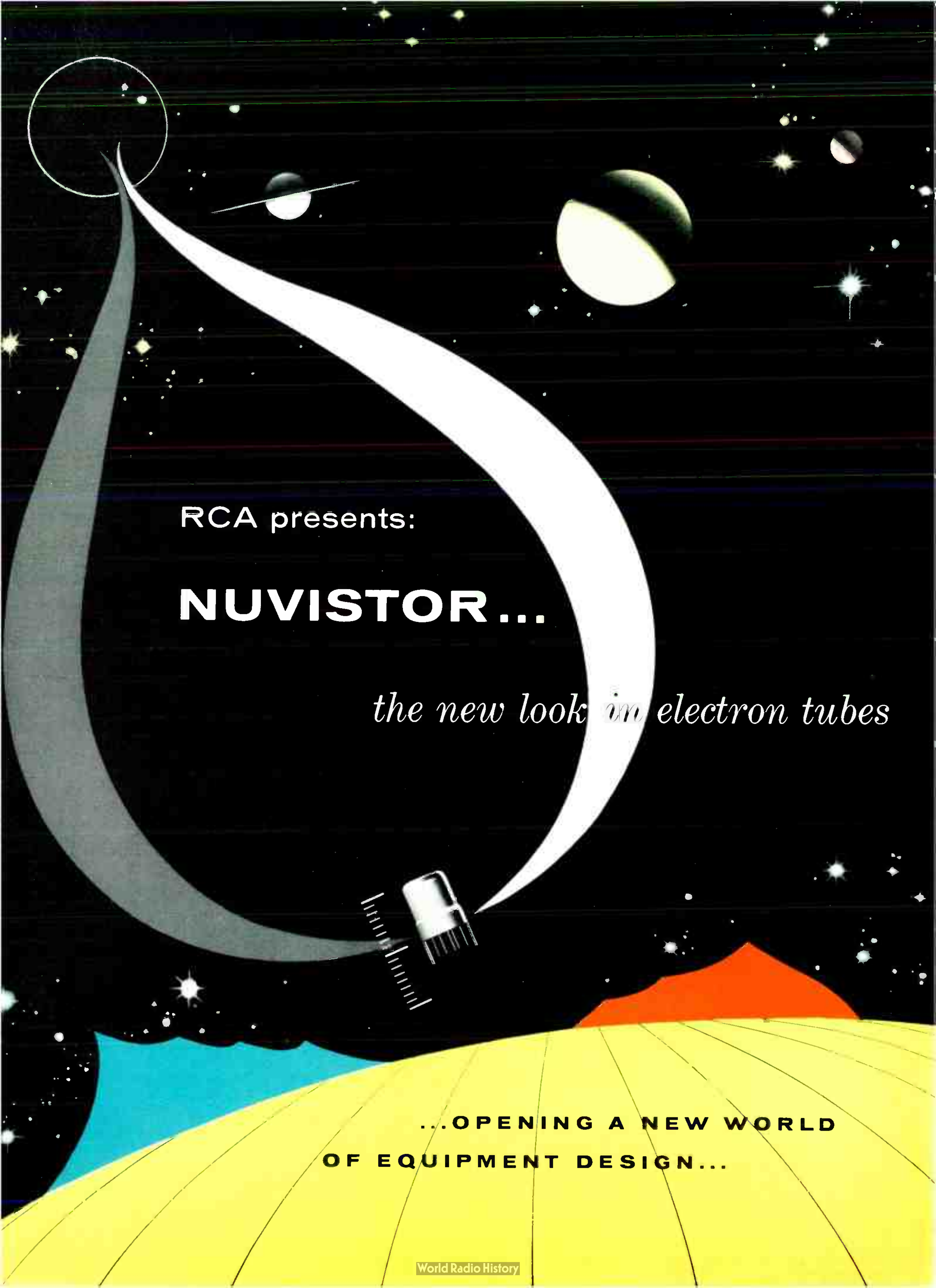
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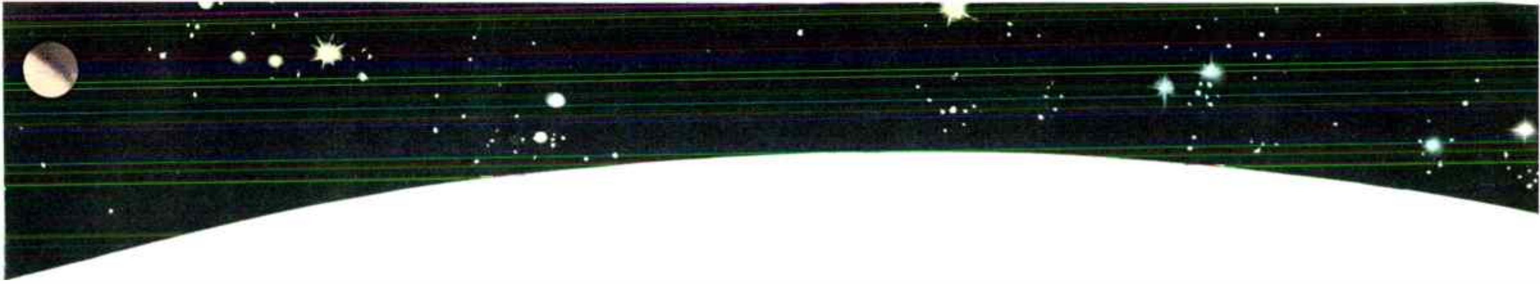
. . . the new design in electron tubes that promises dramatic improvements in quality, performance, and reliability!



NUVISTOR... *a new era in electron tubes!*

The NUVISTOR *concept promises tube structures that are truly rugged.*

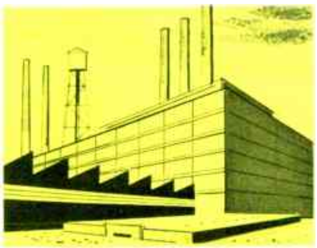
Each tube electrode is brazed to its supporting member, an open-ended conical structure. The platform for the structure is a strong ceramic base-wafer. Electrodes are extraordinarily small, lightweight cylinders. Neither mica nor glass is used. Spot welding is eliminated. This combination of strong structural assembly, brazed joints, all ceramic-metal construction, small size, extra low mass, and high-temperature processing has resulted in a tube design in a small envelope that holds promise of fine performance under thermal or mechanical shock and continuous vibration. For example, NUVISTOR triodes have been subjected to more than 1000 blows each of 850 g's for 0.75 millisecond. After such tests, no shorts were indicated...either permanent or temporary.

NUVISTOR *is given its start in a brazing furnace.*

Ceramics and strong metals such as steel, molybdenum, and tungsten—processed at high temperatures in brazing and vacuum exhaust furnaces—form the basic structure of the tube. Such high-temperature processing eliminates many of the gases and impurities that cannot be eliminated when tubes of conventional design are processed at temperatures limited by glass and mica. This new processing technique significantly reduces the residual gases that might contaminate the tube as the elements heat and age. And, because the tubes have been outgassed at high temperatures, they offer promise of operating at ambient temperatures considerably higher than conventional tubes can withstand. NUVISTOR tubes have been subjected to temperatures of 660°F...and continued to function. At normal operating temperatures, therefore, reliable operation over long periods of time can be anticipated.

NUVISTOR *can withstand the test of freezing cold.*

In several tests, NUVISTOR tubes continued to function when immersed in liquid nitrogen at a temperature of −320°F.

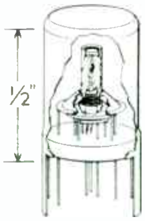


what NUVISTOR *will mean to defense electronics*

NUVISTOR seems destined to have significant impact upon equipment designed for military applications. NUVISTOR promises an extremely high level of performance and reliability never before anticipated from electron tubes produced in large quantities. Under unusual conditions of environment, the reliability of NUVISTOR promises to make radical improvements in "mean-time-to-failure hours". NUVISTOR tubes offer miniaturization capabilities that can significantly increase payload capacities of military vehicles. The electrical characteristics of NUVISTOR tubes make them suitable for many different services...hold out the prospect of designing a large number of circuits "around" just a few tube types. These NUVISTOR features can reduce requirements for replacement equipment and service personnel, can increase mobility of the equipped "arm".

what NUVISTOR *will mean to industrial electronics and entertainment products*

The high-performance capability of NUVISTOR and its inherent ability to function under difficult environmental conditions seem certain to stimulate new equipment designs for industry. Automation, electronic computers and business machines, closed-circuit television—in fact, the entire range of industrial electronics applications will be given a new platform from which to climb higher. In electronic equipment for home entertainment, more compact, more reliable, more attractive products are in store. New levels of performance can be expected in lightweight AM and FM radios, phonographs, hi fi, and TV sets.



NUVISTOR small-signal TRIODE

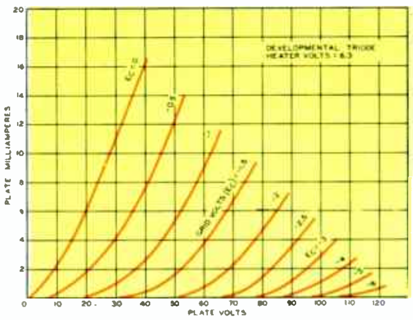
Ready now...on a limited sampling basis...for new equipment designs. First Nuvistor type to be sampled.

High-frequency amplifier performance...

The NUVISTOR triode has shown its mettle as a radio-frequency amplifier in experimental TV-tuner tests. Compared to miniature types 6BQ7-A and 6BN4-A in cascode and neutralized-triode VHF amplifiers, Nuvistor has provided improved gain and at least 1 db less noise measured at television channel 13. In addition, Nuvistor has indicated greatly reduced B+ power drain—about ⅓ the voltage and ½ the current used for the miniature types. Experimental cascode-type tuners using Nuvistors have demonstrated substantially higher performance than commercial tuners, even those using the latest commercial types of receiving tubes...and they required less heater power and only about one watt of B+ power input, as compared to about 7 watts for commercial cascode-type tuners.

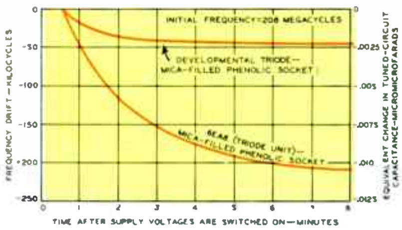
Oscillator performance...

The Nuvistor is a remarkably stable and efficient tube for local oscillator service. Oscillations are obtainable at more than 1000 megacycles with the Nuvistor triode in conventional molded-type sockets. Oscillator efficiency is essentially independent of frequency up to about 450 megacycles, and typical circuits start oscillating with 7 volts or less at the plate of the tube. The low power input needed for the oscillator, as well as amplifier and mixer circuits, helps reduce temperature rise and consequent frequency drift of tuned circuits. The tube itself is particularly stable. Note the accompanying graph which shows the warm-up drift of a 200-megacycle oscillator compared to type 6EA8, a notably good VHF tuner tube by present standards. Each type produces the same output voltage in a conventional circuit from which other causes of drift were removed—yet Nuvistor triode has less than ¼ the warm-up frequency drift of 6EA8.



◀ TYPICAL PLATE CHARACTERISTICS

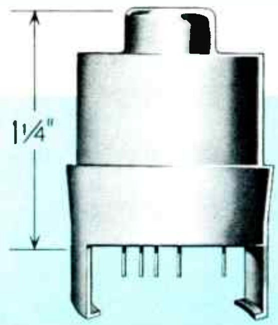
OSCILLATOR FREQUENCY STABILITY CURVE ▼



TYPICAL DATA

ELECTRICAL:

Heater, for Unipotential Cathode:		
Voltage (AC or DC)		6.3 volts
Current		0.14 amp
CHARACTERISTICS, CLASS A_1 AMPLIFIER:		
Plate Voltage	40	75 volts
Grid Resistor	1	— megohm
Grid Voltage	—	−1.35 volts
Amplification Factor	31	31
Plate Resistance (approx.)	—	2600 ohms
Transconductance	12000	12500 µmhos
Plate Current	8.5	12.5 ma
Grid Voltage (approx.) for plate current of 10 µa	—	−6.5 volts
MAXIMUM RATINGS, DESIGN—MAXIMUM VALUES:		
PLATE VOLTAGE		110 max. volts
GRID VOLTAGE		−55 max. volts
PEAK POSITIVE GRID VOLTAGE		2 max. volts
PLATE DISSIPATION		1.2 max. watts
PEAK HEATER—CATHODE VOLTAGE:		
Heater negative with respect to cathode		100 max. volts
Heater positive with respect to cathode		100 max. volts



NUVISTOR BEAM POWER TUBE

Now being developed...plate dissipation objective in the order of 30 watts; intended for beam-power applications in the entertainment, industrial and military fields.

NUVISTOR small-signal TETRODE

Ready soon for limited sampling...an amplifier tube for new equipment designs in entertainment, industrial, and military applications.

what NUVISTOR will mean to you...the designer of electronic equipment

Remember way back when all tubes were "radio tubes", and they earned the name "bottle". They were big, fragile, and relatively inefficient. Miniaturization was a vague dream. Rugged tubes were nonexistent. Portability really meant transportability. Design possibilities were limited. But, new developments in tube designs brought smaller envelopes, sturdier structures, the octal socket, the 7-pin and 9-pin miniatures...new techniques and new processes...electrical uniformity, reliability and efficiency! So, NUVISTOR takes its place in the progressive advancement of the electronics industry with new criteria for electron-tube efficiency and reliability. And you, the design engineer, will participate importantly as NUVISTOR ELECTRON TUBES open a new world of unlimited possibilities in equipment design.

For more details on NUVISTORS and for information on how you may obtain developmental samples of NUVISTOR small-signal TRIODE, call your RCA Field Representative at the Field Office nearest you.

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August, 1959
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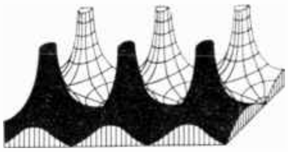
Proceedings of the IRE

Poles and Zeros



Rifles vs Shotguns. Much attention has been given in manpower circles to uncovering possible causes for the reduction of freshman engineering numbers in the colleges last fall. As mentioned in this column in May, this drop approximated eleven per cent from the previous year, and could cause a considerable reduction in the 1962 graduating class.

One suggested motivating influence is that the accomplishments of the space age have more frequently been credited to the scientist who announces the new space discoveries, than to the engineering teams whose efforts and knowledge made the penetration of space possible. The daily prints are full of credit lines to science which should properly include reference to or be the property of the engineer.

We admit that it is often difficult to tell the difference between science and engineering in the field of electronics—did the Venus-bounce signal merely contribute new knowledge of the distance to that planet, or was important new engineering work accomplished in the development of the maser and correlation techniques which made reception of the return signal possible? Where doubt exists let us at least point out that engineering contributed to a project—that the engineer and pure scientist frequently are an indissoluble team in electronics—sometimes the same person.

We also see announcement of some dozens of summer "science" institutes to be conducted for the benefit of science- (and we think engineering-) oriented high school students and teachers. We hurry to admit that the subject matter taught in these institutes will properly be of scientific nature—mathematics, chemistry, and physics, since these are the high school foundation stones for further work in the natural sciences. However, should not we in engineering take steps to see that for 1960 these institutes be properly labelled as "science and engineering" summer institutes? Should not all engineers start personal campaigns to obtain credit for the profession of engineering where such credit is due, in any communication to the student and to the public?

The necessity for these steps can be readily ascertained by an interview with a high-school guidance counselor. The training of these people gives little opportunity for contact with engineers or engineering. In fact, they may too often look upon engineering as a difficult and demanding field, its college pathways strewn with scholastic failures, and they are therefore reluctant to give positive guidance advice. They seem on somewhat surer ground when discussing the sciences, physics, biology, and the like. The publicity of 1957 concerning cutbacks in "engineers" in portions of the aircraft industry found good reception in the guidance area, and no one was present to point out to them that many of the released engineers were in fact technicians, that well trained and capable engineers were still being hired by those same companies, and that for those willing to work and learn, the field of engineering could be a very rewarding one.

The information concerning the profession of engineering which is available to the high school student is meager, often dated and inaccurate. Particularly, it fails to recognize the shift of engineering toward research, a shift of particular importance to a science-directed boy. Electronics, while well covered by the public prints in recent years, has never made an attempt to explain itself, and most vocational information on electrical engineering mentions the country's fifth largest industry as an also-ran compared to machinery manufacturing. Our colleges continue to receive many inquiries concerning the lack of curricula in electronics, showing that no one has pointed out the unity between electronics and electrical engineering which is present on most campuses today.

There seems general agreement among engineering educators that too high a percentage of our entrants to engineering colleges are neither prepared nor motivated for the quality and quantity of work expected of the engineering student. Too many do not know why they entered engineering study, and too many lack the mathematical preparation on which college engineering work is based.

All the discussion seems to indicate that the publicity, the tumult and the shouting of recent years, on the subject of the engineering shortage was not on target. We hope that for the next go-around our side will choose its weapons more carefully and realize that while a shotgun brings in rabbits, it takes a rifle to bring in the elephants, and real ivory is what we are looking for in engineering manpower.

In fact, we might suggest that the orientation of high school students toward engineering is a major problem in psychology and public relations. Are engineers expert in these fields?

The King's English. The IRE Professional Group on Engineering Writing and Speech announces that to better serve its membership, it intends to hold its annual symposium on September 17 in simultaneous East Coast and West Coast sessions—Boston and Los Angeles.

Does these peeple mean us midwesterners alreddy kin rite and speke, or is weuns jist hoples?—J.D.R.

Charles E. Harp

Director 1959–1960

Charles E. Harp (A'51–M'51–SM'55) was born in Garfield County, Oklahoma, on February 4, 1910. He received the B.A. degree in 1932 from Phillips University, Enid, Oklahoma, with a major in physics and mathematics. In 1938 he received the M.S. degree from the University of Oklahoma in Norman, where he studied physics and electrical engineering.

From 1934–1943 he taught high school mathematics, physics, and geology in Oklahoma. For the next four years he was employed as special engineer of laboratory research by Black, Sivalls and Bryson, Inc. in Oklahoma City. In 1947 he became an associate professor of electrical engineering at the University of Oklahoma, an appointment he holds at the present time.

He has been vice-chairman and chairman of the Oklahoma City Section of the IRE, member and Chairman of the Region 6 Subcommittee on Education, member of the National Committee on Education, and has represented the Institute at the University of Oklahoma. He has also served on the IRE Appointments and Nominating Committees. He was general chairman for the Eighth Annual Southwest IRE Conference and Electronics Show, and has been a member and secretary of the SWIRECO Advisory Board.

Mr. Harp is a Registered Professional Engineer in the State of Oklahoma, and is a member of the American Institute of Electrical Engineers, Sigma Pi Sigma, Sigma Tau, and the Oklahoma Academy of Science.

Scanning the Issue

The Parametron, A Digital Computing Element Which Utilizes Parametric Oscillation (Goto, p. 1304)—The PROCEEDINGS presents this month a long-awaited description, the first complete one to appear in the English language, of one of the most important technical developments to have come out of Japan in many years. The parametron, invented by the author in 1954, represents an entirely new approach to computing in which binary digits are represented by the phase of a parametric subharmonic oscillation. The fact that a resonant circuit with a suitable nonlinear reactive element will produce a subharmonic oscillation at one-half the driving frequency has been known for many years. The key ingredient added by the author was the realization that the oscillating wave will be stable in either of two phases, 180° apart, and that these two phases can be used to represent the binary digits "zero" and "one." The late John von Neumann independently hit upon the same idea the same year, as discussed in these pages last April by Wigington. However, it remained for the author and his colleagues in Japan to reduce the idea to practice. So successful and important have been their efforts that today nearly half of the digital computers in Japan utilize parametrons. Nonlinear reactance is provided by ferrite-core coils, while the rest of the circuit consists only of capacitors and resistors—no diodes or rectifiers are required. This leads to a very durable and inexpensive form of computer circuit. This paper contains a lot of very important information, not only from the standpoint of computer engineers, but also from that of the many people now interested in parametric amplifying devices. The parametron represents one of the first modern applications of the parametric phenomenon, a subject which since has become one of the most widely discussed topics in the electronics field.

Microwave Parametric Subharmonic Oscillators for Digital Computing (Sterzer, p. 1317)—As was mentioned above, at the time the parametron was conceived in Japan, von Neumann independently made a similar proposal in the U. S., discussed in these pages last April by Wigington. As Wigington pointed out, however, von Neumann had in mind an additionally exciting aspect of using parametric subharmonic oscillators—the possibility of operating them at microwave frequencies to achieve greatly increased computer speeds. The first successful step toward this important goal is now reported in this paper. The oscillators discussed here are based on the same basic concepts as the parametrons described in the preceding paper. The parametric element, however, is a variable capacitance diode rather than a variable inductance ferrite-core coil. The operating frequencies, of course, are much different. The computer circuits described here involve oscillator output frequencies of 2000 mc and pulse rates over 100 mc, whereas the maximum corresponding figures for the parametron are 6 mc and 140 kc, respectively. This work opens up a broad new area of computer development which will lead to new machines that will be able to operate many times faster than has been heretofore possible. Indeed, interest in microwave computers has already risen so high that the IRE TRANSACTIONS ON ELECTRONIC COMPUTERS is publishing a special issue on the subject next month. As a final word, it might be noted that this is the first major application of microwave techniques outside the fields of communications and radar.

The Radiansphere Around a Small Antenna (Wheeler, p. 1325)—An old subject is looked at in a refreshingly new and clear way. In the course of 15 years work in the field, the author has developed a number of novel concepts that are helpful in visualizing and remembering the rules governing the behavior of electrically small antennas, especially dipoles and loops. The topic, although elementary, is one that has until now been appreciated by a relative few. This paper was prepared with the express intent of reaching the broader, less specialized PROCEEDINGS audience and will be of tutorial interest to all non-specialists.

Voltage Breakdown Characteristics of Microwave Antennas (Chown, *et al.*, p. 1331)—Under the influence of an RF field, free electrons in the atmosphere can attain sufficient energy to have ionizing collisions with gas molecules, thus producing more free electrons. If the RF field is strong enough, the production of free electrons will build up to the point where a gas-discharge breakdown will occur. While the theory of high-frequency gas-discharge breakdown has been well explored, very little is known about its occurrence in connection with the operation of antennas. For voltage breakdown to occur at standard atmospheric pressure, the radiated power would have to be a good deal greater than is normally encountered in practice. At the low pressures now being encountered by high-altitude vehicles, however, there are indications that it takes only very low power to initiate and maintain breakdown. To find out more about high-altitude breakdown, the authors built a four-foot Plexiglass sphere, placed an antenna inside it, and operated it under various levels of power and of reduced pressure. Their findings about breakdown power levels and the effects on antenna performance will be of high interest to those who deal with high-powered radars and with antennas for high altitude and re-entry vehicles.

Some Broad-Band Transformers (Ruthroff, p. 1337)—Using ferrite toroids as small as 0.08 inch in diameter, the author has designed a number of transmission line transformers having extraordinary bandwidths, encompassing a frequency range of from a few tens of kilocycles to over a thousand megacycles—a ratio of 20,000 to 1. A varied assortment of practical transformer designs is presented in this short, but meaty paper. An equally varied assortment of applications present themselves: reversing the polarity of pulses, connecting transmission lines to television receivers, broadband amplifier interstages, power dividers, balanced amplitude and phase detectors, and directional couplers, to name a few. Thus, this development offers a valuable solution to a difficult problem encountered in many different fields.

Dissipation Loss in Multiple-Coupled-Resonator Filters (Cohn, p. 1342)—The design of filters consisting of resonators coupled in cascade has received considerable attention, since they are widely used in all frequency ranges, whether they be microwave cavities or low frequency quartz crystals. The usual design approach is first to synthesize an equivalent low-pass prototype filter, assuming it to be lossless, and then to calculate the resonator that will yield the same response in the desired frequency band. However, a practical filter is never in reality lossless. As a result, the actual response of the resonator will inevitably turn out to be somewhat different from the theoretical response of the ideal prototype. It is this source of difference and how to take account of it in the design that is the subject of this paper. It is a topic of real practical interest and the new results produced by the author will be useful to many engineers working in network theory and in low-frequency and microwave filter design.

IRE Standards on Navigation Aids: Direction Finder Measurements (p. 1349)—This is one of the largest standards that the IRE has issued in several years. It prescribes methods of measuring the sensitivity, accuracy, interference, and signal fields associated with DF systems. It also includes a list of abbreviations and definitions of terms used in this field and describes standard test conditions and equipment. The general reader may be especially interested in the note on standard frequency band designations which prefaces the Standard. He will find, for example, that what some of us call the Very-Low Frequency Band, others call Band No. 4 and still others call Myriametric Waves.

Scanning the Transactions appears on page 1387.

The Parametron, a Digital Computing Element which Utilizes Parametric Oscillation*

EIICHI GOTO†

Summary—**The following is a brief description of the basic principles and applications of the parametron, which is a digital computer element invented by the author in 1954. A parametron element is essentially a resonant circuit with a nonlinear reactive element which oscillates at one-half the driving frequency. The oscillation is used to represent a binary digit by the choice between two stationary phases π radians apart. The basic principle of logical circuits using the parametron is explained, and research on and applications of parametrons in Japan are described.**

I. Introduction

In keeping with the remarkable progress of electronic computers in recent years, studies on digital computing elements and memory devices have been energetically conducted in various laboratories. Among them, one will find new applications of physical phenomena and effects that have never before been utilized in the field of electronics; the cryotron, which uses superconductivity, and the spin echo memory are typical examples.

In 1954 the author discovered that a phenomenon called parametric oscillation, which had been known for many years, can be utilized to perform logical operations and memory functions, and gave the name "Parametron" to the new digital component made on this principle [1], [21]-[23].

A digital computing circuit made of parametrons may consist only of capacitors, ferrite-core coils and resistors, while diodes and rectifiers may be dispensed with. The parametron, therefore, is considered to be extremely sturdy, stable, durable, and inexpensive. Owing to these advantages, intensive studies have started in several laboratories in Japan to apply parametrons to various digital systems. At present, nearly half of the Japanese electronic computers in operation use parametrons for logical elements. Further applications have been made to such devices as telegraphic equipments, telephone switching systems and numerical control of machine tools.

Parametric oscillation, from which the name "Parametron" derives, is not a unfamiliar phenomenon—a playground swing and Melde's experiment are examples of parametric oscillations in mechanical systems. In order to drive a swing, the rider bends and then straightens his body and thereby changes the length l between the center of gravity of his body and the fulcrum of the ropes. The swing is a mechanical resonant system and its resonant frequency is determined by this length l and the gravitational constant g. The oscillation of the swing is energized by the periodic variation of the parameter l which determines the resonant frequency. Similarly, in Melde's experiment, shown in Fig. 1, a periodic variation is given to the tension, which is a parameter that determines the resonant frequency of the string. In this case, the exciting energy which varies the tension is supplied from a tuning fork of resonant frequency $2f$, which is twice the resonant frequency f of the string. In other words, the oscillating frequency of the string is a subharmonic equal to half the frequency of the energy source, that is, it is the second subharmonic. The mechanism of building up of this subharmonic is shown in Fig. 2. As the string moves away from the equilibrium position, the tension is weakened and the maximum amplitude increases; as the string returns to the center position, the tension is strengthened and the kinetic energy increases.

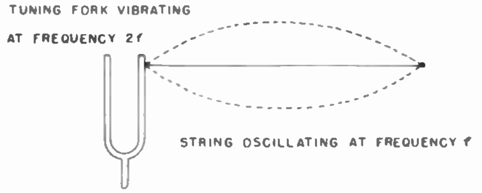


Fig. 1—Melde's experiment.

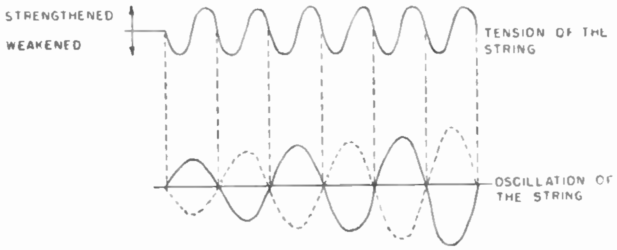


Fig. 2—Build up of oscillation of the string.

In an electrical system, inductance and capacitance are the parameters which determine the resonant frequency. Parametric oscillation therefore can be produced in a resonant circuit by periodically varying one of the reactive elements composing the resonant circuit [18].

A parametron element is essentially a resonant circuit with a reactive element varying periodically at frequency $2f$ which generates a parametric oscillation at the subharmonic frequency f. In practice, the periodic

* Original manuscript received by the IRE, December 9, 1958; revised manuscript received, May 14, 1959.
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variation is accomplished by applying an exciting current of frequency $2f$ to a balanced pair of nonlinear reactors, such as ferrite-core coils and nonlinear capacitors made of ferroelectric material or of the barrier capacitance of semiconductor junctions.

The subharmonic parametric oscillation thus generated has a remarkable property in that the oscillation will be stable in either of two phases which differ by π radians with respect to each other. Utilizing this fact, a parametron represents and stores one binary digit, "0" or "1," by the choice between these two phases, 0 or π radians. The solid line and the dotted line in Fig. 2 illustrate the building up of these two kinds of oscillation.

Under certain resonance conditions, the oscillation generated in the parametron is "soft," that is, it is easily self-started from any small initial amplitude. In this case, the choice between the two stable phases of the oscillation having a large amplitude can be made by controlling the phases of the small initial oscillation. This fact may be regarded as amplification and its mechanism may best be understood as superregeneration with the phase of the oscillation quantized to two states. In order to make use of this effectively, quenching means are provided in parametron circuits to interrupt parametric oscillation. Besides the memory and amplifying action, parametrons can also perform various logical operations based on a majority principle by applying the algebraic sum of oscillation voltages of an odd number of parametrons to another parametron in which the algebraic sum voltage works as the small initial oscillation voltage.

Mathematical studies on parametric oscillations of small amplitude in a linear region have been conducted in detail in the past. The results will be found in textbooks on differential equations under such headings as linear differential equations with periodic coefficients, Mathieu's equation, Hill's equation, and Floque's theorem [16], [17]. However, in order to describe the actual behavior of parametrons quantitatively, one has to take nonlinearity into consideration, and this will be treated in the Appendix.

The application of parametric oscillation to amplifying electrical signals is not a new idea. We find in Peterson's patent of 1932 [29], an idea for an amplifier based on the same principle as the parametric amplifier, which is now one of the most discussed topics in the field of electronics. In a parametric amplifier, two resonant circuits, respectively tuned to signal frequency f_s and idling frequency f_i, are coupled together regeneratively through a nonlinear reactor to which is applied a voltage of pumping frequency f_p, satisfying the condition $f_p=f_i+f_s$. A parametric amplifier performs regenerative amplification of signals and may produce, as well, a pair of spontaneous oscillations at frequency f_s and f_i.

A parametron producing a subharmonic oscillation may be regarded as a degenerative case of a parametric amplifier, in which the two resonant circuits for f_s and f_i are reduced to a single common circuit, so that $f_s=f_i=f$, and $f_p=2f$. Consequently, the basic principle of the amplifying mechanism of the parametron may be considered the same as that of the parametric amplifier. The degeneracy in the number of resonant circuits, however, makes possible the phase quantizing nature of the oscillation. While this is generally unfavorable for amplifying ordinary continuous waves, it is very useful for representing and storing a binary digit in the parametron.

Parametric oscillation of the second subharmonic mode in an electrical system has been known for many years and has been applied to frequency dividers [18]. On the other hand, the idea that two stable phases exist and can be applied to digital operations can be found only in a patent [30] of the late Professor von Neumann, so far as the author knows. Von Neumann proposed, completely independent of the author, a scheme similar to the parametron. His idea, however, seems to have not yet been developed into practical use.

If the resonance condition of a circuit which produces the subharmonic parametric oscillation is slightly altered, a "hard" oscillation, *i.e.*, not self-starting, will be produced. This circuit, generally, has three stable states, namely, "no oscillation," "oscillating at 0 phase," and "oscillating at π-radian phase." In Japan such an element is usually called a "tristable parametron," while in the case of "soft" oscillation it is called a "bistable parametron." In the hard oscillation circuit, *i.e.*, the tristable parametron, a binary digit can be represented by the presence or absence of oscillation. This scheme has also been proposed independently by Clary [31].

II. Basic Principle

The parametron is essentially a resonant circuit in which either the inductance or the capacitance is made to vary periodically. Fig. 3 shows circuit diagrams for parametron elements. The parametron element in Fig. 3(a) consists of coils wound around two magnetic ferrite toroidal cores $F1$ and $F2$, a capacitor C, and a damping resistor R, and a small toroidal transformer T. Each of the cores $F1$ and $F2$ has two windings and these are connected together in a balanced configuration, one winding $L=L'+L''$ forming a resonant circuit with the capacitor C and being tuned to frequency f. An exciting current, which is a superposition of a dc bias and a radio frequency current of frequency $2f$, is applied to the other winding, $l'+l''$, causing periodic variation in the inductance $L=L'+L''$ of the resonant circuit at frequency $2f$.

The parametron in Fig. 3(b) consists of two nonlinear capacitors C' and C'' which form the resonant circuit with the inductance L. An exciting voltage of frequency $2f$ is supplied between the neutral point of the two nonlinear capacitors C', C'' and the neutral point of the inductance L, causing periodic variation in the tuning capacitance $C(1/C=1/C'+1/C'')$ at frequency $2f$. As

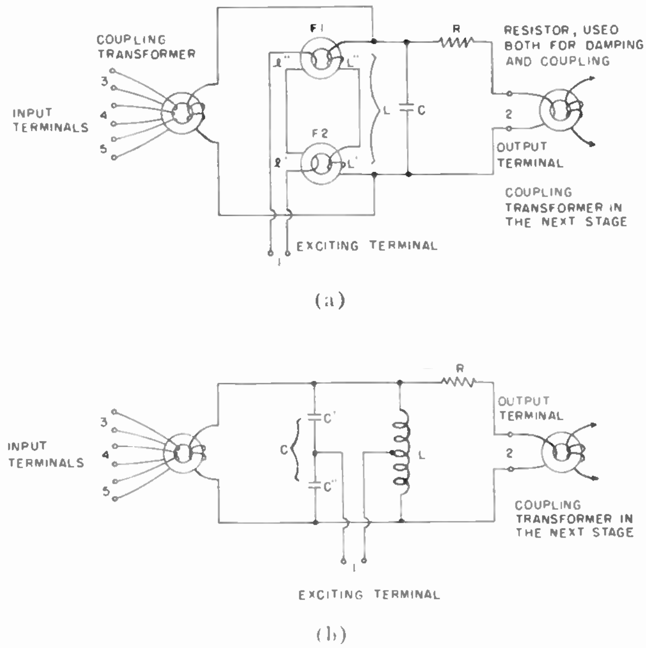

Fig. 3—Circuit diagram of parametrons, (a) Magnetic type. (b) Capacitive type.

the results are entirely analogous in both cases, the following explanations will be given only for the former case.

The operation of the parametron is based on a spontaneous generation of a second-subharmonic parametric oscillation, that is a self-starting oscillation of frequency f, in the resonant circuit. Parametric oscillation is usually treated and explained in terms of Matheiu's equation. A more intuitive explanation, however, may be obtained by the following consideration.

Let the inductance L of the resonant circuit be varied as

$$L = L_0(1 + 2\Gamma \sin 2\omega t) \tag{1}$$

where $\omega = 2\pi f$, and let us assume the presence of a sinusoidal ac current I_f in the resonant circuit at frequency f, which can be broken down into two components as follows:

$$I_f = I_s \sin(\omega t) + I_c \cos(\omega t). \tag{2}$$

Then, assuming that the rate of the variation of amplitudes of the sine and cosine components, I_s and I_c, are small compared with ω, the induced voltage V will be given by

$$\begin{aligned} V = d/dt(LI_f) &= \omega L_0(I_s \cos \omega t - I_c \sin \omega t) \\ &+ 3\Gamma\omega L_0(I_s \sin 3\omega t + I_c \cos 3\omega t) \\ &+ \Gamma\omega L_0(-I_s \sin \omega t + I_c \cos \omega t). \end{aligned} \tag{3}$$

The first term shows the voltage due to a constant inductance L_0, and the second term or the third harmonic term may be neglected in our approximation, since it is off resonance. The third term, which is essential for the generation of the second subharmonic, shows that the variable part of the inductance behaves like a negative resistance $-r = -\Gamma\omega L_0$ for the sine component I_s, but behaves like a positive resistance $+r = \Gamma\omega L_0$ for the cosine component I_c.

Therefore, provided that the circuit [Fig. 3(a)] is nearly tuned to f, the sine component I_s of any small oscillation (Ⓐ in Fig. 4), will build up exponentially (Ⓑ in Fig. 4), while its cosine component will damp out rapidly. If the circuit were exactly linear, the amplitude would continue to grow indefinitely. Actually, the nonlinear B-H curve of the cores causes detuning of the resonance circuit and hysteresis loss also increases with increasing amplitude, so that a stationary state (Ⓒ in Fig. 4) will rapidly be established, as in vacuum-tube oscillators. Details of the amplitude limiting mechanism, which is essentially a nonlinear problem, will be treated in the Appendix. The solution of the problem will be illustrated most intuitively by showing the locus of the sine and cosine components, I_s and I_c in the (I_s, I_c) plane. Fig. 5 shows an example of such loci for a typical case $\alpha = 0$, $\delta = \Gamma/2$ (*cf.* Appendix). The abscissa represents the sine component I_s and the ordinate, the cosine component I_c. If we introduce polar coordinates (R, ϕ) in the (I_s, I_c) plane, it will be seen easily from (1) that R and ϕ, respectively, indicate the instantaneous amplitude and phase of the oscillation. The saddle point at the origin indicates the exponential build up of oscillation which is in a definite phase relation to the excitation wave of frequency $2f$. Spiral points A and A' in the figure indicate the stable states of stationary oscillation. The existence of two possible phases in this oscillation which differ by π radians from each other, corresponding to A and A', should be noted. These two modes of oscillation are respectively shown by the solid line and dotted line in Fig. 4. An especially important feature is that the choice between these two modes of stationary oscillation is effected entirely by the sign of the sine component of the small initial oscillations that have existed in the circuit (A in Fig. 4). In other words, the choice between A and A' in Fig. 5 depends on which side of the thick curve B-B' (called separatrix) the point representing the initial state lies. An initial oscillation of quite small amplitude is sufficient to control the mode or the phase of stationary oscillation of large amplitude which is to be used as the output signal. Hence, the parametron has an amplifying action which may be understood as superregeneration. The upper limit of this superregenerative amplification is believed to be determined only by the inherent noise, and an amplification of as high as 100 db has been reported.[1]

The existence of dual mode of stationary oscillation can be made use of to represent a binary digit, "0" and "1" in a digital system, and thus a parametron can store

[1] A personal communication from Z. Kiyasu, of Electrical Communication Laboratory, Nippon Telephone and Telegraph Co., Tokyo, Japan.

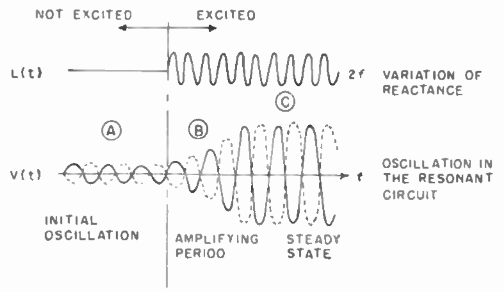

Fig. 4—Oscillation of parametrons.

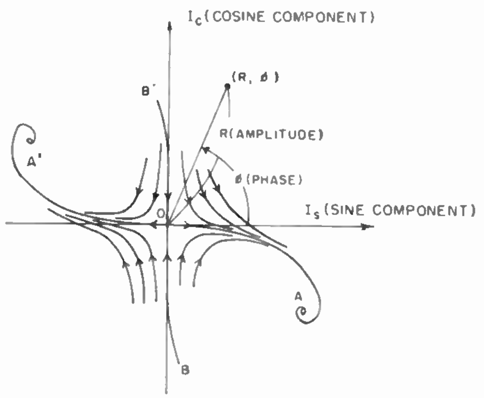

Fig. 5—The amplitude-to-phase (R, ϕ) locus of an oscillating parametron.

1 bit of information. However, oscillation of parametrons in this stationary state is extremely stable, and if one should try to change the state of an oscillating parametron from one mode to another just by directly applying a control voltage to the resonant circuit, a signal source as powerful as the parametron itself would be necessary. This difficulty can be got around by providing a means for quenching the oscillation, and making the choice between the two modes, *i.e.*, the rewriting of information, by a weak control voltage applied at the beginning of each building up period, making use of the superregenerative action.

Actually, this is done by modulating the exciting wave by a periodic square wave which also serves as the clock pulse of the computer. Hence, for each parametron there is an alternation of active and passive periods, corresponding to the switching on and off of the exciting current. Usually, the parametron device uses three clock waves, labeled I, II and III, all having the same pulse recurrence frequency, but switched on and off one after another in a cyclic manner as shown in Fig. 6. This method of exciting each of the parametrons in a digital system with either one of the three exciting waves I, II and III is usually called the "three beat" or the "three subclock" excitation.

III. Basic Digital Operations by Parametrons

Digital systems can be constructed using parametrons by intercoupling parametron elements in different

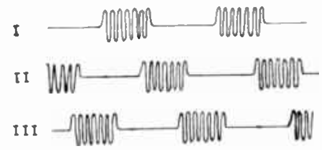

Fig. 6—The exciting current of three groups, I, II and III.

groups by a coupling element, the toroidal transformers shown in Fig. 3.

Figs. 7 to 9 show the basic parametron circuits.

The parametron is a synchronous device and operates in rhythm with the clock pulse. Each parametron takes in a new binary digit ("1" or "0") at the beginning of every active period, and transmits it to the parametrons of the next stage with a delay of one-third of the clock period. This delay can be used to form a delay line. Fig. 7 shows one such delay line which consists of parametrons simply coupled in a chain, each successive parametron element belonging each to the groups, I, II, III, I, · · · . Hence, the phase of oscillation of a parametron in the succeeding stage will be controlled by that in the preceding stage, and a binary signal x applied to the leftmost parametron will be transmitted along the chain rightwards in synchronism with the switching of the exciting currents. Hence, the circuit may be used as a delay line or a dynamic memory circuit.

Fig. 8 shows how logical operations can be performed using parametrons. In the figure, the outputs of the three parametrons X, Y and Z in stage I, which are all oscillating at a voltage V, are coupled to the single parametron U in stage II with a coupling factor k. As the effective phase control signal acting on U is the algebraic sum of the three signals from X, Y and Z, each of which has the value $+kV$ or $-kV$, the mode of U representing a binary signal u will be determined according to the majority of the three binary signals x, y and z, respectively represented by the oscillation modes of X, Y and Z. It would be possible, in principle, to generalize the majority circuit of Fig. 8(a) to 5, 7, 9, · · · inputs, that is, to any odd number of inputs. In practice, however, the nonuniformity in the characteristics of each parametron causes disparity in the input signals and makes the majority decision inaccurate, and this fact limits the allowable number of inputs to 3 or 5 in most cases.

It is easily seen that the majority operation just outlined includes the basic logical operations "and" and "or" as special cases. Suppose that one of the three inputs in Fig. 8(a), say z, is fixed to a constant value "1," then we obtain a biased majority decision on the remaining two inputs x and y, and the resulting circuit gives "x or y" as shown in Fig. 8(c). Similarly, if z is fixed to a constant value "0," we obtain a circuit for "x and y" as shown in Fig. 8(d). These constant signals are actually derived from a special parametron called constant parametron, or some other voltage source equiva-

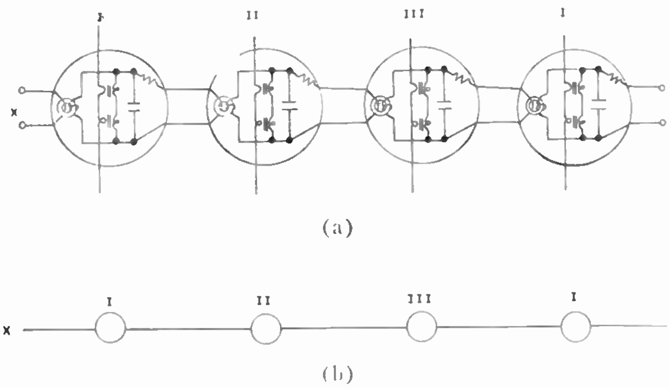

Fig. 7—A parametron delay-line circuit.

lent to it. If 2 out of 5 inputs in a "5-input majority operation" are made constants, either "1" or "0," we shall obtain either a "or" or "and" circuit respectively for three input variables x, y and z, as shown in Figs. 8(e) and 8(f).

"Complementation" or "not" operation can be made most simply in parametron circuits. In order to change the binary signal "1" into "0" and vice versa, we have only to reverse the polarity of the input signal, and this can be done by coupling two parametrons in reversed polarity as shown in Fig. 9. In the schematic diagram, such coupling in reversed polarity will be indicated by a short bar in the coupling line as shown in Fig. 9.

Since a digital system of any complexity can be synthesized by combining the four basic circuit elements, namely "delay," "and," "or," and "not," it will be seen that a complete digital system, *e.g.*, a general purpose electronic computer, can in principle be constructed using only one kind of circuit element—the parametron. It should be noted that the above conclusion presupposes that some means for logical branching, that is amplification of signal power, is provided. Now parametrons have a large superregenerative amplification and the output of a single parametron can supply input signals to a rather large number of parametrons in the next stage. For the parametrons currently used, the maximum allowable number of the branching is from 10 to 20. This feature adds flexibility in design of digital systems using parametrons.

IV. Simple Examples of Parametron Circuits

A complete digital apparatus may consist of hundreds or thousands of parametrons, coupled to each other by wires (via resistors and transformers) to form a network. Such a network of parametrons may be conveniently described by a schematic diagram.

At this point we will give a short summary of the rules and conventions for schematic diagrams currently in use in Japan.

Each parametron is represented by a small circle, as shown in the figures. Each pair of circles is connected by a line if corresponding parametrons are coupled, one

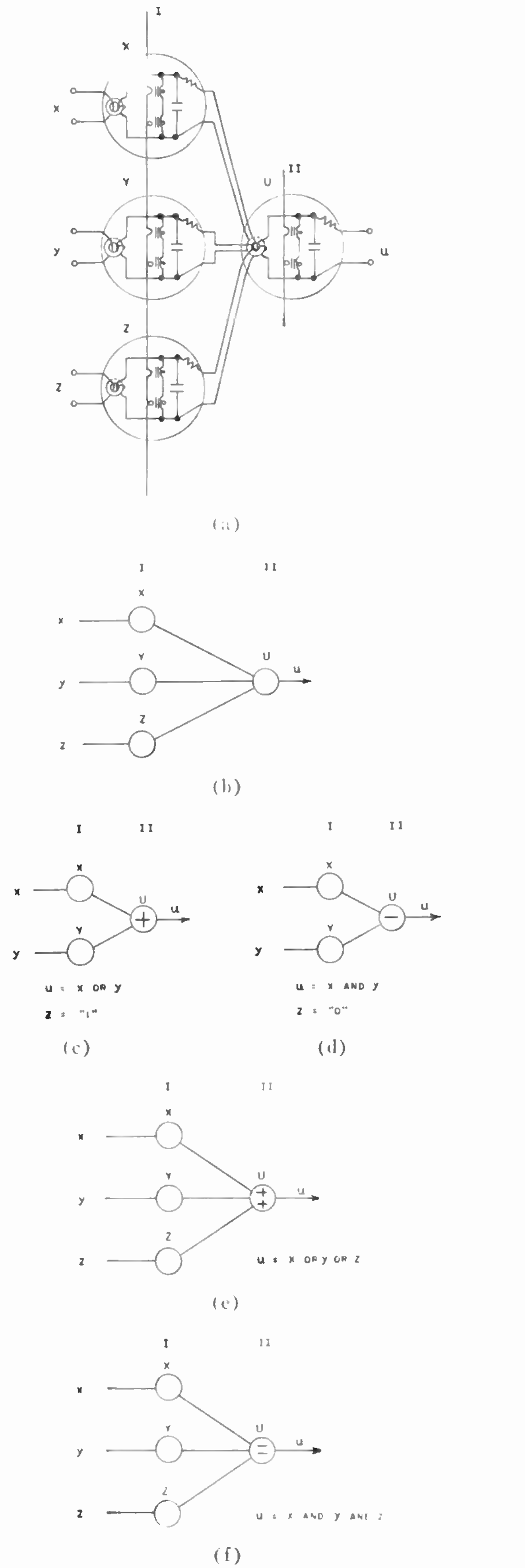

Fig. 8—A three-input majority operation circuit. (a) Circuit diagram. (b) The schematic diagram of (a). (c) An "or" circuit for two inputs. (d) An "and" circuit for two inputs. (e) An "or" circuit for three inputs. (f) An "and" circuit for three inputs.

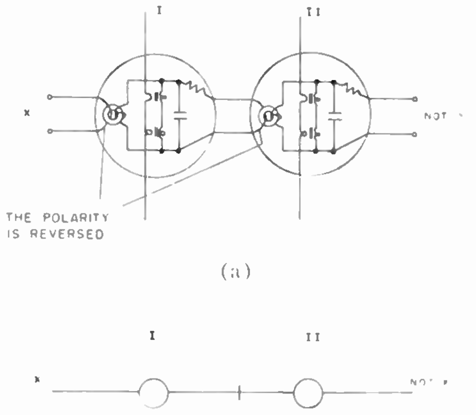

Fig. 9—(a) A "not" circuit. (b) The schematic diagram of the "not" circuit (a).

line being used per unit coupling intensity. Hence, a double line between circles will indicate that both parametrons are coupled at double coupling intensity (*cf.* Fig. 14). A short bar across any coupling line denotes complementation, that is, both parametrons are coupled with reversed polarity (Fig. 9), and otherwise it is understood that they are coupled in the same polarity.

If not specified, parametrons are supposed to be excited with the three-beat excitation. Accordingly, only parametrons belonging to different groups (I, II and III) can be coupled, and the information is transmitted along these lines always in the direction: I→II, II→III and III→I. Therefore, each coupling line has a definite direction of transmission, and to show this direction, usually the output lines from a parametron will come from the right side of the circle and go into the left side of another circle as input to it. As has been explained in Section III, there may be many parametrons which take some of their input signals from special parametrons called constant parametrons. These belong to a special triplet of parametrons, connected in a ring and always holding the digit "1," and serving as the phase reference. Since there may be a great many lines that come from these constant parametrons, these lines are usually omitted from the diagram, in order to avoid complication, and one "+" symbol is inscribed in the circle per unit constant input of positive polarity, and also one "−" symbol is inscribed per unit constant input of negative polarity. Accordingly, a circle with a "+" having two input lines corresponds to an "or" element, a circle with a "−" having two input lines corresponds to an "and" element, and a circle with "++" having three input lines corresponds to a 3-input "or" element, etc. It should be noted that the distinction between "0" and "1" in a parametron circuit is only possible by referring to the oscillation phase of these constant parametrons, since the phase is a relative concept.

The following figures show some simple examples of actual parametron circuits in schematic diagrams. The reader will not find it difficult to trace the functioning of these circuits. Fig. 10 shows a parametron flip-flop or a 1-bit memory circuit. Three parametrons, coupled in ring form, are required to store 1 bit of information. In Figs. 10(a) and 10(b) it is assumed that the signals in the set and reset inputs are both normally "0." The flip-flop will be set to "1" when a "1" signal is applied to the set input, and the flip-flop will be reset to "0" when a "1" signal is applied to the reset input. The functional difference between Figs. 10(a) and 10(b) consists in that, when both the set and the reset signal are applied simultaneously, the stored information will not change in the circuit of Fig. 10(a), but it will be reset to "0" in the circuit of Fig. 10(b).

Fig. 10(c) shows a flip-flop with a gate. As long as "0" is applied to the gate, the stored information does not change, but when "1" is applied to the gate, the signal from the input is transferred to the flip-flop.

Fig. 11 shows three stages of binary counting circuits connected in cascade, thus forming a scale-of-8 counter. Three flip-flops are included in this circuit to store a 3-bit count. In the quiescent state, in which "0" is applied to the input, the bits stored in each flip-flop do not change, but each time a "1" is applied to the input for a single clock period, the registered binary number is increased by 1 (mod 8). Figs. 12, 13 and 14 show respectively a binary full-adder circuit for three input signals, a parity check circuit for five input signals and a circuit for "x and (y or z)." These examples will show how majority operations can be made use of advantageously compared to the "and" and "or" operations. These circuits would have required many more parametrons if they were composed of "and" and "or" operations as in the usual diode networks. Flexibility of circuit design by use of a three- or five-input majority operation will be regarded as one of the characteristic features of parametron circuits.

The reason for the necessity of three subclock waves I, II and III, shown in Fig. 4, will be shown in Fig. 15. In Fig. 15, $P1$, $P2$, etc., indicate parametrons and $C1$, $C2$, etc., indicate coupling elements provided between parametrons. Each of the parametrons is supposed to be excited with either one of the two kinds of radio-frequency waves, I′, and II′, as shown in Fig. 16. These two waves are switched on and off alternately and will be called the two subclock exciting waves. If the coupling between two parametrons consists of a passive linear circuit, which is essentially a bilateral system, and if the two parametrons $P1$ and $P3$ in Fig. 15 are generating oscillations, voltages will be transmitted to $P2$ from both $P1$ and $P3$ with substantially the same intensity, and the phase-controlling action of $P2$ will become uncertain. Therefore, in order to use the two subclock exciting waves I′, and II′ in a parametron circuit, it is necessary to use unilateral coupling means. This may be accomplished by using a unilateral element, such as vacuum tubes and transistors, or by varying the coupling coefficient of the coupling elements as $K1$ and $K2$ in Fig. 16 by means of applying a gating signal to

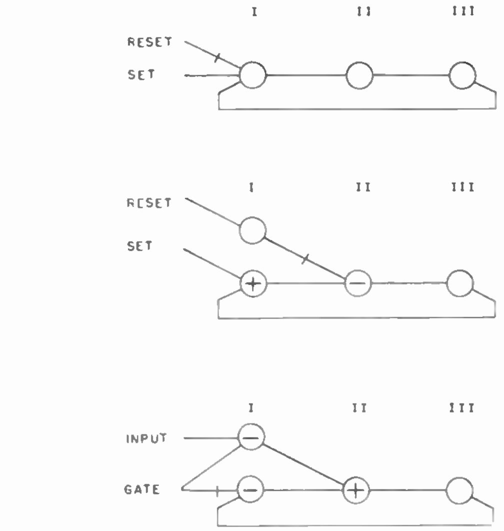

Fig. 10—Flip-flop circuits. (a) A flip-flop circuit. (b) A flip-flop circuit. (c) A flip-flop circuit with an input gate.

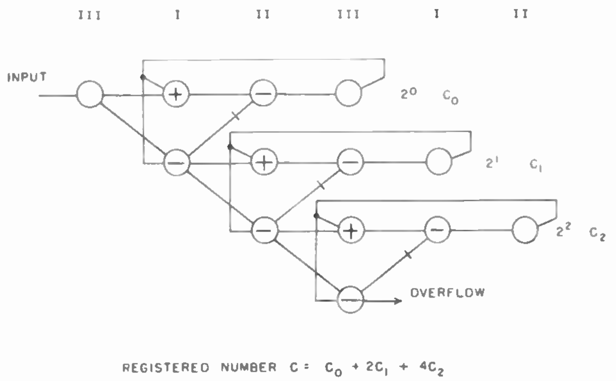

Fig. 11—Three stages of binary counters forming a scale of eight circuits.

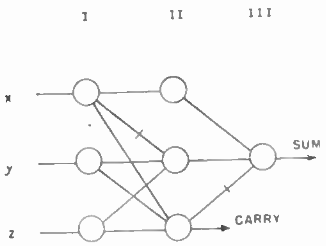

Fig. 12—A binary full-adder circuit.

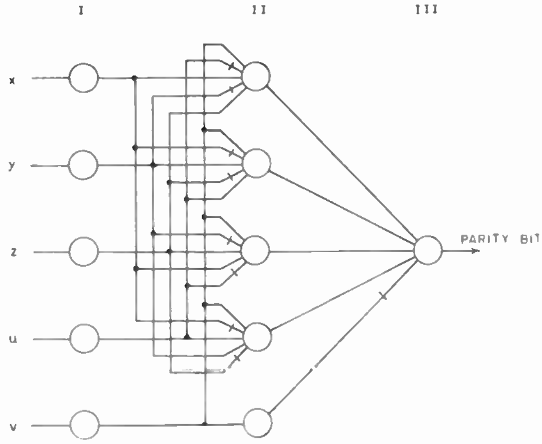

Fig. 13—A parity-check circuit for five input signals.

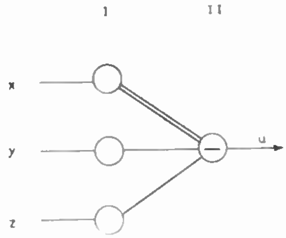

Fig. 14—A circuit for "x and (y or z)."

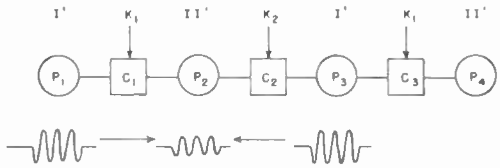

Fig. 15—Coupling system for two-subclock excitation.

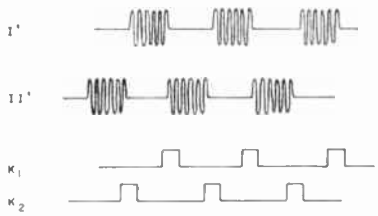

Fig. 16—Two-subclock excitation.

nonlinear elements, such as diodes and magnetic cores [27].

In the three-beat or the three-subclock exciting method, each of the parametrons will be excited once in every clock cycle at a definite time. In this respect the method may be called stationary excitation. On the other hand, we may think of a more general method, usually called "non-stationary excitation" or "gated excitation" in Japan, in which the excitation of parametrons is switched in accordance with gating signals [28]. Fig. 17 shows a selecting circuit using the "gated excitation." $S_1, S_2, \cdots, S_n$ indicate binary phased information sources and $P_1, P_2, \cdots, P_n$ are gating parametrons. Supposing that the exciting wave I is applied selectively to only one of the gating parametrons, say P_2, by controlling the excitation with a gating signal so as to produce oscillation only in P_2, the information from S_2 will be selectively transmitted to the parametron P, since the oscillation of P_2 is controlled by S_2 and the oscillation of P is controlled by that of P_2. For comparison, Fig. 18 shows a selecting circuit for one out of four channels using the three-subclock (stationary) ex-

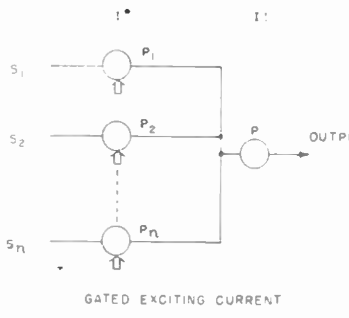

Fig. 17—Channel-selecting circuit using gated excitation.

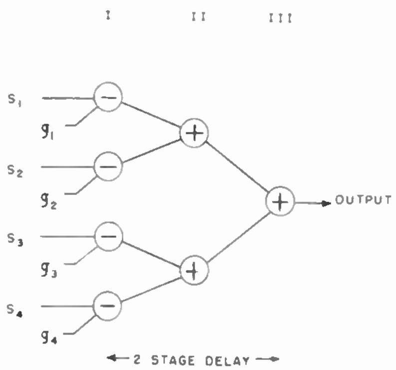

Fig. 18—Channel-selecting circuit using three-beat excitation.

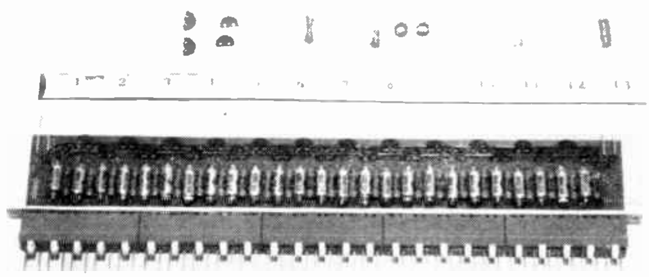

Fig. 19—A parametron unit (25 parametrons).

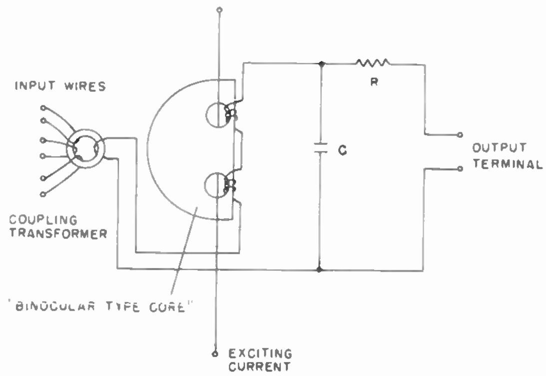

Fig. 20—The circuit of a parametron with a "binocular type core" and a series type coupling transformer.

citation. The channel selecting arrangement using gated excitation will generally reduce the access time and the number of parametrons at the expense of employing rather complicated exciting circuits.

V. Characteristic Features of Parametrons

Fig. 19 shows a commercial unit composed of 25 parametrons and the component parts. In this unit a ferrite disc with two small holes (known as a "binocular type core" [7]) is used instead of the two toroids in Fig. 3. The coupling transformer consists of a single-turn coil wound on a ferrite toroid and is connected in series to the resonant circuit as shown in Fig. 20. As the life of parametrons is considered to be practically permanent, the parametron units are usually not made in a "plug-in" style, but are directly wired into the logical networks.

As may be seen from Figs. 3, 7, and 8, the wiring of parametron circuits is done in an unusual way. A wire connected to the output terminal of a parametron in a preceding stage is passed through the coupling transformers of all the parametrons in the succeeding stage which are to receive the input signal from the parametron in the preceding stage. This has resulted in a remarkable simplification in the construction of complex logical networks, such as general purpose computers, since the whole system can be assembled from identical standardized units, and the units can be wired to form the specific machine using only wires and with a minimum number of soldering points. Table I shows the

TABLE I

Characteristics of Commercial Parametron Units

	High Speed Type	Standard Type	Low Power Type
Exciting frequency $2f$	6 mc	2 mc	200 kc
Maximum clock frequency	140 kc	25 kc	2 kc
Exciting power per one parametron for continuous excitation	120 mw	30 mw	5 mw
DC bias	0.6 amp	0.6 amp	0.6 amp
Maximum number of inputs	3 or 5	3 or 5	3 or 5
Maximum number of output branching	12	15	15
Coupling coefficient*	−35 db	−40 db	−40 db

* *Note:* The coupling coefficient k is defined as the ratio:

k = voltage of unit input measured at the resonant circuit / voltage of stationary oscillation

typical characteristics of commercial parametrons in Japan.

For application to digital computers we are most concerned in the speed of operation, which is essentially determined by the clock frequency F_k. The upper limit of F_k is limited by the rates of building up and damping of parametric oscillation.

From (3) it follows that the oscillation builds up proportionally to $e^{\pi\Gamma f t}$ (*cf.* Appendix), and hence the maximum clock frequency will be proportional to the product Γf, which we call the "figure of merit" of the parametron, owing to its analogy to the figure of merit of vacuum tubes $g_m/2\pi C$.

The figure of merit of a parametron naturally depends on the frequency and amplitude of the exciting current, and the value for conventional parametrons in normal operation lies between 20kc and 1.5 mc. For reliable operation, the clock frequency should be chosen around $Pf/10$ if the coupling factor is $k=1/50$ $(-34$ db), and hence the upper limit for the clock frequency is about 150 kc for commercial parametron units.

In the past, most effort has been made to develop parametrons using variable inductance, but it is apparent that the same principle applies when the capacitor is the variable element. Parametrons using ceramic nonlinear capacitors (barium titanate) have been studied by Oshima and Kiyasu [8].

Studies of parametrons using the variable barrier capacitance of germanium and selenium diodes have also been made, and a parametric oscillation at $f=60$ mc has been realized [5], [9].

and will limit their use in small-scale digital devices. At the present stage, parametrons seem to be unfavorably compared with vacuum tubes and transistors in speed of operation, but this point may be much improved by further development.

VI. Application

All the characteristics of parametrons just mentioned make them ideally suited to applications in large-scale digital devices, and particularly to general purpose digital computers. Soon after the invention of parametrons in 1954, a project was launched to construct general purpose computers using control and arithmetic units entirely composed of parametrons. At present, nearly half of the digital electronic computers built in Japan are parametron computers [11], [14]. Table II shows the characteristics of these computers.

TABLE II
The Characteristics of General Purpose Parametron Computers

Type (Date of Completion)	Place of Installation	The Number of Parametrons (Number System)	Exciting Frequency	Clock Frequency	Speed of Operation (for Fixed Point) Including Access		Main Memory	Power
					Addition	Multiplication		
FACOM 212 (March, 1959)	Fuji Elec. Co. Kawasaki	8000 (Decimal)	2 mc	10 kc	4 ms	15 ms	49 words Core Matrix	5 kw
HIPAC-1 (December, 1957)	Cent. Lab. Hitachi Elec. Co. Kokubunji, Tokyo	4400 (Binary)	2 mc	10 kc	10 ms	19 ms	1024 words Magnet Drum	6 kw
MUSASINO-1 (March, 1957)	Elec. Communication Lab. Musasino, Tokyo	5400 (Binary)	2 mc	6 kc	4 ms	20 ms	256 words Core Matrix	5 kw
NEAC-1101 (April, 1958)	Cent. Lab. Nippon Elec. Co. Kawasaki	3600 (Binary)	2 mc	20 kc	3.5 ms	8 ms	128 words Core Matrix	5 kw
PC-1 (March, 1958)	Department of Physics University of Tokyo Tokyo	4200 (Binary)	2 mc	15 kc	270 μs	3.4 ms	256 words Core Matrix	3 kw
PC-2* (August, 1959)		9600 (Binary)	6 mc	100 kc	40 μs	340 μs	1024 words Core Matrix	10 kw
SENAC-1 (November, 1958)	Elec. Communication Lab. University of Tohoku Sendai	9600 (Binary)	2 mc	20 kc	2 ms	3 ms	160 words Magnetic Drum	15 kw

* *Note:* The construction of PC-2 will be completed in August 1959.

Parametrons are composed of capacitors, resistors and coils with ferromagnetic cores which are all stable and durable components. Unlike the more conventional switching circuits using magnetic amplifiers, parametrons require no diodes for their operation. These features guarantee for parametron circuits extremely high reliability and long life. In several digital computers now in operation in Japan, troubles with parametrons are extremely rare.

The necessity of a high-frequency power supply may be one of the inherent disadvantages of parametrons

In the core matrix memory of these parametron computers, an entirely new method, proposed by the author in 1955 [24]–[26], is employed both for reading and writing. Writing is effected by impressing on each memory core the superposition of two ac currents, supplied from parametrons and having frequencies of f and $f/2$. Reading is also effected with parametrons by amplifying and sensing the phase of the second harmonic component of frequency f which is generated in each memory core by impressing an ac current of frequency $f/2$ on it.

The new method is called "dual frequency memory system," and the following are considered to be characteristic features:

1) Memory cores are driven by output ac currents of parametrons.
2) Only two windings, X and Y, pass through each memory core.
3) Reading is nondestructive.

The details will be discussed in a separate paper to follow.

The application of parametrons to other digital devices has also been made in a number of laboratories. The Japan Overseas Telephone and Telegraph Company has constructed regenerative repeaters, telegraph code converters which convert Morse code to five-unit teleprinter code [6], and ARQ (automatic request) systems, which have all been in commercial use for some years.

The Japan Telegraph and Telephone Corporation has built a number of experimental common-control telephone switching systems, employing parametrons in control circuits [15]. The Fuji Electric Company and the Government Mechanical Laboratory have built experimental numerically controlled machine tools [13], in which parametrons are used for all numerical and control operations. Among other applications are automatic recording systems for a meson monitor used in cosmic-ray observation and multichannel pulse-height analyzers for nuclear research [4].

Appendix

Amplitude Limiting Mechanism of the Parametron

First, we shall derive the equation governing the oscillation in a parametric resonant circuit including a variable inductance $L(t)$ as shown in Fig. 21.

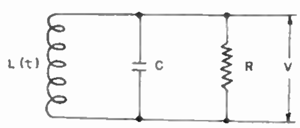

Fig. 21—A parametrically-excited resonant circuit.

The voltage V in the resonant circuit will be given by

$$V = \frac{d}{dt}(Li) \qquad (4)$$

where i is the current passing through the inductance. From Kirchhoff's law, we obtain

$$i + \frac{V}{R} + \frac{d}{dt}(CV) = 0. \qquad (5)$$

We shall assume that the inductance is varying as

$$L(t) = L_0(1 + 2\Gamma \sin 2\omega t). \qquad (6)$$

Putting

$$I = \frac{L}{L_0} i = (1 + 2\Gamma \sin 2\omega t) i \qquad (7)$$

$$\delta = \frac{1}{\omega CR} = \frac{1}{Q} \qquad (8)$$

$$\frac{1}{CL_0} = \omega^2(1 + \alpha) \qquad (9)$$

and assuming that Γ and α are much smaller than unity so that $(1+\alpha)\ (1+2\Gamma \sin 2\omega t)^{-1}$ may be replaced by $1+\alpha-2\Gamma \sin 2\omega t$, (6) will be rewritten as

$$\left[\frac{d^2}{dt^2} + \delta\omega \frac{d}{dt} + \omega^2(1 + \alpha - 2\Gamma \sin 2\omega t)\right] I = 0. \qquad (10)$$

We may call δ the loss factor, α the detuning of the resonant circuit from the second-subharmonic frequency ω, Γ the modulation index of the inductance and L_0 the constant part of the inductance. As the difference between I defined by (7) and the actual current i is of the order of Γ, the results to be obtained from the following analysis of I may be regarded as substantially the same as that of the actual current i when Γ is small.

In case α and δ are constants, (10) represents a linear differential equation, well known as Mathieu's equation [16]–[18]. In practice, however, ferromagnetic cores are used in the inductance to effect the variation, and with increasing amplitude the nonlinear B-H curve will cause detuning of the resonant circuit and hysteresis loss will also increase. Consequently, the loss δ and the detuning α of (10) will generally be functions of the amplitude I^2 and (10) becomes a nonlinear differential equation.

Now, we shall assume the presence of nonlinearity of the form βI^2 as the detuning. Then (10) becomes

$$\left[\frac{d^2}{dt^2} + \delta\omega \frac{d}{dt} + \omega^2(1 + \alpha + \beta I^2 - 2\Gamma \sin 2\omega t\right] I = 0. \qquad (11)$$

Breaking down I into two sinusoidal components as

$$I = I_s \cdot \sin \omega t + I_c \cdot \cos \omega t, \qquad (12)$$

(11) will be rewritten as

$$\begin{aligned}
&[2\dot{I}_s\omega + \delta\omega^2 I_s + \alpha\omega^2 I_c - \Gamma\omega^2 I_s + \tfrac{3}{4}\beta\omega^2(I_s{}^2 + I_c{}^2)I_c] \cos \omega t \\
&+ [-2\dot{I}_c\omega - \delta\omega^2 I_c + \alpha\omega^2 I_s - \Gamma\omega^2 I_c + \tfrac{3}{4}\beta\omega^2(I_s{}^2 + I_c{}^2)I_s] \sin \omega t \\
&+ [\ddot{I}_c + \delta\omega \dot{I}_c] \cos \omega t \\
&+ [\ddot{I}_s + \delta\omega \dot{I}_s] \sin \omega t \\
&+ [\Gamma\omega^2 I_s + \tfrac{1}{4}\beta\omega^2 I_c{}^3 - \tfrac{3}{4} I_s{}^2 I_c] \cos 3\omega t \\
&+ [-\Gamma\omega^2 I_c - \tfrac{1}{4}\beta\omega^2 I_s{}^3 + \tfrac{3}{4} I_s I_c{}^2] \sin 3\omega t = 0.
\end{aligned} \qquad (13)$$

In order to obtain an approximate solution of the nonlinear differential equations (11) or (13), we shall assume that α, Γ and δ are much smaller than unity.

Then I_s and I_c in (13) will vary much more slowly than ω, and the third and fourth terms of (13) may be neglected since they are much smaller than ω^2. The third harmonic terms may also be neglected since they are off resonance and thus we will obtain the following approximate equations for I_s and I_c:

$$\frac{2}{\omega}\dot{I}_s = -\delta I_s + \Gamma I_s - (\alpha + \tfrac{3}{4}\beta(I_s^2 + I_c^2))I_c$$

$$\frac{2}{\omega}\dot{I}_c = -\delta I_c - \Gamma I_s + (\alpha + \tfrac{3}{4}\beta(I_s^2 + I_c^2))I_s. \quad (14)$$

Each term of (14) has the following intuitive meaning: the first term with δ represents the loss in the circuit; the second term with Γ indicates negative resistance effect for the sine component I_s and damping (positive resistance) effect for the cosine component I_c; and the third term with α and β represents detuning of the resonant circuit which is a function of the amplitude R,

$$R = \sqrt{I_s^2 + I_c^2}.$$

In case of no detuning, *i.e.*, $\alpha = 0$, and of small amplitude, the solution of (14) is given simply by

$$I_s = I_{s0} \exp(\pi f(\Gamma - \delta)t)$$

$$I_c = I_{c0} \exp(-\pi(\Gamma + \delta)t) \quad (15)$$

where $\omega = 2\pi f$. Therefore, in case $\Gamma > \delta \geq 0$ holds, the sine component I_s will increase exponentially as described in Section II, while the cosine component I_c decreases exponentially.

The solution of a nonlinear differential equation such as (14) will be presented as integral curves or loci in the (I_s, I_c) plane and the behavior of these curves will be characterized by the singular points, *i.e.*, points in (I_s, I_c) plane where both $\dot{I}_s$ and $\dot{I}_c$ vanish (*cf.* [19], [20]).

The singular points of (14) will be obtained by placing $\dot{I}_s = \dot{I}_c = 0$ into (14) and the result may be classified into three cases 1, 2 and 3 depending on the magnitude of the parameters α, Γ and δ, as shown in Fig. 22. In Fig. 22, the abscissa represents $-\epsilon\alpha$ and the ordinate, δ, where $\epsilon = +1$ if $\beta > 0$ and $\epsilon = -1$ if $\beta > 0$. The characteristic curves which form the boundary lines of the three cases are two half-lines parallel to the α axis and a circle of radius Γ with its center at the origin. These three cases will be characterized by the following features.

Case 1

There are three singular points: One unstable saddle point at the origin $I_s = I_c = 0$, and two stable nodal or spiral points at

$$I_s = \pm\sqrt{\frac{2(\Gamma + \delta)}{3\Gamma|\beta|}(-\epsilon\alpha + \sqrt{\Gamma^2 - \delta^2})}$$

$$I_c = \pm\epsilon\sqrt{\frac{2(\Gamma - \delta)}{3\Gamma|\beta|}(-\epsilon\alpha + \sqrt{\Gamma^2 - \delta^2})}. \quad (16)$$

The integral curves of this case 1 have been shown in Fig. 5 for typical values $\alpha = 0$, $\delta = \Gamma/2$, $\beta < 0$. The existence of two stable states, the exponential build up of the small initial oscillation and all other characteristic features of parametrons described in Sections II and V will be explained by the behaviors of the integral curves of this Case 1.

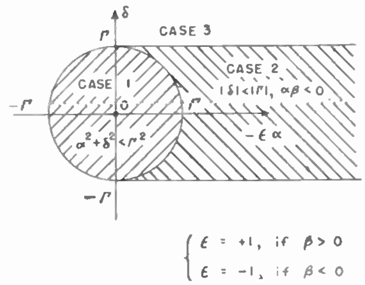

Fig. 22—Classification of the three cases of singular points in (α, δ) plane.

Case 2

There are five singular points: One stable nodal or spiral point at the origin $I_s = I_c = 0$, and two unstable saddle points at

$$I_s = \pm\sqrt{\frac{2(\Gamma + \delta)}{3|\beta|\Gamma}(-\epsilon\alpha - \sqrt{\Gamma^2 - \delta^2})}$$

$$I_c = \mp\epsilon\sqrt{\frac{2(\Gamma - \delta)}{3|\beta|\Gamma}(-\epsilon\alpha - \sqrt{\Gamma^2 - \delta^2})} \quad (17)$$

and two stable nodal or spiral points at

$$I_s = \pm\sqrt{\frac{2(\Gamma + \delta)}{3|\beta|\Gamma}(-\epsilon\alpha + \sqrt{\Gamma^2 - \delta^2})}$$

$$I_c = \pm\epsilon\sqrt{\frac{2(\Gamma - \delta)}{3|\beta|\Gamma}(-\epsilon\alpha + \sqrt{\Gamma^2 - \delta^2})}. \quad (18)$$

The integral curves of this Case 2 are shown in Fig. 23 for typical values $\delta = \Gamma/2$, $\alpha = 7\Gamma/4$, and $\beta < 0$. In Fig. 23, S, S' indicate the two unstable saddle points and A, A' indicate the two stable spiral points. The presence of the stable saddle point at the origin O indicates that the oscillation is not self-starting. If a suitable initiating voltage is applied to the circuit so as to place the point representing the initial oscillation either in the + region or in the − region of Fig. 23, stationary oscillation respectively represented by point A or A' will be produced. On the other hand, if the point representing the initial oscillation were within the O-region, even a voltage of very large amplitude would not initiate stationary oscillation. As there are three stable states respectively represented by O, A, A' in this Case 2, parametron elements corresponding to this case are usually called "tristable" or "ternary" parametrons, while those corresponding to Case 1 are called "bistable" or "binary" parametrons. In principle, a tristable parametron element may either represent a ternary digit by

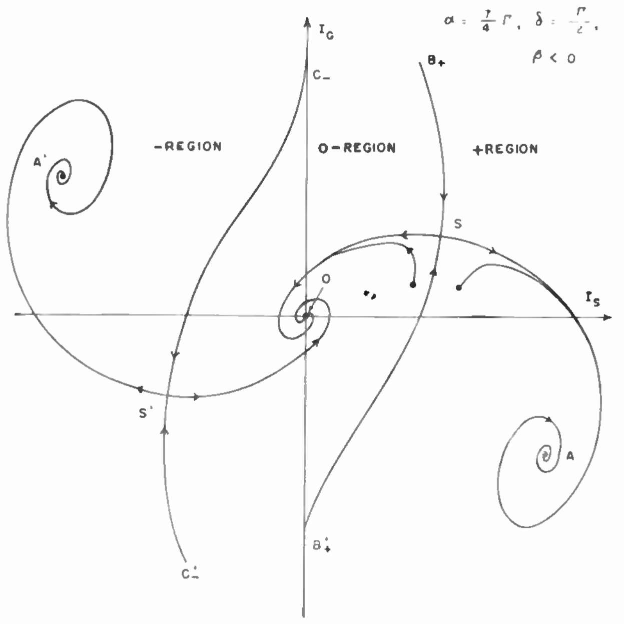

Fig 23—Integral curves of a tristable parametron.

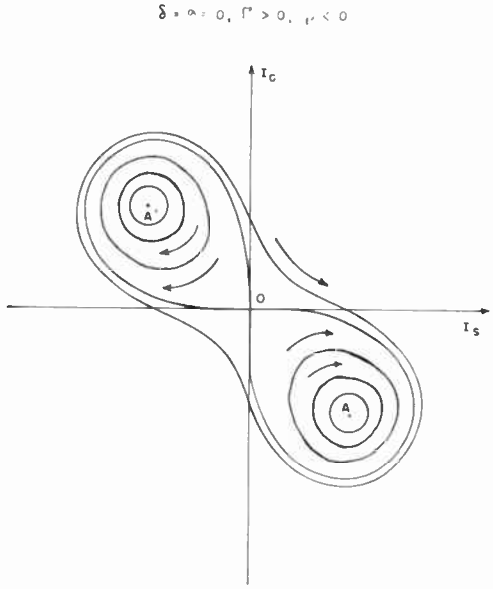

Fig. 24—Integral curves for a loss-free case.

the choice among the three stable states or a binary digit by the choice between the two states, namely, "no oscillation (O)" and "in oscillation (A and A')."

Case 3

There is only one stable singular point at the origin. As the magnitude of the parameters α, Γ and δ are inappropriate, stationary oscillation is not produced in this case.

Now, the functions of the damping will be considered. If there were no damping in (14), *i.e.*, $\delta = 0$, the permissible types (*cf.* [19], [20]) of singular points will be unstable saddle points and elliptic points, the stability of the latter being neutral. Fig. 24 shows the integral curves for a case in which $\alpha = \delta = 0$, $\Gamma > 0$, $\beta < 0$. 0 indicates a saddle point at the origin and A, A' indicate two elliptic plints. (For a point P on each curve, $AP \cdot A'P =$ constant is satisfied, and the curves are known as Cassini's ovals.) The point in the (I_s, I_c) plane, representing both the phase and the amplitude of the oscillation, will oscillate indefinitely around the points or point A and/or A', and a generally stationary state of oscillation with a definite amplitude and phase will never be reached. Further, if there were no damping, the oscillation in a parametron would never damp out, even if the parametric excitation were interrupted and it would be impossible to make use of the super-regenerative amplification explained in Section II.

Hence, we come to the following conclusion—damping is indispensable both for amplitude stabilization and interruption of parametric oscillation.

On the other hand, if the damping is too large, the building-up rate exp $(\pi f\ (\Gamma - \delta))$ of the sine component I_s, given by (15), will become so small as to reduce the speed of the superregenerative action. Therefore, there should exist an optimum value of the magnitude of the damping and experimental results show that the optimum value lies in the range $\Gamma/4 < \delta < \Gamma/2$.

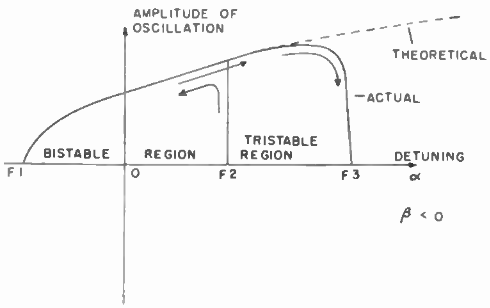

Fig. 25—Amplitude to detuning characteristic of a parametron.

Fig. 25 shows a typical example of the amplitude to detuning characteristic of an actual parametron element. In the figure, the abscissa represents the detuning α and the ordinate represents the amplitude of oscillation of a parametron element. In practice, the detuning α may be varied either by varying the tuning capacitance C in Fig. 3(a), or the tuning inductance L in Fig. 3(b), or by varying the frequency or the dc bias of the exciting current in the cases of both Figs. 3(a) and 3(b). The region $F1$ to $F2$ in Fig. 25 corresponds to the above mentioned case 1 and is called "bistable region" since it represents a bistable parametron. The region $F2$ to $F3$, corresponding to Case 2, is called "tristable region," since it represents a tristable parametron. When α is varied continuously a hysteresis jump will occur at the boundary $F2$ between the bistable and tristable region, as indicated by the arrows in Fig. 25. If we assume the presence of nonlinearity only in the detuning as in (11) and (14), the theoretical results indicate that the tristable region should extend indefinitely, as shown by the dotted line in Fig. 25 or by the two half-lines in Fig. 22. Actually, there exists an upper limit $F3$ and this fact will be explained by introducing nonlinearity also in the damping, for example by replacing δ in (11) and (14) by $\delta+\theta I^2$. For bistable parametrons, however, the present analysis assuming the presence of nonlinearity only in the detuning is in good agreement with the experimental facts and generally it is considered satisfactory.

In regard to the nonlinearity of the detuning βI^2, one might think it were caused by saturation of the magnetic cores. If this were the case, β should be positive since the inductance would decrease and the detuning would increase with increasing amplitude. Experiments made on various ferrite and ferroelectric materials, however, show that β is always negative for these materials. On the other hand, it is observed that β is always positive for parametrons using barrier capacitance of semiconductor junctions.

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Microwave Parametric Subharmonic Oscillators for Digital Computing*

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Summary—In a digital information handling system, a binary one can be represented by an RF signal of a given phase, frequency, and amplitude, and a binary zero by RF of the same frequency and amplitude but with opposite phase. The use of subharmonic oscillators to switch, store, and amplify binary information coded in this manner is reviewed. A variable capacitance subharmonic oscillator having an output frequency of 2000 mc is described, and the use of this oscillator in circuits for amplifying, scaling, and performing logic functions is discussed. The circuits described operate at pulse repetition rates exceeding 100 mc. By raising the carrier frequency to *X*-band, it should be possible to increase the maximum rate to a few hundred megacycles.

Introduction

In a digital computer operating at an effective pulse repetition rate of several hundred megacycles, each binary digit is allotted a time interval of only a few millimicroseconds. A baseband system[1] capable of handling such digits must have a bandwidth extending from dc well into the UHF or even the microwave region. An alternative to the baseband system is the use of a carrier system where the required pass band is centered about a suitable carrier frequency.

For operation at a pulse repetition rate of several hundred megacycles, a carrier system offers significant advantages over baseband systems. It is very difficult to design active and passive components which operate, starting from dc, with the necessary wide bandwidth.[2] In a carrier system, on the other hand, the design of components is greatly simplified by the fact that, at a high carrier frequency, components with a comparatively small percentage bandwidth have a large absolute bandwidth. Furthermore, carrier-type devices such as traveling-wave amplifiers, parametric amplifiers and oscillators, hybrid rings, ferrite isolators, etc., can be used advantageously in high-speed carrier systems [3]–[10], but are not applicable to baseband systems.

In a digital information handling system, a binary one can be represented by an RF signal of a given phase, and a binary zero by RF of the same frequency and amplitude but with opposite phase. Recently, it has been pointed out that subharmonic oscillators can be used to switch, store, and amplify binary information coded in this manner [3], [4]. Computing circuits using parametric variable inductance subharmonic oscillators with a carrier frequency of a few megacycles and a clock rate of up to 150 kc have been successfully built [4], [10].

In this paper the application of subharmonic oscillators to digital computing is briefly reviewed. A variable capacitance subharmonic oscillator having an output frequency of 2000 mc is described, and the use of this oscillator in novel circuits for amplifying, scaling, and performing logic functions is discussed.

The circuits described can operate at pulse rates exceeding 100 mc. By raising the carrier frequency to *X*-band, it should be possible to increase the maximum pulse rate to a few hundred megacycles. Thus microwave digital computing systems which are an order of magnitude faster than present experimental baseband systems appear to be feasible.[3]

Description of Microwave Subharmonic Oscillator

When a variable reactor is driven from a source, or pump, having a frequency f, a negative conductance is established across the reactor at or near the frequency $f/2$. (If the reactance is a nonlinear function of the drive, this negative conductance can also be developed at $f/3$, $f/4$, $\cdots$, f/n.) When connected to a low-loss circuit tuned to $f/2$, this negative conductance can overcome the circuit loss and produce stable oscillations at the frequency $f/2$ (*i.e.*, subharmonic oscillations).[4]

Fig. 1 shows a subharmonic oscillator, built from strip line, which produces a 2000 mc output. The important elements of this oscillator are: a 2000 mc quarter-wave resonator (a) having a variable-capacitance diode attached at one end; a 4000 mc half-wave resonant bar (b), which permits the 4000 mc drive (or "pump") power to enter resonator (a), but prevents 2000 mc oscillation power from escaping; and a loosely coupled output arm (c). Input and output are connected by conventional coaxial connectors. In the experiments described here, an experimental RCA variable capacitance germanium point-contact diode housed in a standard 1N23 mount was used. The capacitance-voltage relationship of this diode is approximated in Fig. 2. A

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[1] In a baseband system the signals occupy a frequency band starting at or near zero and extending to an upper limit.

[2] Logic circuits so far reported, using baseband pulses, are limited to pulse repetition rates of about 50 mc [1], [2]. This speed limitation is primarily due to the limited gain-bandwidth product of the devices used for amplifying the pulses.

[3] Computing circuits using subharmonic oscillators can also be used in conjunction with other high-speed microwave computing techniques [8].

[4] Subharmonic oscillations were already described by several 19th century observers [11], [12].

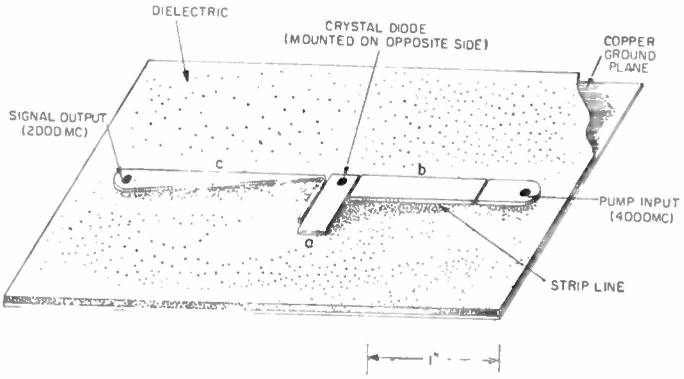

Fig. 1—A strip line subharmonic oscillator with 2000 mc output frequency.

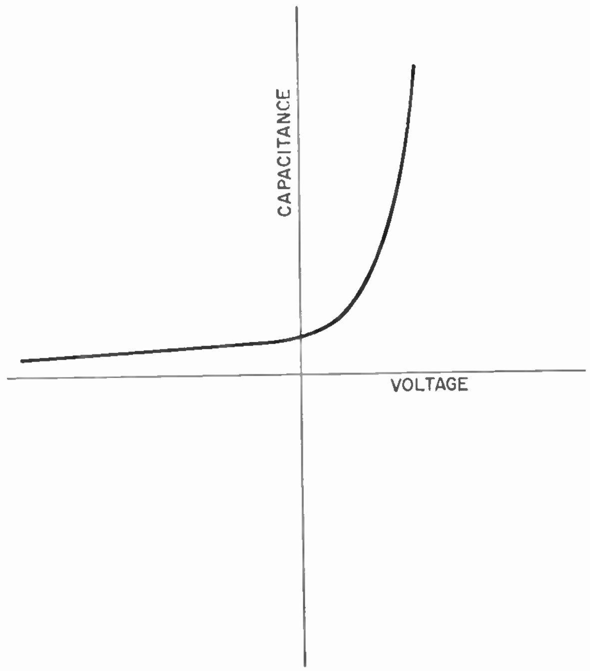

Fig. 2—Typical diode capacitance-voltage characteristics.

variable capacitance junction diode has since been developed at the RCA Laboratories. This diode is encapsulated in a ceramic cylinder of 0.040-inch height and 0.085-inch outside diameter. The packaged diode fits into a small hole drilled in the strip transmission line, and permits the construction of very compact oscillator circuits.

Fig. 3 shows the 2000 mc RF output power of the oscillator as a function of the 4000 mc RF input power for three values of back bias on the diode. The three curves have similar shapes. In each case, as the pump power is increased, the signal output increases to a maximum value and then drops rapidly to zero. The drop in output at high input-power levels is the result of losses in the diode when it is driven into conduction. At some value of input power these losses become too large to be overcome by the negative resistance, and oscillations stop. The higher the back bias on the diode,

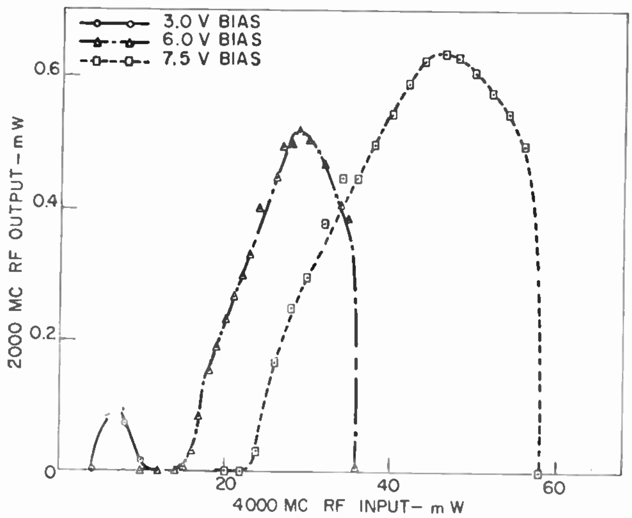

Fig. 3—RF power output vs RF power input for subharmonic oscillator.

the higher the pump power which can be applied to the diode without causing conduction, and the higher the maximum signal output which can be obtained from the oscillator.[5]

The output oscillations may occur in either of two exactly opposite phases, because either phase has the same time relationship with the pump, as shown in Fig. 4. The two phases may be distinguished by comparison with a reference signal of fixed phase.

The phase in which the oscillator operates is determined by the conditions in the oscillator at the instant the driving frequency is applied. If noise alone is present, then either phase is equally probable.[6] If, however, a sufficiently strong locking signal at the subharmonic frequency is present in the tank during the time oscillations are starting to build up, then oscillations will start in the phase closest to the phase of this initial signal. Initially, therefore, it is possible to select whichever of the two phases one desires. Once the circuit oscillates, however, the phase of the output remains fixed unless it is forcibly changed.

Coding of Binary Information

Information can be represented in binary form by the presence or absence of dc pulses in "time slots." In such a system, as shown in Fig. 5(a), binary ones are represented by the presence of dc pulses and binary zeros by the absence of such pulses (dc pulse script). Similarly, the presence or absence of RF pulses (RF pulse script) can be used to represent binary information, as shown in Fig. 5(b). The use of modulator and

[5] The subharmonic output power also shows hysteresis effects with pump power and pump frequency. These effects are described in detail by W. T. Clary, Jr., "Nonlinear resonant circuit devices," U. S. Patent No. 2,838,687; June 10, 1958.

[6] This fact makes it possible to construct random number generators. See F. Sterzer, "Random number generator using subharmonic oscillators," *Rev. Sci. Instr.*, vol. 30, pp. 241–243; April, 1959.

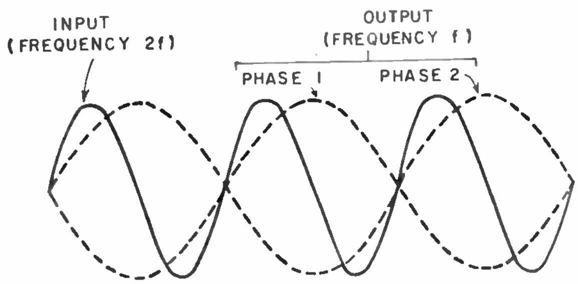

Fig. 4—Two equally probable output phases which can be generated by a subharmonic oscillator.

demodulator circuits[7] makes it possible to convert dc pulse script to RF pulse script, and vice versa.

In another way of coding binary information, shown in Fig. 5(c), a binary one is represented by an RF pulse having a particular phase, and a binary zero by an RF pulse having the same frequency and amplitude but opposite phase (RF phase script). This type of coding is particularly useful in conjunction with subharmonic oscillators. One of the phases of the subharmonic oscillations can be used to represent a binary one; the other a binary zero. Because the phase of the oscillations stays fixed (unless forcibly changed), each subharmonic oscillator can be used to store one bit of information. Furthermore, because the locking signal which is used to direct the oscillations into the desired phase can be much smaller than the final signal output, subharmonic oscillators can also be used to amplify binary information coded in phase script.

The hybrid circuit shown in Fig. 6 can be used to convert RF pulse script to RF phase script, or vice versa. For the conversion of pulse script to phase script, the RF pulses are fed into terminal 1 of the hybrid. A continuous wave (CW) RF signal having the same frequency but only one-half the amplitude of the pulses is fed into arm 3. The two signals are adjusted to arrive at the circumference of the ring in the same phase. Because of the superposition of the CW RF signal and the RF pulses in the output arm (terminal 4), the RF output is of one phase when an RF input pulse is present, and of the opposite phase (but same amplitude) when no input is present. Similarly, if phase script having the same amplitude as the CW RF signal is fed into arm 1, the output of arm 4 will be RF pulse script, provided the phase of the CW RF signal arriving at the ring is the same as either of the two phases of the input.

Use of the circuits described above makes it possible to transform the information coding at will. In a complete system it might be convenient to have input and output in dc pulse code, while logic and memory functions are performed in either one or both of the RF codes.[8]

[7] Such circuits have been described elsewhere [13].
[8] For logic circuits using RF pulse script see [8].

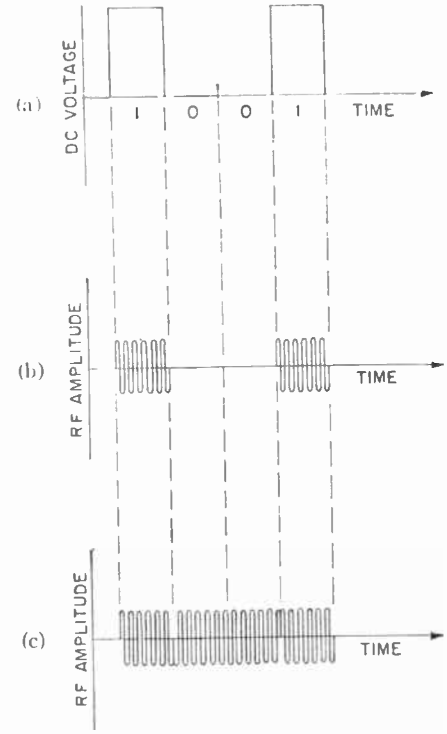

Fig. 5—Three types of script to represent binary information. (a) DC pulse script, (b) RF pulse script, (c) RF phase script.

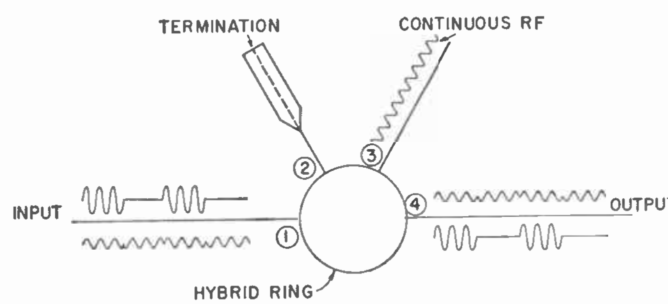

Fig. 6—Hybrid circuit for converting pulse script to phase script, or vice versa.

Amplification of Phase Script Using Subharmonic Oscillators

It was pointed out in the previous section that subharmonic oscillators can be used to amplify phase script by the introduction of a locking signal of the desired phase when oscillations are about to start. Experimentally it was found that, for the oscillator shown in Fig. 1, a locking signal 60 db below the full output of the oscillator is sufficient to assure that oscillations start in the desired phase (*i.e.*, a gain of 60 db can be obtained).

Trains of phase script pulses can be amplified by subharmonic oscillators if the oscillations are stopped periodically by short clock pulses. This is illustrated in Fig. 7. At time τ_1 a clock pulse is applied to the oscillator and oscillations start to decay. (Methods for interrupting oscillations are discussed below.) At τ_2 conditions for oscillations are restored, and oscillations grow to full output at τ_3. The cycle is repeated at τ_4. The locking signal is introduced into the tank of the oscillator a short time before τ_2. This signal can be broken up into two components, one component in quadrature with the two possible phases of oscillations, and one component in phase with one of the two oscillation phases. To assure proper phase locking, the in-phase component of the locking signal must have a greater amplitude at time τ_2 than the amplitude of the oscillations still remaining in the tank. The saturated output oscillations (between τ_3 and τ_4) represent the amplified phase script. It should be noted that the amplified pulses are both retimed and reshaped.

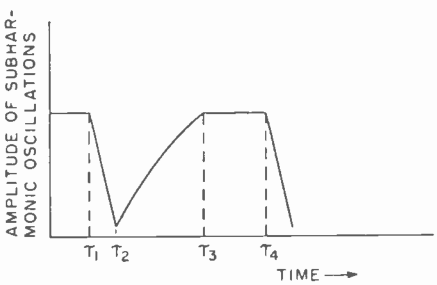

Fig. 7—Diagram illustrating the application of subharmonic oscillators to the amplification of trains of binary digits coded in RF phase script.

Subharmonic oscillations can be switched on and off by pulsing the pump power. For the circuit of Fig. 1, however, this method of switching is not useful if high-speed operation is required. The pump power has to pass through a 4000 mc half-wave resonant bar before it enters the tank circuit. This bar acts as a sharply tuned filter and prevents rapid changes of pump power level. A much faster method of switching subharmonic oscillations is to change the bias on the variable-capacitance diode. In this scheme the diode is back-biased, and the pump power is adjusted for maximum subharmonic output. Oscillations are turned off by a applying a dc clock pulse which drives the diode into the forward direction. The conducting diode adds resistance to the tank circuit and sharply lowers its Q. Therefore, energy in the tank at the subharmonic frequency decays rapidly. Upon removal of the clock pulse, oscillations resume.

The ultimate speed of the subharmonic oscillator as a pulse amplifier is determined primarily by the rate at which oscillations in the tank can be damped, and the rate at which they can build up again. The rise and decay times were measured as follows. First, the diode was biased into conduction so that no oscillations could be observed. A dc pulse with rise and decay times of a fraction of millimicrosecond was then applied to the diode. This pulse changed the bias to a value which permitted maximum power output from the oscillator. The rise time of the oscillations was measured to be between 6 and 7 db per millimicrosecond at low levels, and fell to 3 db per millimicrosecond at saturation. The output decayed from saturation to a value too small to be measured in less than 1.5 mμsec, although a small amount of ringing was evident afterwards. These measurements were made using a typical diode; it is believed that some of the rise and decay time was due to mismatch between the dc pulse generator and the diode. It can be expected that improved variable capacitance diodes and improved oscillator circuits will result in oscillators with considerably reduced rise time.[9]

If the rise time measured with the circuit of Fig. 1 is compared with the rise time of similar oscillators operating at a carrier frequency of a few megacycles [7b], it is found that the *gain per cycle of subharmonic oscillation* is approximately the same in both cases. This result is in agreement with theoretical predictions [7c]. Initial results on *C*-band subharmonic oscillators indicate that it will be possible to raise the output frequency of subharmonic oscillators to *X*-band with available diodes. Such oscillators can be expected to have much faster rise times than the oscillator of Fig. 1.

The phase of a subharmonic oscillator can also be changed without prior interruption of the oscillations. For example, a signal at the subharmonic frequency and of phase opposite to the oscillations may be injected into the tank circuit. If the injected signal is considerably larger than the output of the oscillator, forced phase switching occurs.

It is also possible to switch the phase of a subharmonic oscillator by a signal which is smaller than the output of the oscillator. This effect, which may be called "forced phase switching with gain," occurs because oscillation ceases if the tank circuit of a subharmonic oscillator is loaded beyond some critical value. Fig. 8 illustrates this method. The output antenna of the oscillator provides coupling just below the critical value. An input signal is applied at point *A* of the tee. The phase of this signal is adjusted to be either in phase or out of phase with the signal from the oscillator traveling along line *B–C*. The effective length of line *B–D* is made one and one-half wavelengths. The two phases of the output oscillation can be called 1 and 0. Assume that the input signal is in phase with phase 1 in line *B–C*. In this case the electric fields of phase "1" and the input signal add in line *B–C*. Because the power in the line is proportional to the square of the electric field, the total power when both signals are present is larger than the sum of the powers if each signal were present alone. The input signal, therefore, causes the oscillator to deliver more power to the tee, and phase 1 is loaded down. On the other hand, the electric fields of phase 0 and the input signal subtract in line *B–C*. Therefore,

[9] The influence of diode parameters on the rise time of subharmonic oscillators is discussed in [7c].

the presence of the input signal reduces the loading of phase 0. If oscillations are in phase 0, the input signal causes no change in oscillator phase. However, if oscillations are in phase 1, and the increased loading due to input signal exceeds a critical value, oscillations will switch to phase 0. Experimentally it has been found that signals several db below the oscillator output can induce switching.

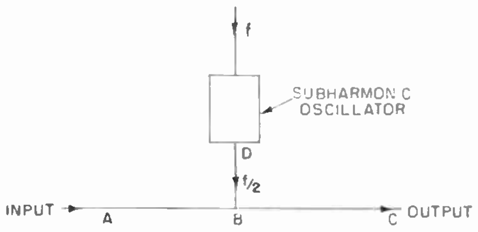

Fig. 8—Circuit used for forced switching with gain.

Circuit for Separating Input and Output of Subharmonic Oscillators

In a subharmonic oscillator the same terminal serves as input for the locking signal as well as output for the subharmonic oscillations. The simplest method for using a subharmonic oscillator as an amplifier is to put a tee at the output of the oscillator. The input locking signal is fed into one arm of the tee, and the output is taken from the second arm. In this arrangement, only half the input signal goes to the subharmonic oscillator; the other half goes directly to the output terminal. Similarly, the output of the subharmonic oscillator is divided equally between input and output arms. Thus this method of amplifying has two major disadvantages.

1) Half the input power and half the output power are lost.
2) Power flows back to the input.

The second disadvantage is very serious for computer applications, since in a computer, information must flow in a specified direction.

A microwave circuit which overcomes both of the disadvantages of the simple tee circuit is shown schematically in Fig. 9.[10] The input signal is introduced in arm 2 of a hybrid ring and splits equally between arms 1 and 3. A subharmonic oscillator is placed in arm 1 a distance (a) from the circumference of the hybrid. A second subharmonic oscillator is placed in arm 3 a distance $(a+\lambda/4)$ (λ = signal wavelength) from the circumference. The input signal has to travel an additional $\lambda/4$ to reach the oscillator in arm 3 and the output of this oscillator has to travel another additional $\lambda/4$ to return to the hybrid. (Since the phases of the input locking signals to the two oscillators differ by 90°, the oscillators must be pumped by signals of opposite phase.) The output signals from the two oscillators reach the hybrid 180° out of phase, and the ratio of the power output at terminal 4 (P_4) to the power appearing at terminal 2(P_2), is given by (assuming an ideal hybrid)

$$\frac{P_4}{P_2} = \frac{(1+\alpha) + 2\sqrt{\alpha}}{(1+\alpha) - 2\sqrt{\alpha}} \tag{1}$$

where α is the ratio of the output powers of the two oscillators. For $\alpha = 1$ (*i.e.*, for equal power output from each oscillator) the entire output of the oscillators appears at terminal 4, and there is perfect isolation between input and output. If α differs from 1, then some power is reflected back to the input terminal. However, considerable difference in the power output of the two oscillators can usually be tolerated. For example, for $\alpha = 2$ (*i.e.*, the power outputs of the two oscillators differ by 3 db), only about 3 per cent of the total power appears at terminal 2. The circuit of Fig. 9 provides, therefore, distinct input and output terminals, as long as the two subharmonic oscillators are approximately equal in output power. Experimentally, no difficulty has been experienced in keeping $P_4/P_2 > 20$.

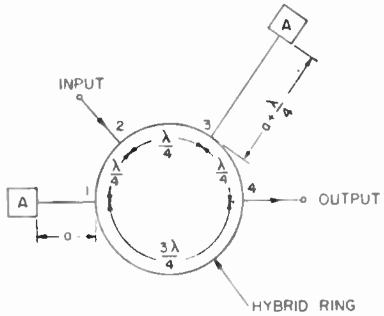

Fig. 9—Circuit for separating input and output of subharmonic oscillators. A = subharmonic oscillator.

The required directivity of information flow can also be obtained by using time division schemes [3], [4], [7b], [10], but such schemes are generally quite complex and introduce significant delays. Ferrite circulators or isolators can also provide directivity [7d], but they are not available at all frequencies of interest, and also are usually quite bulky.

Logic Circuits Using Phase Script

The three basic logic functions are the NOT, AND, and OR functions. In principle, any combinatorial logic circuit can be built using a combination of NOT circuits and either AND or OR circuits.

A NOT circuit has one input terminal, and one output. If the input is a binary one, the output is a binary zero, and vice versa. In phase script a NOT gate is

[10] A similar circuit has been proposed for use with masers. See S. H. Autler, "Proposal for a maser-amplifier system without nonreciprocal elements," Proc. IRE, vol. 46, pp. 1880–1881; November, 1958.

simply a transmission line one-half wavelength long. If the signal frequency is f, then the delay τ is given by $\tau = 1/(2f)$ (for $f = 2000$ mc, $\tau = 0.25$ mμsec).

AND and OR circuits have two inputs and one output. In an AND gate the output is a binary one if, and only if, both inputs are binary ones. In an OR gate the output is a binary one if either or both inputs are binary ones. For all other input conditions, the output of the two gates is a binary zero.

Subharmonic oscillators can be used to perform AND and OR functions in phase script [3], [4], [10]. The two input signals, coded in RF phase script, and a bias signal of fixed phase and of the same frequency as the inputs are combined additively in a transmission line. All three signals are adjusted to have the same amplitude. The output of the transmission line provides a locking signal to a subharmonic oscillator. If the bias signal is chosen to have the phase of a binary zero, then, because of the superposition of the three signals in the transmission line, the locking signal and therefore the output of the subharmonic oscillator, will have the phase of a binary one if, and only if, both inputs are binary ones (*i.e.*, the circuit performs the AND function). Similarly, an OR gate is obtained if the bias signal has the phase of a binary one.

Several basic logic circuits have been combined into a binary full adder. This adder has been operated at a clock rate of 100 mc [14].

The ability of a subharmonic oscillator to amplify and store information can be used to simplify the design of more complicated logic circuits. In the simple shift register shown schematically in Fig. 10, for example, a

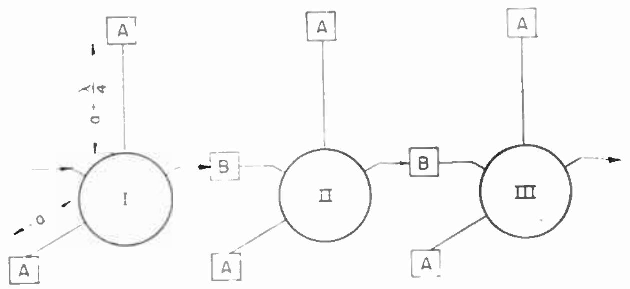

Fig. 10—Shift register. A = subharmonic oscillator, B = delay line.

number of the units shown in Fig. 9 are serially connected by means of delay lines (B) an integral number of wavelengths long. The arrows indicate the direction of information flow. Information is written into the oscillators, in either serial or parallel fashion, by the coding methods described previously. Information is moved one step to the right by interruption of the oscillations for a time interval slightly shorter than the delay in line B. When oscillations resume, each pair of oscillators locks into the previous phase of the oscillators immediately to the left because the previous output of these oscillators is still stored in the delay line.

In the shift register shown in Fig. 10, a dc pulse must be used to interrupt oscillations and shift the information. It is possible to design shift registers in which all oscillators are turned off periodically by dc clock pulses, but where the information is shifted only upon the application of a signal at the subharmonic frequency. Such registers are, however, considerably more complicated than the circuit of Fig. 10, and a description of them is outside the scope of this paper.

Scaling Circuits

Subharmonic oscillators can be used in the construction of scaling circuits, but the scaling circuits described here require dc input pulses, and are therefore not suitable for a digital computing system using only RF phase script. However, high-speed dc scaling circuits have many other important applications. Furthermore, as will be pointed out below, the scaling circuits described can be modified to provide bias sources for phase script logic circuits of the type discussed in the previous section. It is also possible to build scaling circuits which use only RF phase script, but these circuits are quite complicated and, as in the case of shift registers, their description is beyond the scope of this paper.

Fig. 11 is a schematic diagram of one type of scaling

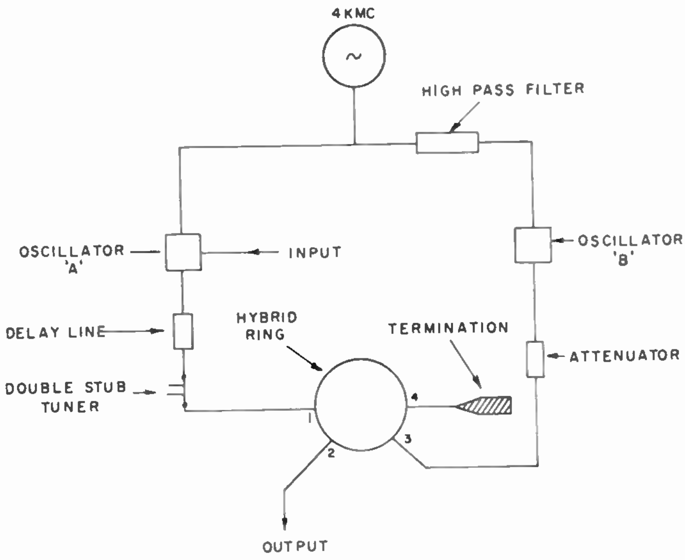

Fig. 11—Schematic diagram of scale-of-two circuit.

circuit. Two subharmonic oscillators are driven from a common 4000 mc pump. A filter which passes 4000 mc, but rejects 2000 mc, is inserted in the line carrying the pump frequency to reduce any coupling between the oscillators. The output of oscillator A passes through a delay line and a double-stub tuner. This tuner reflects part of the oscillator output back to the oscillator. The length of the delay line is adjusted so that this reflected signal is 180° out of phase with the original output of the oscillator. Short dc switching pulses are applied to the diode of oscillator A, and oscillations are briefly interrupted. Oscillations then resume in the phase of the still present reflected signal, *i.e.*, 180° out of phase with the original signal. The duration of the dc pulse must be limited to assure that the signal remaining in the delay line has sufficient amplitude to re-initiate oscillations in the correct phase.

The output power of oscillator B is adjusted by means of an attenuator to be equal to that part of the output of A transmitted by the tuner. The two signals are combined in a hybrid ring; the difference in phase between the two signals at the circumference of the hybrid is adjusted to be either 180° or 360°. [The hybrid converts from RF phase script to RF pulse script (see Fig. 6).] Each dc input pulse switches the phase of oscillator A by 180°. For one of these phases there will be an RF output; for the other there will be no output. This circuit acts, therefore, as a scale of two.

This scaler was first tested with pulse trains from a conventional hard-tube pulse generator. The pulses had rise and fall times of 18 mμsec each. Maximum duty cycle was 10 per cent. A 20 mμsec delay line was used. Without any adjustments, reliable scaling was obtained with pulse widths ranging from 0.05 to 1 μsec and peak pulse voltages ranging from 1 to 5 volts.

Next, tests were made with pulses from a discharge-line-type pulse generator equipped with a coaxial mercury relay. This pulser can produce pulses as narrow as 1 mμsec, but the maximum pulse repetition rate is limited to 150 cps. With a delay line of about 1 mμsec, scaling was obtained with pulse widths ranging from 1 to 25 mμsec and peak pulse voltages ranging from 1 to 5 volts.

For measurement of the resolving time, the scaler was tested with four equally spaced pulses. These pulses were produced by dividing the pulse generator power into four delay lines. The opposite ends of these delay lines were again combined into a common coaxial line. Each delay line could be individually adjusted so that short pulse trains of any desired pulse spacing could be produced. Fig. 12 shows the 4 dc input pulses (spaced about 9 mμsec apart), and the corresponding rectified RF output pulses. The resolving time was measured to be about 8 mμsec.[11] It should be possible to substantially reduce the resolving time by using higher frequency oscillators.

It is possible to obtain scaling in a subharmonic oscillator by simply interrupting oscillations for a definite time interval τ. Consider an oscillator with subharmonic frequency f_s which differs by a few per cent from the natural resonant frequency f_T of its tank circuit. When oscillations are interrupted, the energy stored in the tank decays at frequency f_T. If conditions for oscillations are restored now, before the stored energy has decayed below noise, then the phase of the new oscillations is determined by the phase of the stored energy.

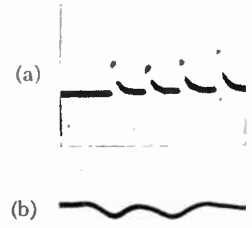

Fig. 12—Oscilloscope tracings of (a) four dc input pulses to scale-of-two circuit, and (b) corresponding RF output pulses.

For $\tau = m/2|f_s - f_T|^{-1}$ (m = odd integer), an odd number of half cycles is lost or gained during the interruption of oscillations, and the new oscillations will be 180° out of phase with the original oscillations; *i.e.*, the device acts as a scale of two.

This principle of operation was successfully applied to a 2000 mc subharmonic oscillator.[12] Scaling was achieved by pulsing the diode of the oscillator with 1 volt dc pulses having a duration of about 1 mμsec. The resolving time was not measured.

The AND and OR circuits described in the previous section require subharmonic bias signals with fixed phase. To obtain proper addition of all input signals to these circuits, it is desirable that the amplitude of the bias signals vary in the same manner as that of the input phase script pulses. Ideal phase script pulses have constant amplitude [Fig. 5(c)]. However, the amplitude of phase script pulses produced by subharmonic oscillators is by no means constant (Fig. 7). Signals with constant phase, but amplitude variation similar to Fig. 7, can be conveniently produced by slightly modifying either of the two scaling circuits just described. In the scaler illustrated in Fig. 11, the length of the delay line has to be adjusted so that the reflected signal is *in phase* with the output of oscillator A. In this case, if oscillator A is turned off periodically by short clock pulses, oscillations will always remain in the same phase, but will be amplitude modulated as shown in Fig. 7. Similar results are obtained with the second type of scaler if oscillations are periodically interrupted for a time $\tau = m'|f_s - f_T|^{-1}$ (m' = integer).

Acknowledgment

The author extends his thanks to Dr. W. R. Beam for collaboration in the design of the subharmonic oscillator and for many valuable suggestions; Dr. C. W. Mueller and C. F. Stocker for supplying the variable capacitance diodes; D. J. Blattner, G. B. Herzog, Dr. A. W. Lo, L. S. Onyshkevych, Dr. J. A. Rajchman, A. H. Solomon, and D. L. Thornburg for their discussions and assistance.

[11] A scale-of-two with a resolving time of 7 mμsec has recently been reported. This scaler uses high-frequency transistors in flip-flop circuits. See C. G. Thornton and J. B. Angell, "Technology of micro-alloy diffused transistors," Proc. IRE, vol. 46, pp. 1166–1176; June, 1958.

[12] This scaler was designed in collaboration with Dr. W. R. Beam.

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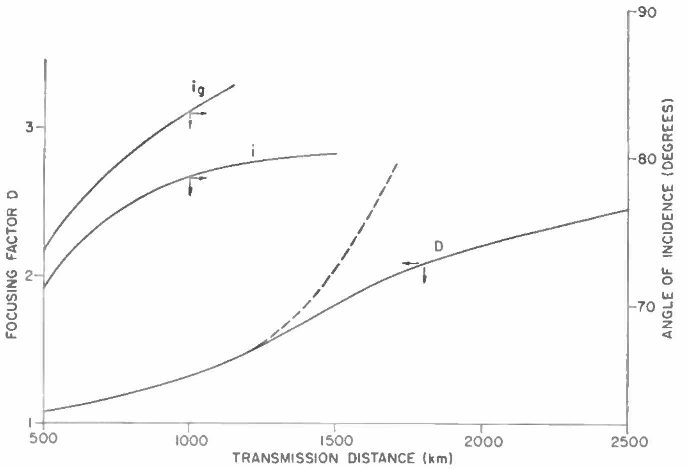
[14] F. Sterzer, "RF logic circuits using subharmonic oscillators," presented at the PGMTT National Symp., Harvard University, Cambridge, Mass.; June 3, 1959.

CORRECTION

The following correction has been brought to the attention of the editor. In "The Engineering of Communication Systems for Low Frequencies," by J. S. Belrose, W. L. Hatton, C. A. McKerrow, and R. S. Thain, pp. 661–680, of the May, 1959, issue of PROCEEDINGS, Fig. 1 on p. 663 should have appeared as below, in place of the figure reproduced in error.



The Radiansphere Around a Small Antenna*

HAROLD A. WHEELER†, FELLOW, IRE

Summary—**The "radiansphere" is the boundary between the near field and the far field of a small antenna. Its radius is one radianlength ($\lambda/2\pi$), at which distance the three terms of the field are equal in magnitude. A "small" antenna is one somewhat smaller than the radiansphere, but it has a "sphere of influence" occupying the radiansphere. The power that theoretically can be intercepted by a hypothetical isotropic antenna is that which flows through the radiansphere or its cross section, the "radiancircle."**

From a small electric dipole, the far field of radiation is identified as a retarded magnetic field. Between two such dipoles, the far mutual impedance is that of mutual inductance, expressed in terms of space properties and the radiansphere.

A small coil wound on a perfect spherical magnetic core is conceived as an ideal small antenna. Its radiation power factor is equal to the ratio of its volume over that of the radiansphere. A fraction of this ratio is obtainable in various forms of small antennas (C or L) occupying a comparable amount of space.

A radiation shield, in the form of a conducting shell the size of the radiansphere, enables separate measurement of radiation resistance and loss resistance.

Introduction

THE subject of small antennas deals with the problems of effective radiation and interception by structures whose dimensions are much less than one wavelength. This assumption of small size reduces to simplest terms the antenna properties and the resulting limitations in practical applications. The concepts and rules to be presented are readily appreciated and easily retained for future reference.

The scope of this paper is limited to some principles and viewpoints that are elementary but have not previously been integrated and clearly presented. They come from various sources and have been assembled by the writer in the course of occasional studies and design experience for widely diversified purposes over the past 15 years or so.

Several concepts appear to have been original with the writer, although based on well-known principles, The "radiansphere" is developed to describe the boundary of the transition between near field and far field, and is given significance as the "sphere of influence." The "radiancircle" is the interception area of the hypothetical isotropic radiator. The "radiation power factor," previously introduced by the writer, is formulated for an idealized spherical antenna much smaller than the radiansphere. The "radiation shield," a spherical conductor located at the radian sphere, is presented to enable separate determination of radiation resistance and loss resistance, hence the radiation efficiency. The mutual impedance between small dipoles is simple and useful but seldom stated; here it is analyzed into the three kinds of impedance components (C, R, L), and is formulated directly in terms of the mean radiation resistance of the sending and receiving antennas.

After a list of symbols, the presentation will start with a brief reference to each principal concept, stated in the terminology to be used here.

Symbols

(MKS units: meters, seconds, watts, volts, amperes, ohms, henries, farads.)

l = length of small dipole ($l \ll \lambda/2\pi$)($l \ll r$)
r = radial distance ($r \gg l$)
h = height above plane
a = radius of sphere (inductor)
A = area of small loop
A = interception area of antenna
V = volume (of sphere)
λ = wavelength
$\lambda/2\pi$ = radianlength
f = cycle frequency
$\omega = 2\pi f$ = radian frequency
Z = impedance (complex)
R = resistance (radiation)
L = inductance
C = capacitance
I = current
V = voltage
E = electric field
H = magnetic field
P_1 = power radiated from sending antenna
P_2 = power available from receiving antenna
$R_0 = 377$ = wave resistance of square area of plane wave in free space
μ_0 = magnetivity in free space
ϵ_0 = electrivity in free space
k_m = magnetic ratio (in core of inductor)
n = number of turns (in coil of inductor)
$p = R/\omega L$ = power factor (radiation)
g = power ratio of directivity
sub-a = inductor sphere
sub-r = radian sphere
sub-1, 2 = sending, receiving (antennas)
sub-12 = mutual (between antennas)
* = subject to retardation by distance angle

Basic Concepts

Radiansphere

The radiansphere is a hypothetical sphere having a radius of one radianlength from the center of an antenna

* Original manuscript received by the IRE, December 23, 1958; revised manuscript received, April 14, 1959. This topic has been presented to meetings of graduate seminars in electrical engineering at Johns Hopkins Univ., Baltimore, Md.; December 2, 1954; and at Polytech. Inst. of Brooklyn, Brooklyn, N. Y.; October 12, 1956.
† Wheeler Labs., Great Neck, N. Y.

much smaller than the sphere. Physically, it marks the transition between the "near field" inside and the "far field" outside. While sending, the radiation field comprises stored energy and radiating power, the former predominating in the near field and the latter in the far field. The radiansphere is a measure of the "sphere of influence" of the antenna. It is a convenient reference for all radial distances.

Radiancircle

The radiancircle is the projection of the radiansphere and, conceived as such, is the interception area of the hypothetical isotropic radiator (to be defined) [2].

Radianlength

The radianlength is $1/2\pi$ wavelength (denoted $\lambda/2\pi$) which appears in many formulas for antennas and waves. Its principal significance is its role as the radius of the radiansphere and radiancircle. Any length dimension (l) may be eppressed in terms of its ratio over the radianlength ($2\pi l/\lambda$).

Wave Resistance

The wave resistance of free space ($R_0=120\pi=377$ ohms) is the apparent resistance (V/I or E/H) of a square area of a plane wave in free space. It may be included in any impedance formula to provide the required dimension (ohms) in a significant and convenient form. For example, the reactance of an inductor usually includes the factor $\omega\mu_0$, for which may be substituted $R_0(2\pi/\lambda)$; the latter more directly provides the same dimensions, ohms per meter [5].

Small Antenna

A "small" antenna is one which is much smaller than the radiansphere. Conversely, it is one operating at a frequency so low that its sphere of influence is much greater than its size. It is characterized by a small power factor of radiation, meaning that its radiation resistance is much less than the principal component of its self-reactance. A small antenna is usually a simple electric or magnetic dipole. The near field depends on which kind of dipole, while the far field is the same for either kind. The electric dipole is a current element physically realizable, while the magnetic dipole is a flux element simulated by a current loop [5], [6].

Mutual Impedance

Fig. 1 shows the definition of the complex mutual impedance (Z_{12}) between two electric dipoles (as examples of small antennas). It includes the attenuation of amplitude and the retardation of angle with the distance from sending antenna to receiving antenna [2], [3].

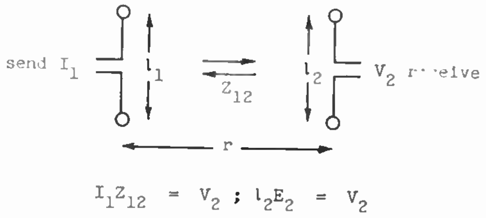


Fig. 1—Definition of mutual impedance between two small electric dipoles.

Efficiency

This is here defined as the maximum efficiency of transmission from a first antenna to a second. It is equal to the ratio of the power available from the second over the power input to the first (P_2/P_1). For present purposes, the associated connection circuits are assumed to be free of dissipation. The second antenna delivers the available power if its resistance is matched to a load resistance while tuning out the reactance of both. If the antennas are separated far enough to give low efficiency, the efficiency may be expressed simply in terms of the radiation resistance of both antennas and the magnitude of mutual impedance therebetween (R_1, R_2, $|Z_{12}|$) [1], [2], [4].

Isotrope

The isotropic radiator or isotrope is one which is conceived to radiate the same in all directions over the sphere in space. It is physically realizable in longitudinal waves (such as sound) but not in transverse waves (such as radio). In any case, it is a helpful concept as a reference for evaluating directivity [2], [4].

Directivity

The usual antennas concentrate their radiated power in some part of the sphere in space. In the direction of greatest concentration, the power ratio of directivity (g) has its maximum value (greater than unity). Inversely, we may say that effectively $1/g$ of the sphere is filled with radiation. The doughnut pattern of a small dipole fills $2/3$ of the sphere, so $g=3/2$ [2], [4].

Electric Dipole

The electric dipole is one that radiates by virtue of a current flowing in a length of conductor and returning through the capacitance in the surrounding space. By reciprocity, when exposed to an electric field, it receives an induced voltage proportional to its length. It is the simplest type of radiator for theoretical analysis.

Magnetic Dipole

The magnetic dipole is one that radiates by virtue of magnetic flux from the dipole returning through the surrounding space. It is realized by current in a coil of conductor having a certain total area of coaxial turns. It is distinguished from the electric dipole in that the current returns in the conductor and not in the space capacitance. Its radiation may be computed by regarding each small element of conductor as an electric dipole. Some, but not all, of the general properties to be stated for the electric dipole are valid also for the magnetic dipole.

Far Component of Mutual Impedance

At radial distances much greater than the radianlength, the dominant component of mutual impedance is the one caused by the far field of radiation. Its magnitude may be computed from the mutual inductance between current elements. In doing this, we consider only the magnetic field, ignoring the electric field. The only deficiency is the absence of the retardation caused by the interaction of both fields.

Referring to Fig. 1, the mutual inductance between the two short current elements is given by the Neumann formula (Ramo-Whinnery), [9]:

$$L_{12} = \mu_0 \frac{l_1 l_2}{4\pi r}. \quad (1)$$

From this is computed the mutual impedance, expressed in terms of wave quantities:

$$|Z_{12}| = \omega L_{12} = \frac{R_0}{4\pi} \frac{l_1 l_2}{r(\lambda/2\pi)} = R_0 \frac{l_1 l_2}{2r\lambda} = 60\pi \frac{l_1 l_2}{r\lambda}. \quad (2)$$

The 4π in the denominator appears when formulating a spherical problem in terms of rationalized (cylindrical) units. It is notable that all length dimensions appear in ratios, while the impedance dimension is provided by R_0.

The phase angle of inductive reactance and the retardation by distance are easily added to this formula, as will be shown below in a complete formula.

In radial directions different from Fig. 1, the magnetic-field coupling is opposed in some degree by electric-field coupling to give the characteristic doughnut pattern.

Radiation Resistance

Since the radiation resistance is determined by the radiated power in the far field, it can be computed from the simple formula for mutual impedance. We use also the concept that the doughnut pattern fills only $\frac{2}{3}$ of the sphere. The radiation field is

$$|E_2| = \frac{V_2}{l_2} = \frac{|Z_{12}I_1|}{l_2} = \frac{R_0}{4\pi} \frac{l_1}{r(\lambda/2\pi)} |I_1|. \quad (3)$$

The radiated power, which determines the radiation resistance (R_1), is computed as the product of $\frac{2}{3}$ the area of the distance sphere times the power density of radiation outward through this sphere.

$$P_1 = R_1 |I_1|^2 = \frac{2}{3}(4\pi r^2)|E_2|^2/R_0$$

$$= \frac{2}{3} \frac{R_0}{4\pi}\left(\frac{2\pi l_1}{\lambda}\right)^2 |I_1|^2. \quad (4)$$

The radiation resistance is therefore

$$R_1 = \frac{2}{3} \frac{R_0}{4\pi}\left(\frac{2\pi l_1}{\lambda}\right)^2 = 20\left(\frac{2\pi l_1}{\lambda}\right)^2. \quad (5)$$

In this formula, the length of the dipole is expressed as a fraction of the radianlength ($2\pi l_1/\lambda$).

Four such small dipoles may form the basis for computing the radiation resistance of a small square loop (of area $A_1 = l_1^2$). In a direction parallel to one pair of sides, only the other pair radiate and they nearly cancel each other. The residual far field is $2\pi l_1/\lambda$ of that of one side because this is the angle of the difference of their distance and retardation. The directive pattern is that of a small magnetic dipole which, like the small electric dipole, fills $\frac{2}{3}$ of the sphere in space. Therefore the radiation resistance of the loop is that of one side, multiplied by the power ratio $(2\pi l_1/\lambda)^2$.

$$R_1 = \frac{2}{3} \frac{R_0}{4\pi}\left(\frac{2\pi l_1}{\lambda}\right)^4 = 20\left(\frac{2\pi l_1}{\lambda}\right)^4$$

$$= 20\left[\frac{A_1}{(\lambda/2\pi)^2}\right]^2. \quad (6)$$

The strength of the equivalent magnetic dipole is proportional to the area (A_1). If there are several parallel turns carrying the same current (I_1), the effective area is the total area of all turns.

Efficiency in Terms of Interception Area

The available-power efficiency (if small) is simply formulated from the radiation quantities:

$$\frac{P_2}{P_1} = \frac{|Z_{12}|^2}{4R_1R_2}. \quad (7)$$

Substituting for these quantities in terms of length dimensions, and generalizing each R by changing from $\frac{2}{3}$ to $1/g$:

$$\frac{P_2}{P_1} = \frac{1}{4} g_1 g_2 \left(\frac{\lambda}{2\pi r}\right)^2 = g_1 g_2 \frac{\pi(\lambda/2\pi)^2}{4\pi r^2}$$

$$= g_1 g_2 \frac{\text{area of radian circle}}{\text{area of distance sphere}}. \quad (8)$$

The last two forms were discovered by the writer [2]; the first form was published by Friis [4].

Fig. 2 illustrates this rule for the basic simple case of two isotropes, while Fig. 3 does the same for the more general case, exemplified by two small dipoles.

Since sending and receiving are reciprocal functions, it is natural to identify the interception area of each one. This is diagramed in Fig. 3, showing the area each presents to the other. Letting this area be $A = g\pi(\lambda/2\pi)^2 = g$ radiancircles, for each antenna, the efficiency becomes [2], [4]:

$$\frac{P_2}{P_1} = \frac{A_1 A_2}{(4\pi r^2)\pi(\lambda/2\pi)^2} = \frac{A_1 A_2}{r^2\lambda^2}$$

$$= \frac{(\text{sending area})(\text{receiving area})}{(\text{distance sphere})(\text{radiancircle})}. \quad (9)$$

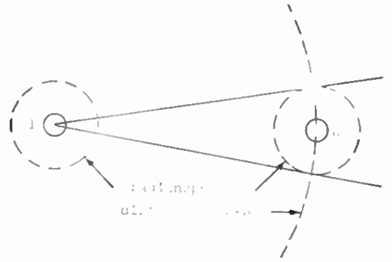


Fig. 2—Area of interception for two isotropes.

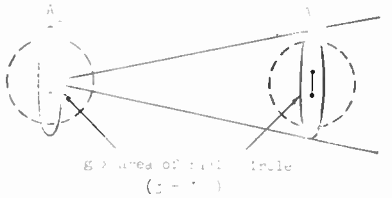


Fig. 3—Area of interception for two small dipoles.

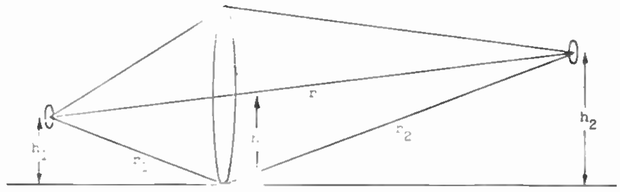


Fig. 4—Intermediate area of interception for two antennas over plane ground.

By the simple formulas, two isotropes at a distance of one radianlength have a coupling efficiency of $\frac{1}{4}$. This is approximately valid, being in the transition between high and low efficiency. In general, this occurs at a distance of $\sqrt{g_1g_2}$ radianlengths, by (8). At lesser distances, the interaction complicates the formula for efficiency.

The mutual impedance may be expressed in terms of the values of radiation resistance by rearranging (7) and (8).

$$|Z_{12}| = 2\sqrt{R_1R_2}\sqrt{P_2/P_1} = \frac{\lambda}{2\pi r}\sqrt{g_1g_2R_1R_2}. \qquad (10)$$

This is a corollary to the theorem of interception area [2]. It was independently discovered by Huntoon at NBS during the war while studying the problem of proximity fuzes [3].

The receiving antenna reradiates an amount of power equal to the available power it delivers to the matched load. If instead the antenna is tuned without adding any resistance, the received current is doubled. The second antenna then reradiates four times its available power. This rule is limited to a small antenna.

A large flat array with a reflector can be designed to intercept all the power incident on its area. Its power ratio of directivity, by comparison with the isotope, is then

$$g = \frac{\text{area}}{\pi(\lambda/2\pi)^2} = \frac{4\pi(\text{area})}{\lambda^2} = \frac{\text{area}}{\text{radiancircle}}. \qquad (11)$$

If the area is covered by many dipoles pitched $\frac{1}{2}$ wavelength in a rectangular array, the power ratio of directivity is seen to be π times the number of dipoles.

Two antennas may be located above the ground at heights so low that there is near-cancellation of direct and reflected waves. Fig. 4 shows the geometry of such a case. It is assumed that the path difference is less than one radianlength ($h_1h_2 < r\lambda/4\pi$) and that the ground is a flat surface with a reflection coefficient of minus one (which is typical of imperfect conductors near grazing incidence). It can be shown that

$$|Z_{12}| = \frac{2h_1h_2}{r^2}\sqrt{g_1g_2R_1R_2}; \qquad \frac{P_2}{P_1} = g_1g_2\left(\frac{h_1h_2}{r^2}\right)^2. \qquad (12)$$

Taking the partial distances as shown,

$$r_1 = r\frac{h_1}{h_1 + h_2}; \qquad r_2 = r\frac{h_2}{h_1 + h_2}. \qquad (13)$$

The intermediate height (h) is that of the direct line over the point of reflection:

$$h = \frac{2h_1h_2}{h_1 + h_2}; \qquad 1/h = \tfrac{1}{2}(1/h_1 + 1/h_2). \qquad (14)$$

This is taken as the radius of an intermediate circular area. It is found that the transmission efficiency is the product of two values, one computed by (9) from the first antenna to the intermediate circle, and the other from this circle to the second antenna. The proximity of the ground has the effect of an intermediate aperture as shown.

All Components of Mutual Impedance

In Fig. 1, the complex mutual impedance of two small dipoles has three terms at distances much greater than the dimension of the dipoles but not necessarily greater than the radianlength. These components are readily derived from the formula for the transverse electric field given in textbooks:

$$Z_{12} = \frac{R_0}{4\pi}\frac{j2\pi l_1}{\lambda}\frac{j2\pi l_2}{\lambda}\left[\left(\frac{2}{j2\pi r}\right)^3 + \left(\frac{\lambda}{j2\pi r}\right)^2 + \left(\frac{\lambda}{j2\pi r}\right)\right]\exp - \frac{j2\pi r}{\lambda}. \qquad (15)$$

(ohms) (sphere) — (length angles) — (C) — (R) — (L) — (retard)

(distance angle)

The coefficient in front of the brackets [ ] is equal to $-\frac{3}{2}\sqrt{R_1R_2}$, in terms of radiation resistance. In Ramo-Whinnery [9] is found an expression which emphasizes the significance of the three components (C, R, L); this expression is revised as follows to give the three components the dimensions of impedance:

$$Z_{12} = \frac{l_1l_2}{4\pi r^2}(1/j\omega\epsilon_0 r + R_0 + j\omega\mu_0 r)\exp - j2\pi r/\lambda. \quad (16)$$

This form is instructive and is also useful for evaluating the equivalent circuit elements (C, R, L). The preceding form (15) is the ultimate in dimensional simplicity.

Fig. 5 shows the network equivalent to two small dipoles, giving a breakdown of the three components of mutual impedance, and their variation with distance (r). They are marked (*) to denote that they are subject to retardation with distance.

Fig. 6 shows the variation of the three components with distance. At a distance of one radianlength, the three components are equal in magnitude, so that first and third cancel, leaving only the resistance. At lesser distances, the capacitive coupling predominates; at greater distances, the inductive coupling predominates, as derived above for the far field.

In any other direction, these components are modified. The far component disappears if either dipole is in line with the radial distance.

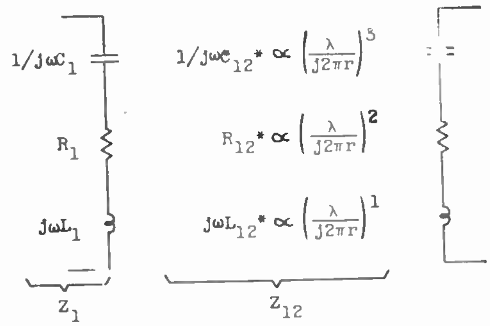


Fig. 5—Network equivalent to two small electric dipoles.

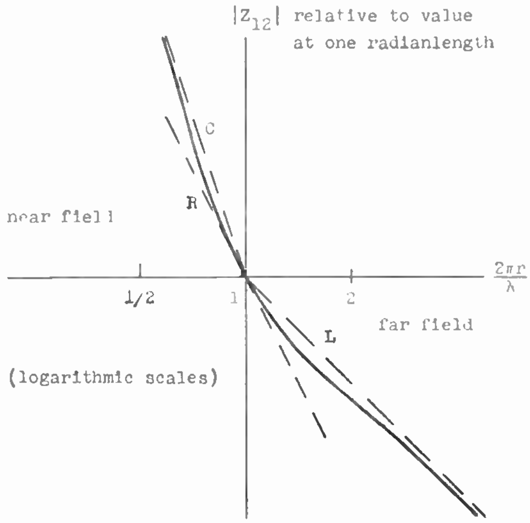


Fig. 6—Variation of components of mutual impedance.

Spherical Small Antenna

In relation to a spherical wave and the radiansphere, the ideal shape of a small antenna might be spherical. There is one such antenna that is significant. It is a "magnetic dipole" simulated by a spherical inductor [10], [12].

Fig. 7 shows such an inductor. Its winding is pitched uniformly in the axial direction. Its core may be filled with magnetic material (k_m).

If the length of wire is much less than the resonant length, the magnetic field inside is uniform, and outside has the same pattern as that of a small magnetic dipole. (Such an inductor is mentioned by Maxwell but is seldom found in the more recent literature; the writer made use of this concept about 1941.)

The inductance of this sphere is

$$L = \frac{2\pi}{3}\mu_0 an^2 \frac{1}{1 + 2/k_m}. \quad (17)$$

Its radiation resistance is

$$R = \frac{2\pi}{3}R_0 n^2 \left(\frac{2\pi a}{\lambda}\right)^4 \left(\frac{1}{1 + 2/k_m}\right)^2. \quad (18)$$

Its inductive reactance is

$$\omega L = \frac{2\pi}{3}R_0 n^2 \frac{2\pi a}{\lambda}\frac{1}{1 + 2/k_m}. \quad (19)$$

Therefore the radiation power factor is

$$p = R/\omega L = \left(\frac{2\pi a}{\lambda}\right)^3 \frac{1}{1 + 2/k_m}$$

$$= \frac{\text{volume of inductor sphere}}{\text{volume of radiansphere}} \frac{1}{1 + 2/k_m}. \quad (20)$$

This relation reaches the ultimate simplicity for the ideal case of a perfect magnetic core ($k_m = \infty$) so that there is no stored energy inside the coil. This limiting case is represented in Fig. 8.

The radiansphere may be regarded as a hypothetical inductor whose internal energy is the stored energy of the magnetic field, and whose external energy is the radiating power. The small antenna radiates by virtue of its coefficient of coupling with the radiansphere; the above ratio (20) is proportional to the square of this coefficient of coupling.

Practical Small Antennas

In a previous paper, the writer has treated the topic of practical small antennas [5]. Special emphasis was placed on the role of the volume occupied by the antenna in determining its radiation power factor. A cylindrical volume was taken as a basis for comparing electric dipoles with magnetic dipoles (air-core coils).

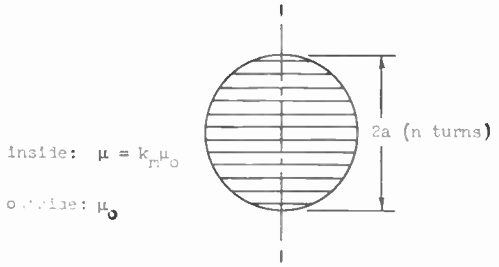


Fig. 7—Spherical inductor.

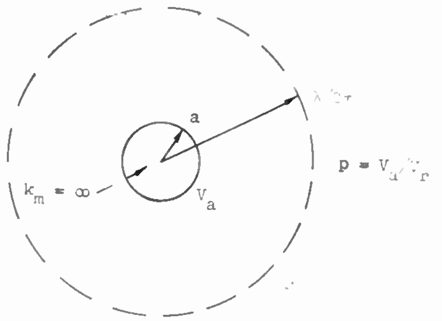


Fig. 8—Spherical inductor in radiansphere.

Some of the most common forms of small antennas are of such shape that the occupied volume is no longer significant. This is true of an electric dipole made of a straight wire or rod or tower. It is also true of a magnetic dipole made of a thin loop of wire. Either of these would require a certain size of sphere to contain it. Since this volume is only partially utilized, it is presumptive that the antenna would have a radiation power factor much less than the theoretical upper limit for this size of sphere.

The opposite extreme is a flat capacitor with air-dielectric or a long inductor with air core. In these cases, the radiation power factor approaches a lower limit of 2/9 the value for an ideal sphere (with perfect magnetic core) of the same volume.

It is interesting to compare two small antennas of opposite kinds occupying the same circular-cylindrical space, namely the disk capacitor (C) and the solenoid inductor (L), each having an air core. The shape chosen is a cylinder of equal diameter and height. As compared with an ideal sphere of the same volume (having no energy stored inside), each kind has a power factor less than the ideal by the following factors:

$$C: \qquad \frac{8}{\pi}\,\frac{2}{9} = 0.57$$

$$L: \qquad \left(1 + \frac{4}{3\pi}\right)\frac{2}{9} = 0.32.$$

In this rating, the power factor of the capacitor is about twice that of the inductor. However, the latter can be increased by a factor of two or more by inserting an iron core, while the former cannot be increased by any known materials.

The comparison with air cores brings out a basic difference between the two kinds. The external (useful) stored energy of the capacitor is about $\frac{2}{3}$ of the total, while that of the inductor is about $\frac{1}{3}$. This is because the inside and outside flux paths differ in impedance in a ratio of about two to one; these paths are in parallel for the capacitor and in series for the inductor. Decreasing the effective length of internal flux path by inserting some material has the effect of increasing the stored energy in the capacitor but decreasing it in the inductor. The latter is advantageous.

If a small antenna is restricted in its maximum dimension but not in its occupied volume, the radiation power factor is increased by utilizing as much as possible of the volume of a sphere whose diameter is equal to this dimension. The cylinder discussed above is a good practical compromise. The practical limitations of capacitor and inductor are only slightly different, so the choice may be determined by other considerations (such as wave polarization, loss power factor, associated circuits, construction, and environment).

A special case is a small antenna operating underground or underwater. These mediums are dissipative toward a electric field but not a magnetic field. Therefore the loop antenna is much to be preferred for efficiency of radiation in either of these environments [11].

Radiation Shield

For purposes of measurement, it may be desired to remove the radiation resistance of a small antenna while retaining its other properties (loss resistance, capacitance, inductance). This can be accomplished to a close approximation by enclosing the antenna in a radiation shield which ideally is a perfectly conducting spherical shell whose inner surface is located at the radiansphere. (See Fig. 8, for example.) This prevents the radiation while causing little disturbance of the near field. In practice, the size, shape, and material are not critical. A cylinder with one or both ends open may suffice.

The writer devised this test for a very small loop antenna operating at a frequency such that the radiansphere had a convenient size; the loop was in an oscillating circuit so the radiation shield caused an increase in the amplitude of oscillation. The increase in amplitude was a measure of the radiation efficiency. In general, the radiation shield enables the separate determination of loss resistance and radiation resistance.

Conclusion

The radiansphere around a small antenna is logically regarded as the boundary between the near field of stored energy and the far field of radiating power. There is not a definite boundary but rather a transition, since the terms associated with the near field predominate inside and those associated with the far field predominate outside. The interception area defined for the hypothetical isotropic antenna is the area of the radiancircle, a projection of the radiansphere, so the latter is logically regarded as the sphere of influence of such an antenna. An idealized small spherical antenna is found to have a radiation power factor equal to the ratio of its volume over that of the radiansphere. A radiation shield is described whose ideal location is at the radiansphere. All of these concepts are helpful in visualizing and remembering the rules governing small antennas, especially their near field and far field.

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Voltage Breakdown Characteristics of Microwave Antennas*

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Summary—The problem of voltage breakdown and its effects is discussed for a pulse antenna system. Voltage breakdown occurs at power levels when the pressure is reduced. The minimum breakdown potential occurs approximately at the pressure where the frequency of collision between electrons and gas atoms is equal to the frequency of the applied field. Experiments were made to determine the power levels required to produce breakdown and the effect of breakdown on the VSWR, pulse shape, radiation pattern, and radiated power. It is shown that all four of the quantities vary with pulse width and peak power.

Introduction

At low pressures, antennas are susceptible to voltage breakdown. In the case of antennas on high-altitude vehicles, there are indications that very low power is sufficient to initiate and maintain breakdown.[1–3] When voltage breakdown occurs, the effect is fourfold: the input impedance is altered; the pulse shape is modified; the total radiated power is decreased; and the radiation pattern is changed.

Any evaluation of a system that is to perform at high altitude must consider the voltage breakdown effect. Therefore, an experimental investigation of antenna breakdown and the problems associated with it was initiated. A brief description of the voltage breakdown problem is presented here, followed by a report on a series of measurements made on a particular antenna type to determine its electrical characteristics under breakdown conditions.

Voltage Breakdown Phenomena

The theory of high-frequency gas-discharge breakdown has been well covered in the literature for nonradiating structures.[4–6] It has been shown that primary

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ionization due to electron motion is the principal source of electron production at high frequencies. These electrons gain energy from the radio-frequency (RF) field by having their ordered oscillatory motion changed to random motion on collision. On the average, free electrons in an RF field gain energy with each collision until they attain sufficient energy to have an ionizing collision. A gas discharge occurs when the gain in electron density due to ionization of the gas becomes equal to the loss of electrons by diffusion, recombination, and attachment.

At high pressures, the mean free time of the electron is small compared to the RF period, and the energy gained per collision is small. In this region, the field strength required to ionize the gas varies linearly with pressure. On the other hand, at very low pressures the mean free time of an electron is large compared to an RF period, and the electrons make many oscillations per collision. Since the electrons gain energy only through collision, the ionizing field varies inversely with pressure. At some intermediate pressure, the mean free time will be such that the frequency of collision between electron and gas atom is equal to the frequency of the applied field. This is approximately the pressure at which minimum voltage is required for breakdown.

The theories that have so far been developed to predict the power at which voltage breakdown will occur depend upon a knowledge of the field strength throughout the region of interest. Experimental verification of the theories is based on experiments with parallel plates, transmission lines, or cavities in which the field strength is known and the concept of diffusion length is applicable. For most antennas, the field configuration is very complex. Furthermore, in unbounded regions such as the space into which the antenna radiates, the concept of diffusion length is not readily applicable. Consequently, an experimental program was initiated to measure the parameters of importance in the design of antennas for high altitude. In addition to the qualitative description presented here, experiments are being carried on to obtain quantitative data on the field required to initiate breakdown for various antenna configurations.

Experimental Set-Up

Measurements were made at X-band because of the availability of the pulsed-magnetron source and because it was more convenient to use a small antenna and make measurements inside the laboratory. The experimental set-up used for the measurement is shown in Fig. 1. The magnetron had 25-kw peak-power output

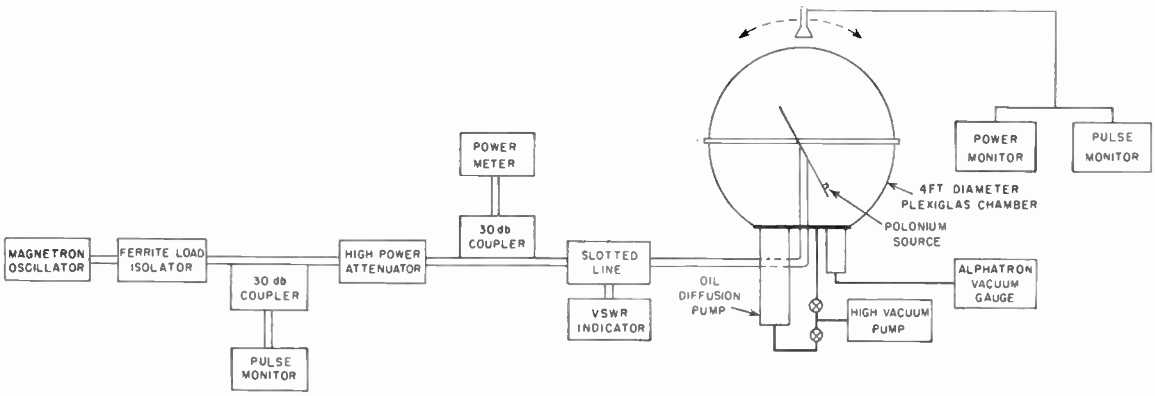

Fig. 1—Experimental set-up used for X-band voltage-breakdown measurements.

and was triggered to run at a pulse repetition frequency of 200 to 400 pulses per second (pps) and pulse widths of 0.5, 1.0, and 2.0 μs. The magnetron output was fed through a ferrite isolator to an attenuator to decrease the power level to any desired value. The incident power and pulse shape were monitored using directional couplers. A slotted line was connected in series with the main power line to monitor the input standing-wave ratio of the antenna under test. A monitor horn was provided, which could be rotated about the top hemisphere as shown in Fig. 2. The horn rotated about the center of the sphere and monitored the radiated signal at various angles from the antenna enclosed within the chamber. The chamber itself is a Plexiglas sphere 4 feet in diameter, which is made in two sections. The minimum obtainable pressure for the system is about 0.003 millimeter of mercury (mm Hg).

In order to ensure the presence of electrons to start the ionizing collisions, a 1000 μcurie source was placed adjacent to the antenna. A polonium source was chosen because it requires no special handling, as do the cobalt-60 sources in common use. The alpha particles emitted from the polonium source have low energy but a large collision cross section, and therefore, produce a large number of ionizing collisions. The effective radius of ionization by polonium is about $1\frac{3}{8}$ inches at atmospheric pressure. However, the effective radius is inversely proportional to the pressure, so that at low pressures where the measurements presented were obtained, the polo-

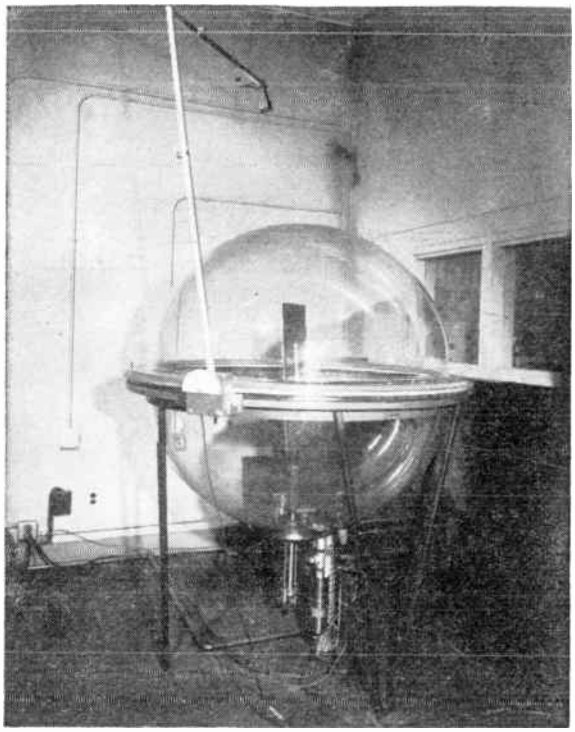

Fig. 2—Photograph of Plexiglas vacuum chamber.

nium will provide ionization over the entire surface of the antenna.

Experimental Results

Several types of antennas have been tested. Some typical results of the breakdown characteristic for a flush-mounted, dielectric-loaded, end-fire antenna with a gain of approximately 20 and 12 db are presented. The antenna was located in the chamber as shown in Figs. 1 and 2 with the main lobe of the radiation pattern pointed upward.

Minimum Breakdown Power

Fig. 3 is a plot of the power required for breakdown as a function of pressure and pulse width. Both the initiating and extinguishing power levels are shown. Breakdown was defined as the first appearance of a glow discharge on the surface of the antenna. As previously discussed, the minimum breakdown potential exists where the collision frequency is approximately equal to the frequency of the applied field. This condition occurs at X band at a pressure of about 5 mm Hg, as shown in Fig. 3. The minimum peak power required to initiate breakdown is 3.5 kw for a 2-μs pulse, and 4.8 kw for an 0.5-μs pulse on this particular aperture.

Around the minimum power for breakdown, the initiating and extinguishing peak powers differ by only about 0.2 kw or less. Without an external source of radiation to provide ionizing collisions, the level of the power required to initiate breakdown is quite erratic, since the breakdown cannot proceed without some initial free electrons to be accelerated by the RF field.

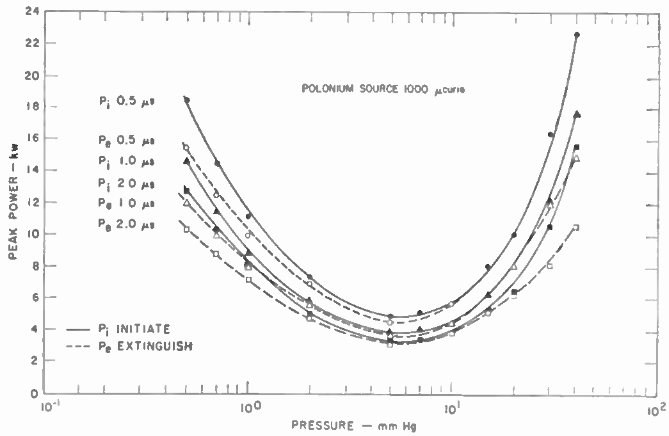

Fig. 3—Breakdown power as a function of pressure for a 20-db X-band traveling-wave slot antenna.

Without the source, the process depends upon stray electrons reaching the region about the antenna.

Voltage Standing-Wave Ratio (VSWR) and Radiated Power

The next series of voltage breakdown tests were made to indicate the variations in the VSWR and in the power radiated in the main lobe of the antenna as a function of the pressure for a constant peak power.

In these tests, a constant peak power was applied to the antenna. As the pressure was reduced, the VSWR of the antenna and the power received by the monitor horn were recorded. Figs. 4 and 5 show the results obtained for peak powers of 5 and 25 kw. For 5-kw peak power applied, the data show a decrease in the VSWR during the time breakdown occurs. Thus, as the plasma created on the surface of the antenna absorbs energy from the RF field, the conditions are such that the match of the antenna to the feed system improves. When the peak power is increased to 25 kw, the match is still improved for a major portion of the breakdown region, and only slightly exceeds the VSWR before breakdown, for a small portion of the breakdown period. The variation in the VSWR is not a severe limitation, at least for the power conditions used here. However, for higher average powers, the VSWR variations will become quite large.

The power radiated under breakdown conditions was measured by the monitoring horn which was located outside the chamber and on the main lobe of the antenna. As the pressure was reduced, the power radiated on the main lobe reached a minimum at 5 mm Hg, the same pressure where minimum breakdown potential exists, as shown in Fig. 5. As the peak power increases, the minimum power radiated decreases and the pressure range over which the condition of reduced radiated power occurs becomes greater. Thus the maximum power will be radiated at 5 mm Hg when the transmitter peak power is kept just below the minimum breakdown level.

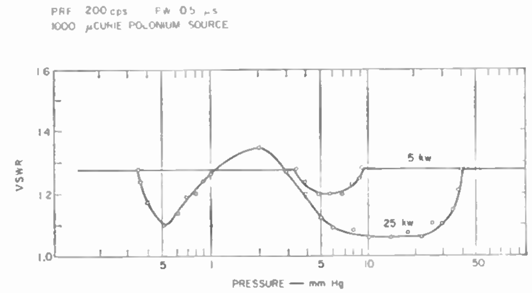

Fig. 4—VSWR as a function of pressure for 5 and 25 kw peak power.

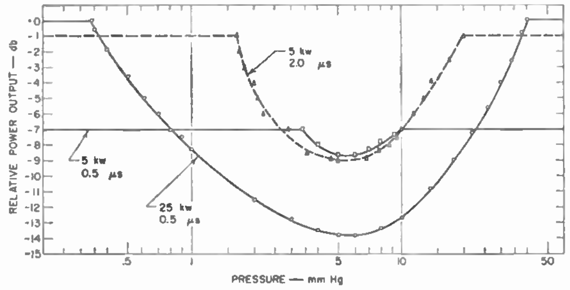

Fig. 5—Power transmitted on main lobe as a function of pressure with 5 and 25 kw peak power applied.

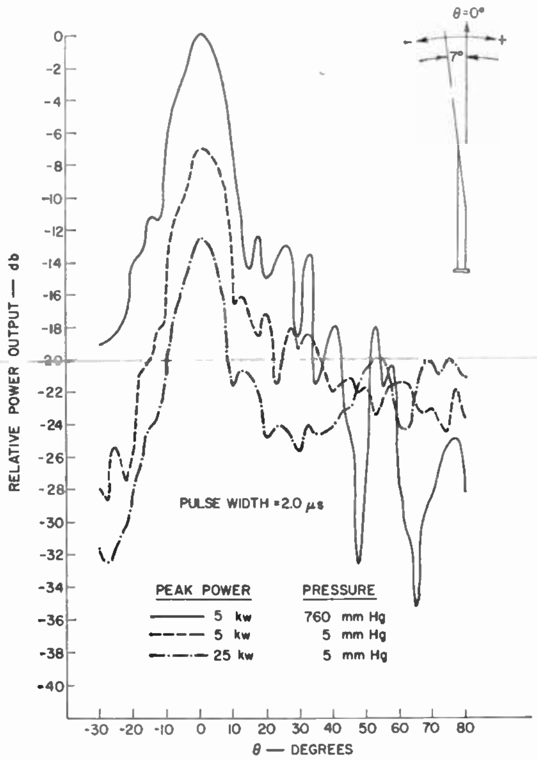

Fig. 6—*E*-plane radiation pattern of 20-db traveling-wave antenna under breakdown conditions.

It is interesting to note that when breakdown has occurred, the power radiated is a function of only the peak power. This is illustrated by the two curves in Fig. 5 for 5-kw peak power at 0.5- and 2.0-μs pulse width which indicate that essentially the same average power was radiated during the time breakdown was present for the two conditions.

Radiation Patterns and Pulse Shape

To ensure that reasonably good approximations of the radiation patterns would be obtained in the altitude chamber, radiation patterns were made both with and without the Plexiglas cover; they showed good agreement with each other as well as with pattern measurements made on the pattern range.

To determine the effect of breakdown on the pattern of the traveling-wave slot antenna, *E*-plane radiation patterns were made by swinging the monitor horn above the antenna. Patterns of the antenna under three conditions are shown in Fig. 6. The top pattern was the normal radiation pattern of the antenna prior to breakdown. The other patterns were measured at a pressure of 5 mm Hg, with 5- and 25-kw peak power applied to the antenna. The major effect of the breakdown was to reduce the amplitude of the main lobe. For example, at 5-kw peak power the main lobe was reduced approximately 7 db. Increasing the peak power to 25 kw reduced the power radiated in the main lobe another 5.5 db, down to 12.5 db below the power radiated for 5 kw before breakdown. The shape of the main lobe was not changed, but the side-lobe structure was changed materially. In Fig. 7, the data from Fig. 6 have been normalized and replotted to make this variation more apparent. As can be seen in Fig. 7, the side lobes increased when breakdown took place and increased also as the peak power was increased. For example, with 25-kw peak power at 5 mm Hg, the side-lobe level at $\theta = 70°$ was only about 7.5 db below the power radiated on the main lobe. Similar radiation pattern distortion existed in the *H*-plane pattern, which is illustrated in Fig. 8.

The radiation pattern variations indicate that the plasma set up by the discharge not only absorbs energy but also serves as a scatterer. Measured field distributions prior to breakdown show a traveling-wave distribution across the aperture. After breakdown, the discharge forms a distinct standing-wave pattern, which varies as a function of the antenna input power and the pressure, thus modifying the aperture distribution. Fig. 9 shows two typical standing-wave patterns on the surface of a 2.25-wavelength traveling-wave slot antenna under breakdown conditions at pressures of 1 and 5 mm Hg. It is interesting to note that the standing-wave pattern which is produced at 1.0 mm Hg corresponds to a frequency twice that of the *X*-band power source, *i.e.*, the distances between the maxima of the standing wave are one-half wavelength at 20 kc instead of 10 kc. The amount of second harmonic energy radiated during breakdown was found to be only a few per cent of the fundamental.

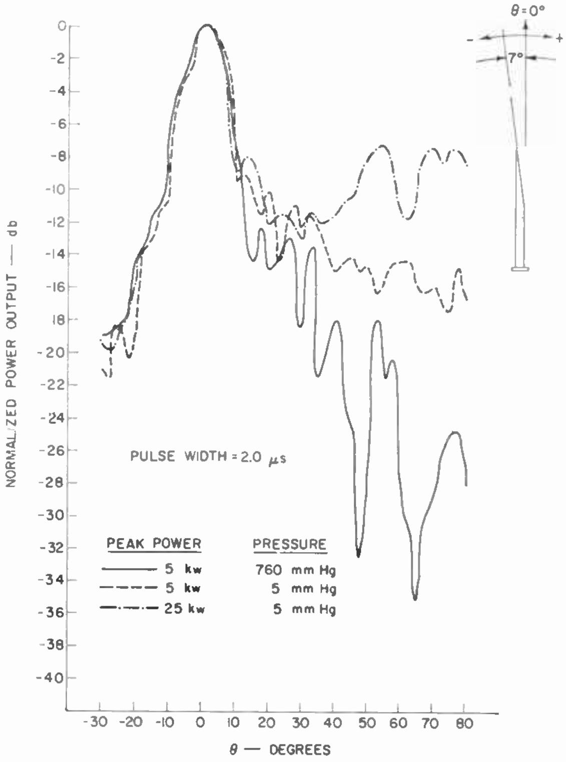

Fig. 7—Normalized *E*-plane radiation pattern of 20-db traveling-wave antenna under breakdown conditions.

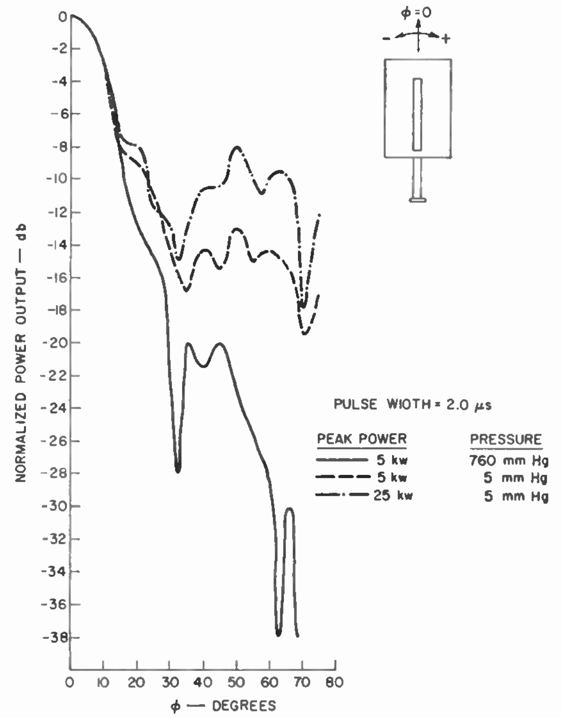

Fig. 8—Normalized *H*-plane radiation pattern of 20-db traveling-wave antenna under breakdown conditions.

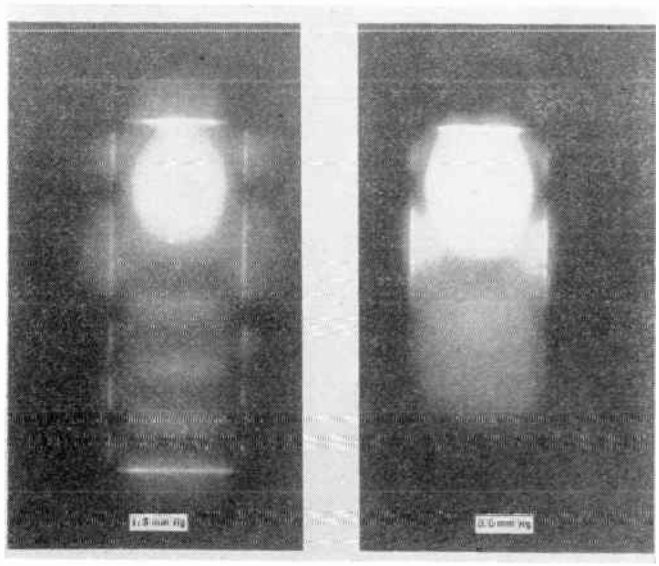

Fig. 9—Photograph of a 12-db traveling-wave slot antenna under voltage breakdown conditions.

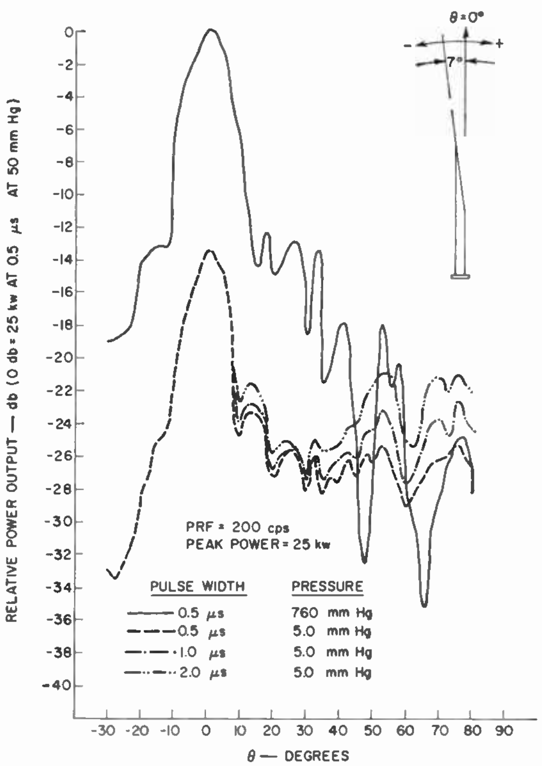

Fig. 10—*E*-plane radiation pattern for 20-db traveling-wave antenna under breakdown conditions.

A similar increase in the side-lobe level is shown in Fig. 10. Here the peak power is held constant and the pulse width is varied. It is also evident from Fig. 10 that the power radiated in the main lobe remains constant under breakdown conditions even though the average power is increased by 6 db by increasing the pulse width from 0.5 to 2.0 μs. Fig. 11 shows the reason for this behavior. In Fig. 11 are shown the pulse shapes radiated in the main lobe, at $\theta = 0°$, and also at $\theta = 52.5°$ where variation in the radiated power is experienced as the pulse width is varied. At $\theta = 0°$, the pulse shape changes

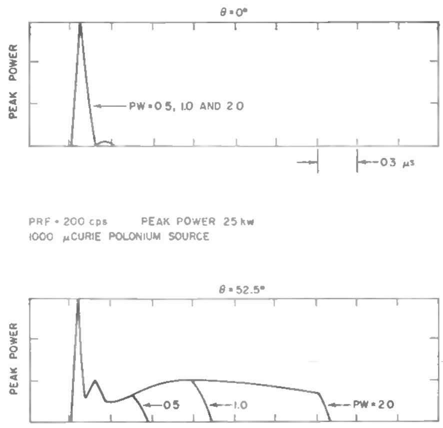

Fig. 11—Pulse shapes radiated by 20-db traveling-wave antenna under breakdown conditions.

to only a sharp spike independent of pulse width. This indicates that when the breakdown occurs, a major portion of the additional power contained in the pulse following the breakdown point becomes absorbed in the plasma, and a small portion is scattered and appears as an increase in energy in the side lobes. This is evidenced by the pulse shape variation shown for $\theta=52.5°$ in Fig. 11. In fact, except for the pulse shapes in the vicinity of the main lobe where the shape of the radiation pattern remains the same under breakdown conditions, the pulse shapes vary radically as a function of angle. Since breakdown initiates on each pulse and extinguishes at the end of each pulse, the shape of the main beam remains unaltered because it is primarily the pattern of the initial pulse prior to breakdown and is, therefore, the radiation pattern of the antenna before breakdown. The variation in pulse shape as a function of pulse length indicates that the breakdown plasma does not reach an equilibrium condition during the 2-μs pulse.

The pulse radiated on the main lobe of the antenna is reduced in length when breakdown occurs, until the pulse length corresponds to the time the given peak power must be applied before breakdown is initiated. Thus the minimum power transmitted on the main beam is dependent only on the magnitude of the peak power. A curve showing this effect for the 20-db traveling-wave slot antenna for 5-mm pressure is shown in Fig. 12. The example shown in Fig. 12 is for a 5-kw peak-power pulse of 2-μs duration. The pulse radiated on the main lobe is reduced to about 0.5 μs, corresponding to the point where breakdown is initiated. Pulse shapes for the example given in Fig. 12 are shown in Fig. 13 for various angles in the E plane.

When the antenna is broken down at 5-mm pressure (Fig. 12), the breakdown occurs on the leading edge of the pulse for peak powers greater than about 12.5 kw. Any increase in peak power beyond this point will increase the side-lobe level, but the power radiated in the direction of the main lobe will remain essentially constant. Increasing the pulse width of course will also increase the side-lobe level. This condition is illustrated in Fig. 9 where the peak power applied was 25 kw.

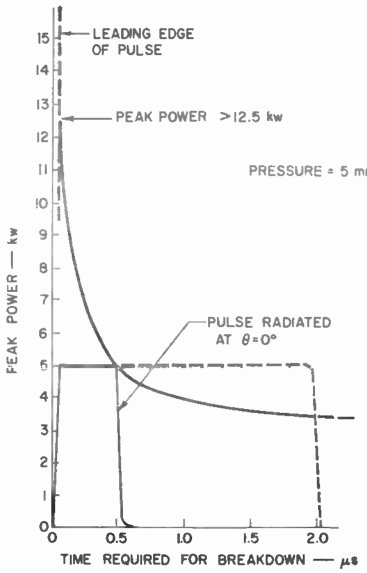

Fig. 12—Time required for breakdown as a function of peak power for 5 mm Hg pressure.

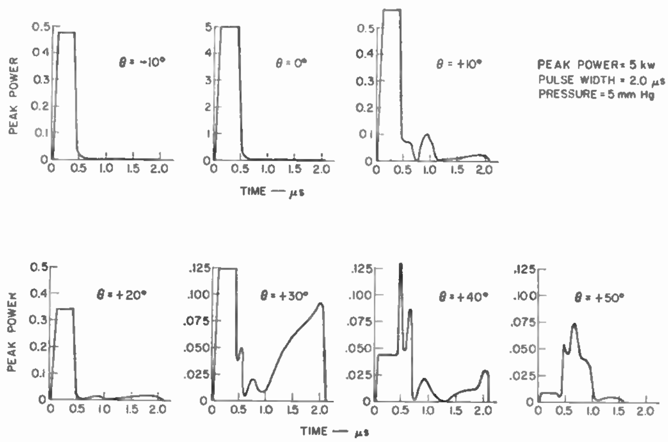

Fig. 13—Pulse shapes radiated by 20-db traveling-wave antenna under breakdown conditions.

Short Antenna

In the case of shorter traveling-wave slots, the effects are more pronounced. From measurements on a 2.25-wavelength traveling-wave antenna with 12-db gain, it was noted that the VSWR increased more rapidly than the VSWR of the longer antenna as the input power was increased. For example, with 25-kw peak power applied and 0.5-μs pulse width, the VSWR of the 12-db antenna increased from 1.2:1 to 2.14:1 at breakdown; while the VSWR of the 20-db antenna only increased from 1.28:1 to 1.35:1 under the same conditions.

The minimum breakdown potential was substantially the same for both antennas, as was the reduction in width of the transmitted pulse when breakdown occurred. This was to be expected from measurements of the aperture distribution, which showed that the maximum field strength for a given input power was the same for both antennas. The modification in radiation pattern was considerably less, however, for the short antenna.

Conclusions

Over the range of peak powers and pulse repetition rates considered here, several important conclusions may be drawn regarding the operation of traveling-wave slot antennas under breakdown conditions:

1) When breakdown occurs, the power radiated on the main lobe is essentially dependent on the peak power only.
2) For an amount of power that produces large over-voltage conditions, breakdown will occur on the leading edge of the applied pulse, and power radiated on the main lobe is constant and becomes independent of the peak power applied.
3) When large powers must be employed, it is advisable to include load isolators in the system because of the large reflection present during breakdown.
4) In the design of systems that must operate at altitudes where breakdown is likely to occur, wherever possible the peak power should be kept below the minimum breakdown potential, since the decrease in power radiated and the modification of pulse shapes are quite severe when breakdown occurs. The altitude range over which the breakdown condition exists also increases as the power is increased. For the same average power some increase in power-handling capacity may be obtained by decreasing the pulse width and increasing the pulse rate.

It should be remembered that the complex environment surrounding high-speed vehicles (air turbulence, high temperature, and excess ionization due to rocket flame and aerodynamic heating) may considerably alter the final results from those obtained in a static test. Methods for simulating some of these environmental conditions are now being considered.

Acknowledgment

The authors wish to express their appreciation to C. C. Allen and P. P. Keenan of the General Electric General Engineering Laboratory and Dr. Robert L. Tanner of Stanford Research Institute for their helpful discussions and assistance.

Some Broad-Band Transformers*

C. L. RUTHROFF†, MEMBER, IRE

Summary—**Several transmission line transformers are described which have bandwidth ratios as high as 20,000:1 in the frequency range of a few tens of kilocycles to over a thousand megacycles. Experimental data are presented on both transformers and hybrid circuits.**

Typical applications are: interstage transformers for broad-band amplifiers; baluns for driving balanced antennas and broad-band oscilloscopes; and hybrids for use in pulse reflectometers, balanced modulators, etc.

These transformers can be made quite small. Excellent transformers have been made using ferrite toroids having an outside diameter of 0.080 inch.

SEVERAL transmission line transformers having bandwidths of several hundred megacycles are described here. The transformers are shown in Figs. 1–9. When drawn in the transmission line form, the transforming properties are sometimes difficult to see. For this reason, a more conventional form is shown with the transmission line form. Some winding arrangements are also shown. Certain of these configurations have been discussed elsewhere and are included here for the sake of completeness [1–4].

In conventional transformers the interwinding capacity resonates with the leakage inductance producing a loss peak. This mechanism limits the high frequency response. In transmission line transformers, the coils are so arranged that the interwinding capacity is a component of the characteristic impedance of the line, and as such forms no resonances which seriously limit the bandwidth. Also, for this reason, the windings can be spaced closely together maintaining good coupling. The net result is that transformers can be built this way which have good high frequency response. In all of the transformers for which experimental data are presented, the transmission lines take the form of twisted pairs. In some configurations the high frequency response is determined by the length of the windings and while any type of transmission line can be used in principle, it is

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† Bell Telephone Labs., Inc., Holmdel, N. J.

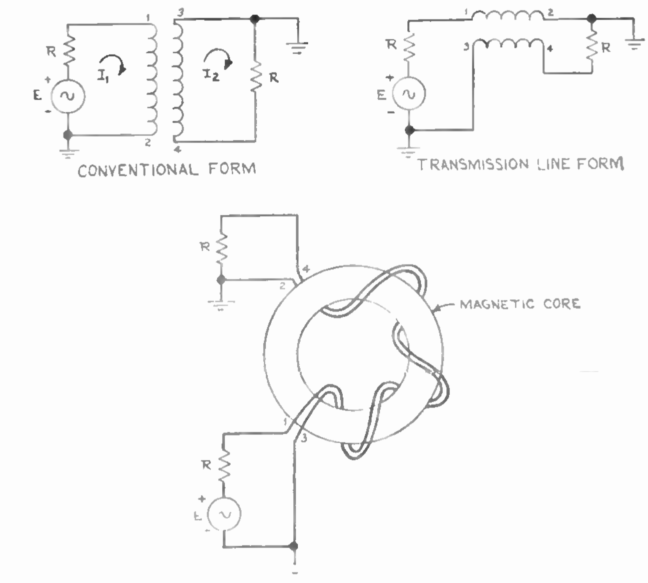

Fig. 1—Reversing transformer.

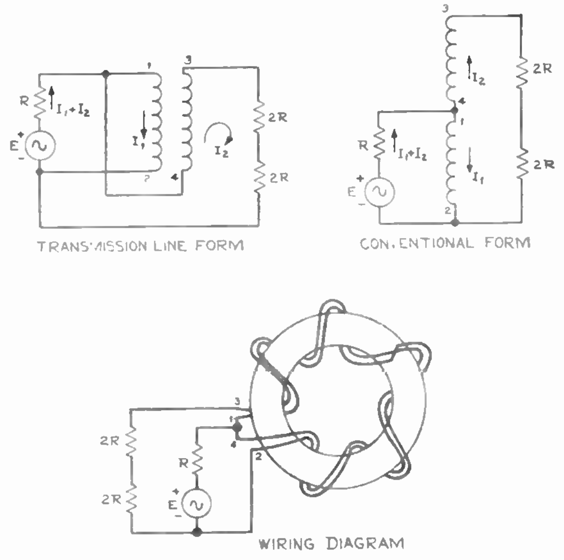

Fig. 3—4:1 Impedance transformer.

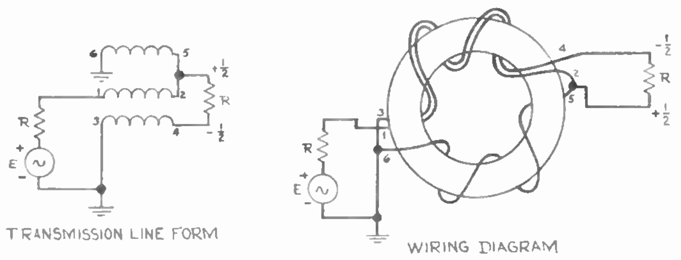

Fig. 2—Unbalanced to balanced transformer.

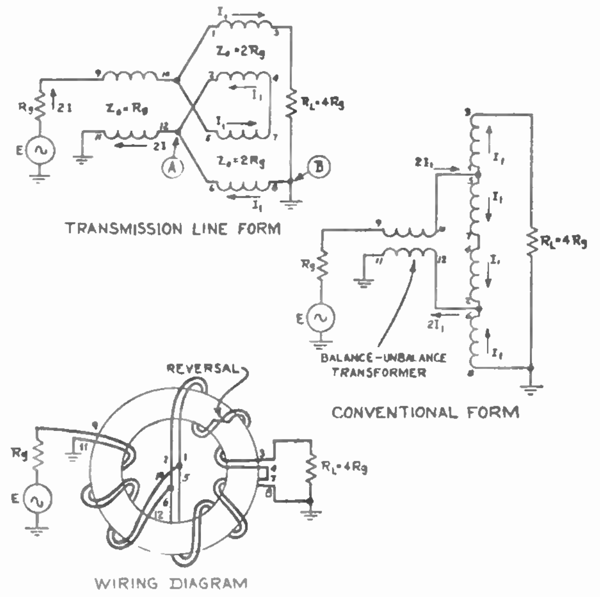

Fig. 4—4:1 Impedance transformer. Unbalanced—symmetrical.

quite convenient to make very small windings with twisted pairs.

The sketches showing the conventional form of transformer demonstrate clearly that the low frequency response is determined in the usual way, *i.e.*, by the primary inductance. The larger the core permeability, the fewer the turns required for a given low frequency response and the larger the over-all bandwidth. Thus a good core material is desirable. Ferrite toroids have been found very satisfactory. The permeability of some ferrites is very high at low frequencies and falls off at higher frequencies. Thus, at low frequencies, large reactance can be obtained with few turns. When the permeability falls off the reactance is maintained by the increase in frequency and good response is obtained over a large frequency range. It is important that the coupling be high at all frequencies or the transformer action fails. Fortunately, the bifilar winding tends to give good coupling. All of the cores used in the experimental transformers described here were supplied by F. J. Schnettler of the Bell Telephone Laboratories, Inc.

Polarity Reversing Transformer—Fig. 1

This transformer consists of a single bifilar winding and is the basic building block for all of the transformers. That a reversal is obtained is seen from the conventional form which indicates current polarities. Both ends of the load resistor are isolated from ground by coil reactance. Either end of the load resistor can then be grounded, depending upon the output polarity desired. If the center of the resistor is grounded, the output is balanced. A suitable winding consists of a twisted pair of Formex insulated wire. In such a winding, the primary and secondary are very close together, insuring good coupling. The interwinding capacity is absorbed in the characteristic impedance of the line.

At high frequencies this transformer can be regarded as an ideal reversing transformer plus a length of transmission line. If the characteristic impedance of the line is equal to the terminating impedances, the transmission is inherently broadband. If not, there will be a dip in the response at the frequency at which the transmission line is a quarter-wavelength long. The depth of the dip

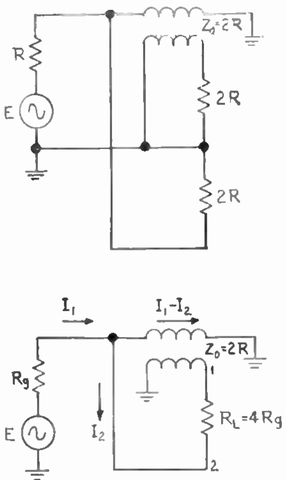

Fig. 5—Balanced—unbalanced 4:1 impedance transformer.

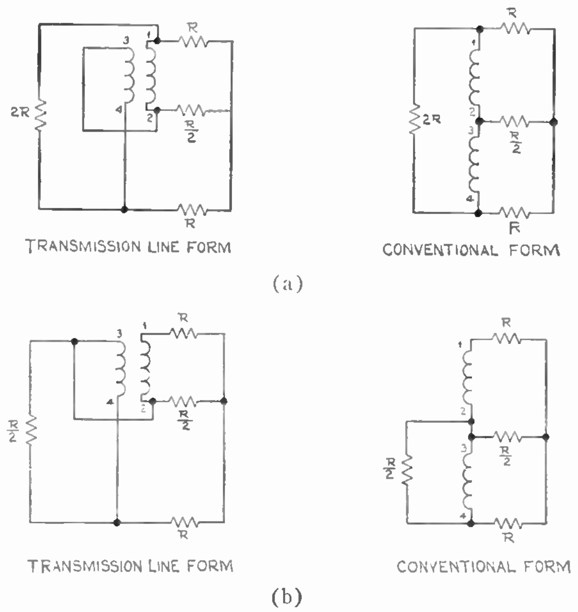

Fig. 6—(a) Basic hybrid. (b) Unsymmetrical hybrid with equal conjugate impedances.

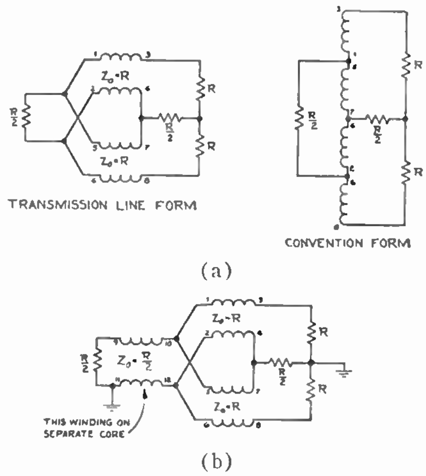

Fig. 7—(a) Symmetrical hybrid with equal conjugate impedances. (b) Unbalanced symmetrical hybrid with equal conjugate impedances.

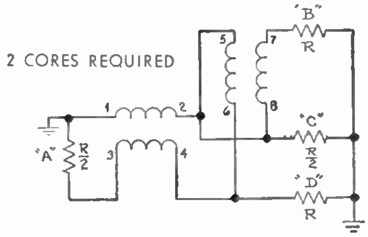

Fig. 8—Hybrid with equal conjugate impedances. Each arm single ended.

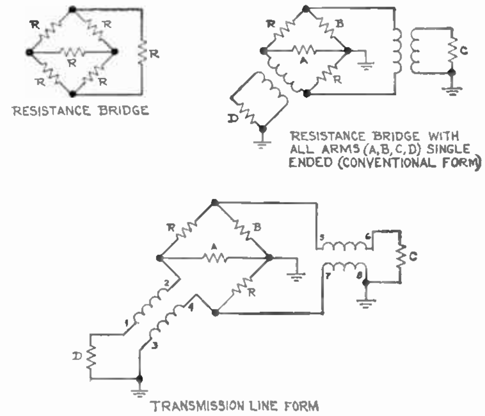

Fig. 9—Resistance hybrid with equal impedance loads. (This hybrid has 3 db loss in addition to transformer loss.)

is a function of the ratio of terminating impedance to line impedance and is easily calculated.

Experimental data on a reversing transformer are shown in Figs. 10 and 11. Fig. 10 is the response of a transformer with no extra impedance matching. The return loss of this transformer to a 3 mμ sec pulse is 20 db. The transformer of Fig. 11 has been adjusted to provide more than 40 db return loss to a 3 mμsec pulse. The transformer loss (about 0.5 db before matching) is matched to 75 ohms with the two 3.8-ohm resistors. The inductance is tuned out with the capacity of the resistors to the ground plane. The match was adjusted while watching the reflection of a 3 mμsec pulse.

Balanced-to-Unbalanced 1:1 Impedance Transformer—Fig. 2

This is similar to Fig. 1 except that an extra length of winding is added. This is necessary to complete the path for the magnetizing current.

Unbalanced-Unsymmetrical 4:1 Impedance Transformer—Fig. 3

This transformer is interesting because with it a 4:1 impedance transformation is obtained with a single bifilar winding such as used in the reversing transformer. The transforming properties are evident from Fig. 3. Not so easily seen is the high frequency cutoff characteristic.

The response of this device at high frequencies is derived in the Appendix and only the result for matched impedances is given here.

$$\frac{\text{Power Available}}{\text{Power Output}} = \frac{(1 + 3\cos\beta l)^2 + 4\sin^2\beta l}{4(1 + \cos\beta l)^2}. \quad (1)$$

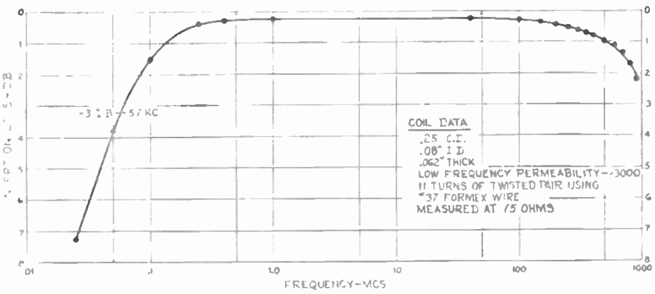

Fig. 10—1:1 Reversing transformer. Insertion loss vs frequency.

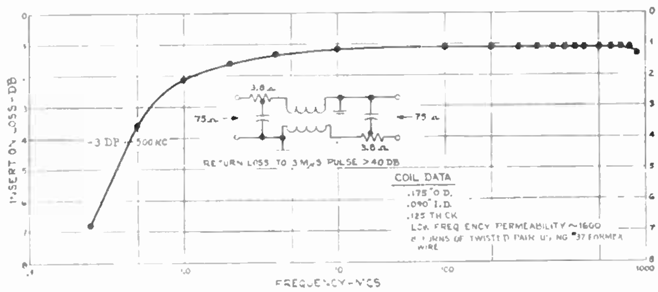

Fig. 11—Matched reversing transformer. Insertion loss vs frequency.

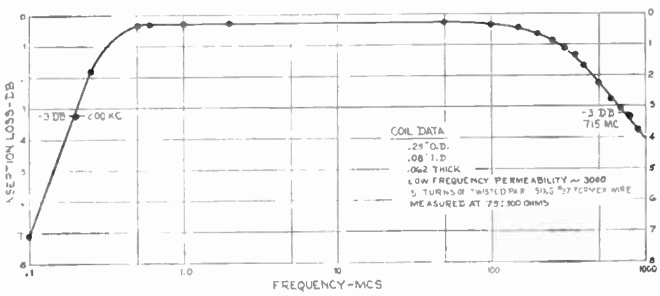

Fig. 12—1 Winding 4:1 impedance transformer unbalanced—unsymmetrical.

where β is the phase constant of the line, and l is the length of the line. Thus, the response is down 1 db when the line length is $\lambda/4$ wavelengths and the response is zero at $\lambda/2$. For wideband response this transformer must be made small. For a plot of (1) see Fig. 16.

Experimental data are given for a transformer of this type in Fig. 12.

Unbalanced-Symmetrical 4:1 Impedance Transformer—Fig. 4

This configuration requires three bifilar windings as shown in Fig. 4. All three windings can be placed on one core, a procedure which improves the low frequency response.[1] When winding multiwinding transformers the following well-known rule should be followed: with the generator connected and the load open, a completed circuit should be formed by the windings so that the core will be magnetized. The fields set up by the currents should be arranged so as to aid each other.

[1] Pointed out to the author by N. J. Pierce of Bell Telephone Labs., Inc., Holmdel, N. J.

Balanced-to-Unbalanced 4:1 Impedance Transformers—Fig. 5

The circuit of Fig. 5 is quite simple. The single bifilar winding is used as a reversing transformer as in Fig. 1. The high frequency cutoff is the same as that for the transformer of Fig. 3.

In some applications it is desirable to omit the physical ground on the balanced end. In such cases, Fig. 5(b) can be used. The high frequency cutoff is the same as for the transformer of Fig. 3. The low frequency analysis is presented in Appendix B.

Hybrid Circuits: Figs. 6–9

Various hybrid circuits are developed from the basic form using the transformers discussed previously. The drawings are very nearly self-explanatory. In all hybrids in which all four arms are single-ended, it has been found necessary to use two cores in order to get proper magnetizing currents.

Two hybrids have been measured and data included here. The response of a hybrid of the type shown in Fig. 8 is given in Fig. 13. For this measurement $R=150$ ohms. In order to measure the hybrid in a 75-ohm circuit, arms B, D were measured with 75-ohm series resistances in series with the 75-ohm measuring gear. This accounts for 3 db of the loss. Under these conditions arms B and D have a 6 db return loss.

The transmission of the resistance hybrid of Fig. 9 is given in Fig. 14. This hybrid has been matched using the technique described previously for the reversing transformer. The results of this matching are included in the figure. This hybrid was designed for use in a pulse reflectometer, the main part of which is a stroboscopic oscilloscope with a resolution of better than 3 mμsec. The oscilloscope was designed by W. M. Goodall.

Applications

Many applications for these transformers will occur to the reader. For purposes of illustration, a few of them are listed here.

1) The reversing transformer of Fig. 1 can be used to reverse the polarity of short pulses, an operation which is frequently necessary. It has also been used in balanced detectors and to drive push-pull amplifiers from single-ended generators.
2) The transformers of Figs. 2 and 5(b) are useful for driving balanced antennas. The circuit of Fig. 5(b) may find application in connecting twin lead transmission line to commercial television receivers.
3) The transformer of Fig. 3 has found wide use in broadband amplifier interstages. It will also be useful in transforming the high output impedances of distributed amplifiers to coaxial cable impedances. They can also be cascaded to get higher turns ratios.

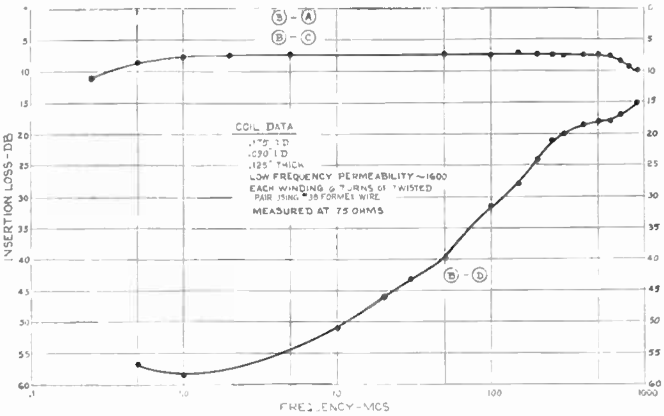

Fig. 13—Hybrid of Fig. 8. Insertion loss vs frequency.

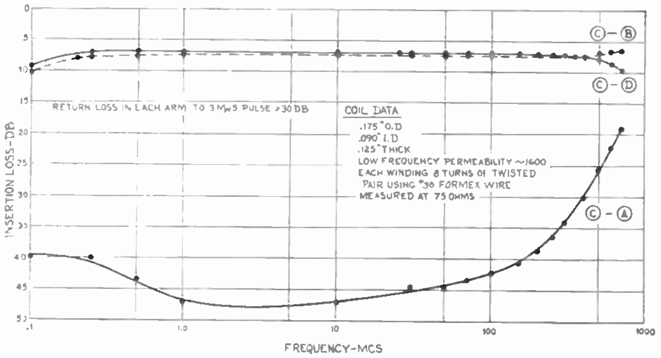

Fig. 14—Matched resistance hybrid. Insertion loss vs frequency.

4) The circuit of Fig. 5(a) has been used to drive broadband oscilloscopes, with balanced inputs, from single-ended generators. It can also find use in balanced detectors.
5) Hybrids have many uses such as in power dividers, balanced amplitude and phase detectors; as directional couplers for pulse reflectometers, IF and broadband sweepers. They might also be used as necessary components in a short pulse repeater for passing pulses in both directions on a single transmission line.

Appendix A

The high frequency response of the circuit of Fig. 3 is derived from Fig. 15. The loop equations are as follows:

$$e = (I_1 + I_2)Rg + V_1$$

$$e = (I_1 + I_2)Rg - V_2 + I_2R_L$$

$$V_1 = V_2 \cos \beta l + jI_2Z_0 \sin \beta l$$

$$I_1 = I_2 \cos \beta l + j\frac{V_2}{Z_0} \sin \beta l. \quad (2)$$

This set of equations is solved for the output power P_0. $P_0 = |I_2|^2R_L$

$$P_0 = |I_2|^2R_L = \frac{e^2(1+\cos\beta l)^2R_L}{[+2Rg(1+\cos\beta l) + R_L\cos\beta l]^2 + \left[\frac{RgR_L + Z_0^2}{Z_0}\right]^2 \sin^2\beta l}. \quad (3)$$

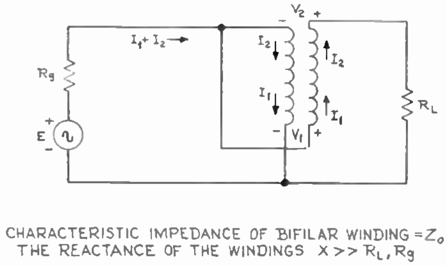

Fig. 15—Transformer schematic.

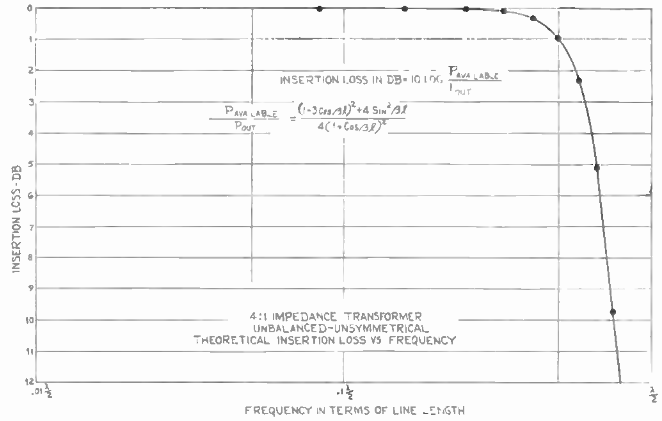

Fig. 16—Theoretical insertion loss vs frequency.

From this expression, the conditions for maximum power transmission are obtained by setting $l = 0$ and setting $dP_0/dR_L|_{l=0} = 0$. The transformer is matched when $R_L = 4Rg$. The optimum value for Z_0 is obtained by minimizing the coefficient of $\sin^2 \beta l$ in (3). In this manner the proper value for Z_0 is found to be $Z_0 = 2Rg$.

Now, setting $R_L = 4Rg$ and $Z_0 = 2Rg$, (3) reduces to

$$P_0 = \frac{e^2(1+\cos\beta l)^2}{Rg[(1+3\cos\beta l)^2 + 4\sin^2\beta l]}. \quad (4)$$

Also,

$$P_{\text{available}} = \frac{e^2}{4Rg}, \quad (5)$$

and dividing (4) by (3):

$$\frac{\text{Power Available}}{\text{Power Output}} = \frac{(1+3\cos\beta l)^2 + 4\sin^2\beta l}{4(1+\cos\beta l)^2}. \quad (6)$$

This function is plotted in Fig. 16.

The impedances seen at either end of the transformer with the other end terminated in Z_L have been derived. They are:

Z_{in}(low impedance end)

$$= Z_0\left(\frac{Z_L\cos\beta l + jZ_0\sin\beta l}{2Z_0(1+\cos\beta l) + jZ_L\sin\beta l}\right) \quad (7)$$

and

Z_{in}(high impedance end)

$$= Z_0\left(\frac{2Z_L(1+\cos\beta l)+jZ_0\sin\beta l}{Z_0\cos\beta l+jZ_L\sin\beta l}\right). \quad (8)$$

Appendix B

In the low frequency analysis of the transformer of Fig. 5 the series impedance of each half of the bifilar winding is denoted by Z. The loop equations are:

$$E = (Rg + Z)I_1 - (Z + kZ)I_2$$

$$E = (Rg - kZ)I_1 + (R_L + Z + kZ)I_2, \quad (9)$$

from which

$$\frac{I_1}{I_2} = \frac{R_L + 2Z(1+k)}{Z(1+k)} \approx 2 \text{ if } Z \gg R_L. \quad (10)$$

We now proceed to calculate the voltages from points 1 and 2 to ground

$$V_{2G} = E = I_1 Rg.$$

When the transformer is matched, $E = 2I_1Rg$ and

$$V_{2G} = I_1 Rg. \quad (11)$$

Similarly,

$$V_{1G} = I_2 Z - kZ(I_1 - I_2).$$

With the aid of (10) this can be rearranged to

$$V_{1G} = ZI_1\left[\frac{Z(1+k)^2 - kR_L - 2kZ(1+k)}{R_L + 2Z(1+k)}\right]. \quad (12)$$

Now let the coupling coefficient $k=1$, then

$$V_{1G} = I_1 Z\left[\frac{-kR_L}{R_L + 2Z(1+k)}\right] \approx -\frac{I_1 R_L}{4}$$

for $Z \gg R_L$.

When the transformer is matched, $R_l = 4Rg$ so that

$$V_{1G} = I_1 Rg = -V_{2G}, \quad (13)$$

and the load is balanced with respect to ground.

From (13) it is clear that the center point of R_L is at ground potential. This point can therefore be grounded physically, resulting in Fig. 5(a).

Acknowledgment

In addition to those mentioned in the text, the author is indebted to D. H. Ring for many stimulating discussions on every aspect of these transformers.

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[1] Willmor K. Roberts, "A new wide-band balun," Proc. IRE, vol. 45, pp. 1628–1631; December, 1957.
[2] H. Gunther Rudenberg, "The distributed transformer," Raytheon Mfg. Co., Waltham, Mass.
[3] G. Guanella, "New method of impedance matching in radio frequency circuits," *Brown-Boveri Rev.*, vol. 31, p. 327; 1944.
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[5] C. A. Burrus, unpublished memorandum.

Dissipation Loss in Multiple-Coupled-Resonator Filters*

SEYMOUR B. COHN†, senior member, ire

Summary—This paper examines the effect of dissipation on the response of multiple-coupled-resonator filters designed from lossless prototype low-pass filters. A simple approximate formula makes possible the computation of center-frequency loss in terms of bandwidth, unloaded Q of the resonators, and the parameters of the prototype filter. It is shown how the insertion loss elsewhere in the pass band and stop band may be computed from the prototype filter after modifying its circuit to take account of dissipation in the resonators. The computational techniques are used to compare several symmetrical designs with each other and with unsymmetrical designs having exact maximally-flat and equal-ripple response in the presence of dissipation. It is found that the symmetrical designs offer lower pass-band loss than the unsymmetrical designs. It is proven that a symmetrical filter based on an equal-element prototype has minimum-possible center-frequency loss for given unloaded Q and stop-band bandwidth, subject to assumptions that the loss per resonator is small and that the stop-band insertion loss may be determined accurately from the highest-power term of the insertion-loss polynomial.

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I. Introduction

FILTERS consisting of resonators coupled in cascade are widely used in all frequency ranges. At microwave frequencies the resonators are usually waveguide cavities or lengths of coaxial or strip line. At lower frequencies they may be resonant circuits of capacitors and inductors, or they may be quartz crystals or other mechanically-vibrating structures.

Because of the importance of coupled-resonator filters, their design has received considerable attention. The most convenient design approach is to synthesize first a low-pass prototype filter having the desired insertion-loss response, and then to calculate the resonator and coupling parameters that will yield the same insertion-loss response on a transformed frequency scale. It is most simple to assume nondissipative elements in the prototype filter. In that case closed-form formulas are available for designing low-pass filters of any number of elements to have maximally-flat or equal-ripple response. However, power dissipation is always present in a practical filter, and as a result the actual insertion-loss response function of the coupled-resonator filter will deviate somewhat from the theoretical response of the ideal prototype. The deviation is most evident in the pass band, where it usually appears as an increase in the minimum insertion loss, a rounding near the cutoff points, and a partial or complete obliteration of ripples. In the stop band the effect is usually very slight. This paper will present a simple approximate formula by which the center-frequency dissipation loss may be determined. A computational method is also described by which the insertion loss may be evaluated at all frequencies in the pass band and stop band.

The approximate approach used in computing center-frequency loss is equivalent to calculating the fields in lossless resonators coupled to yield a desired response function, and then calculating the power dissipated when these fields act upon the actual dissipative regions of the resonators. The formula obtained is simple and requires a knowledge only of the unloaded Q of the resonators, the filter bandwidth, and the element values of the equivalent low-pass prototype from which the multiple-resonator filter was designed. The formula applies only to the center of the pass band and assumes that the reflection loss is small and that the dissipation loss does not exceed n db for good accuracy, or $2n$ db for fair accuracy where n is the number of resonators in the filter. However, it is shown with examples how all of these conditions may be removed to obtain the actual insertion loss at all frequencies through computations on the low-pass prototype circuit.

Although the method used here is to assume first a nondissipative filter and then to compute the effect of finite-Q elements, this is not the only possible approach to the design problem. Narrow-bandwidth coupled-resonator filters can be synthesized to have any physically-realizable response function in the presence of dissipation. Dishal gives data that may be used for the design of such filters to yield maximally-flat, equal-ripple, and maximally-linear-phase response functions when resonators of finite unloaded Q are used.[1,2] It turns out that for more than two resonators the filter must be constructed unsymmetrically in order to obtain these exact response functions, and that for any given number of resonators an infinite number of sets of design parameters will yield the same response function. Taub and Bogner[3] have shown for three resonators, and Fubini and Guillemin[4] for any number of resonators, that if the requirement of minimum pass-band loss is added to the filter specification, a single design will then be uniquely determined in the case of exact maximally-flat or equal-ripple response. By means of Taub and Bogner's graphs, the design parameters may be obtained quite readily for three-resonator maximally-flat filters, but for the three-resonator equal-ripple case and for all cases with more than three resonators a laborious computational procedure is necessary.

The work of Taub and Bogner and of Fubini and Guillemin on minimum-loss designs apply in detail only to the synthesis of filters having exact maximally-flat or equal-ripple response, for which it is necessary for the filter structure to be unsymmetrical (except for $n=1$ or 2). This dissymmetry produces mismatch loss at band center, which is needed to overcome the rounding effect of dissipation loss. The rounding results from the greater dissipation loss toward the edges of the pass band than at the center, but by introducing mismatch loss properly the response may be flattened and the exact maximally-flat or equal-ripple function achieved. However, it is clear that if this center-frequency mismatch is eliminated, the insertion loss will be reduced. Therefore, the minimum-loss design for exact maximally-flat or equal-ripple response does not give the least center-frequency insertion loss that can be achieved with the same unloaded Q, number of resonators, and bandwidth.

It should be realized that for many applications a reduced insertion loss would be preferred to an idealized response shape. An important practical problem, therefore, is to find design parameters yielding the true minimum-possible center-frequency loss, and to determine the value of this loss and the shape of the response curve. This problem is studied in this paper with the aid of the simple formula for center-frequency loss. The formula permits the various factors to be quickly evaluated and designs to be found yielding very close to the true minimum-possible loss.

[1] M. Dishal, "Design of dissipative band-pass filters producing desired exact amplitude-frequency characteristics," Proc. IRE, vol. 37, pp. 1050–1069; September, 1949.

[2] "Reference Data for Radio Engineers, 4th Ed.," IT&T Corp., New York, N. Y., pp. 188–204; 1956. (See list of other references in footnote, p. 199.)

[3] J. J. Taub and B. F. Bogner, "Design of three-resonator band-pass filters having minimum insertion loss," Proc. IRE, vol. 45, pp. 681–687; May, 1957.

[4] E. G. Fubini and E. A. Guillemin, "Minimum insertion loss filters," Proc. IRE, vol. 47, pp. 37–41; January, 1959.

II. Computation Methods

Convenient design formulas have been given by which multiple-resonator band-pass filters may be designed to have the response function (transformed in frequency) of the low-pass prototype filter.[5,6] The basic parameters entering into the design are the desired bandwidth of the multiple-resonator filter and the element values g_i of the low-pass prototype. For convenience, formulas for the element values of nondissipative maximally-flat and equal-ripple low-pass prototype filters have been gathered from several sources and are included by Cohn.[5-7] The use of these element values will yield good approximations to maximally-flat and equal-ripple response in the multiple-resonator filter if the resonator unloaded Q's are sufficiently high. Usually, however, there will be sufficient dissipation loss to alter noticeably both the center-frequency loss and the shape of the response curve. Methods of calculating these effects will now be presented.

1. *Center-Frequency Loss*

The following formulas derived in Section V give the insertion loss due to dissipation at the center of the pass band of a multiple-resonator filter:

$$L_0 = 4.343 \frac{\omega_1'}{w} \sum_{i=1}^{n} \frac{g_i}{Q_{ui}} \text{ db} \tag{1}$$

where, as shown in Fig. 1, ω_1' is a point on the low-pass-prototype frequency scale corresponding to frequencies f_1 and f_2 on the band-pass frequency scale, w is the relative bandwidth $(f_2-f_1)/f_0$ where f_0 is the center frequency, $g_1, g_2, \cdots, g_n$ are the respective element value of the prototype filter in farads and henries as shown in Fig. 2. $Q_{u1}, Q_{u2}, \cdots, Q_{un}$ are the respective unloaded Q's of the resonators, and n of the number of resonators in the filter. As is made clear in the derivation, this formula usually has very good accuracy for L_0 up to about n db, and fairly good accuracy up to about $2n$ db. In order for (1) to be valid, the filter must be well-enough matched at f_0 so that mismatch loss will be small. When this is not the case, the insertion loss will usually lie between the value given by (1) and that value plus the mismatch loss of the nondissipative filter, which is given by $10 \log_{10} [(1+r)^2/4r]$ where r ohms and 1 ohm are the terminating resistances shown in Fig. 2.

2. *Exact Calculation Using Low-Pass Prototype*

The approximations involved in (1) may be avoided

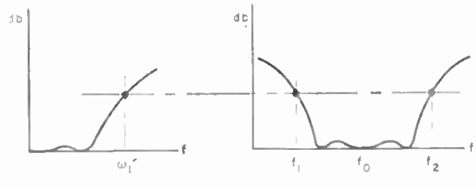

Fig. 1—Correspondence between low-pass prototype response and equivalent band-pass response.

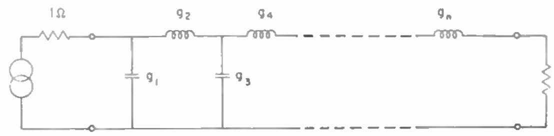

Fig. 2—Nondissipative low-pass prototype filter.

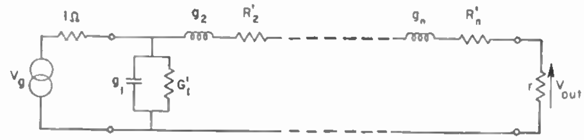

Fig. 3—Dissipative low-pass prototype filter.

if exact network calculations are made on an equivalent circuit of the multiple-resonator filter. The low-pass-prototype filter circuit of Fig. 3 is the most convenient for this purpose. The series resistances and shunt conductances are determined from the respective resonator unloaded Q's by the following formulas, which are derived in Section V:

$$R_i' = \frac{\omega_1' g_i}{w Q_{ui}} \quad \text{for } i \text{ even} \tag{2}$$

$$G_i' = \frac{\omega_1' g_i}{w Q_{ui}} \quad \text{for } i \text{ odd.} \tag{3}$$

The capacitances and inductances g_i are related to the resonator and coupling parameters of the multiple-resonator filter by the same formulas used for the nondissipative case.[5,6]

With the dissipative prototype filter of Fig. 3 thus fully determined, the frequency response on the ω' scale can be obtained exactly by direct calculation, and then the frequency response of the multiple-resonator band-pass filter may be found by means of the frequency transformation between ω' for the low-pass filter and f for the band-pass filter. For bandwidths up to a few per cent, the following simple transformation gives good results:

$$\frac{|f-f_0|}{f_0} = \frac{w}{2} \cdot \frac{\omega'}{\omega_1'} . \tag{4}$$

More precise transformation formulas are available for certain lumped-constant, waveguide, and strip-line configurations, and should be used for bandwidths of more than a few per cent.[5]

At the center frequency f_0, corresponding to $\omega'=0$, the computation is particularly simple since the circuit is pure resistive and all quantities are real. At other

[5] S. B. Cohn, "Direct-coupled-resonator filters," Proc. IRE, vol. 45, pp. 187–196; February, 1957.

[6] S. B. Cohn, "Parallel-coupled transmission-line-resonator filters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 223–231; April, 1958.

[7] As explained by Cohn,[5] the use of these formulas results in symmetrical coupled-resonator structures in all cases, although the low-pass prototype is unsymmetrical for equal-ripple response with n even. That is, although $g_1 \neq g_n$ and $r \neq 1$ in the latter case, the coupled-resonator filter derived from the prototype is symmetrical and has equal terminating impedances. Therefore, the insertion loss for the coupled-resonator filter is not strictly equal to the insertion loss of the prototype, but is equal to the difference in decibels between the maximum power available from the generator and the power delivered through the filter to the load r.

frequencies, the impedances and admittances are complex numbers, and the voltages and currents must also be treated as complex. In either case, the most convenient procedure is to assume $V_{out}=1$ volt and then to compute the voltages and currents back through the filter until V_g is determined. Then, since the power available from the generator is $(V_g/2)^2$ and the output power is V_{out}^2/r, the insertion loss of the coupled-resonator filter[8] is related to V_g/V_{out} by

$$L = 20 \log_{10} \left| \frac{V_g}{V_{out}} \right| - 10 \log_{10} \frac{4}{r} \text{ db}. \quad (5)$$

This procedure gives directly the combined effect of mismatch and dissipation loss and is valid at all frequencies, in the pass band, transition band, and stop band.

III. Minimum Loss for Symmetrical Designs

1. Approximate Minimum-Loss Design

The design parameters of multiple-resonator filters having very nearly minimum-possible center-frequency loss, irrespective of response-curve shape, may be arrived at easily in the case of given values of unloaded Q and stop-band bandwidth . The results are subject to the assumptions that the loss is small (not more than about n db) and that the insertion-loss ratio at the edges of the stop band is accurately given by the highest-power term in the insertion-loss polynomial. When the first assumption is met, (1) is accurate, and when the second is met, the stop-band insertion loss is given by the following formula derived in Section V:[9]

$$L_s = 20 \log_{10} (\omega_s'^n g_1 g_2 g_3 \cdots g_n) + C \quad (6)$$

where the subscript s indicates values at the stop-band limits, and C is a constant dependent upon the load resistance r, as discussed in Section V. Thus, if w_s, Q_u, n, and r are assumed fixed and the element values g_i are allowed to vary, L_s will remain constant if

$$(\omega_s')^n g_1 g_2 \cdots g_n = \text{constant}, \quad (7)$$

and L_0 will be minimum if

$$\omega_s'(g_1 + g_2 + \cdots g_n) = \text{minimum}. \quad (8)$$

Differentiating (7) and (8) yields

$$\frac{\delta(\omega_s' g_1)}{\omega_s' g_1} + \frac{\delta(\omega_s' g_2)}{\omega_s' g_2} + \cdots + \frac{\delta(\omega_s' g_n)}{\omega_s' g_n} = 0$$

and

$$\delta(\omega_s' g_1) + \delta(\omega_s' g_2) + \cdots + \delta(\omega_s' g_n) = 0.$$

These two equations can hold in general only if the quantities $\omega_s' g_1$ are all equal. Thus, subject to the approximations, minimum dissipation loss at f_0 is obtained when the elements in the prototype filter are equal:

$$g_1 = g_2 = g_3 = \cdots = g_n. \quad (9)$$

It is further necessary that r be close to unity; that is, that the terminating resistances be almost equal. If this were not the case, excessive mismatch loss would occur. It is likely that the true minimum possible loss will be achieved in a given case by a set of g_i values that are somewhat unequal, and possibly with an r value slightly different from unity, but the center-frequency insertion loss of a symmetrical filter designed with $r=1$ and $g_1=g_2= \cdots =g_n$ will certainly be extremely close to the true minimum-possible loss in cases where both (1) and (6) are valid.

2. Exact Minimum-Loss Design for Symmetrical Filter with $n=3$

Schiffman has derived exact design formulas for the three-resonator symmetrical filter yielding minimum-possible loss when the unloaded Q and stop-band bandwidth are specified.[10] Upon converting Schiffman's formulas into the notation of this paper, it was found that the elements of his low-pass prototype approach equality as L_0 approaches zero. This agrees with the approximate analysis above. As an example of the effect of a high value of L_0 on the accuracy of the approximate analysis, the exact minimum-loss design having $L_0=3$ db has elements g_i in the ratio 1:0.775:1. An equal-element filter with the same unloaded Q and stop-band bandwidth has $L_0=3.23$ db, about 8 per cent higher. This discrepancy vanishes very rapidly as L_0 is reduced.

IV. Comparative Performance of Different Designs

1. Pass-Band Response

Exact calculations were made of the pass-band insertion-loss response of various coupled-resonator filters having $n=3$ and $n=5$. A comparison of three response curves for three-resonator filters is shown in Fig. 4. The same Q_u and 60-db bandwidth, w_s, are assumed for each case; that is, *all curves, if extended, would intersect at the 60-db points.* One of the curves is for the minimum-loss maximally flat case of Taub and Bogner.[3] A second curve is labelled pseudo maximally flat , since it is the curve for a filter designed from a nondissipative maximally-flat prototype. The third curve is for the minimum-loss symmetrical design of Schiffman.[10]

A number of interesting facts are evident from Fig. 4. 1) Although the exact maximally-flat case has minimum loss compared to all other possible maximally-flat filters having the same n, Q_u and w_s, it has higher center-frequency loss than the other two curves in the figure. 2) The rounding effect of dissipation is clearly evident in the other curves. 3) As predicted above, the minimum-loss symmetrical design has the least loss of the three curves at f_0. This case also has the least loss throughout the pass band, and offers the greatest 3-db

[8] See preceding footnote.

[9] Eq. (6) holds in the case of maximally-flat response if $L_s \geq 20$ db, while in the other cases considered in this paper experience has shown (6) to be within 1.5 db at 60 db for $n=5$, and much closer for n smaller.

[10] J. F. Cline and B. M. Schiffman, "Tunable passive multicouplers employing minimum-loss filters," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 121–127; January, 1959.

bandwidth. It may also be regarded as a pseudo-equal-ripple case, since the nondissipative low-pass prototype of the minimum-loss symmetrical filter has an equal-ripple response with ripple level of about 0.2 db. Note that dissipation has removed all but a suggestion of these ripples.

Fig. 5 shows a similar set of response curves for various five-resonator filters. The same Q_u and same 60-db bandwidth are assumed throughout, as before. The results are qualitatively the same as for the three-resonator filters. 1) The minimum-loss exact maximally-flat curve has higher midband loss than the other curves, which are again rounded by dissipation. 2) The equal-element curve offers the least loss at center frequency, although the 0.1-db pseudo-equal-ripple curve is almost as good. 3) The equal-element and pseudo-equal-ripple curves have less loss everywhere in the pass band than the exact maximally-flat case. 4) All ripples are obliterated.

It is thus clear that the minimum-loss exact maximally-flat design does not give the least possible loss when restrictions on response-curve shape are removed. If the maximally-flat response is definitely needed in a given application, it should of course be used. In many applications, however, the rounded response curves of the other cases would be satisfactory and therefore would be favored because of their lower loss and better match in the pass band. Further advantages of these other cases are their ease of design from simple available formulas and their symmetrical physical structures. The rounding to be expected depends upon the amount of dissipation loss occurring in the filter. For example, if L_0 were 1.0 db, the response curves in Fig. 4 and Fig. 5 would conform much more closely to the curves for the lossless prototypes.

Fubini and Guillemin have shown that exact equal-ripple filters have considerably higher pass-band loss than a maximally-flat filter of the same number of resonators, unloaded Q, and 3-db bandwidth.[4] This is true even for ripple levels as small as 0.001 db, and the loss increases very rapidly as the ripple level is increased. The reason for this behavior may be deduced from the curves of Figs. 4 and 5, where the ripples in the equal-element and pseudo-equal-ripple curves have been removed by dissipation. Evidently, it is inherently difficult for a filter to produce ripples in the presence of dissipation, and to accomplish this a large amount of reflection loss must be introduced, thus yielding a high pass-band insertion loss. This conclusion does not apply, however, to the pseudo-equal-ripple case, where the ripples of the nondissipative prototype are allowed to diminish or disappear in the presence of dissipation. In fact, Figs. 4 and 5 show that the pseudo-equal-ripple designs are superior to the pseudo maximally flat designs as far as both minimum loss and pass-band shape are concerned.

2. *Center-Frequency Loss*

The approximate formula for center-frequency loss, (1), has been checked against the exact insertion-loss curves of Figs. 4 and 5. In the case of three resonators, (1) gives errors of only +0.09 and −0.07 db respectively for the minimum-loss (symmetrical) and pseudo-maximally-flat cases. Eq. (1) should not be applied to the exact maximally-flat case because of the mismatch in that design at f_0. In the case of five resonators, (1) gives errors of +0.02, 0.00, and +0.01 db, respectively, for the equal-element, pseudo-equal-ripple, and pseudo-maximally-flat cases.

Eq. (1) has been used to compare the center-frequency loss of filters with various response functions, and the results are plotted in Fig. 6 vs the number of resonators. As a basis of comparison, the product of unloaded Q and relative bandwidth between 60-db points in the stop band is assumed to be equal to 100 in all cases. Since w and Q_u appear as a product in (1), the data will apply to any pair of values, such as 0.01 and 10,000 for example, having the product 100. Or, if wQ_u differs from 100, L_0 in Fig. 6 should be scaled inversely proportional to wQ_u. The selection of stop-band bandwidth as the reference bandwidth instead of pass-band bandwidth is reasonable when isolation between channels is the most important

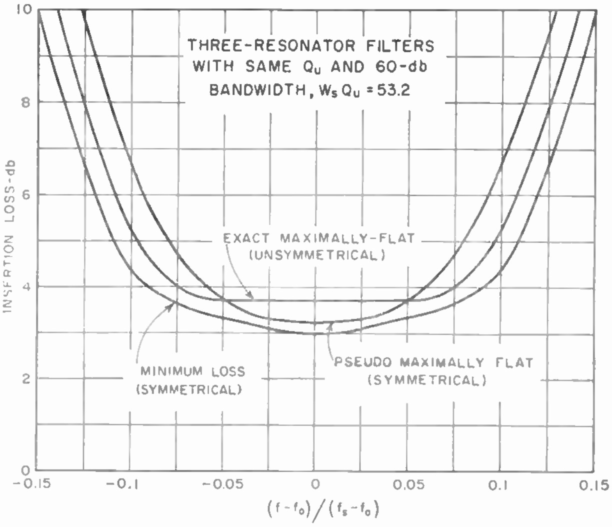

Fig. 4—Pass-band insertion-loss curves for three different three-resonator filter designs.

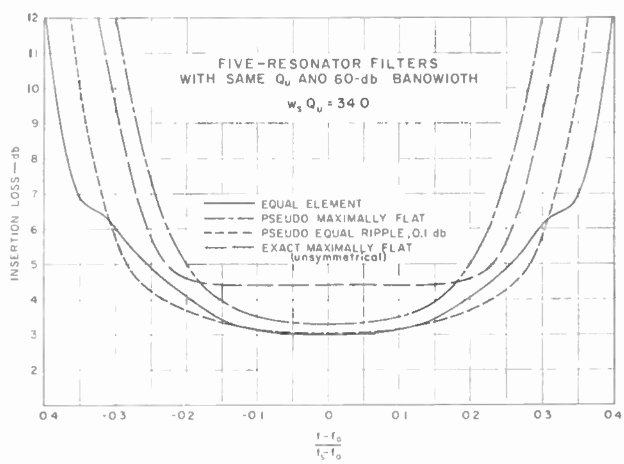

Fig. 5—Pass-band insertion-loss curves for four different five-resonator filter designs.

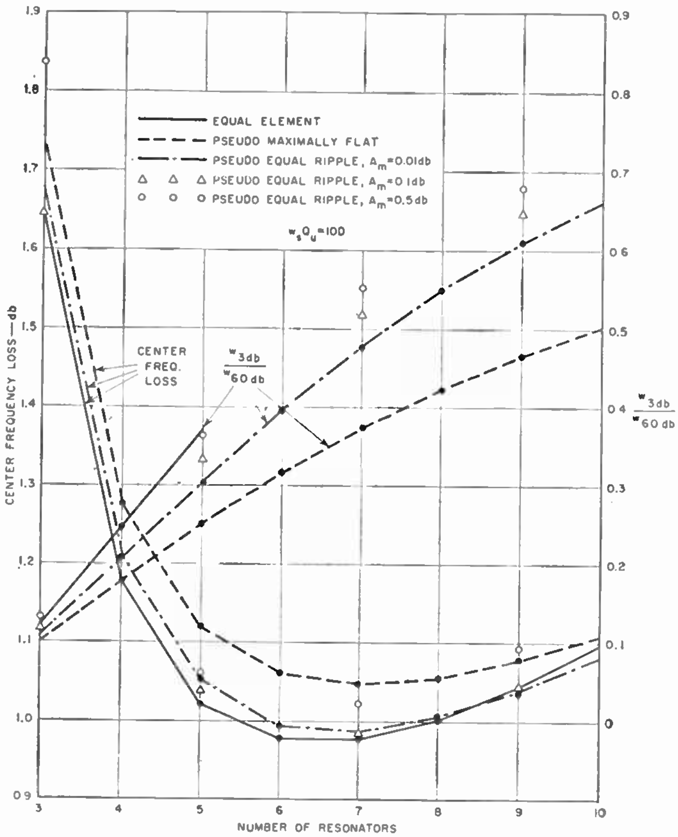

Fig. 6—Center-frequency dissipation loss and relative bandwidth for various symmetrical multiple-resonator filters.

consideration. In such cases, the number of resonators should be made large enough so that the pass band will equal or exceed the desired signal bandwidth.

The following cases are considered in Fig. 6: 1) equal-element prototype; 2) pseudo maximally flat; and 3) pseudo equal ripple. In the latter category, three different ripple levels are assumed for the nondissipative prototype—0.01 db (shown as a dash-dot curve), 0.1 db (plotted as triangular points), and 0.5 db (plotted as circular points). The latter two cases are shown only for n odd, since for n even they have substantial mismatch loss at f_0. Also plotted in Fig. 6 is the ratio of pass-band to stop-band bandwidth, $w_{3\,db}/w_{60\,db}$. These bandwidths were computed assuming no dissipation. Dissipation will reduce $w_{3\,db}$ moderately, while hardly affecting $w_{60\,db}$.

A number of important facts may be deduced from Fig. 6: 1) The spread in loss among the different designs for a given value of n is only about 10 per cent, a surprisingly small range. 2) The bandwidth ratio $w_{3db}/w_{60\,db}$ increases with n, the slope being greatest for small n. 3) The center-frequency loss drops sharply with n, reaching a minimum at $n=6$ or 7, and then rises slowly. This last observation is readily explained by the fact that the rapid increase in 3-db bandwidth with n reduces the loss more rapidly than the number of resonators added in cascade increases it.

The equal-element curve in Fig. 6 is of special interest since it was shown above to approximate the minimum-possible-loss case within a certain range of validity. This curve lies below the others for n up to 8, but not beyond. This behavior is reasonable, since the assumption expressed by (6) breaks down for $n>5$.

The bandwidth data is also worth inspecting. For example, a ratio of bandwidths of 0.37 can be obtained either by means of five resonators with an equal-element design or by seven resonators with a pseudo maximally flat design. In either case, the midband loss would be about the same.

If a stop-band bandwidth other than the 60-db bandwidth were used as a reference, the general appearance of Fig. 6 would not change. However, quantitative differences in center-frequency loss and bandwidth ratio could be considerable. Also, the broad minimum in the loss curves would be likely to shift to another value of n.

V. Derivation of Formulas

1. *Low-Pass Equivalent of Dissipative Band-Pass Filter*

The low-pass filter of Fig. 3 will now be justified as the equivalent of a band-pass filter having dissipative resonators. It has been shown previously that a band-pass filter consisting of coupled nondissipative resonators can be made equivalent in a narrow-bandwidth approximation to the lumped-constant band-pass filter of Fig. 7(a). The latter filter is equivalent to the low-pass prototype filter of Fig. 7(b), with the frequency transformation indicated in Fig. 1. The equivalence of Figs. 7(a) and 7(b) requires that the series reactances or shunt susceptances of corresponding arms be equal at corresponding frequencies; for example, for series arms $\omega' g_i = \omega L_i - 1/\omega C_i$. This relationship between reactances and susceptances causes equal voltages and currents to appear at all corresponding points in the two filters, and hence results in the insertion losses of the filters being the same. When the resonators have finite unloaded Q's, one must introduce resistances and conductances into the lumped-constant band-pass circuit as indicated in Fig. 8(a). Then, to achieve equal dissipation loss in corresponding elements, the same resistances and conductances must be placed in the low-pass circuit of Fig. 8(b). Thus, for corresponding series arms $R_i' = R_i$. Therefore

$$\frac{\omega' g_i}{R_i'} = \frac{1}{R_i}\left(\omega L_i - \frac{1}{\omega C_i}\right) \equiv Q_{ui}\left(1 - \frac{\omega_0^2}{\omega^2}\right) \qquad (10)$$

where $Q_{ui} = \omega L_i / R_i$ and $\omega_0^2 = 1/L_i C_i$. Now, assuming narrow bandwidth, we have

$$1 - \frac{\omega_0^2}{\omega^2} = \frac{\omega^2 - \omega_0^2}{\omega^2} \approx 2\,\frac{\omega - \omega_0}{\omega_0}.$$

Let $\omega' = \omega_1'$ and $\omega = \omega_2$ be corresponding frequencies and note that

$$1 - \frac{\omega_0^2}{\omega_2^2} \approx w, \qquad (11)$$

where w is the relative bandwidth $(f_2 - f_1)/f_0$ as previously defined. Then (10) yields

$$R_i' = \frac{\omega_1' g_i}{w Q_{ui}}. \qquad (12)$$

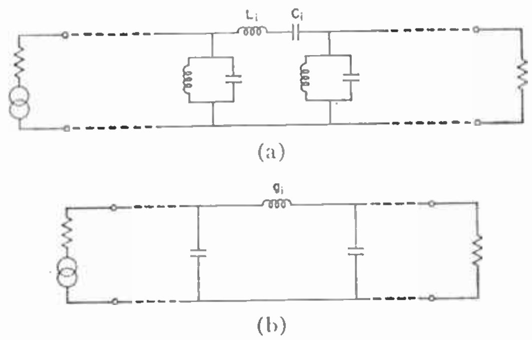

Fig. 7—(a) Nondissipative lumped-constant band-pass filter, and (b) equivalent low-pass prototype filter.

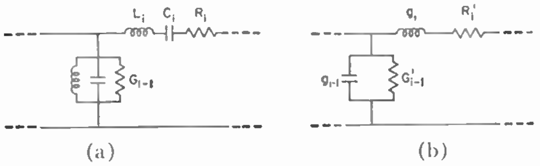

Fig. 8—(a) Dissipative lumped-constant band-pass filter, and (b) equivalent low-pass prototype filter.

In a similar manner, we obtain the relation for the shunt conductance G_i':

$$G_i' = \frac{\omega_1' g_i}{w Q_{ui}}. \tag{13}$$

The two identical formulas, (12) and (13), provide the desired relationship between the unloaded Q's of the resonators in the band-pass filter and the equivalent resistances and conductances in the low-pass prototype.

2. *The Center-Frequency Loss Formula*

Eq. (1) can be obtained very simply from the low-pass circuit of Fig. 3, since calculations only at zero frequency are involved. Let the load resistance r be 1 ohm for convenience. It will be assumed that the resistances and conductances are small compared to unity so that they affect the match at $\omega' = 0$ only slightly. Then the resistance looking to the right or left will be approximately 1 ohm anywhere in the filter. Thus in the vicinity of the ith arm, if we assume a shunt voltage of 1 volt, the series current will be 1 ampere. Then, by (12) and (13), the power dissipated in the ith arm will be

$$P_{di} = \frac{\omega_1' g_i}{w Q_{ui}} \text{ watts.} \tag{14}$$

The input and output powers at the ith arm are

$$P_{\text{in}} \approx 1 + \tfrac{1}{2} P_{di} \text{ watts}, \qquad P_{\text{out}} \approx 1 - \tfrac{1}{2} P_{di} \text{ watts},$$

and therefore the loss in the ith arm may be expressed in decibels as

$$L_{0i} = 10 \log_{10} \left(\frac{1 + \frac{1}{2} P_{di}}{1 - \frac{1}{2} P_{di}} \right) \approx 4.343 P_{di} \text{ db} \tag{15}$$

for $P_{di} < 0.5$. The total loss at $\omega' = 0$, or $f = f_0$, is

$$L_0 \approx \sum_{i=1}^{n} L_{0i} = \frac{4.343 \omega_1'}{w} \sum_{i=1}^{n} \frac{g_i}{Q_{ui}} \text{ db}. \tag{16}$$

The approximation in (15) holds within 2 per cent for L_{0i} as large as 2 db. Calculations for numerous specific cases have shown that the other important approximation—that the resistance level anywhere in the filter is not affected by dissipation loss—causes very little error for L_0 up to n db, and only moderate error up to $2n$ db. This is true because the errors in the various terms of the summation in (16) tend to cancel each other.

3. *The Stop-Band Loss Formula*

The insertion loss of the low-pass filter of Fig. 2 may be expressed rigorously in terms of a polynomial in ω' as

$$L = 10 \log_{10} (a_n \omega'^{2n} + a_{n-1} \omega'^{2n-2} + \cdots + a_1 \omega'^2 + a_0) \text{db} \tag{17}$$

where the constants a_i are related to the element values and terminating resistance in Fig. 2. In the stop band, only the higher powers of ω' are important, and where ω' is sufficiently large,

$$L_s \approx 10 \log_{10} (a_n \omega_s'^{2n}) \text{ db} \tag{18}$$

where the subscript s denotes a point in the stop band.

Assume that the element g_n adjacent to r is a series element. Then the ratio of voltage across r to that across g_{n-1} is $r/(r + j\omega_s' g_n) \approx r/j\omega_s' g_n$. The admittance Y to the right of the g_{n-1} element is very much smaller than the susceptance $j\omega_s' g_{n-1}$, and hence the ratio of the voltages across g_{n-1} and g_{n-3} is

$$\frac{\dfrac{1}{Y + j\omega_s' g_{n-1}}}{j\omega_s' g_{n-2} + \dfrac{1}{Y + j\omega_s' g_{n-1}}} \approx \frac{1}{(j\omega_s' g_{n-1})(j\omega_s' g_{n-2})}.$$

If we assume the first element g_1 to be a shunt element, the ratio of input voltage to generator voltage will be $V_{\text{in}}/V_g = 1/j\omega_s' g_1$. Now, multiplying together all the voltage ratios in the filter

$$\left| \frac{V_{\text{out}}}{V_g} \right| = \frac{r}{\omega_s'^n g_1 g_2 g_3 \cdots g_n}. \tag{19}$$

The output power is

$$P_{\text{out}} = \frac{|V_{\text{out}}|^2}{r} = \frac{r |V_g|^2}{(\omega_s'^n g_1 g_2 \cdots g_n)^2}, \tag{20}$$

and the available power is $P_a = |V_g/2|^2$. Therefore, the stop-band power loss in decibels is

$$L_s = 20 \log_{10} (\omega_s'^n g_1 g_2 \cdots g_n) - 10 \log_{10} (4r) \text{ db}. \tag{21}$$

Eq. (21) assumes the terminating resistance r to be connected to a series element in the filter. If it were connected to a shunt element, the equation would be

$$L_s = 20 \log_{10} (\omega_s'^n g_1 g_2 \cdots g_n) - 10 \log_{10} \left(\frac{4}{r} \right) \text{db}. \tag{22}$$

These formulas would be unchanged if the element g_1 next to the 1-ohm generator resistor were a series element instead of a shunt element. It is also evident that reversing the direction of power flow would not alter these formulas.

IRE Standards on Navigation Aids: Direction Finder Measurements, 1959*

59 IRE 12. S1

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NOTE ON THE USE OF STANDARD FREQUENCY BAND DESIGNATIONS

In the following Standard, reference is made to Frequency Bands by number (*e.g.*, see page 1354). For the benefit of the user who is not familiar with those band designations, a few words of historical background and explanation are in order.

Attempts have been made to designate portions of the RF spectrum by such nomenclatures as "long waves," "short waves" and similar names since radio's early beginnings. One of the earliest classifications was adopted at the first CCIR meeting at The Hague in 1929. In this system, the spectrum from below 100 kc to above 30,000 kc was divided into five bands: "low frequency," "medium frequency," "medium-high frequency;" "high frequency" and "very-high frequency."

At the Atlantic City Radio Conference of 1947, a further modification was adopted as below:

VLF	(Very-low frequency)	Below 30 kc	Myriametric waves
LF	(Low frequency)	30–300 kc	Kilometric waves
MF	(Medium frequency)	300–3,000 kc	Hectometric waves
HF	(High frequency)	3,000–30,000 kc	Decametric waves
VHF	(Very-high frequency)	30,000 kc–300 mc	Metric waves
UHF	(Ultra-high frequency)	300–3,000 mc	Decimetric waves
SHF	(Super-high frequency)	3,000–30,000 mc	Centimetric waves
EHF	(Extremely-high frequency)	30,000–300,000 mc	Millimetric waves

This usage has persisted to the present day, as evidenced by frequent references to the "VHF" and "UHF" television bands. It has obvious disadvantages in that the designations are qualitative, ambiguous, and not extendable without coining new terms which add to the potential confusion.

Realizing the limitations of the above system, the CCIR, meeting in London and Warsaw (in 1953 and 1956) adopted a number designation system, based on CCIR Recommendation No. 225. The following table and notes are taken from this Recommendation:

Band No.	Frequency Range (lower limit exclusive, upper limit inclusive)	Metric Subdivision
4	3 to 30 kc	Myriametric waves
5	30–300 kc	Kilometric waves
6	300–3,000 kc	Hectometric waves
7	3,000–30,000 kc	Decametric waves
8	30–300 mc	Metric waves
9	300–3,000 mc	Decimetric waves
10	3,000–30,000 mc	Centimetric waves
11	30,000–300,000 mc	Millimetric waves
12	300,000–3,000,000 mc	Deci-millimetric waves

Note 1: "Band N" extends from 0.3×10^N to 3×10^N cps.

Note 2: When a service adopts a reference number or letter to designate a specific frequency band allocated to it and situated, wholly or for the most part, in band "N" of the above nomenclature, the prefix N should normally precede the reference in question. For example, for the 41- to 68-mc band, to which broadcast users give the reference "I," the appropriate designation is "broadcast band 8-I," since it refers to a part of "band 8." This practice, applicable in the drafting of CCIR documents, is generally recommended for all cases where such a definition would obviate the risk of confusion in designating the numerous frequency bands and subbands.

It is hoped that the above words of explanation will enable the reader to translate readily from one system to the other and further, will eventually result in wider use of the numerical references.

—*IRE Standards Committee*

INTRODUCTION

THE TERM "Radio Direction Finding," as used in these standards, is a procedure for determining the bearing, at a receiving point, of the source of a radio signal by observing the direction of arrival and other properties of the signal. Direction Finders may be used for navigation and other purposes without necessitating the specialized transmissions generally required by other radio navigational devices.

The purpose of standardizing measurement methods and procedures is to enable the determination of a Direction Finder's characteristics which will permit analysis of DF performance in a uniform manner or the correlation of data when two or more types of Direction Finders are to be compared. An effort has been made to follow and adapt previously-used methods of measurement and limit the measurement procedures to those suitable for the majority of types of Direction Finders. It is probable that certain tests have been omitted which might be required for some specialized types. Such shortcomings may be offset by supplementing the standardized procedures, as necessary, for a particular design.

ABBREVIATIONS AND DEFINITIONS OF TERMS USED IN THIS STANDARD

Accuracy (in Direction Finding). The correctness of an indication in terms of its deviation from the true value of the quantity indicated when the probability that this deviation will be exceeded is less than a stated value.

Apparent Bearing. The direction of arrival of the signal with respect to some reference direction.

Bearing Accuracy (in Direction Finding). The correctness of DF indication expressed as the deviation (of the indicated bearing from the direction of arrival of the signal) whose probability of being exceeded is less than some stated value.

Bearing Accuracy, Instrumental DF. The systematic component of *Bearing Accuracy*. The deviations involved include such factors as structure and imbalance among elements of the *DF Antenna System*, Goniometer, balanced modulator of the DF equipment itself, etc., and errors in the calibration of the indicating system. It does not include errors due to distortions of the signal field caused by effects exterior to the DF equipment, nor does it include offsets which can be corrected by a fixed displacement of the indicator scale.

Bearing Error Curve (DF Equipment). A plot of the *Instrumental Bearing Errors* vs Indicated Bearings.

Bearing Error Curve (DF Installation). A plot of the combined *Instrumental Bearing Error* (DF Equipment) and site error vs Indicated Bearings.

Bearing Offset, Indicated. The difference between the indicated and apparent bearings of a number of signal sources, substantially uniformly distributed in azimuth.

Bearing Reciprocal (in Direction Finding). The opposite direction to a bearing.

Blur (in Null-Type DF Systems). In null-type systems, the output (including noise) at the bearing of minimum response expressed as a percentage of the output at the bearing of maximum response.

DF Antenna. A *DF Antenna* may consist of a single loop, orthogonal loops, spaced differentially-connected dipoles or Adcock antennas, or any other antenna combination included in a Direction Finder for obtaining a phase or amplitude reference with respect to the received signal.

DF Antenna System. One or more *DF Antennas*, their combining circuits and feeder systems, together with the shielding and all electrical and mechanical items up to the termination at the receiver input terminals.

DF Dummy Antenna. An electrical network that simulates the impedance characteristics of the *DF Antenna*.

DF Dummy Antenna System. An electrical network which simulates the impedance characteristics of the *DF Antenna System*.

Note: When a signal generator is used to excite a *DF Dummy Antenna* or *DF Dummy Antenna System*, the generator impedance must be considered in the design of the *Dummy*.

DF Noise Level. In the absence of the desired signals, the average power or rms voltage at any specified point in a Direction Finder System.

Note: In RF and audio channels, the *Noise Level, DF* is usually measured in terms of the power dissipated in a suitable termination. In a video channel, it is customarily measured in terms of voltage across a given impedance, or of the cathode-ray deflection.

Null. In direction finding systems wherein the output amplitude is a function of the direction of arrival of the signal, or of the rotation in bearing of the response pattern of the *DF Antenna System*, the minimum output amplitude (ideally zero).

Note: The *Null* is frequently employed as a means of determining bearing. The term "minimum" is often used to indicate an imperfect Null.

Overload Point, Signal. For any setting of receiver controls, and with an input signal increasing from any level within the linear operating range of the receiver, that input signal amplitude at which the ratio of output to the input first differs by 3 db from the ratio of output to input observed within the linear operating range.

Pick-up Factor, DF Antenna System. An index of merit expressed as the quotient of the voltage across the receiver input impedance divided by the signal field-strength to which the antenna system is exposed, the direction of arrival and polarization of the wave being such as to give maximum response.

Polarization, Desired. The polarization of the radio wave for which the *DF Antenna System* is designed.

Note: The *Desired Polarization* is ordinarily either vertical or horizontal.

Polarization, Undesired. Any polarization of the radio wave other than that for which the *DF Antenna System* is designed.

Note: When the *Desired Polarization* is vertical or horizontal, then the *Undesired Polarization* is horizontal or vertical, respectively.

Reference Test Field. That field strength, in microvolts per meter, numerically equal to the DF Sensitivity.

Sensitivity, DF. That field strength, in microvolts per meter, to which the *DF Antenna System* is exposed at the DF site, which produces a ratio of signal-plus-noise to noise of 20 db in the receiver output, the direction of arrival of the signal being such as to produce maximum pickup in the *DF Antenna System* (see Sensitivity at Maximum Response Position, 1.2).

Note: If, because of equipment limitation, a 20-db signal-plus-noise to noise ratio cannot be attained, the sensitivity can be calculated by extrapolating from an attainable signal-plus-noise to noise ratio within the linear region.

Standard Multiples. The *Standard Multiples* of measurement shall be 1×10^n and 3×10^n for all pertinent (*i.e.*, positive, negative and zero) integral values of n.

Standard Output Levels (Audio). The *Standard Output Levels*, into a *Standard Output Load*, shall be 0.006, 0.050 or 0.3 watt, depending upon the output capabilities of the equipment.

Standard Output Load (Audio). The *Standard Output Load (Audio)* shall be resistive and shall be of a value equal to the load into which the audio channel of the receiver is designed or specified to operate.

Standard Test Frequencies. The *Standard Test Frequencies* shall be the mid-frequency and nominal limits of each tuning band of the DF receiver. Where the band-tuning ratio is less than one and one-half to one, two frequencies, approximately 10 per cent inside the nominal limits of the band coverage, will suffice.

Standard Wave Error. The DF bearing error produced by a wave incident at 45°, having equal vertically- and horizontally-polarized electric fields, the relative phases of the two components being such as to produce the maximum DF bearing error.

Target Transmitter. A source of radio frequency energy suitable for providing test signals at the test site.

STANDARD TEST CONDITIONS

Test Sites

Two types of test sites, suitable for DF measurements, are described, together with methods of calibrating field strength.

The selection of and method of establishing known field strengths at a site such as may be used for actual operation are described under Section 1. Where the DF Antenna System is sufficiently compact, the use of a screen room and transmission line is recommended and this is described in Section 2.

Standard conditions of temperature, installation alignment, warmup, and modulation are described in Section 3.

1. Site Requirements for DF Testing

For proper evaluation of Radio Direction Finders, it is necessary to make measurements at a site where the electrical characteristics are such that the effects of absorption, reflection, refraction, and radiation of radio frequency energy are negligible. Therefore, a site should be selected very carefully with regard to the terrain and electrical characteristics.

1.1 Visual Inspection

1.1.1 The area should be substantially flat in all directions from the DF Antenna for a distance of at least one wavelength at the lowest operating frequency and should have no more than a gentle slope for several times that distance. Mountainous or hilly country should be avoided.

1.1.2 In order that shoreline refractive errors shall be negligible, the site must be located a distance of five wavelengths or more from the shoreline of large bodies of water.

1.1.3 The conductivity of the soil at the site should be uniform and high. Areas uniformly covered with grass or vegetation usually meet this requirement. Rocky or sandy soil generally is unsatisfactory. Sites having low but uniform conductivity are preferable to sites having high conductivity spotted with rock formation, sand or varying moisture content.

1.1.4 Regions where there are abrupt terrain irregularities such as cliffs, cuts, fills, ravines, or gaps should be avoided.

1.1.5 The site should be free from buildings, tall trees, wire fences, radio antennas, railroad tracks, sharp ground contours, buried metal conductors, overhead conductors, chimney stacks and small bodies of water or other objects capable of reradiating RF energy. No hills or objects should appear above an elevation angle of 3°.

1.1.6 Distances to be maintained between the Direction Finder and various types of obstruction to minimize their effect on DF accuracy are given in Table I.

TABLE I

Obstruction	Minimum Distance to be Maintained
Scattered trees and single small buildings	150 yards
Wire fences	150 yards
Buried conductors (other than DF supply lines)	300 yards
Towers, etc.	500 yards
Overhead conductors and railroad tracks	500 yards
Small bodies of water	150–500 yards
Forests and metal structures	500–1,000 yards
Mountains	5–25 miles

1.2 Electrical Inspection

After the available sites have been visually inspected, the following electrical tests should be made.

1.2.1 Noise Measurement. The noise level of a proposed site should be checked with a field-strength meter to ensure that excessive electrical noise will not prohibit the performance of any desired measurement selected from this standard.

1.2.2 Field Pattern. The purpose of this test is to determine the suitability of a site for Target Transmitter testing of a Direction Finder. This test shall be made prior to the installation of any ground screen.

1.2.2.1 Place a field-strength meter at the spot where the DF Antenna System is to be erected.

1.2.2.2 Position a Target Transmitter at a point at least two wavelengths from the field-strength meter and in a known direction (such as magnetic north); record the field strength at this bearing for all standard test frequencies. Repeat the procedure after moving the Target Transmitter at a constant radius for all specified bearings.

1.2.2.3 Plot the data on rectangular coordinate paper as field strength vs bearing for each frequency. Any irregularities indicate an absorption or reflection or refraction of the wave which would affect the accuracy of the Direction Finder.

1.2.2.4 If significant irregularities are evident in the plot, compute the mean value of the field strength for each frequency. If the field strength deviates more than 5 per cent from the mean at any point, the site should not be used without taking corrective steps.

1.2.3 Ground Conditions. Site conditions shall be recorded, including measurements of ground conductivity and dielectric constant and statement made of the methods employed.

1.3 Discussion

A site intended for Target Transmitter tests need not satisfy requirements of *1.1* (*Visual Inspection*) as far as regions beyond the distance to the Target Transmitter are concerned. A site to be used for Statistical Bearing Data, however, should be selected with the greater emphasis upon *1.1* (*Visual Inspection*).

1.4 Method of Establishing a Known Field Strength at the DF Antenna System Site

Where measurement of DF Sensitivity or Pick-up Factor is to be made at the DF site, it is necessary to establish a known field at the center of the DF Antenna Array. The most convenient procedure for establishing a known field depends upon the characteristics of the particular equipment being measured.

1.4.1 Conditions. A Target Transmitter shall be coupled to an antenna connected to provide the Desired Polarization.

1.4.2 Normal Procedure.

1.4.2.1 Install a Target Transmitter at least two wavelengths from the center of the test site.

1.4.2.2 With the DF equipment removed, locate a field-strength meter at the center of the test site. Adjust the Target Transmitter to produce the desired field strength at this test site.

1.4.2.3 Locate a second field-strength monitor or a second field-strength meter at a convenient point behind the Target Transmitter and record the level corresponding to the desired field strength at the test site and record a measure of the target transmitter power.

1.4.2.4 Remove the first field-strength meter and install the DF equipment.

1.4.2.5 Set the Target Transmitter to the power recorded in 1.4.2.3 and read the monitor. This reading is the reference level.

1.4.2.6 Perform the required tests, while adjusting the Target Transmitter to produce the monitor-level determined in 1.4.2.5.

Where the DF Antenna Array cannot be moved without inconvenience, a known field can often be established at its center as follows:

1.4.3 Alternate Procedure.

1.4.3.1 Locate a Target Transmitter at a point at least two wavelengths from the test site.

1.4.3.2 Locate a field-strength meter at a point that is the same distance from the Target Transmitter as is the DF Antenna, and removed by at least two wavelengths from the DF Antenna.

1.4.3.3 Orient the Target Transmitter antenna to produce maximum field-strength response and adjust the Target Transmitter to produce the desired field strength at the field-strength meter location.

1.4.3.4 Reorient the Target Transmitter antenna to produce maximum signal at the DF.

1.4.3.5 Observe the new reading of the field-strength meter as a reference level, and maintain the signal at this level. Under these conditions, the signal field strength at the DF Antenna site has approximately the value obtained in 1.4.3.3 provided that the field at the Monitor is not appreciably distorted by DF Antenna.

1.4.4 Special Requirements for Low-Level Measurements. When measurements requiring controlled field strengths at low levels are to be made in the field, the following procedure may be used for calibrations or monitoring the Target Transmitter.

It is assumed that the available field-strength measuring equipment does not have sufficient sensitivity to measure the low field-strength levels which are required by some of the measurements. Also, it is often the case that the Target Transmitter is not equipped with a calibrated attenuator, although generally some means are provided for decoupling the power from the transmitter to the antenna.

A suggested procedure is to measure the field strength from the Target Transmitter with the transmitter adjusted to produce a sufficiently strong field to be recorded on the meter. The field-strength meter may then be moved close to the Target Transmitter, preferably behind the transmitter and on a line with the center of the collector system and the field strength again established at that point. If the Target Transmitter is readjusted to a new level, a measurement of the field at the second location will establish the ratio of change from which the corresponding field at the center of the collector system may be readily calculated. It is often convenient to monitor the Target Transmitter with an absorption type of wave-meter equipped with a thermocouple meter. The change in transmitter output may be obtained from the meter. The type of meter should be noted to determine whether the meter indications are proportional to the power or to the current.

2. Screen Room and Transmission Line for DF Testing

A laboratory method of simulating, in a shielded room, a radiated field having vertical polarization and

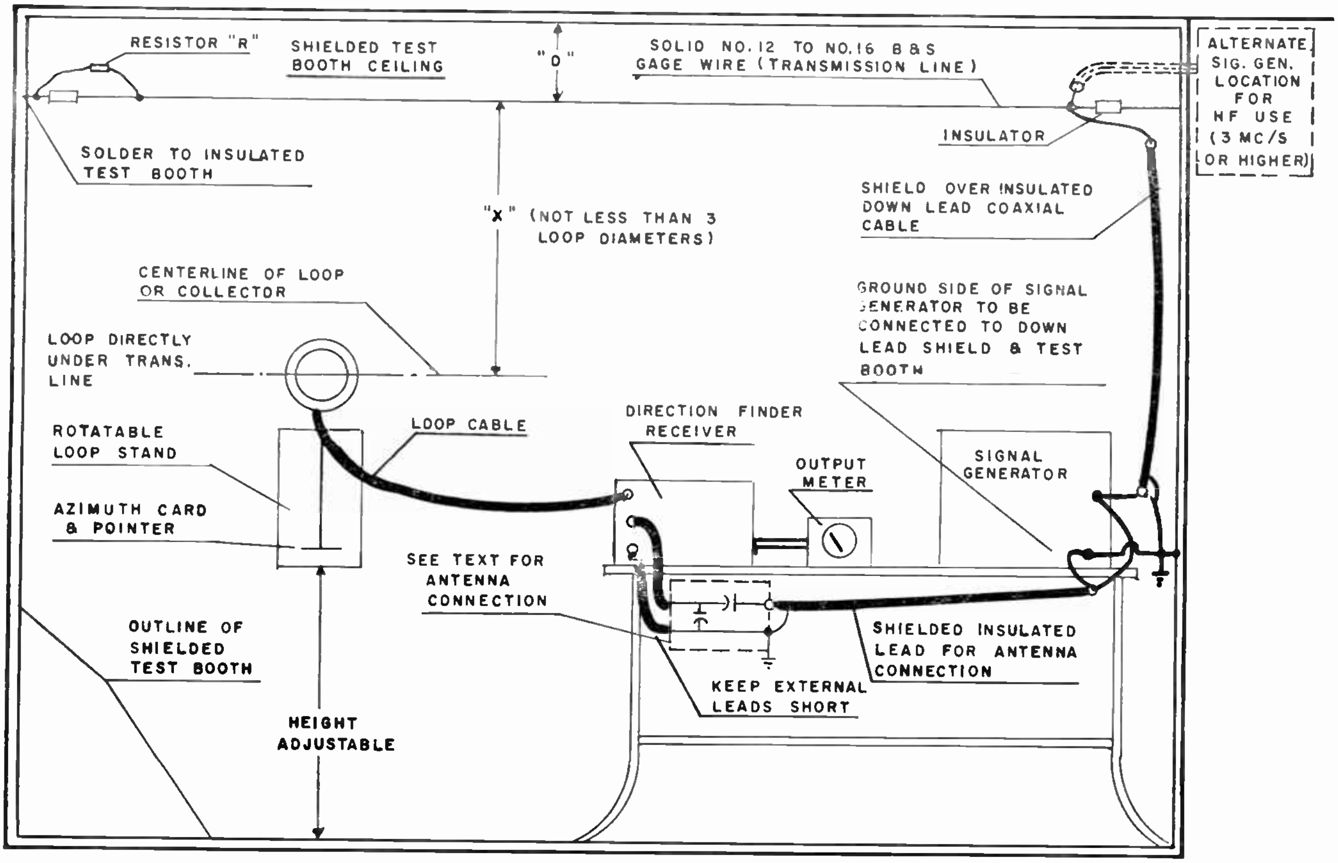


Fig. 1—Shielded transmission line.

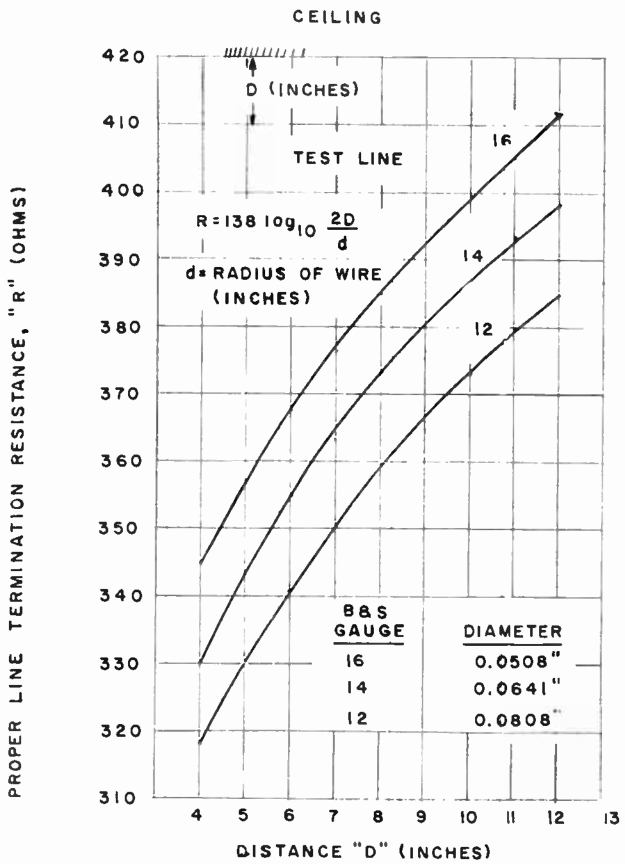


Fig. 2—Terminating resistance for test line.

controllable properties of strength is of considerable value in the measurement of Direction Finders, which are sufficiently compact to be tested in the shielded room.

The setup to be described will furnish a field of known direction and strength,[1] at all frequencies in general up to Band 6.[2] This setup may also be arranged to provide voltage of proper phase and amplitude to circuits (in the DF) used for Sense and Balance purposes.

2.1 *Installation*

The details of the test installation are shown by Figs. 1 and 2.

2.2 *Calibration*

The calibration consists of the determination of a relationship between the input voltage from the signal generator to the test line and the field produced at the position chosen for the loop.

The relationship is the line constant K.

$$K \text{ (meters)} = E/F \tag{1}$$

[1] Alternative methods of known reliability may be employed.

[2] This method fails at higher frequencies due to standing-wave effects in the shielded room and parasitic impedance in the measuring circuits. The method can be extended to higher frequencies by taking these effects into account, but such corrections are not described in this standard.

where

E = microvolts input to the test line,

and

F = microvolts per meter equivalent field intensity at the loop.

The value of K may be found by using the Direction Finder receiver as a voltmeter and a single-turn auxiliary loop of the same diameter as the loop to be tested. The following discussion gives the principles involved in the method to be used. If a loop is placed in a radiation field of intensity F with the loop oriented for maximum induced voltage, the voltage, e_L, effectively in series with the loop will be

$$e_L = Fh_L \tag{2}$$

where

h_L is the effective height of the loop.

Conversely

$$F = e_L/h_L$$

where

F is the *equivalent* homogeneous field (even though the actual field varies over the area of the loop as when obtained from the test line).

The effective height may be determined by the equation

$$h_L = \pi ANf/150 \tag{3}$$

where

h_L is in meters,
A is the enclosed loop area in square meters,
N is the number of turns on the loop, and
f is the frequency in megacycles per second.

The voltage induced in the loop-circuit also appears across the loop terminals unless the terminating impedance is comparable to the impedance looking back into the loop.

The three relationships of K, e, and h may be combined to give the equation

$$K = 1.06 \times 10^{-5} d^2 NfE/e_L \tag{4}$$

where

d is the diameters of the loop in inches,
N is the number of turns on the loop, and
f is the frequency in megacycles per second.

The method of calibration consists of: 1) applying a voltage E of frequency f, to the test line, 2) measuring the open circuit voltage e_L induced in the loop when the loop is at the selected distance X of Fig. 1, and 3) substituting the values used and measured in (4).

If the input impedance of the first tube of the receiver is large, compared to the impedance looking back into the loop, the value of e_L may be measured with the aid of the Direction Finder receiver as a sensitive detector. The lead normally connected to the grid of the first tube is removed. One of the loop terminals is then connected to the grid and the other to the chassis ground, care being exercised to retain normal grid bias conditions. The receiver is then tuned to resonance as indicated by an output meter. Sufficient input (E) is applied to the test line to give a usable reading on the output meter with the sensitivity control adjusted to produce negligible tube-hiss or noise. Next the signal generator is temporarily disconnected from the test line and is connected from the grid to ground in place of the calibration loop. The generator output must be adjusted to produce the same receiver output reading as was obtained when the generator was applied to the line and the loop was connected between the grid and ground.

It is important that the receiver tuning, sensitivity-control adjustment and input frequency be undisturbed after the first measurement.

In this manner, the value of K may be checked over the frequency range of the direction-finder receiver. It is important that the frequency used be known within 1.0 per cent since it enters directly into the determination of K. As previously stated, the value of K should remain the same over the band of frequencies checked. There are three principal causes for variation in the value of K: 1) improper termination of the line, 2) resonance effects in the loop circuit, and 3) resonance effects of the room. The first cause may be checked by correcting the value of R and checking for any inductive effect (which is unlikely if a carbon resistor is used). The second cause can usually be avoided by using the untuned one-turn auxiliary loop of the same diameter as the loop to be measured. A convenient method of constructing the auxiliary loop is to fasten a single loop of the required diameter to a sheet of cardboard which may be hung on the transmission line at the required spacing. A twisted pair connects the loop to the receiver input grid for the previous measurements.

The loading effect of the test line on the signal generator may also affect the calibration and should be checked. Usually the lower attenuator taps of the generator are relatively free of this effect, but at high output settings of the generator coarse-control of the step-attenuator, such as may be required for the value of E [see (4)], the effect may be considerable, thus producing an incorrect line constant if not accounted for. The corrected value of E may be found in the following manner:

1) Connect the generator between the grid of the input tube and ground. Connect a resistor, approximately equal to that used for the test-line termination (R), between the grid and ground. The resistance is sufficiently accurate if only nominally the same as R.

2) Reduce the sensitivity control setting and set the generator output to that read apparently as E. Call this value E'.

3) Adjust the sensitivity control to produce an output meter reading well below the overload point of the receiver but near a maximum of one of the low-voltage scales of the output meter (for example, 4 volts on the 5-volt scale). Note the reading.

4) Remove the resistor between the input grid and ground. The output reading will increase if the shunting effect being checked is present. Reduce the generator output to produce an output meter reading as in 3) above. The generator now reads substantially the correct value of E which should be used instead of E' in the calculation of line constant. [See (4).]

The loading effect of R may vary with the attenuator setting. The effect may be checked in the same manner as described for obtaining the corrected value of E. A correction factor may then be applied to the field strength as determined by the line constant (measured as previously described) and the generator output reading. For example, the field strength would apparently be 100 μv per meter for a generator reading of 600 μv and a line constant of 6.0. However, if the line-termination resistance-load caused a reduction in generator-output voltage of 5 per cent (as determined by the loading-effect check), the actual field would be 95 μv per meter. An inaccuracy of this order could be ignored in the usual test work. This inaccuracy and its negligibility should not be confused with the inaccuracy of the line constant caused by the lack of correction of the value of E of (4), for which the correction should be applied as described.

2.3 *Dummy Sense or Balance Antenna*

When the Direction Finder is to be checked as a nondirectional receiver, the generator output is coupled to a standard dummy antenna, which, for the sake of example, let us assume has a capacity of 100 $\mu\mu$f. The capacitor simulates a representative antenna capacitance with which the receiver is to be used, but does not account for the effective height of the antenna. When the Direction Finder is used as a left-right indicating Direction Finder, or requires an open antenna for any other purpose, the effective height of the simulated antenna should be comparable with those in actual use. An antenna effective-height of $\frac{1}{4}$ meter is representative for certain applications and is used here as an example. An antenna of $\frac{1}{4}$ meter effective-height implies that the voltage induced in the antenna of the receiver is $\frac{1}{4}$ of the field intensity figure expressed in volts per meter. For example, a $\frac{1}{4}$-meter antenna in a 1000-μv-per-meter field produces 250 μv at the antenna post. Thus related,

$$e_A = h_A F \tag{5}$$

where

e_A is the open circuit antenna voltage in microvolts,
h_A is the effective height in meters, and
F is the field intensity in microvolts per meter.

In the discussion of line calibration, (1) states $K = E/F$ (or $E = KF$). By combining this relationship with (5), we obtain

$$h_A/K = e_A/E. \tag{6}$$

By connecting a capacitance divider across the signal generator as shown in Fig. 3, the antenna input may be reduced to the receiver so that when the value of E microvolts is applied to the test line, producing a field strength of F microvolts-per-meter at the loop, the proper value of e_A is applied across the receiver antenna and ground points to simulate a $\frac{1}{4}$-meter antenna. The relationship of e_A/E (and e_A/K) to C_1 and C_2 is

$$e_A/E = C_1/(C_1 + C_2) = h_A/K.$$

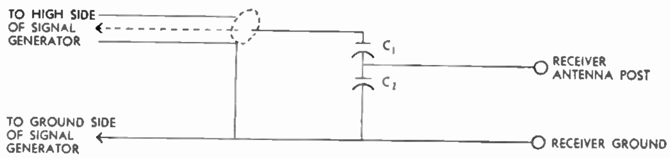


Fig. 3—Capacitance divider connections for simulated antenna.

The value of $(C_1 + C_2)$ is the total effective capacitance of the simulated antenna at the receiver. Thus, all relations are known for simulating the antenna. As an example, if $K = 6$, $h_A = \frac{1}{4}$ meter, and $(C_1 + C_2) = 100\mu\mu$f.

$$C_1 = h_A(C_1 + C_2)/K = \frac{1/4}{6} \times 100 = 4.2\ \mu\mu\text{f}$$

$$C_2 = 100 - 4.2 = 95.8\ \mu\mu\text{f}.$$

Ordinarily, for this example, small fixed-mica capacitors nominally 5 $\mu\mu$f (for C_1) and 100 $\mu\mu$f (for C_2) would be suitable, resulting in an effective height of 0.28 meter at 105 $\mu\mu$f at the nominal values.

The antenna and ground connections of the receiver may be at a relatively large distance from the output terminals of the generator, as illustrated in Fig. 1. As shown, a shielded lead is used for connection between the signal generator and the dummy antenna (C_1 and C_2) which is located at the receiver connection posts. The dummy antenna should *not* be located at the generator and the shielded lead connected across C_2, running thence to the receiver, or the division of voltages will be incorrect.

3. Operating Conditions

Ambient Temperature

Unless otherwise specified, the ambient temperature within the protective shelter normally housing portions of the equipment shall be maintained between 20° and 30°C.

Installation and Alignment

The alteration of adjustments specifically provided for installation or manufacturing alignment of the equipment is not permissible during tests.

Modulation

When modulation is required, a signal modulated to a depth of 30 per cent at 400 cps shall be used unless otherwise specified.

Warm-up Period

The warm-up period shall be sufficiently long to stabilize all operating characteristics.

TEST EQUIPMENT

Signal Generator

An RF signal source providing modulated or unmodulated output at calibrated levels.

Note: For use in the Standard Measurements which follow, the output voltage of the signal generator shall be continuously adjustable from approximately 0.5 to at least 100,000 μv. The output level should be within ±10 per cent of the specified value throughout the frequency range. The RF output should be free of frequency modulation.

The RF harmonic content preferably should be less than 2 per cent and not more than 5 per cent. Modulation shall be 400 cycles and, unless otherwise specified, shall be 30 per cent.

For the majority of Direction Finder measurements, the shielding must be such that direct radiation into the antenna system does not occur.

1. DIRECTION FINDER SENSITIVITY

1.1 DF Antenna System Pick-up Factor

1.1.1 Purpose. The purpose of this measurement is to determine the Pick-up Factor of the DF Antenna System (see Fig. 4).

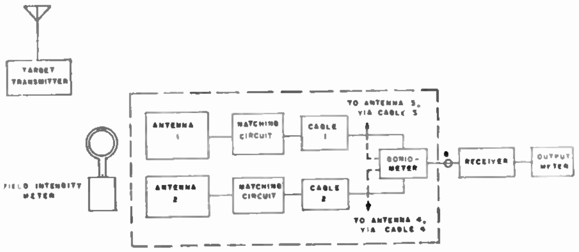


Fig. 4—Typical "DF antenna system."

1.1.2 Conditions. Standard Test Conditions shall apply. AGC, if provided, shall be disabled for this measurement and a manually operated sensitivity control substituted. If the DF does not contain an output indicator, a meter or oscilloscope shall be connected to indicate the signal level from the DF detector. The DF Antenna shall be oriented in bearing for maximum reception. Measurements shall be conducted at a sufficient number of Standard Test Frequencies to determine the performance required.

1.1.3 Procedure:

1.1.3.1 Apply a known field strength at one of the Standard Test Frequencies to the DF Antenna System (See Standard Test Conditions 2 and 3) of sufficient strength to override the noise. Record the reading of the output meter and the field strength.

For this test, the DF Antenna System (or goniometer) shall be positioned for maximum antenna pick-up and this bearing recorded. If the display device depends upon continuous rotation of the antenna pattern, this rotation shall be maintained and measurements shall be made at the bearing of maximum antenna pick-up.

1.1.3.2 Adjust the receiver sensitivity control to produce an output below the Overload Point and record this output amplitude.

1.1.3.3 Without readjusting the receiver controls, transfer the receiver to a shielded room, if available. (Measurements on the receiver may be made at the Test Site when due precautions are taken to prevent the reception of external noise.)

1.1.3.4 Across the receiver input terminals connect an adjustable susceptance which has a sign opposite to that of the receiver input susceptance and adjust for zero total susceptance at the receiver input terminals. (See Appendix A.)

1.1.3.5 Connect a Signal Generator to the input terminals of the receiver (and in shunt with the susceptance of 1.1.3.4 if applicable). Record the reading of the output meter of the Signal Generator (See Appendix A) required to produce the same output indication as 1.1.3.2.

1.1.3.6 Connect a resistance, equal to that of the generator, across the generator output and the receiver input and also the susceptance of 1.1.3.4. Record the reading of the output meter of the Signal Generator now required to produce the same receiver output indication as 1.1.3.2.

1.1.3.7 Compute the receiver input voltage as:

Receiver Input Voltage = Signal Generator readings of paragraph 1.1.3.6, minus readings of paragraph 1.1.3.5.

1.1.3.8 Compute the DF Antenna System Pick-up Factor as:

Pick-up Factor (meters)

$$= \frac{\text{Receiver input volts (from Section 1.1.3.7)}}{\text{Field Strength (from Section 1.1.3.1)}}$$

1.1.4 Alternate Test Procedure Above 100 Mc.

1.1.4.1 Establish and record the Reference Test Field.

1.1.4.2 If necessary, adjust the readio-receiver sensitivity control to produce an output below the Overload Point of the receiver. Record this output.

1.1.4.3 Without readjusting the controls of the radio receiver, disconnect the DF Antenna System from the receiver. Replace the DF Antenna System with a half-wave dipole and matching cable. Locate the dipole at the center of the DF Antenna System and orient it to the same polarization. If horizontal polarization is employed, orient the dipole to obtain maximum pick-up from the Target Transmitter. Connect the receiving end of the cable to a slotted line or other measuring device suitable for determining SWR. Then, connect the measuring device and a variable resistor to the receiver input. Connect the resistor in series with the receiver input, if the receiver input conductance is greater than that of the line and in parallel if less than that of the line. Connect a matching stub or other suitable reactive element in shunt with the receiver input terminals.

1.1.4.4 Adjust the variable resistance and the stub line for unity SWR. Record the value of resistance.

1.1.4.5 Readjust the Target Transmitter ouput to produce a field strength giving the same receiver output as obtained in Section 1.1.4.2. Record the field strength.

1.1.4.6 Determine the effective height of the dipole and substitute the value in the following equation:

$$\frac{\text{Field Strength of Section 1.1.4.5}\left(\dfrac{\text{Effective Height of Dipole of Sec. 1.1.4.6}}{2}\right)\left(\dfrac{1 - \text{R Series of Sec. 1.1.4.4}}{\text{Dipole Cable Imped.}}\right)}{\text{Field Strength of Section 1.1.4.1}}$$

Transmitter. The signal source shall be unmodulated. The transmitter dipole shall be placed at a distance of at least 20 times the diameter of the DF Antenna System to minimize error in measurement resulting from parallax. The transmitting dipole may be elevated, if necessary, to be in the same horizontal plane as the center of the collector. The field intensity at the center of the DF Antenna System shall be known for all transmitter output levels employed in the tests. Suitable methods for determining and monitoring the field strength are suggested under Standard Test Conditions.

Couple the Direction Finder receiver to the Antenna System under test and connect the ouput of the receiver to an audio output meter or other device suitable for obtaining accurate readings of the output. Use the beat-frequency oscillator to provide audio output or if the receiver is not equipped with a BFO, provide an alternate means to read the IF level. Disable the AGC, if used in the receiver system under test, and employ a manually operated sensitivity control.

1.2 Sensitivity at Maximum Response Position

1.2.1 Purpose: This test is similar to the over-all measurement of sensitivity of conventional receivers. Its purpose is to determine the over-all Direction Finder System sensitivity (at the bearing of maximum response) in terms of the minimum field strength of a CW signal, which when turned on and off will produce a 20-db change in the Direction Finder output.

Note: If a 20-db level change cannot be obtained, record the maximum change attainable.

Three methods of performing the test are described below.

1.2.2 Direct Method: This method is the simplest, but will not be suitable in many cases.

1.2.2.1 Conditions: A CW measurement of the over-all Antenna System and receiver sensitivity shall be made at the maximum response orientation using one of the following signal sources.

a) *VLF through MF (band 6 and below) Direction Finders:* Provide a calibrated signal source. This may be a well-shielded Signal Generator coupled to a transmission line in a shielded room, as shown in Section 2 of Standard Test Conditions, or it may be any other signal source which will establish a known field of the Desired Polarization.

b) *HF through SHF (band 7 through band 10) Direction Finders:* Provide a calibrated signal source. This may be either a well-shielded Signal Generator coupled to a balanced dipole capable of being oriented to the Desired Polarization or it may be a Target Transmitter.

1.2.2.2 Procedure:

1.2.2.2.1 Tune-in the signal from the Target Transmitter and rotate the Antenna System (or goniometer, if used) to the bearing, giving the maximum receiver output. Record the bearing. If an electronic goniometer is used, it should be kept running and measurements made at the bearing of maximum response. Turn off the Target Transmitter.

1.2.2.2.2 Adjust the receiver sensitivity control to produce a noise output at least 30 db below the Overload Point of the receiver

1.2.2.2.3 Turn on the Target Transmitter and adjust the output to that level required to produce a receiver output 20 db above the reference noise level. Record the field strength required to produce the above signal-plus-noise to noise ratio. This is the DF Sensitivity and is numerically equal to the Reference Test Field.

1.2.2.2.4 Maintain the sensitivity setting obtained in Section 1.2.2.2.3. Turn off the Target Transmitter and recheck and record the reference noise-output level.

1.2.2.2.5 Replace the DF Antenna elements with their shielded equivalent impedances and remeasure and record the noise-output level.

1.2.2.2.6 Divide the noise-output level of Section 1.2.2.2.4 (as expressed in volts) by the noise-output level of Section 1.2.2.2.5. If this ratio, converted to decibels, exceeds 6 db, the Indirect Method of 1.2.3 should be used.

Note: If the change is less than 6 db, the DF Sensitivity may be computed approximately by multiplying the Reference Test Field of Section 1.2.2.2.3 by the reciprocal of the ratio.

1.2.3 Indirect Method: System Divided at Receiver Input Terminals

When the DF employs a large Antenna System which cannot be enclosed conveniently within a shielded room; where external noise at the test site, such as atmospherics, precludes an accurate measurement at high sensitivities; or where the frequencies employed are such that reflections from the inside walls of shielded rooms will cause errors, it is necessary to make separate measurements of the Antenna System and the receiver and then calculate the required data to obtain the DF Sensitivity.

1.2.3.1 Procedure:

1.2.3.1.1 Measure the DF Antenna System Pickup Factor as directed in Section 1.1.

1.2.3.1.2 Without changing the receiver controls, transfer the receiver to a shielded room (if available). Measurements on the receiver may be made at the test site when due precautions are taken to prevent the reception of external noise.

1.2.3.1.3 Replace each collector element of the DF Antenna with an equivalent impedance having negligible pickup. Adjust the receiver sensitivity control to produce a noise level (measured across the DF detector load) 30 db below the receiver Overload Point.

Note: If the display device depends upon continuous rotation of the antenna pattern through the use of electronic goniometers, etc., such rotation shall be maintained.

1.2.3.1.4 Across the receiver input terminals connect an adjustable susceptance which has a sign opposite to that of the receiver input susceptance and adjust for zero total susceptance at the receiver input terminals.

Note 1: If the input admittance is a simple susceptance (for example, a pure capacity), this adjustment may be obtained by connecting the signal to the input terminals in series with a resistance 10 or more times the impedance of the receiver input and adjusting the variable susceptance for maximum output from the receiver.

Note 2: If the electrical characteristics of the input circuitry are such that simple maximizing of the response of Note 1 does not produce zero susceptance, this adjustment must be performed with the aid of an RF Susceptance Bridge.

Note 3: If the input impedance of the receiver is nonreactive, *i.e.*, a pure resistance, then Section 1.2.3.1.4 may be omitted.

Note 4: If the input impedance of the receiver is very much greater (10 or more) than the output impedance of the Signal Generator, then Sections 1.2.3.1.4 and 1.2.3.1.6 may be omitted.

1.2.3.1.5 Connect a Signal Generator to the input terminals of the receiver in shunt with the susceptance in Section 1.2.3.1.4, if present. (See Note 4.) Record the Signal Generator output voltage e_1 (see Appendix A), required to produce an output indication 20 db above the noise determined in Section 1.2.3.1.3.

1.2.3.1.6 Connect a resistance equal to that of the generator resistance across the generator output in shunt with the receiver input and the susceptance of Section 1.2.3.1.4. Record the Signal Generator output voltage e_1 (see Appendix A), now required to produce the same receiver output indication as Section 1.2.3.1.5.

1.2.3.1.7 Compute the receiver input voltage E (for 20-db signal-plus-noise to noise ratio): $E=e_2-e_1$.

1.2.3.1.8 Compute the Sensitivity At Maximum Response by dividing the receiver input voltage E (Section 1.2.3.1.7) by the DF Antenna Pickup Factor. (See Section 1.1.3.8 or 1.1.4.6.) The result is expressed in microvolts per meter.

1.2.3.1.9 Measurements shall be conducted at the same Standard Test Frequencies as used in measurement 1.1.

1.3 DF Antenna System Response Pattern

1.3.1 Purpose: The purpose of this test is to determine the DF Antenna System response pattern in the horizontal plane.

1.3.2 Conditions: The Direction Finder under test shall be adjusted for optimum performance. A signal source sufficient to produce an output of 20 db above noise shall be used. Either the Target Transmitter may be moved around the DF Antenna System or the DF Antenna System may be rotated about its vertical axis. It is desirable that the transmitter level be adjusted to maintain constant receiver output as the DF Antenna System is rotated, or the transmitter is moved. If a transmitter of adjustable output is not available, then, as an alternative, the Director Finder receiver may be calibrated and used with a transmitter of constant output.

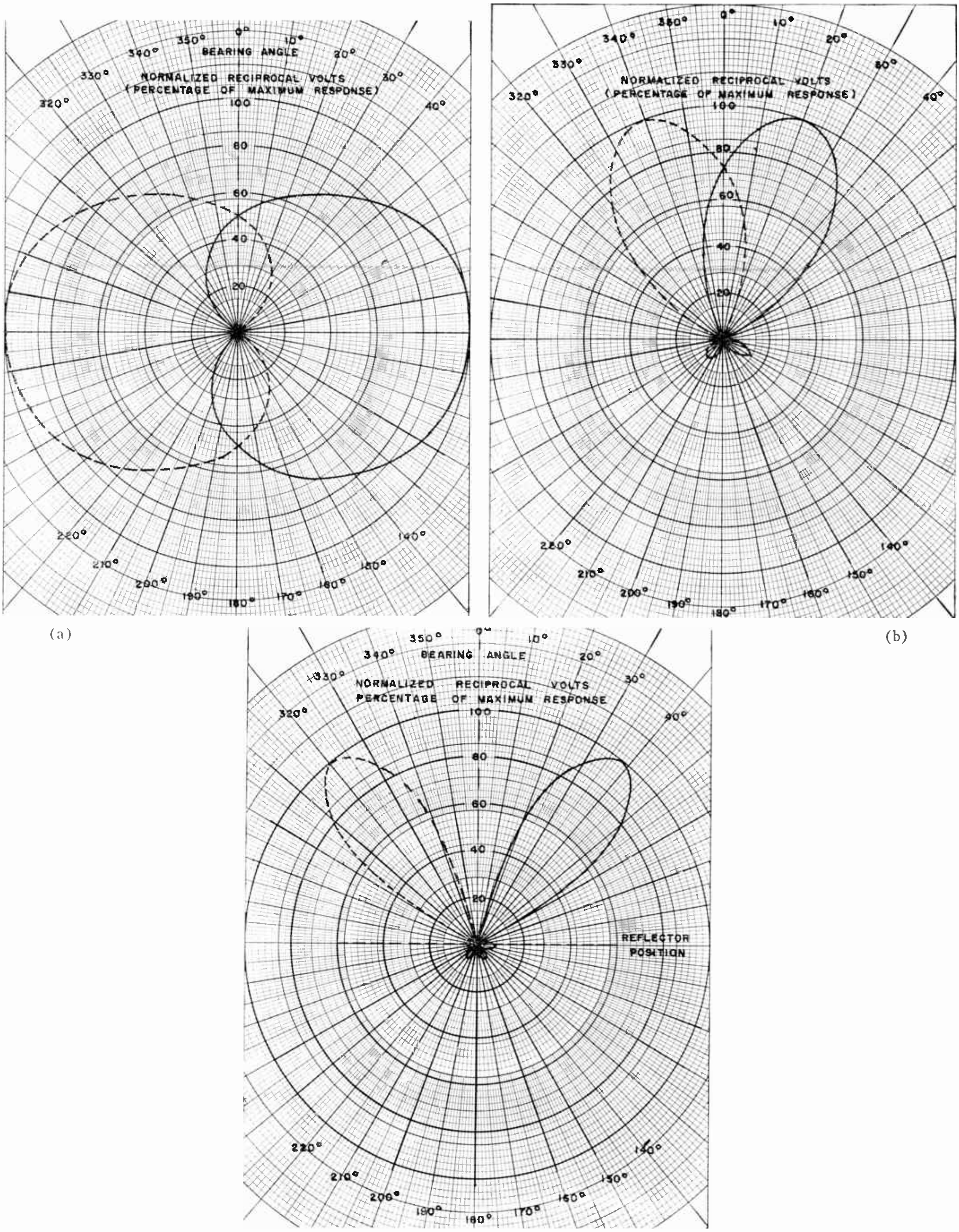
Measurements shouldbe made at a sufficient number of Standard Test Frequencies to determine the effect of frequency upon the pattern.

1.3.3 Procedures:

1.3.3.1 With the receiver adjusted for optimum performance, rotate the DF Antenna System or goniometer in increments of 10°. (Alternatively, the transmitter may be moved about the DF.) Maintain constand receiver output by adjusting the transmitter output levels. Record these levels.

Note: Additional smaller increments may be required near points of maxima or minima to assure an accurate plot.

1.3.3.2 Calculate the reciprocals of the recorded transmitter output-voltage. Plot these data on polar coordinate paper, using a scale sufficiently large to show any minor lobes. Frequently, these data are normalized. (See Fig. 5.)



(c)

Fig. 5—DF antenna system response pattern. (a) Switched cardioid system; (b) lobe switching system; (c) antenna in front of reflector.

Note: The values of maximum and minimum should be recorded at their proper bearings. Where lobe-switching systems are measured, data should include each lobe showing the normal intersection point. Where switched cardoid systems are measured, means should be provided to obtain both patterns under normal antenna gain conditions.

1.3.4 Alternate Procedure:

1.3.4.1 Conditions: With the DF Antenna System oriented for maximum response, adjust the transmitter level and receiver sensitivity control to obtain a signal-plus-noise ratio of not less than 40 db in the receiver output. Maintain these values of transmitter output and receiver gain.

1.3.4.2 Procedure:

1.3.4.2.1 Rotate the DF Antenna System or goniometer in increments of 10° and record the receiver output levels. (Additional smaller increments may be required at points of maxima and minima to assure an accurate plot.)

1.3.4.2.2 Plot these data on polar coordinate paper, using a scale sufficiently large to show any minor lobes. Frequently these data are normalized. (See Fig. 5.)

Note: The values of maximum and minimum should be recorded at their proper bearings. Where lobe switching systems are measured, data should include each lobe showing the normal intersection point. Where switched cardoid systems are measured, means should be provided to obtain both patterns under normal antenna gain conditions.

1.4 Bearing Sensitivity

1.4.1 Purpose: The purpose of this test is to establish:

a) The minimum field required to maintain the Bearing Accuracy, as determined by different operators, within 5°.
b) The minimum field required to obtain repeatable bearings within the bearing accuracy of the equipment. (See Section 1.4.3.8.)

1.4.2 Conditions: The Target Transmitter shall be keyed CW and the speed of transmission shall be approximately 25 wpm.

Introduce a known angular displacement between the DF Antenna System and the bearing indicator so as to disguise the actual bearing position by an indefinite number of degrees. Other means of obtaining equivalent results may be substituted for the displaced bearing scale. The object is to require the operator to work with a scale such that his performance is not influenced by his previous knowledge of the correct bearing. It shall be permissible to readjust the receiver sensitivity control of such other controls as are normally used to obtain maximum performance. The tests shall be performed at one of the Standard Test Frequencies which shall be provided. Probable performance at other Test Frequencies may be predicted from data obtained in Paragraph 1.1.

1.4.3 Procedure: A group of not less than five (5) observers shall be used in determining the Bearing Sensitivity. In order to reduce the personal equation, the bearing observations of each operator shall be kept from the other operators. If the design of the equipment permits, it is advantageous to mask the bearing scale from the observers and have the recorder read the actual indicated bearings.

1.4.3.1 Adjust the output of the Target Transmitter until an indication of a bearing is just discernible.

1.4.3.2 Detune the receiver and maladjust normal operating controls.

1.4.3.3 Have one operator adjust the equipment and report to the recorder his observation of the bearing.

1.4.3.4 Repeat Sections 1.4.3.2 and 1.4.3.3 with each operator.

1.4.3.5 Record the field strength and each reported bearing observation, noting the identity of the observers.

1.4.3.6 Increase the output of the transmitter sufficiently to permit somewhat more accurate bearings to be obtained.

1.4.3.7 Repeat Sections 1.4.3.2–1.4.3.5 inclusive.

1.4.3.8 Again, increase the transmitter power in incremental steps, repeating the procedure of Sections 1.4.3.2–1.4.3.5 for each power employed until it is apparent that no further increase will improve the bearing accuracy.

1.4.3.9 Arithmetically average the bearings reported for the highest field strength, using this value as the average bearing.

1.4.3.10 Determine the error with respect to this average bearing for each operator and plot these errors as discrete points against respective field strengths using semi-log paper. It is advantageous to employ different symbols for each operator.

1.4.3.11 Compute the arithmetical average of the calculated errors at the discrete field intensities used. Plot these averaged values as a function of field intensity. The resulting curve indicates the Averaged Observational Error. (See Fig. 6.)

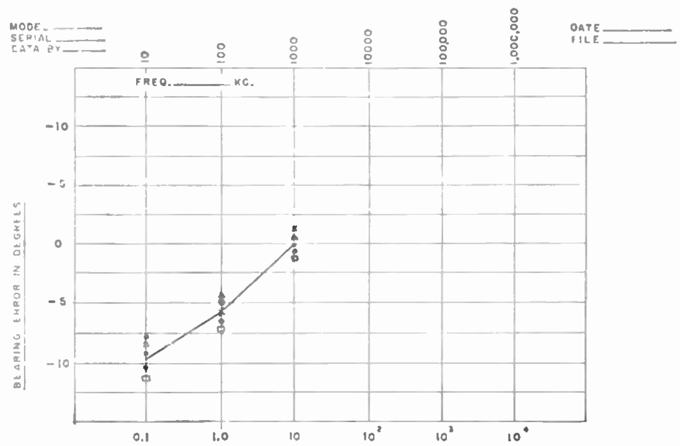


Fig. 6—Bearing sensitivity (average bearings of five observers).

2. DF SYSTEM ACCURACY

2.1 DF System Accuracy—Desired Polarization

2.1.1 Systematic Bearing Error

2.1.1.1 Purpose: To measure the systematic error of the DF Bearing indication. A measure of Systematic DF bearing Accuracy is given by the curve of the systematic deviation of the indicated bearing from the direction of arrival of the signal, as a function of indicated bearing.

2.1.1.2 Methods of Measurement—General: The curve of Systematic Deviation vs Indicated Bearing is obtained by taking[3] bearings on a number of signals of different known bearings with respect to the DF equipment, determining the difference between each indicated bearing and the direction of arrival of the corresponding signal, and plotting the deviations from the mean of these differences vs the indicated bearings. This procedure eliminates that portion of the systematic displacements between the indicated bearing and the direction of arrival of the signal which could be corrected by a fixed displacement of the indicator scale, retaining only that part of the systematic deviation which is a function of bearing. The measurement of bearing accuracy can be obtained either by 1) locating a Target Transmitter successively at a number of points around the test site, or by 2) rotating the DF equipment as a whole in bearing, while taking bearings on a Target Transmitter at a fixed location.

Where the position of the Target Transmitter is fixed and the DF equipment is rotated to obtain bearings as in Sections 2.1.1.3 and 2.1.1.4 below, it may be assumed that the direction of arrival of the signal is constant except for effect due to the DF equipment itself. Where the DF equipment is of such a form or size that it cannot be moved as a unit (as in Section 2.1.1.5 below), so that the test of DF system accuracy must be obtained by carrying a Target Transmitter around the test site, any distortion of the signal field due to nonuniformity of terrain, etc., which causes the direction of the field at the center of the test site at different azimuths to vary with respect to the geographical bearing of the Target Transmitter will appear as a deviation in the measurement. Hence, in performing this test, the actual direction of the field at the test site, which may be determined as directed in Appendix II, must be used in place of the geographical bearing of the Target Transmitter.

2.1.1.3 Bearing Accuracy (*A*)

2.1.1.3.1 Conditions: DF equipment readily portable and small enough to be enclosed and operated in a Screen Room.

Where the DF equipment is physically small and readily portable, this test can most conveniently be performed in a Screen Room fitted with a Transmission Line Antenna which establishes a field of the Desired Polarization, as described in Section 2. of Standard Test Conditions. The Screen Room shall be equipped with a turntable upon which to mount the DF equipment, and the turntable shall accommodate the entire equipment so that the relative positions of the equipment components are not changed as the equipment is rotated in bearing.

An azimuth scale, calibrated to better than one-tenth the error within which it is desired to determine the accuracy of the equipment, shall be attached to the turntable mounting to indicate the heading of the DF equipment relative to the field. The indicated heading shall increase with clockwise rotation of the mounting.

2.1.1.3.2 Procedure:

2.1.1.3.2.1 With the equipment installed in the Screen Room, adjust the Signal Generator to produce a signal field strength 100 times the Reference Test Field at one of the Standard Test Frequencies.

2.1.1.3.2.2 With the DF and turntable at any convenient initial heading, adjust the DF to take the bearing of the Test Signal. Repeat 6 times and record the averaged bearing.

> *Note 1:* If the equipment is manually operated, in repeating the readings, approach the final adjustment with opposite sense in successive readings.
>
> *Note 2:* If the equipment is direct-indicating or automatic, rotate the turntable 10° or more in alternating directions, 6 times in succession, each time returning to the specified heading.

2.1.1.3.2.3 Repeat Section 2.1.1.3.2.2 with the turntable set successively to headings spaced 15° apart, continuing until one full rotation is covered.

2.1.1.3.2.4 To each average relative bearing found in Section 2.1.1.3.2.3, add the corresponding turntable heading.

2.1.1.3.2.5 Calculate the average value of the quantities found in Section 2.1.1.3.2.4.

2.1.1.3.2.6 From each quantity determined in Section 2.1.1.3.2.4, subtract the average quantity obtained in Section 2.1.1.3.2.5 and plot the difference vs the corresponding relative heading as indicated by the DF in Section 2.1.1.3.2.3. This is the curve of Instrumental Bearing Error vs Indicated Bearing.

2.1.1.3.2.7 Repeat the procedure at all pertinent Standard Test Frequencies.

2.1.1.4 Bearing Accuracy (*B*)

2.1.1.4.1 Conditions: A DF of such size and form that it can be rotated in heading as a unit when set up and in normal operating condition, but, because of size or the presence of unwanted reflections, satisfactory operation is not possible inside a Screen Room.

This test shall be performed at a Test Site as described under Section 1 of Standard Test Conditions. The equipment under test shall be mounted on a turntable or other rotatable mounting. The rotatable mounting shall be symmetrical with respect to the DF An-

[3] In determining each such bearing, a sufficient number of readings is averaged to render insignificant the random component of errors.

tenna so as not to produce bearing errors due to the presence of the mounting, and shall be provided with an azimuth scale calibrated to read the heading of the DF equipment with respect to any convenient reference, with an error less than one-tenth the accuracy to be determined. The indicated heading shall increase with clockwise rotation of the mounting.

A Target Transmitter producing a signal of the Desired Polarization shall be erected at a point at least two wavelengths distant from the DF Antenna or 10 times the aperture of the DF Antenna, whichever is greater.

2.1.1.4.2 Procedure:

2.1.1.4.2.1 Adjust the Target Transmitter to produce a signal having an intensity 100 times the Reference Test Field at the center of the DF Antenna.

2.1.1.4.2.2 With the DF and turntable at any convenient initial heading, adjust the DF to take the bearing of the Test Signal. Repeat 6 times and record the average bearing.

Note 1: If the DF equipment is manually operated, approach the final adjustment with opposite sense in successive readings.

Note 2: If the DF equipment is automatic, displace the goniometer, loop or antenna drive to one side and then the other and release to obtain successive readings.

Note 3: If the DF equipment is an instantaneous (cathode-ray-tube display) indicating system, one reading is sufficient.

2.1.1.4.2.3 Repeat Section 2.1.1.4.2.2 with the DF equipment set successively to headings approximately 15° apart, continuing until one full rotation is covered.

2.1.1.4.2.4 To each average bearing found in Section 2.1.1.4.2.3 add the corresponding turntable heading.

2.1.1.4.2.5 Calculate the average of the quantities found in Section 2.1.1.4.2.4.

2.1.1.4.2.6 From each quantity found in Section 2.1.1.4.2.4, substract the average quantity found in Section 2.1.1.4.2.5.

2.1.1.4.2.7 Plot each value found in Section 2.1.1.4.2.6 vs the corresponding average indicated bearing found in Section 2.1.1.4.2.3. This is the curve of Systematic Bearing Error vs Bearing. (See Fig. 7.)

2.1.1.4.2.8 Repeat the procedure at all Standard Test Frequencies.

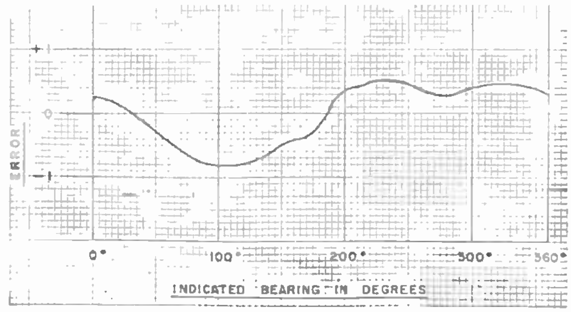


Fig. 7—Systematic bearing error vs error.

2.1.1.5 Bearing Accuracy (C)

2.1.1.5.1 Conditions: A DF which cannot be moved due to size, type of construction, etc. The test shall be performed at a Test Site selected as described under Standard Test Conditions. Prior to installation of the DF equipment, the Apparent Bearing of the signal provided by a Target Transmitter at each of 24 different locations, shall be established as directed in Appendix II. Where a ground-screen is a component part of the DF, the Apparent Bearings should be determined without and with the ground-screen installed. The Apparent Bearings showing the smaller deviations shall be taken as the reference.

2.1.1.5.2 Procedure:

2.1.1.5.2.1 Install the DF at the Test Site and adjust it in accordance with its instructions for installation. The DF Antenna System shall be centered upon the point at which the center of the Test DF in Appendix II was previously located.

2.1.1.5.2.2 Erect the Target Transmitter at any convenient one of the transmitting sites for which the Apparent Bearing has been determined.

2.1.1.5.2.3 Set the Target Transmitter to one of the Standard Test Frequencies and adjust its output to produce at the center of the site a signal field that is 100 times the Reference Test Field.

2.1.1.5.2.4 Measure and record the Indicated Bearing of the signal field with the DF equipment being tested. Repeat the measurement 6 times, approaching the reading with opposite sense in successive readings. Record the Indicated Bearing of the signal field as the average of the readings so obtained, and record the transmitter frequency and the identification of the transmitter site.

2.1.1.5.2.5 Repeat Sections 2.1.1.5.2.3 and 2.1.1.5.2.4 at all pertinent Standard Test Frequencies.

2.1.1.5.2.6. Move the Target Transmitter to another transmitter location for which the Apparent Bearing has been established and repeat Sections 2.1.1.5.2.3 to 2.1.1.5.2.4, continuing until all 24 transmitting locations have been occupied.

2.1.1.5.2.7 Tabulate the data for each Standard Test Frequency, as shown in the example, Table II, putting the station identification symbol in Column I, the Apparent Bearing as determined by the procedure of Appendix II in Column II and the Indicated Bearing as determined by Sections 2.1.1.5.2.1–2.1.1.5.2.6 above in Column III.

2.1.1.5.2.8 Subtract the Indicated Bearing, Column III, from the Apparent Bearing, Column II, and tabulate as the difference in Column IV.

2.1.1.5.2.9 Determine the mean difference by summing Column IV and dividing the sum by 24.

2.1.1.5.2.10 Subtract the mean difference of Section 2.1.1.5.2.9 from each difference tabulated in Column IV and tabulate as the Deviation in Column V, taking due regard for sign.

TABLE II

I Trans-mitter	II Apparent Bearing	III Indicated Bearing	IV Difference	V Deviation
A	43.65	6.1	37.55	0.23
B	59.74	22.3	37.44	0.12
C	71.00	33.7	37.30	−0.02
D	85.28	48.2	37.08	−0.24
E	95.33	58.4	36.93	−0.39
F	110.62	73.9	36.72	−0.60
G	119.78	83.2	36.58	−0.74
H	144.12	107.6	36.52	−0.90
I	158.74	122.2	36.54	−0.78
J	174.55	137.9	36.65	−0.67
K	190.26	153.4	36.86	−0.46
L	205.63	168.5	37.13	−0.19
M	217.73	180.3	37.43	0.11
N	230.99	193.4	37.59	0.27
O	245.33	207.6	37.73	0.41
P	248.63	210.8	37.83	0.51
Q	275.16	237.3	37.86	0.54
R	292.17	254.4	37.77	0.45
S	307.72	270.1	37.62	0.30
T	329.85	292.2	37.65	0.33
U	345.53	307.8	37.73	0.41
V	4.28	326.5	37.78	0.46
W	21.33	343.6	37.73	0.41
X	36.34	358.7	37.64	0.32

Sum 897.66

$$\text{Mean Difference} = \frac{897.66}{24} = 37.319$$

2.1.1.5.2.11 Plot the Deviation (Column V) vs the Indicated Bearing (Column III) and connect the plotted points with a smooth curve. This is the curve of Bearing Accuracy for the DF at that Standard Test Frequency.

2.1.1.5.2.12 Repeat Sections 2.1.1.5.2.7–2.1.1.5.2.11 for all pertinent Standard Test Frequencies.

2.1.2 DF Off-Resonant Operation

2.1.2.1 Purpose: To determine the variations in bearings caused by mis-tuning of the DF receiver.

2.1.2.2 Conditions: The test setup shall be the same as previously used for establishing a known field of the Desired Polarization. (See Standard Test Conditions.) Measurements shall be made at Standard Test Frequencies. The frequency of either the receiver or the transmitter may be varied to provide the nonresonant operation of the receiver. Section 2.1.2.3 applies to receivers fitted with a manual sensitivity control; Section 2.1.2.4 applies to receivers having AGC.

2.1.2.3 DF Receivers Equipped with a Manual Sensitivity Control

2.1.2.3.1 Procedure:

2.1.2.3.1.1 With the Target Transmitter adjusted to produce a field strength of 10 times the Reference Test Field, adjust the DF receiver to produce Standard Output and record the bearing.

2.1.2.3.1.2 Decrease the Target Transmitter output by 6 db and increase the gain of the receiver to obtain Standard Output.

2.1.2.3.1.3 Restore the Target Transmitter output to produce the initial output of Section 2.1.2.3.1.1 and detune the receiver (or vary the frequency of the transmitter) each side of resonance, recording the bearing and frequencies at which Standard Output is obtained.

2.1.2.3.1.4 Repeat Sections 2.1.2.3.1.2 and 2.1.2.3.1.3, continuing until the maximum receiver gain has been reached.

2.1.2.3.1.5 Repeat Sections 2.1.2.3.1.1–2.1.2.3.1.4, adjusting the Target Transmitter output specified in Section 2.1.2.3.1.1 successively to 100 and 1000 times the Reference Test Field.

2.1.2.4 DF Receivers Equipped with AGC

2.1.2.4.1 Procedure:

2.1.2.4.1.1 If not otherwise available, determine the bandwidth of the receiver at 80-db points. Determine the increments of 9 equally-spaced frequencies so that the outer frequencies (1 and 9) are at the 80-db points with number 5 at center of pass band.

2.1.2.4.1.2 With the Target Transmitter adjusted to produce a field strength of 10 times the Reference Test Field, tune the DF receiver to resonance and adjust the audio output control to produce Standard Output. Record the bearing.

2.1.2.4.1.3 Increase the transmitter output to produce 100 times the Reference Test Field. Detune the receiver (or vary the transmitter frequency) each side of resonance to the discrete intervals obtained in Section 2.1.2.4.1.1 and record the departure of the bearing from the original bearing at each of the frequency intervals. Record the maximum departure of the bearing should it occur between the test frequencies.

2.1.2.4.1.4 Repeat Section 2.1.2.4.1.3 but with the Target Transmitter output adjusted to produce a field 1000 times the Reference Test Field.

2.1.2.4.1.5 Repeat Section 2.1.2.4.1.3 with the Target Transmitter adjusted to produce a field 10,000 times the Reference Test Field, but in addition to the nine-frequency adjustments above, continue to tune each side of the pass band until the signal is lost in the noise. Record departure of bearings and the frequencies at which these occurred.

2.1.3 Operational Test

2.1.3.1 Purpose: To determine the Statistical Bearing Accuracy under actual conditions of operation.

2.1.3.2 Conditions: The DF to be measured is to be completely installed on either a test site or the final site on which it will be used.

2.1.3.3 Procedure:

2.1.3.3.1 Record the indicated bearings of the sources of at least 200 transmissions, the locations of which are known. These should be distributed in frequency throughout the DF frequency range and in bearing throughout the service area. Insofar as practicable, make bearing measurements at random seasons and times of day.

Notations of relative field strength, degrees of swing, and operator's judgement of classification of the bearing should be made. Note whether the recorded bearing is a single reading of a stated time interval or results from the averaging of a specified number of readings.

2.1.3.3.2 Compute the actual bearings of the transmitters in respect to the Direction Finder, by utilizing information of latitude and longitude of transmitter and DF Locations.

2.1.3.3.3 Summarize the data showing the percentage of bearings which are within 1, 3, 5 and 10° of the actual bearing. Also, plot the error as a function of the bearing.

2.2 Factors Affecting DF System Accuracy—Effects of

2.2.1 Undesired Polarization (The resulting errors are commonly called Polarization Error.)

2.2.1.1 Purpose: The purpose of this test is to determine the Standard Wave Error. This error is determined by subjecting either a vertically- or a horizontally-polarized DF Antenna System to a wave arriving from an angle of elevation of 45°; this wave having equal electric-field components which are respectively in and at right angles to the vertical plane which includes the DF Antenna and the test transmitter; the phase relation of the two electric-field components being adjusted to produce maximum Direction Finder error.

2.2.1.2 Conditions: Measurements shall be made at a site described under Section 1 of Standard Test Conditions. The test transmitting antenna shall be elevated such that at a distance of 10 or more wavelengths, the angle of elevation of the transmitting antenna relative to the center of the DF Antenna System is 45°.

The signal source shall be capable of adjustment to provide the fields specified under Section 2.2.1.1. A signal of the required characteristics may be obtained by means of an antenna structure consisting of three dipoles mutually perpendicular about a common point. These dipoles project from a housing (symmetric about the common point) which encloses and shields the transmitter. (See Fig. 8.) The transmitting antenna system shall be so mounted on nonconductive supports that one dipole is horizontal and perpendicular to the line joining it to the center of the DF Antenna System. The transmitting antenna system shall be rotatable about the horizontal dipole as an axis. The dipoles which are in the vertical plane shall be excited, respectively, in phase and 90° out of phase with the horizontal dipole. All antennas shall be adjusted to radiate equal amounts of energy. Rotation of the transmitting antenna system about the horizontal axis produces a signal with polarization changes between limits of +45° plane-polarization, through circular polarization, to −45° plane-polarization.

2.2.1.3 Procedure: Measurements of the polarization error of Direction Finder operating in the VHF, UHF and SHF (bands 8, 9, and 10) bands may be accomplished using a transmitter-antenna system elevated by a fixed, nonconducting structure. Measurements of HF Direction Finders may be made using similar radiators supported by aircraft or balloons. Means shall be provided to determine the correct bearing of the transmitting antenna system. (Where such procedures are not practicable, measurements may be made at angles of elevation down to 10°. Since the significance of the results is a function of the angle of elevation the exact conditions of the test should be described.)

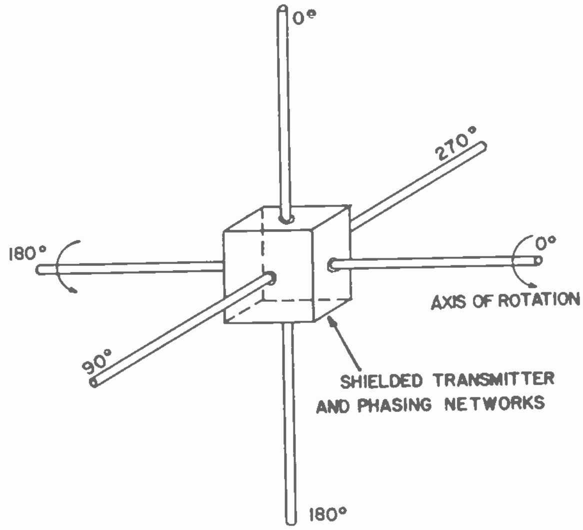


Fig. 8—Transmitter for determining standard wave error.

2.2.1.3.1 Excite the elevated three-dipole transmitting-antenna to provide the Reference Test Field (±6 db). Rotate the antenna in small increments and record the DF Bearing in respect to the transmitting-antenna rotational position.

2.2.1.3.2 Determine the total cyclic variation of the DF Bearings. The Standard Wave Error is expressed as a numerical value of one-half the total.

2.2.1.3.3 Repeat measurements at all pertinent Standard Test Frequencies.

> *Note:* Bearings should be taken using normal DF operating adjustments, but all other installation adjustments shall remain unchanged throughout the measurement.

2.2.2 DF Antenna System—Reciprocal Bearing Error

2.2.2.1 Purpose: To determine the Reciprocal Bearing Error of Direction Finders which produce bearing indications having 180° ambiguity.

2.2.2.2 Conditions: Standard Test Conditions.

2.2.2.3 Procedure:

2.2.2.3.1 Establish the Reference Test Field at one of the Standard Test Frequencies.

2.2.2.3.2 Determine and record the actual and reciprocal bearings. Adjust the receiver sensitivity control as may be necessary to obtain well-defined nulls.

2.2.2.3.3 Determine the difference between the actual bearing and its reciprocal bearing. The amount by which this difference departs from 180° is the Reciprocal Bearing Error. Record the algebraic value of this departure.

2.2.2.3.4 Repeat Sections 2.2.2.3.2 and 2.2.2.3.3 at all pertinent Standard Multiples of field strength.

2.2.2.3.5 Repeat Sections 2.2.2.3.2–2.2.2.3.4 at all other Standard Test Frequencies.

2.2.2.3.6 Plot the Reciprocal Bearing Error vs Field Strength for each Standard Test Frequency.

2.2.3 Tube Substitution

2.2.3.1 Purpose: To determine bearing errors resulting from the use of high- and low-limit tubes (or transistors).

2.2.3.2 Conditions: Standard Test Conditions.

2.2.3.3 Procedure:

2.2.3.3.1 Establish the Reference Test Field at the lowest Standard Test Frequency.

2.2.3.3.2 Record the bearing.

2.2.3.3.3 Using various combinations of high- and low-limit tubes (or transistors) in critical circuits, observe and record any resultant deviations from bearing recorded in Section 2.2.3.3.2 and state the conditions under which such deviations occur.

2.2.3.3.4 Repeat Sections 2.2.3.3.2 and 2.2.3.3.3 at the highest Standard Test Frequency.

2.2.3.3.5 Repeat Sections 2.2.3.3.2–2.2.3.3.4 with a field strength 100 times that of Section 2.2.3.3.1.

2.2.4 Maladjustment of Controls

2.2.4.1 Purpose: To determine bearing errors resulting from maladjustment or detuning of controls normally used in operating the Direction Finder.

2.2.4.2 Conditions: Standard Test Conditions.

2.2.4.3 Procedure:

2.2.4.3.1 Establish a field strength 10 times that of the Reference Test Field at the highest Standard Test Frequency.

2.2.4.3.2 Adjust receiver controls to produce Standard Output and record the bearing.

2.2.4.3.3 Decrease the field strength of the Target Transmitter output by 6 db and increase the receiver sensitivity control to restore Standard Output.

2.2.4.3.4 Restore the field strength to the initial value and detune the receiver each side of resonance to obtain Standard Output.

2.2.4.3.5 Measure the Bearing and record any Bearing shift.

2.2.4.3.6 Repeat Sections 2.2.4.3.3–2.2.4.3.5 until the maximum sensitivity control setting is reached.

2.2.4.3.7 Repeat Sections 2.2.4.3.1–2.2.4.3.6 with field strengths of 100 and 1000 times the Reference Test Field.

2.2.4.3.8 This test shall be made at the frequency in the band where previous measurements have indicated minimum sensitivity and with a field strength of 1000 times the Reference Test Field. Maladjust other normal operating controls with the receiver tuned to above and below resonance, and record any observed errors and control combinations which produce them.

2.2.5 BFO Operation

2.2.5.1 Purpose: To determine bearing errors resulting from the operation of the Beat-Frequency Oscillator.

2.2.5.2 Conditions: Standard Test Conditions.

2.2.5.3 Procedure:

2.2.5.3.1 Establish the Reference Test Field at the lowest Standard Test Frequency.

2.2.5.3.2 Record the bearing.

2.2.5.3.3 Turn the BFO on and off while adjusting it throughout the frequency range. Record any bearing errors and the conditions under which they occur.

2.2.5.3.4 Repeat Section 2.2.5.3.3 at the highest Standard Test Frequency.

2.2.6 Bearing Repeater

2.2.6.1 Purpose: To determine bearing errors introduced by a bearing repeater.

2.2.6.2 Conditions: In those cases in which a DF employs a Repeater System, measurement should be made to determine any differences between the bearing indications of the primary indicator and those of the repeater system.

2.2.6.3 Procedure:

2.2.6.3.1 Provide means for changing the primary indication through 360° in a clockwise direction in 5° increments. Operate the DF so that the Indicated Bearing may be changed 360° in a clockwise direction in approximately 5° increments. For each position record the indication of the primary and repeater(s) position. Determine the differences between primary and repeater indicators.

2.2.6.3.2 Repeat 2.2.6.3.1, rotating the primary indicator in a counter-clockwise direction.

2.2.6.3.3 Plot the difference. (See Fig. 9.)

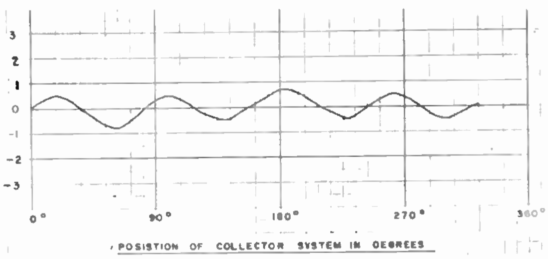


Fig. 9—Plot of repeater system in degrees.

2.2.7 Automatic Gain Control

2.2.7.1 Purpose: To determine the bearing errors introduced by the Automatic Gain Control and to determine the effectiveness of the automatic gain control circuits.

2.2.7.2 Procedure A: Automatic Bearing Indication (Cathode-Ray Types)

2.2.7.2.1 Set the Target Transmitter at the mid-frequency of one DF receiver band to produce a field of 100 times the Reference Test Field. Adjust the Direction Finder for optimum performance and obtain a bearing on the signal.

2.2.7.2.2 Record the ratio of length and width of the bearing pattern. (In addition to quantitative data, a photographic record of patterns resulting from the various conditions of test should be provided.)

2.2.7.2.3 Vary all controls, other than tuning controls and controls provided specifically for the Direction Finder channel selection. Record any change in bearing or pattern as a result of such adjustments.

2.2.7.2.4 Repeat Section 2.2.7.2.3 in Standard Multiples of field strength up to 2 volts per meter. Report any distortion of pattern shape and the sharpness and definition of bearing indication.

2.2.7.2.5 Repeat Section 2.2.7.2.4, employing keyed signals (both CW and ICW), varying in speed from 0 to 500 wpm. Sketch or describe any abnormal patterns and the conditions which produce them. Report any tendency toward "wobbulations."

2.2.7.3 Procedure B: Left-Right and Self-Orienting Types of Direction Finders

2.2.7.3.1 Set the Target Transmitter at the mid-frequency of one DF receiver band to produce a Reference Test Field. Adjust the Direction Finder for optimum performance and obtain a bearing on the transmitter signal.

2.2.7.3.2 Record the bearing and adjust all controls other than tuning controls and controls specifically provided for the Direction Finder channel selection. Record any bearing shift.

2.2.7.3.3. Rotate the DF Antenna System to the maximum pick-up position and return to the bearing position, noting in the case of the Left-Right indicator, whether there is a monotonic change in indication or whether the indication partially reverses its movement. (A partial reverse shall be understood to be an indication which has a tendency to dip and rise, rather than to cross the zero indication as a true reversal.) Plot the indicator deflection in terms of DF Antenna Orientation. (See Fig. 10.) In the case of a Self-Orienting Direction Finder, release the antenna at 90 and 180° from the actual bearing position. Record any tendency to stall.

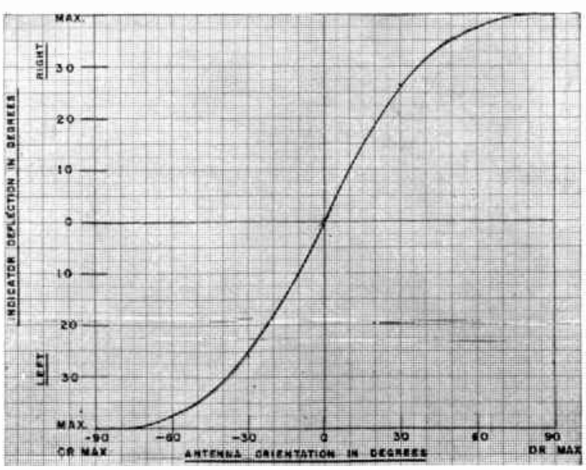


Fig. 10—Indicator deflection vs antenna orientation.

2.2.7.3.4 Repeat Sections 2.2.7.3.2 and 2.2.7.3.3. at Standard Multiples of field strength up to two volts per meter at the mid-frequency of each remaining band.

2.2.7.4 Procedure C: Pointer or Stroboscopic Indicator

2.2.7.4.1 Set the Target Transmitter at the mid-frequency of one DF receiver band to produce a Reference Test Field. Adjust the Direction Finder for optimum performance and obtain a bearing on the transmitter signal.

2.2.7.4.2 Vary the field strength in Standard Multiples and record any bearing deviations and "wobbulation" of the indication.

3. TIME REQUIREMENTS—(Desired Polarization)

3.1 Instrumental Time Requirements

3.1.1 Purpose: To determine the rms bearing deviation error as a function of duration of the received signal.

3.1.2 Conditions: The measurement shall be made at a Standard Test Frequency in a Reference Test Field using Desired Polarization. The test transmitter shall be normally OFF. Upon manual initiation, the transmitter shall emit a signal of predetermined duration which may be adjusted during the test. It is suggested that the duration be adjustable between 0.1 and 10 seconds, but in any case sufficient to adequately test the equipment under examination.

3.1.3 Procedure A: Direct-Reading Cathode-Ray Indicator Types

3.1.3.1 Select by trial the shortest signal duration at which a DF bearing indication with a spread of approximately 5° is discernible. With a signal of this duration, record 10 separate bearing observations, and record the signal duration.

3.1.3.2 Shorten the signal duration (from the preceding signal of Section 3.1.3.1). Record the signal duration. Take at least 10 bearings and record them.

3.1.3.3 Repeat Section 3.1.3.2 until the spread of the observations exceeds 10°.

3.1.3.4 Compute the rms deviation for each signal duration and plot deviation vs duration.

3.1.3.5 To aid in system analysis, submission of pertinent design data on the DF is suggested, particularly the factors affecting speed of response such as type of indicator and circuit, speed of rotation of collector or goniometer, circuit modulation frequency, bandwidth of system, and filtering.

3.1.4 Procedure B: Left-Right, Manually-Operated and Self-Orienting Types.

Special Additional Condition: Before taking each bearing, the antenna or goniometer shall be displaced from its true bearing position by a random amount.

3.1.4.1 Repeat Sections 3.1.3.1–3.1.3.4.

3.1.4.2 Key the signal at various speeds up to 25 wpm (10 cps). Displace the antenna or goniometer by a random amount prior to taking bearings. Note any effects on speed of operation, hunting or tendency to stall and record the keying speed at which such effect is produced.

3.1.4.3 If the DF requires an additional operation to resolve a bilateral bearing, describe the additional time required for the operation under Section 3.1.3.1 of procedure A.

3.2 Operational Time Requirements

3.2.1 Purpose: To determine the time required to "tune-in" a signal, make all necessary adjustment of controls and secure a bearing of some specified rms deviation.

3.2.2 Conditions: Establish the Reference Test Field of the Desired Polarization at a Standard Test Frequency near one end of a band. Turn on the receiver and set the receiver tuning control at the opposite end of the band from the chosen Standard Test Frequency. Place other controls in random positions. The following test should be made by several qualified operators.

3.2.3 Procedure:

3.2.3.1 Tune in the receiver, adjust the controls and take a bearing. Record the bearing and the elapsed time to perform the above operations.

3.2.3.2 Note any additional time required for resolution of a bilateral bearing.

4. INTERFERENCE

4.1 Adjacent Channel Interference

4.1.1 Purpose: The purpose of this test is to determine the minimum separation in frequency between two signals at which a specified error occurs (due to interference) in the DF under test.

4.1.2 Conditions: Two transmitters having the Desired Polarization shall be placed in approximately the same horizontal plane as the DF Antenna System. These shall be located at equal distances from the DF Antenna System, this common distance being not less than 20 times the width of the DF Antenna System. For shielded room operation, the interfering transmitter may be simulated by a Signal Generator feeding a transmission line similar to that used for the desired signal, but physically at right angles to it. One of these transmitters shall hereafter be referred to as the "Desired Transmitter," the other will be designated the "Interfering Transmitter." The Interfering Transmitter shall be displaced in bearing from the Desired Transmitter so as to produce the maximum bearing error.

In some cases, this displacement will be obvious from the geometry of the DF Antenna System and may equal the angle between maximum and minimum responses of the DF Antenna System. In other cases, an experimental test may be necessary.

4.1.3 Procedure:

4.1.3.1 Turn on the Desired Transmitter signal and establish the Reference Test Field. Obtain and record the bearing.

4.1.3.2 Turn on the Interfering Transmitter and adjust it to produce a field strength equal to that of the Desired Transmitter. Vary the frequency until a bearing error of 5° is observed. Record the difference in frequencies between the Desired and Interfering carrier frequencies.

4.1.3.3 Repeat 4.1.3.2 with the Interfering signal at 10, 100 and 1000 times the initial value.

4.1.3.4 Repeat Steps 4.1.3.1 and 4.1.3.2 with both transmitters randomly keyed.

> *Note:* With certain types of Direction Finders it will not be possible to obtain a 5° bearing error. The bearings will either be clearly and separately distinguishable or be mixed in such a way that no bearing will be determined. When such conditions are observed, record the frequency difference between the two transmitters which just causes obliteration of the desired signal bearing.

4.2 Modulation Phase Interference

4.2.1 Purpose: When dot-lock or devices of a similar nature are employed which are capable of differentiating between signals arriving at different time intervals, tests should be made to determine their effectiveness in regard to interference.

4.2.2 Conditions: The transmitters shall be physically located as described in Conditions of Section 4.1. Means should be provided for keying the transmitters from a single source and for introducing time delay of known amounts between the keyed characters of the transmitters producing the "Desired" and "Interfering" signals.

Both transmitters shall be operated at the same frequency and shall produce equal field intensities at the center of the DF Antenna System.

4.2.3 Procedure:

4.2.3.1 Adjust the DF for normal operation using the keyed signal from the transmitter designated to produce the "Desired" signal as the bearing source, and record the bearing.

4.2.3.2 Turn on the "Interfering" signal and adjust the time delay between the keying of the "Desired" and "Interfering" signal until a bearing is obtainable which departs by at least 5° from the recorded bearing of Section 4.2.3.1.

4.2.3.3 Record the time interval difference between the two transmitters determined by Section 4.2.3.2.

> *Note:* With certain types of Direction Finders it will not be possible to obtain a 5° bearing error. The bearings will either be clearly and separately distinguishable or be mixed in such a way that no bearing will be determined. When such conditions are observed, slowly increase the time interval and record

the time interval between the two transmissions which cause obliteration of the "Desired" signal bearing.

APPENDIX I

Supplementary Notes on DF Sensitivity

In a Direction Finder, the term "Pick-up Factor" is defined as the quotient of the voltage across a specified pair of terminals (the receiver input terminals, for instance, as shown in Fig. 11) divided by the strength of field to which the Antenna System is exposed, with the Antenna System oriented for maximum response. To determine the Pick-up Factor, a known field is established at the Antenna System; then the voltage thereby developed at the specified terminals is determined by substituting a Signal Generator for the Antenna System and adjusting its output to produce the same output indication from the Direction Finder. Since the field strength has the dimensions "Microvolts per Meter," and the resulting potential the dimension "Microvolts," the Pick-up Factor must have the dimension "Meters."

In making this substitution measurement, care must be taken that the voltage indicated by the substitution does not differ from the voltage produced by the Antenna System due to the difference in the impedances of the Signal Generator and the Antenna System. The procedure outlined in Section 1.1.3 arrives at the correct value without requiring the use of a Dummy Antenna for establishing the correct impedance relationship; nor does it require that either the receiver input impedance or the Signal Generator impedance be known numerically. The only conditions that need be established are: 1) that the impedance facing the receiver be a pure resistance; 2) that an external resistance shall be available whose value is equal to this resistance; and 3) that some means be provided for neutralizing the susceptance of the terminals to which the Pick-up Factor is referred.

The method is based upon the principle that, if the receiver gain is fixed and the receiver input network is linear, the ratio of receiver output to voltage at any particular specified terminals at any particular frequency is independent of the impedance of the source providing the input voltage. That this must be the case is shown as follows:

Consider Fig. 12. The receiver input circuitry from its input terminals to the grid of the first tube is shown as a four-terminal network, and it is assumed to be evident that no changes in source impedance can affect the system beyond the first tube.

Provided the system is linear, the receiver input circuits can be represented at a single frequency by a single π (or T) section of three impedance elements, z_1, z_2 and z_3, and this is true in general for any input circuitry, regardless of whether it is lumped or distributed, resistive or reactive.

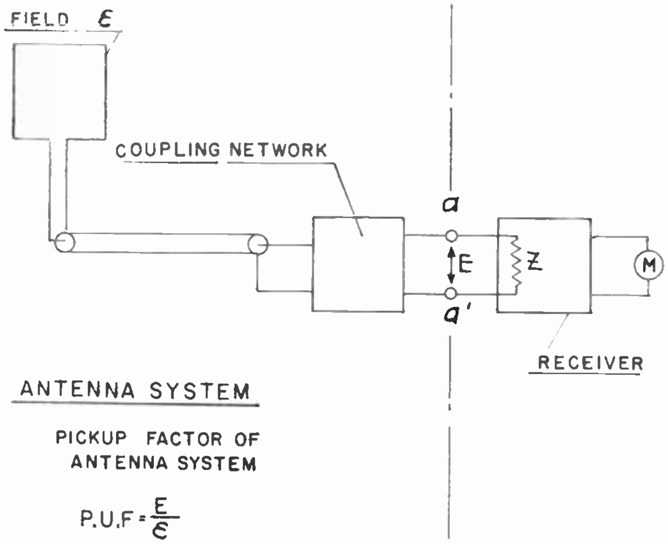


Fig. 11—DF antenna system.

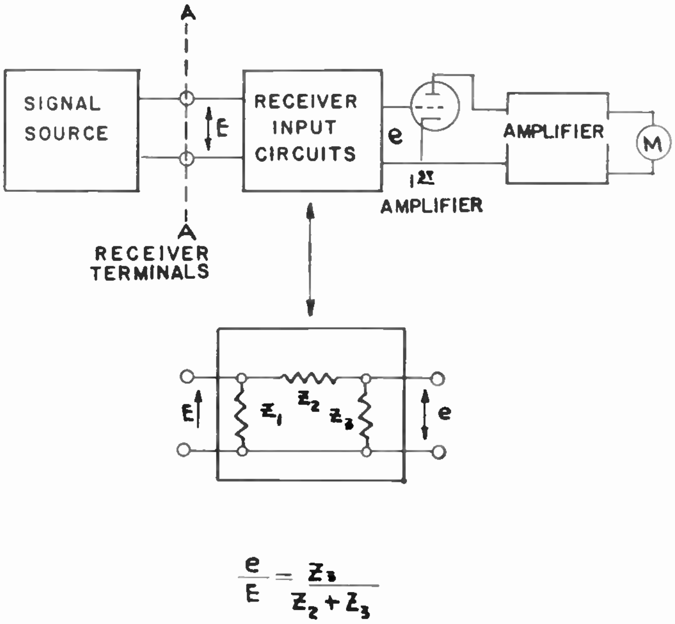


Fig. 12—Sensitivity measurement setup.

If a voltage (E) is applied to the input terminals from any source whatsoever, the ratio of the voltage (e) at the tube grid to the voltage (E) at the input terminals will be determined solely by the network and is independent of the impedance of the source supplying the driving voltage, being simply

$$e/E = Z_3/(Z_2 + Z_3).$$

Hence, it follows that, if the voltage at the input terminals required to produce the same output from the receiver as is obtained with the signal from the Target Transmitter is determined by any means, the pick-up factor is simply the ratio of this voltage to the Field Strength of the signal from the Target Transmitter; and the input impedance of the receiver does not enter into the relation.

The voltage at the receiver input terminals, required to produce the stated output, can be deduced by substitution with a Signal Generator, without knowledge of the receiver input impedance, by the following procedure.

The input to the receiver, as shown in Fig. 13, presents some unknown admittance $Y=G+jB$ at its terminals. An adjustable auxiliary susceptance may be connected across the input terminals and adjusted to provide an admittance $y=g-jB$ whose susceptance $-jB$ is equal but opposite in sign to the input susceptance of the receiver and therefore neutralizes it, so that the total impedance across the receiver terminals is then a pure (although unknown) resistance $r=1/(G+g)$.

When the receiver input is a pure resistance (r) (as can always be obtained by neutralizing the receiver input susceptance as outlined above), the open-circuit voltage of a signal generator having an output impedance that is a pure resistance (R) required to produce a receiver input voltage (E) is (e_1) as shown in Fig. 14(a), where

$$e_1 = (r + R)E/r = E + (R/r)E. \qquad (7)$$

If a resistance equal to the signal generator output resistance (R) is then shunted across the signal generator output as in Fig. 14(b), the open-circuit signal generator output now required to produce the same receiver input E is e_2, where

$$e_2 = \frac{R + \dfrac{rR}{r+R}}{\dfrac{rR}{r+R}} E = 2E + (R/r)E. \qquad (8)$$

Subtracting (7) from (8) eliminates both (r) and (R), and the desired voltage is given by

$$E = e_2 - e_1.$$

Hence, by neutralizing the input susceptance of the receiver and providing a shunting resistor equal to the generator resistance, it is possible to determine the receiver input voltage for the specified output indication as the difference of two generator voltage settings. It is not even necessary to know the signal generator resistance; only that the shunting resistance is equal to it. Nor is it necessary to know the receiver input impedance or the Q of the susceptance neutralizing circuits; only that the receiver input susceptance is neutralized so that the receiver input appears as a pure resistance to the signal generator.

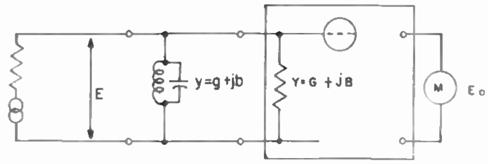


Fig. 13—Susceptance neutralization.

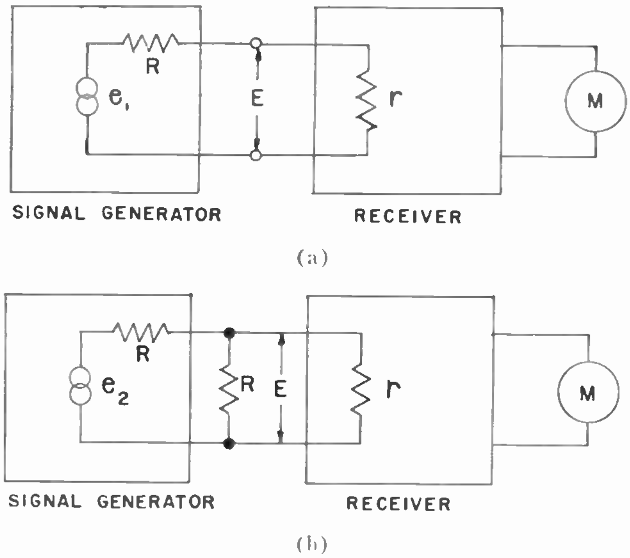


Fig. 14—(a) Receiver input voltage; (b) receiver input voltage, signal generator shunted.

APPENDIX II

METHOD OF ESTABLISHING A SIGNAL FIELD OF KNOWN BEARING

1. Foreword

Since any distortion of a signal field by nonuniformity of terrain or other factors may cause the direction of arrival of the wave at a DF Antenna to be different from the bearing of the signal source, the actual direction of such arrival must be established before the DF Bearing Accuracy can be measured.

The following method of establishing a signal field of known bearing is applicable to those measurements of DF Bearing Accuracy in which it is impracticable to rotate the DF because of its size, type of construction, or for other reasons.

2. Equipment Required

2.1 Target Transmitter

2.2 A Test Direction Finder comprising a self-contained, well-designed battery-operated aural-null Direction Finder, equipped with a well-balanced, shielded loop or equivalent: The Test DF shall be mounted as a single unit on a nonconductive turntable equipped with a su table means whereby the axis of the DF loop can be set and maintained truly vertical. A bearing scale, calibrated in degrees to better than one-tenth the error within which it is desired to determine the accuracy of the equipment, shall be attached to the turntable mounting. The scale calibration shall increase numerically with clockwise rotation of the mounting.

3. Procedure

3.1 Select a Test Site in accordance with the requirements described under Standard Test Conditions.

3.2 Locate 24 Target Transmitter sites more or less evenly spaced in bearing, and distant from the center of the Test Site at least two wavelengths or 10 times the aperture of the DF equipment to be tested, whichever is greater; identify the transmitting sites alphabetically from A to X (or by any other convenient nomenclature).

Note: The geographical locations of the Target Transmitter sites need not be known, but it is essential that it be possible to relocate the Target Transmitter at each transmitting site to within the accuracy with which the test is to be performed.

3.3 Set up the Test Direction Finder at the center of the Test Site with the zero of the bearing scale oriented to any convenient reference direction.

Note: Although the direction of the reference need not be known, the reference must not be changed or varied throughout the test.

3.4 Locate the Target Transmitter at any of the Transmitter Sites and adjust it to produce a field strength at the Test Site 100 times the Reference Test Field at one of the Standard Test Frequencies.

Note: See Standard Test Conditions for the procedure for establishing a known field strength.

3.5 Determine the Apparent Bearing of the signal field with the Test Direction Finder equipment by rotating the turntable. Record the Transmitter Site identity, signal frequency and bearing as indicated by the turntable scale.

Note: In taking the bearings, determine the null 6 times in succession, approaching the null from alternate directions in successive determinations, the average of the 6 measurements being taken as the bearing.

3.6 Repeat Sections 3.4 and 3.5 at all other Standard Test Frequencies pertinent to DF Equipment to be tested.

3.7 Move the Target Transmitter to another of the sites established in Section 3.2 and repeat Sections 3.4, 3.5 and 3.6, continuing until all 24 Target Transmitter sites have been occupied.

3.8 Prepare a Table of Apparent Bearing vs Transmitter Sites for each Standard Test Frequency as shown in the example which follows:

DF Test Site Apparent Bearing

_______ KC

Transmitter Sites	Apparent Bearing	Transmitter Sites	Apparent Bearing
A	43.65	M	217.73
B	59.74	N	230.99
C	71.00	O	245.33
D	85.28	P	248.63
E	95.33	Q	275.16
F	110.62	R	292.17
G	119.78	S	307.72
H	144.12	T	329.85
I	158.74	U	345.53
J	174.55	V	4.28
K	190.26	W	21.33
L	205.63	X	36.34

Correspondence

ASA Sectional Committee N3 on Nuclear Instrumentation*

Representatives from twenty-two professional societies meet quarterly to hasten the development of standards for nuclear instruments and controls. These representatives comprise Sectional Committee N3 on Nuclear Instrumentation of the Nuclear Standards Board, a group of the American Standards Association.

In its deliberations the Committee is attempting to set up means for adoption of standards that are useful to manufacturers and users of nuclear instrument and control equipment. Careful scrutiny to assure universal concurrence by all concerned in proposed standards is made. Then the standard is published by the American Standards Association, indicating acceptance of the proposal for general use.

As a first step in the Committee's functioning, a survey of standards in existence or in the process of preparation was made. The results have been summarized and published by R. F. Shea as "Index of Nuclear Standardization Work."[1]

The scope of work of the Committee is officially stated as follows:

> Standards, specifications and methods of testing for instrumentation in the nuclear field including instrumentation for personnel protection, reactor control, industrial processes, analysis and laboratory work, radiation calibration equipment and components therefor.

Through the International Electrotechnical Commission the N3 Committee is planning to participate in the formulation of international standards. Technical Committee 45 was authorized by the International Electrotechnical Commission in 1958. Germany (Dr. Richard Vieweg) was established as the Secretariat. The United States was designated to nominate the Chairman. The N3 Chairman has subsequently been nominated by the United States for the position of Chairman of TC 45. R. F. Shea has been nominated as the U. S. delegate to the Committee. The opening meeting is planned for late 1959.

Any standards or specifications believed to be acceptable for ASA adoption should be brought to the attention of any one of the members. Specific correspondence to the Committee can be addressed through the

* Received by the IRE, June 5, 1959.

[1] Copies can be obtained by writing to L. G. Cumming, Technical Secretary, The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y.

Institute of Radio Engineers, the sponsor society for N3. Write to L. G. Cumming, Technical Secretary, The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y.

The N3 Committee is not planning to prepare standards. Rather, its present operation is designed to process proposals from member professional societies after the proposal has been accepted by the sponsoring organization.

Two things are earnestly sought by the N3 Committee:

1) Information on the need for standards in particular fields. Once a need is made known, an effort will be made to have a standard developed through appropriate channels.
2) Since the nuclear instrument field is new, early standardization of concepts can achieve a real economy for the industry. For this reason N3 is anxious to receive proposals for adoption by the American Standards Association and will process them into usable standards expeditiously.

W. H. Hamilton
Chairman

FM Multiplex Spectra and Interference*

It has been suggested by several groups that the use of a frequency-modulated subcarrier on an FM signal is the most practical method of transmitting stereophonic programs. The various proposals and physical setups have used different subcarrier frequencies and deviations. Those worked on by Armstrong and Bose used subcarrier frequencies of about 30 kc and low radio-frequency deviations. More recent systems do not hesitate to let the instantaneous subcarrier frequency reach 75 kc. The radio-frequency carrier is deviated by various amounts up to 37.5 kc at the subcarrier rate.

At first glance these proposals are a little frightening as they would appear to widen the transmitting spectrum quite appreciably. (The problem presented itself during discussions of the Audio Engineering Society's Standards Committee.) The fear is strengthened by carrying out an analysis of the signals. However, experimental laboratory work with commercial tuners shows that in practice this spectrum widening has almost no effect on adjacent or alternate channel interference.

Spectrum

As is well known, a simple frequency-modulated signal consists of a carrier and various side frequencies spaced by the modulation frequency. In the case where the modulation frequency is much higher than the frequency deviation ($\Delta\omega/\omega_{\text{modulation}} = m_f \ll 1$) this spectrum simplifies essentially to a carrier and two sidebands. If the whole signal has unit amplitude the carrier is nearly 1 and the sidebands are approximately $m_f/2$ in amplitude. For example if we modulate a transmitter by ± 15 kc at a 50-kc subcarrier rate, $m_f = 15/50 = 0.3$ and we have a carrier and two sidebands each of 15 per cent amplitude spaced 50 kc above and below the carrier.

Now what happens if we add an audio modulation of ± 60 kc at a very low frequency rate, for convenience 1/60 cycle or once a minute? Intuition would indicate that at moments when the low-frequency input is zero we will have a carrier and two 50-kc sidebands. However, when the low-frequency input is for a few seconds at its highest swing, we should expect to find the carrier shifted upwards by 60 kc and, likewise, we should expect to find the two sidebands following it. Thus we should not be surprised to find the sidebands wandering around ± 110 kc from center frequency. We should expect to have the spectrum extended by twice the subcarrier frequency.

Detailed computations show that this naive point of view is justified; the total bandwidth over which the energy density is relatively high is equal to twice the main-channel deviation plus twice the highest instantaneous value of the subcarrier frequency.

Let's take a look at the arithmetic associated with a subcarrier. (This has been done numerous times before but the writer has not found the results tabulated in a form pointing up the physical picture just discussed.) For simplicity we assume that the subcarrier is unmodulated and write:

$$\omega = p + \Delta\omega_q \cos qt + \Delta\omega_r \cos rt \qquad (1)$$

where p is the carrier, q is the audio frequency, and r is the subcarrier frequency. $\Delta\omega_q$ and $\Delta\omega_r$ are the corresponding peak deviations. Then

$$e = \cos\left(\int \omega dt\right)$$
$$= \cos\left[(pt + m_q \sin qt) + m_r \sin rt\right] \qquad (2)$$
$$= \cos(pt + m_q \sin qt)\cos(m_r \sin rt)$$
$$+ \cos\left(pt + \frac{\pi}{2} + m_q \sin qt\right)\sin(m_r \sin rt). \quad (3)$$

Now $\cos(pt + m_q \sin qt)$ is a straight frequency-modulated wave with the well-known spectrum.

$J_0(m_q) \pm J_1(m_q) \cos(p \pm q)t + J_2 \cos(p+2q)t \pm J_3 \cos(p \pm 3q)t + \cdots$. Similarly $(\cos pt + \pi/2 + m_q \sin qt)$ has the same spectrum but $pt + \pi/2$ must be substituted for pt wherever it occurs, purely a matter of phase.

But $\cos(m_r \sin rt) = J_0(m_r) + 2J_2(m_r) \cos 2rt + 2J_4(m_r) \cos 4rt + \cdots$ and $\sin(m_r) \sin rt = 2J_1(m_r) \cos rt + 2J_3(m_r) \cos 3rt + \cdots$.

If we consider the terms in r we notice that each of these terms is acted on by the full audio spectrum. Thus $J_0(m_r)$ (the carrier that would be present with subcarrier modulation and no audio modulation) becomes

$$J_0(m_r)\left[J_0(m_q \cos pt \pm J_1(m_q) \cos(p \pm q)t + J_2(m_q) \cos(p \pm 2q)t \cdots\right].$$

Similarly the upper subcarrier sideband becomes

$$J_1(m_r)\left[J_0(mq)\cos\left(pt + \frac{\pi}{2}\right) \pm J_1(Mq)\cos\left(pt + \frac{\pi}{2} \pm qt\right) + J_2(m_q)\cos\left(pt + \frac{\pi}{2} 2qt\right) \pm \cdots\right]$$

and there is a corresponding term for the lower subcarrier sideband. This shows that each of the simple sideband terms for a wave with r modulation splits into a series of terms when the audio is added and each one of these series can be interpreted as a frequency-modulated wave. Thus the carrier and all of the r sidebands can be thought of as sweeping at the audio ratio q. The sidebands associated with the subcarrier are 20 $\log_{10} J_1(m_r)/J_0(m_r)$ or approximately 20 $\log_{10} (\Delta\omega r/2r)$ db below those in the central region.

The actual situation is of course much more complicated than has been indicated because the subcarrier itself is frequency modulated and so its frequency varies about its center point. This means that the band is widened somewhat beyond the amounts indicated. In any case there will be quite appreciable energy at frequencies differing from center channel by $\pm$ (audio deviation + maximum frequency of subcarrier).

Fortunately the case where there are two subcarriers in addition to audio modulation is not much worse than that with a single subcarrier. While the deviation is considerably greater than in the case of a simple subcarrier the offending terms have amplitudes of $J_1(m_r) \times J_1(m_s)/J_0(m_r) \times J_0(m_s)$ or approximately a fraction $(\Delta\omega r \times \Delta\omega s)/4(r \times s)$ of the main carrier.

Example: Main channel modulated at ± 37.5 kc, 50-kc subcarrier modulated ± 25 kc, and swinging carrier by ± 37.5 kc.

First we let the subcarrier be unmodulated and modulate the main channel with a low-audio frequency. Here $m_r = 37.5/50 = 0.75$, $J_1(0.75) = 0.329$, and $J_2(0.75) = 0.065$. The upper sideband is only 10 db below the carrier and swings up to $50 + 37.5 = 87.5$ kc. The second upper sideband is not entirely negligible, about 24 db below the carrier, and swings up to 137.5 kc above center.

At moments when the subcarrier has its maximum value (75 kc), $m_r = 37.5/75 = 0.5$. $J_1(0.5) = 0.242$, $J_2(0.5) = 0.03$. The first sideband reaches a maximum of $75 + 37.5 = 112.5$ kc and is about 12 db below carrier. The second reaches 187.5 kc above center but is about 30 db below carrier. These results are shown in sweep form in Fig. 1.

The nominal bandwidth of the system (not allowing for increase due to high-audio frequencies) can be considered as approximately the sum of twice the highest instantaneous value of the subcarrier plus twice the main channel deviation. Thus in the example the nominal bandwidth is 2(37.5 + 75) or 225 kc.

In systems like that of the example quoted in which the instantaneous sub-

* Received by the IRE, May 8, 1959.

carrier frequency is allowed to reach 75 kc, the fractional voltage associated with the maximum swings outside the band is roughly given by

$$m_r = \frac{\text{subcarrier deviation}}{2 \times \text{subcarrier frequency}}.$$

This is numerically half the fractional modulation allotted to the subcarrier.

It should be emphasized that the example just treated is statistically worse than practical cases. We have permitted the subcarrier to have its worst possible value of 75 kc continuously and we have also used a sinusoidal modulation on the main channel rather than a program source. The fractional time that the main channel would be expected to be near full instantaneous deviation *simultaneously* with the subcarrier is of course small.

Laboratory Results

In order to get some idea of the ***worst*** interference to be expected from these systems, the writer set up a pair of signal generators. One represented the desired signal and was modulated ±75 kc at a 400 ~ rate. The tuner was tuned to this generator. The second generator was arranged so that it was first modulated by ±75 kc at 50 ~ and then simultaneously by ±37.5 kc at 50 ~ *and* by 37.5 kc at 75 kc. The 75-kc subcarrier was not modulated. The interfering signal was then displaced by varying amounts from the desired signal, leaving the tuner adjustment constant.

The results are shown in Fig. 2 for two receivers of widely different design. Receiver *A* had a flat-topped IF response and broad-band detector; receiver *B* had a somewhat peaked IF response and a detector 300 kc wide. The curves show the minimum ratio of the desired and interfering signals that could be tolerated for 3 per cent audio cross-talk. This ratio is shown as a function of the separation between the center frequencies of the two signals.

The cross-talk with only audio modulation on the interfering signal is shown in the solid curves; the results with the audio and 75-kc multiplex are shown in the dotted curves. Notice that the differences for a given receiver with the same total modulation are very small, much less than the differences between the two receivers.

A third receiver (not shown) with a somewhat peaked IF but a wide-band detector gave very much the same results as receiver *A* except that the ratio for co-channel interference was midway between those for receivers *A* and *B*.

We can summarize these curves by saying that the nature of the modulation of the undesired signal made only about 2-db difference in the amount that could be tolerated; this could be in either direction and was much less than the differences between receivers.

The reason for these seemingly paradoxical results is not difficult to find. In a simplex system it is not improper to think of the signal as a sine wave of unit voltage whose frequency wanders slowly over the full range of deviations. This is indicated in Fig. 3. With a multiplex system with fixed 75-kc subcarrier frequency and 50 ~ audio

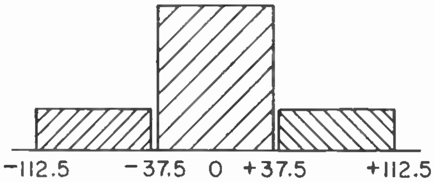


Fig. 1—Audio sweep range of carrier and first-order sidebands for subcarrier at maximum value (75 kc).

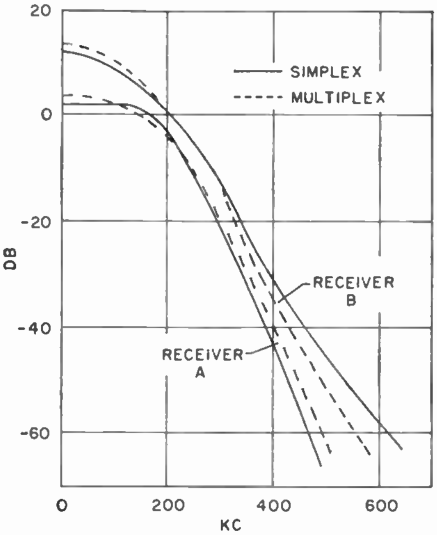


Fig. 2—Permissible signal-to-interference ratio (for three per cent cross talk) as a function of carrier separation.

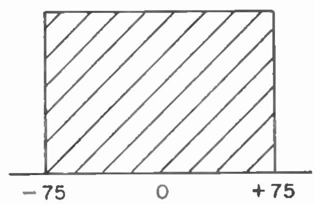


Fig. 3—Sweep pattern of a simple FM signal.

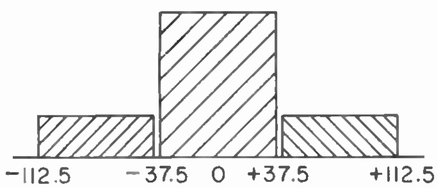


Fig. 4—Sweep pattern with fifty per cent each on audio and 75-kc subcarrier.

deviation we have three main products, the carrier and two 75-kc sidebands, all three moving about by ±37.5 kc. This distribution was indicated in Fig. 1 which is reproduced here as Fig. 4.

It is clear that a receiver with perfect flat-top response and infinite rejection outside this band would be bothered by a multiplex signal in the adjacent channel and not by the standard one. However all actual receivers fall short of this and give appreciable response outside their nominal pass bands. The relative amounts of interference to be expected from such receivers depend upon the details of their resonance curves and upon the capture properties of their limiter-detector arrangements.

There is a minor bother associated with the use of multiplex. Suppose we try to receive such a signal with a tuner that has a bandwidth of 200 kc and falls off sharply outside this band. Twice during each audio cycle one or the other of the subcarrier's sidebands will be forced out of the pass band. Each time this happens the numerical frequency deviation occurring at a subcarrier rate drops by 2:1. In our numerical example the IF output is not always deviated ±15 kc at a 50-kc rate but at the audiopeaks the deviation drops to ±7.5 kc. As a check on this notion the writer simultaneously modulated a signal generator with 50 kc and 100 ~. The output of a tuner was then connected through a high-pass filter to an oscilloscope. The pattern showed that in fact the 50-kc output was varied by about 4 db at a 200 ~ rate.

The foregoing contrast between paper and laboratory work is an interesting one. There is no doubt that the use of a subcarrier causes a widening of the transmitted spectrum and at first sight we should expect trouble. Experiment shows, however, that this widening of the spectrum is not accompanied by any significant change in interference, even when the most selective commercially available tuners are used.

For once we are in luck.

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Low-Field *X*-Band Ruby Maser*

A solid-state maser utilizing ruby[1] has been operated at an *X*-band signal frequency of 9540 mc using an *X*-band pump frequency of 10,850 mc. The maser was operated at low magnetic fields (350 gauss) oriented at $\theta = 32°$ to the ruby *C*-axis.

To obtain spin temperature inversion in a three-level maser, it is necessary[2] that either $f_{23}/f_{12} > \tau_{23}/\tau_{12}$ for amplification at frequency f_{12}, or that $f_{12}/f_{23} > \tau_{12}/\tau_{23}$ for amplification at frequency f_{23}, where the three energy levels have been numbered from 1 to 3, and f_{12}, f_{23} and τ_{12}, τ_{23} are the frequencies and spin-lattice relaxation times, respectively, of the two intermediate transitions.

In most three-level ruby masers previously operated,[3,4] these two relaxation times were approximately equal, so that good inversion was obtained by making the

* Received by the IRE, May 15, 1959. This work is part of a Ph.D. dissertation, Polytechnic Institute of Brooklyn, Bklyn, N. Y.

[1] G. Makhov, C. Kikuchi, J. Lambe, and R. W. Terhune, "Maser action in ruby," *Phys. Rev.*, vol. 109, pp. 1399–1400; February 15, 1958.

[2] N. Bloembergen, "Proposal for a new type solid-state maser," *Phys. Rev.*, vol. 104, pp. 324–327; October 15, 1956.

[3] R. W. DeGrasse, E. O. Schulz-DuBois, and H. E. D. Scovil, "Three-level solid-state traveling-wave maser," *Bell Sys. Tech. J.*, vol. 38, pp. 305–334; March, 1959.

[4] F. R. Arams and S. Okwit, "Tunable *L*-band ruby maser," Proc. IRE, vol. 47, pp. 992–993; May, 1959.

idler frequency f_{13} several times the signal frequency f_{12}. However, we, as well as others,[5] found it difficult to obtain this type of "frequency-ratio" maser operation[6] in ruby at low magnetic fields for an L-band signal frequency $f_{12} = 800$ to 2000 mc for a large range of magnetic field orientations. Our measurements showed that for θ near 32°, the magnetic absorption in the L-band transition increased when pump power was applied. Also, the spin temperature in the idler transition f_{23} becomes more positive when pump power is applied, and, in fact, maser operation at f_{23} is obtained (Fig. 1). Evidently, this is "relaxation-time ratio" operation[6]—that is, $\tau_{1\cdot}$ is considerably shorter than τ_{23} to overcome the unfavorable frequency ratio $f_{12}/f_{23} \approx 1/6$. Measurements of relaxation times and of the influence of the fourth energy level are being made to investigate this.

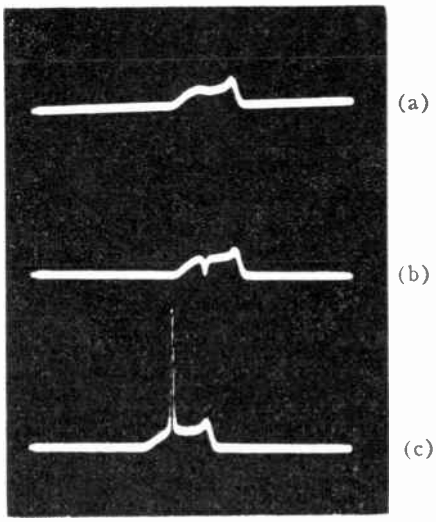

Fig. 1—Oscilloscope display of power reflected from maser cavity as a function of frequency. (a) No pump power. (b) Pump power sufficient to overcome cavity losses. (c) Maser gain with high pump power.

The cavity (operating in the TE_{10} waveguide mode) used a 100-carat ruby crystal having a 0.05-per cent residual chromium content. The measured voltage-gain bandwidth product was 4 mc at a helium bath temperature of 4.2°K. Pump power was approximately 50 milliwatts.

Perhaps the type of operation reported here may find application in millimeter-wave masers using paramagnetic materials with large zero-field splittings. In this application, the relatively low-pump frequency and low-magnetic field requirements of this type of operation may be attractive, even though the achievable gain-bandwidth product will be lower than that for masers using more favorable frequency ratios.

Stimulating discussions with S. Okwit (AIL), M. Birnbaum (Polytechnic Institute of Brooklyn), and S. Shapiro (Harvard University) are gratefully acknowledged.

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[5] Private communication.
[6] E. O. Schulz-DuBois, H. E. D. Scovil, and R. W. DeGrasse, "Use of active material in three-level solid-state masers," *Bell Sys. Tech. J.*, vol. 38, pp. 335–352; March, 1959.

A Surface Wave Parametric Amplifier*

In recent years there have been numerous advances in the theory[1–3] and development[4] of parametric amplifiers. The concept has been extended to include traveling-wave type parametric amplifiers[5–7] for extension of the frequency range to the microwaves. The devices proposed to date have been of the transmission-line type, involving cross-coupling by means of nonlinear mutual inductances,[6,7] or nonlinear capacitances.[5,6] While the inductances and capacitances considered are assumed to be distributed elements, they are all limited to the purely transverse waves, which are not usable at the shorter microwave wavelengths.

A structure is proposed here which should allow the extension of traveling-wave parametric-amplifier concept to the higher microwave frequencies. This structure is the "H-guide"[8,9] with a slab of ferroelectric material replacing the usual slab of dielectric material between the two conducting planes (see Fig. 1). This line, operated in the dom-

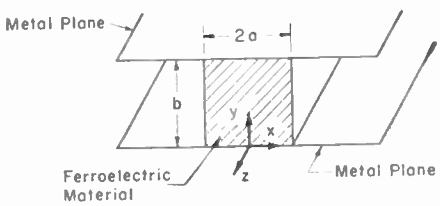

Fig. 1.

inant TE_{10} mode,[8,9] has these advantages:

1) The parallel-plane configuration allows the use of a dc-biasing field for the ferroelectric material, which would not be possible in a closed waveguide.

2) The TE_{10} mode has a zero frequency cutoff, and therefore has the necessary single mode bandwidth to support the frequencies of a two- or three-frequency system.

3) For the surface wave, the adjustable parameters of slab width, dielectric constant, and spacing between the plates are at the disposal of the designer for optimum electrical performance.

4) The adjustable parameters are also an advantage when the operating wavelength has become so short that the size of a conventional waveguide would impose serious problems of mechanical tolerance and fabrication. That is, with "loose" surface-wave "binding," $(\lambda_g \to \lambda_o)$, the entire structure may be made many times larger than conventional waveguide size.

5) Finally, losses in such an open structure are generally lower than in rectangular guide (containing the same material).[9] This is especially important when the use of lossy ferroelectric materials is considered.

The operation of this line as a traveling-wave parametric amplifier would be analogous to the low frequency (transmission line) model,[5,6] where variable capacitors along the line are modulated by a pumping wave to have the following time-length dependence:

$$C(z, t) = C_o\left[1 + \frac{\xi}{2}\exp j(\omega t - \beta z) + \frac{\xi}{2}\exp - j(\omega t - \beta z)\right] \quad (1)$$

where

ω = pump frequency
β = pump propagation constant
ξ = amplitude of the variable part of the capacitance.

In this model, the solutions of coupled transmission line equations, one at the signal frequency (ω_1) and the other at the idler frequency (ω_2), yield dominant growing waves at these two frequencies. For the degenerate case ($\omega_1 = \omega_2$), the signal-wave solution is of the form

$$V_1(z, t) = a_1 \exp(\alpha_1 z) \exp j(\omega_1 t - \beta_1 z) \quad (2)$$

where

$$\alpha_1 = 1/4\, \xi\beta_1$$
$$\beta_1 = \omega_1\sqrt{LC_0}$$

if

$$\omega_1 + \omega_2 = \omega$$
$$\beta_1 + \beta_2 = \beta.$$

In the case of the TE_{10} mode on an H-guide line of ferroelectric material, the derivation is very similar to that for the LF case. It is assumed that the ferroelectric slab is pumped with high power at a frequency ω such that the electric displacement of the low-level signal (or idler) frequency has the form

$$D_{y_1}(x, z, t) = \epsilon E_{y_1}(x, z, t) + \epsilon_0 E_{y_1}(x, z, t) \cdot [\chi_r \exp j(\omega t - \beta z) + \chi_r \exp -j(\omega t - \beta z)] \quad (3)$$

where

χ_r = amplitude of the variable part of the electric susceptibility.

The derivation, involving the three components (E_y, H_x, and H_z) of the signal frequency, then follows from the Maxwell curl relations to give a coupled-wave equation at the signal frequency. The result, again for the degenerate case of $\omega_1 = \omega_2$, is

$$E_{y_1}(x, z, t) = a_1(x) \exp(\alpha_g x) \exp j(\omega_1 t - \beta_{g_1} z) \quad (4)$$

where

$$\alpha_g = \left(\frac{\lambda_{g_1}}{\lambda_{o_1}}\right)\frac{\chi_r \beta_o r}{2}$$

$$\beta_0 = \frac{\omega_1}{c} = \frac{2\pi}{\lambda_{o_1}}$$

* Received by the IRE, May 13, 1959.
[1] J. M. Manley and H. E. Rowe, "Some general properties of nonlinear elements—Part I. General energy relations," PROC. IRE, vol. 44, pp. 904–913; July, 1956.
[2] M. T. Weiss, "Quantum derivation of energy relations analogous to those for nonlinear reactances," PROC. IRE, vol. 45, pp. 1012–1013; July, 1957.
[3] H. A. Haus, "Power-flow relations in nonlinear media," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 317–324; July, 1958.
[4] Solid-State Circuits Conference (IRE-AIEE), University of Pennsylvania, Philadelphia, Pa., February 12–13, 1959.
[5] R. S. Englebrecht, "A low-noise nonlinear reactance traveling-wave amplifier," PROC. IRE, vol. 46, p. 1655; September, 1955.
[6] P. K. Tein and H. Suhl, "A traveling-wave ferromagnetic amplifier," PROC. IRE, vol. 46, pp. 700–706; April, 1958.
[7] P. K. Tein, "Parametric amplification and frequency mixing in propagating circuits," *J. Appl. Phys.*, vol. 29, pp. 1347–1357; September, 1958.
[8] R. A. Moore and R. E. Beam, "Duo-dielectric parallel-plane waveguides," *Proc. NEC*, vol. 12, pp. 689–705; 1956.
[9] M. Cohn, "Propagation in a dielectric-loaded parallel plane waveguide," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT 7, pp. 202–208; April, 1959.

$$r = \frac{\text{Power propagating in the ferroelectric}}{\text{Total power in the wave}}$$

if

$$\omega_1 + \omega_2 = \omega$$

$$\beta_{0_1} + \beta_{0_2} = \beta_0$$

where

$$\begin{cases} \beta_{0_1} = (\text{Prop. constant at } \omega_1) = 2\pi/\lambda_{0_1} \\ \beta_{0_2} = (\text{Prop. constant at } \omega_2) = 2\pi/\lambda_{0_2} \\ \beta_0 = (\text{Prop. constant at } \omega) = 2\pi/\lambda_0. \end{cases}$$

An analysis of the effect of an error term on the condition on propagation constants of the type

$$\beta_0 = \beta_{0_1} + \beta_{0_2} + \Delta\beta \tag{5}$$

also yields results similar to those for the low-frequency model.[5,6] The expression for the gain becomes

$$\alpha_0' = \left[\left(\frac{\lambda_{0_1}}{\lambda_{0_1}}\right)^2 \frac{\beta_{0_1}'^2 \chi^2}{4} - \frac{1}{16}\frac{(2\beta_{0_1}' - \frac{1}{2}\Delta\beta)^2}{\beta_{0_1}'^2}(\Delta\beta)^2\right]^{1/2} \tag{6}$$

where

$$\beta_{0_1}' = \beta_{0_1} + \tfrac{1}{2}\Delta\beta.$$

This reduction in gain is controllable, since λ_0/λ_0 and $\lambda_{0_1}/\lambda_{0_1}$ are determined by the line parameters.

Losses have been assumed to be small enough that the usual assumptions for a lossless analysis may be used. Attenuation due to dielectric and wall losses is then included from the unperturbed line characteristics.[9]

The principle of amplification on such a structure having been established, the next problem is that of the ferroelectric material to be used. Surprisingly enough, computations show that gain is possible even with presently known $BaTiO_3$-$SrTiO_3$ mixtures. The following is a tabulation of the estimated performance of a parametric *H*-guide line, calculated from published data on this type material:[10,11]

Material:

Polycrystalline $BaTiO_3$-$SrTiO_3$

$\epsilon/\epsilon_0 = 2000$, $\tan\delta = 0.1$ } assuming dc-bias field of 12.8 kv/cm[11]

$\chi/E(\text{pump}) = 100$ (per kv/cm of pumping field.[11])

Electrical Characteristics:

$E(\text{pump}) = 1.18$ kv/cm, $\chi = 118$
$2a/\lambda_{0_1} = 0.01$, $\lambda_{0_1}/\lambda_{0_1} = 0.0289$,
$b/\lambda_{0_1} = 0.0266$
$r = 0.760$, $\Delta\beta\lambda_{0_1} = 0.62\pi$ nepers
Attenuation: $\alpha\lambda_{0_1} = 4.68\pi$ nepers
Initial gain: $\alpha_0\lambda_{0_1} = 22.5\pi$ nepers
Length for gain > attenuation:[12]
$l_0/\lambda_{0_1} = 0.072$
Net gain (in length "l_0") ≈ 19.3 db.

These operating characteristics could be attained only by use of a pulsed *X*-band magnetron, with one-kw peak power, as a pumping oscillator. Published data for mixtures having over 40 per cent strontium titanite,[10] indicate that the relaxation frequency is higher than 10 kmc. Thus, it seems reasonable to assume that pulsed operation as shown above could be attained by use of some material like a 60–40 per cent mixture of the two titanites with an *X*-band magnetron as pump to amplify 5-kmc signals.

A much more practical device would be possible if polycrystalline titanites could be suspended in a nonpolar binder, such that the following would hold:

Material:

$\epsilon/\epsilon_0 = 100$, $\tan\delta = 0.01$ } dc-biasing again used
$\chi/E = 5.0$ (per kv/cm of pump field).

A line could then be built which would have the following characteristics:

Electrical Characteristics:[9]

$E(\text{pump}) = 1.14$ kv/cm, $\chi = 5.7$
$2a/\lambda_{0_1} = 0.05$, $\lambda_{0_1}/\lambda_{0_1} = 0.1244$,
$b/\lambda_{0_1} = 0.006$
$r = 0.844$, $\Delta\beta\lambda_0 = 0.88$ neper
Attenuation: $\alpha\lambda_{0_1} = 0.33$ neper
Initial gain: $\alpha_0\lambda_{0_1} = 1.8$ nepers
Length for net gain: $l_0/\lambda_{0_1} = 2.56$
Net Gain ≈ 19.3 db.

This device could be operated with a 200-watt (CW) pump, with pump frequencies in excess of 10 km, since relaxation frequencies of some of the barium-strontium titanites can evidently be raised as mentioned above.[10] Additional encouraging evidence has been found that would indicate that the relaxation frequencies of ferroelectrics can be raised even more. Single domain crystals have been found to have dielectric constant vs frequency behavior[13] which put the relaxation frequency above 50 kmc.

Thus, it would appear that with further development in ferroelectric materials, the *H*-guide parametric amplifier holds promise as the millimeter waveform of the traveling-wave parametric amplifier.

The author should like to acknowledge stimulating discussions and advice on this subject from M. Cohn, C. F. Miller, and J. M. Minkowski.

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[10] J. G. Powles and W. Jackson, "The measurement of the dielectric properties of high-permittivity materials at centimeter wavelengths," *Proc. IEE*, vol. 96, III, pp. 383–389; September, 1949.

[11] L. Davis and L. G. Rubin, "Some dielectric properties of barium-strontium titinate ceramics at 3000 megacycles," *J. Appl. Phys.*, vol. 24, p. 1194; September, 1953.

[12] The gain at the signal frequency will decrease exponentially with length, due to attenuation of the pump power along the line. The length "l_0" is the point where the gain has decreased to the point of equaling the attenuation at the signal frequency.

[13] T. S. Benedict and J. L. Durand, "Dielectric properties of single domain crystals of $BaTiO_3$ at microwave frequencies," *Phys. Rev.*, vol. 109, p. 1091; February, 1958.

Relaxation Phenomena in Diode Parametric Amplifiers*

* Received by the IRE, May 13, 1959.

Relaxation oscillations have been observed in *S*, *C*, and *X* band parametric amplifiers utilizing CW pump sources and no other signal inputs. These oscillations occur when certain diodes are operated with open-circuited or high-resistance dc paths, and are allowed to develop a negative self-bias through the charging path consisting of the parallel combination of the nonlinear resistance and capacitance of the semiconductor junction. The effect was first observed as a Fourier spectrum at signal and idle microwave frequencies, and later as an audio-frequency voltage waveform appearing across the diode (Fig. 1).

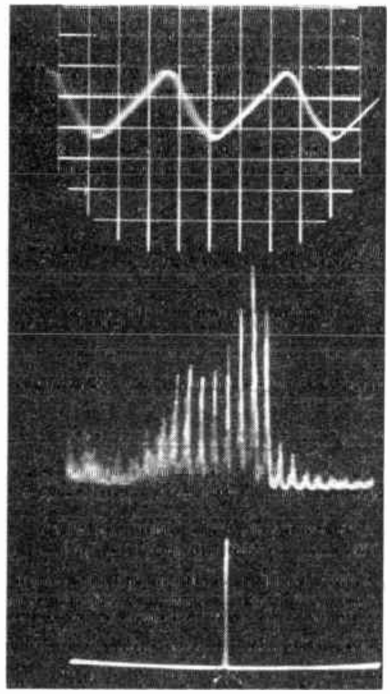

Fig. 1—(a) Diode voltage waveform; (b) typical relaxation oscillation microwave spectrum; (c) stable oscillation for increased pump power.

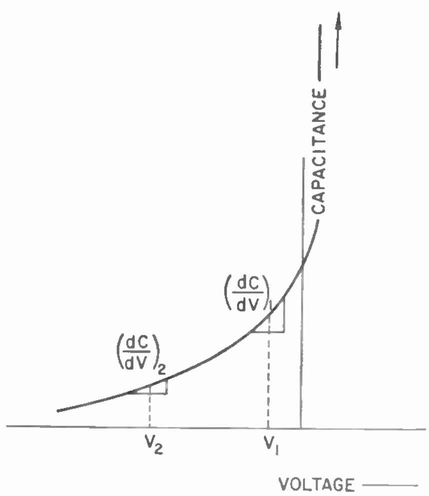

Fig. 2—Capacitance vs voltage characteristic of a diode.

The mechanism is believed to be the following (Fig. 2): As pump power is increased, the diode charges to a bias V_1. At this point, corresponding to a critical pump power P_1, the slope of the capacity-voltage curve is sufficient to cause generation of oscillations at both "signal" and "idle" frequencies; these induce a further bias buildup to V_2. At V_2, however, the capacitance gradient is insufficient to maintain these cavity oscillations for the given amount of pump power, and the system relaxes back to V_1. A further cause for modulation of oscillations arises since the signal, idle, and pump cavities are detuned by the varying capacitance. The frequency, waveform, and amplitude of the diode voltage vary with the type of diode used (germanium point contact or silicon diffused) and the amount of pump power applied; frequencies between 20 and 100 kc have been observed with peak-to-peak amplitudes on the order of 0.1 volt. The period is correlative with the known RC time constant of the diode.

The microwave oscillations, as observed on a spectrum analyzer, exhibit sidebands spaced in frequency by the relaxation-oscillation frequency. A spectrum appears at both signal and idle frequencies in a nondegenerate amplifier, and at $\frac{1}{2}\omega_{\text{pump}}$ in a degenerate case. The spectrum is that of a frequency and amplitude modulated RF signal. As the pump power is increased beyond P_1, the spacing between consecutive sidebands increases since the average capacitance, and consequently the time constant, is decreased. Beyond a second critical value of the pump, P_2, the sidebands disappear but a strong monochromatic oscillation remains (lower part of photograph) and the bias assumes a constant value. This phenomenon is also consistent with the preceding explanation if account is taken of the fact that for high pump powers operation shifts to a flatter region of the capacitance-voltage curve.

Similar relaxation phenomena have already been observed in ferromagnetic single crystals.[1]

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[1] M. T. Weiss, "Microwave and low frequency oscillation due to resonance instabilities in ferrites," *J. Appl. Phys.*, suppl. to vol. 30, pp. 146S–147S; April, 1959.

Experiment Indicating Generation of Submillimeter Waves by an Avalanching Semiconductor*

Experimental Basic Arrangement

Fig. 1 shows a diagram of an experimental arrangement, originally made for investigation of some problems in connection with field emission in air at electrode distances of around 1 micron. The cathode *k* was a needle with a nose radius of 25–35 microns. Tungsten, molybdenum, steel, and goldplated steel were used successively. Much work was done with ordinary phonograph pickup needles. By means of a micromanipulator, the cathode needle *k* could be separated from the anode *p* with an accuracy better than one third of a micron. The anode *p* was made of tungsten, molybdenum, platinum, steel, nickel, copper, silver, and brass. A voltmeter m_I was used as a combined microampere meter (max. 50 μa) and gap series resistor (5 megohms), and another voltmeter m_E was used for measuring the voltage across gap and voltmeter m_I in series. At spacings of around 1 micron, the field emission current was of such a small magnitude that it could not be read on the meter m_I at voltages smaller than 300 v which is the minimum sparking potential at atmospheric pressure.

* Received by the IRE, November 4, 1958; revision received, February 11, 1959.

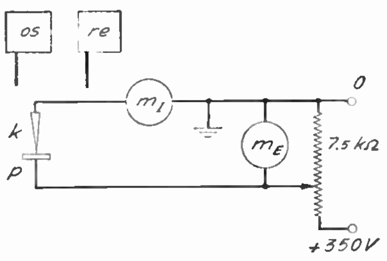

Fig. 1—Diagram of the experimental basic arrangement.

Small Gap Discharges

When the voltage was raised slightly above 300 v, a corona discharge was formed around the nose of the cathode. The corona could easily be seen in a straight tube microscope. The discharge could also be followed by means of an oscilloscope *os* loosely coupled to the cathode *k*. Alternatively, the corona discharge could readily be heard in a radio receiver *re*. The resulting average current was often around 10 μa. In cases where the anode was made of a material with a comparatively low melting point, *e.g.*, copper, silver, or brass, the corona discharge caused a transfer of matter,[1] resulting in the formation of a circular embankment on the anode. Fig. 2 shows how such an embankment *b* is built on the anode *p* around the cathode *k*. The material in the embankment comes primarily from the cathode. Mechanically, the embankment is surprisingly strong. Its electric resistivity is high. Observations indicate that the material is of semiconductor character. Low frequency oscillations in the circuit will often result from light contacts between the cathode and the embankment. Voltage, external series resistance, and external parallel capacitance influence the frequency of these oscillations, which probably are built up on the basis of avalanche breakdown at the contact area between the cathode and the embankment, *cp*, an ordinary glow discharge oscillator.

When the embankment is built up to such an extent that only a few microns separate it from the cathode, the corona discharge ceases and a steady current can be maintained across the gap. Often, a steady gap current is around 10 μa at a total voltage of around 270 v, corresponding to roughly 200 v across the gap. The emission can be increased to around 50 μa without any tendency to corona discharge or sparking. The gap voltage is practically independent of the emission current within these limits.

[1] R. Holm, "Electric Contacts," H. Gebers, Stockholm, Sweden, pp. 309–323; 1946.

Hitherto, it has not been possible to obtain a similar embankment and a similar steady emission current in cases where the anode material has a relatively high melting point, *i.e.* tungsten, molybdenum, platinum, steel, and nickel.

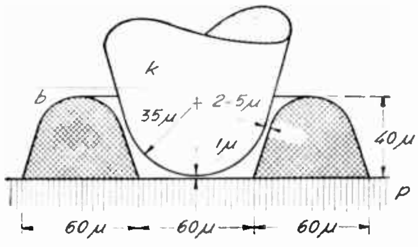

Fig. 2—A corona discharge results in the formation of a circular embankment *b* fastened on the anode *p* and surrounding the cathode *k*.

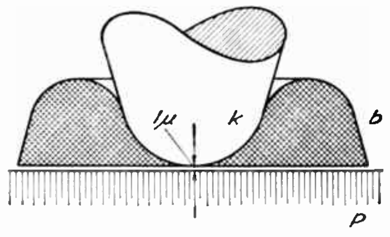

Fig. 3—The embankment is removed from the anode.

It has been found that the embankment may be removed from the anode as shown in Fig. 3. The cathode has been moved downwards to good contact with the inside of the embankment. The adherence between cathode and embankment is often so strong that the embankment comes loose from the anode, when the cathode is withdrawn. This electrode configuration is suitable for a visual investigation of the space between the cathode nose and the anode. As a rule, the steady current is associated with a diminutive luminous discharge between the cathode nose and the anode. The discharge generally has a cross section less than 1 micron at electrode distances of around 1 micron. Cases have been observed, however, where a steady current has been associated with a somewhat more diffuse luminous discharge with a cross section of around 10 microns. An increase of the emission current is associated with an increase of the discharge luminosity. It is believed that the luminosity is an indication of the presence of positive ions in the discharge. Due to the fact that the gap is of the same order of magnitude as the electron mean free path in air at atmospheric pressure, the amount of current carried by positive ions is probably very small as compared with the current carried by electrons. The ions may, however, give rise to an increased potential gradient, thereby causing an increase of field emission current in the gap.[2]

[2] W. S. Boyle, P. Kisliuk, and L. H. Germer, "Electrical breakdown in high vacuum," *J. Appl. Phys.*, vol. 26, pp. 724–725; June, 1955.

Current Jumps

With electrode configurations according to both Fig. 2 and Fig. 3, a small increase above a certain value of the voltage, measured with m_E, occasionally causes a sudden jump in the emission current, measured with m_I. The jump may be from around 5 μa to around 15 μa. Under such conditions, it is impossible to adjust the emission current to values between these two. Above the jump, the emission current can readily be increased to around 50μa by increasing the voltage as measured with m_E. Fig. 4 shows an example of the relationship between emission current and voltage above the jump.

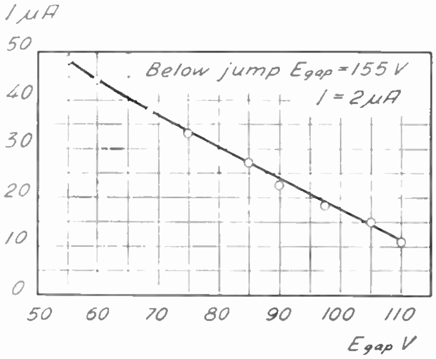

Fig. 4—Relationship between the current I and the gap voltage E_{gap} above a current jump.

It was believed that these jumps were caused by a transition on the current-voltage characteristic of the discharge. A visual inspection of the space between cathode nose and anode showed, however, that the current jumps occurred under conditions where no luminous discharge could be observed. It was concluded that the current jumps are not caused by conditions which are connected with emission currents in the free space between cathode and anode. Thus, the above mentioned possibility of transitions on the current-voltage discharge characteristic of such emission current was ruled out.

A thorough visual inspection of the cathode-anode space under conditions of current jumps seemed to indicate that small particles shorted the gap. Consequently, a very small portion of an embankment was taken loose and moved to a cathode-anode gap of a few microns magnitude. It was found that also in this case a current of the order of 10 μa at gap voltages of around 200 v can be maintained. As in the case of the free-space discharge, the current can be increased to around 50 μa. Furthermore, it was found that electrode pressure on the material taken from the embankment, and voltage across the material, can be so adjusted that current jumps are produced, voltages and currents being of the same magnitude as mentioned earlier. It was concluded that the jumps are caused by avalanche breakdown in the embankment material.

Tuning the Cathode

Avalanche breakdown in silicon diodes has been shown to be associated with generation of microwave transients in the 9 kmc region.[3] Attempts have been made to find out whether microwaves are generated also in this case. The accessible equipment has not been well suited for such purpose, however, and no positive results have been obtained as far as detection of microwaves is concerned. An experiment has been carried through, however, which seems to indicate generation of submillimeter waves with a wavelength of around 100 microns.

In Fig. 5 the cathode k consists of a tungsten wire with a diameter of 30 microns. The end of the cathode wire has been well rounded by electrolytical etching in an 0.6 normal NaOH solution. The length of the wire is approximately 500 microns. The anode p consists of brass and between cathode and anode is placed an embankment portion s, approximately 10–20 microns in length and 5 microns in cross section. A grid g, consisting of gold-plated tungsten wires with a diameter of 5 microns, stretched with a center to center spacing of 25 microns, is threaded on the cathode in such a way that the axis of the cathode is perpendicular to the plane of the grid. The grid is adjusted so that the grid wires on each side of the cathode exert equal contact pressures against the cathode. By means of a micromanipulator, the grid may be slid along the cathode. Further, the cathode and the anode may be moved in relation to each other and in relation to the grid.

If the device is adjusted for a current slightly above the jump, the current drops several microamperes when the grid is placed around 10 microns from the cathode tip, measured axially, [$\simeq(\lambda/4)$]. Current dips have also been found approximately 50 and 100 microns [$\simeq(\lambda/2)$ resp. $\simeq\lambda$] further away from the cathode nose. It has been possible, at times, to cause a current jump instead of a mere current dip when the grid has been adjusted near the cathode nose. Investigations by means of the oscilloscope (Fig. 1) seem to show that the current dips are not associated with mechanical macro-resonances in the device. The experiment supports a hypothesis of generation of submillimeter waves with a wavelength of around 100 microns. It also indicates a method of increasing the radiation of power from the hypothetical generator.

It is suggested that submillimeter oscillations are built up on a basis of avalanches across a potential barrier at the contact area between the cathode nose and the embankment material, *e.g.*, at a dislocation. The capacitance across a diminutive avalanche region, and the resistance of the semiconductor near the avalanche region and between this region and the anode, may form an *RC* network giving rise to an intermittent avalanche current, thus causing the hypothetical generation of submillimeter waves.

This proposal is a micro-analogy to the suggestion which was set forth earlier in this report in connection with the generation of low-frequency oscillations at light-pressure contacts between the cathode and the embankment. The proposal is purely hypothetical, however, and other explanations may still be found.

Influence of Surface States

It appears natural to expect that the properties of a very small semiconductor element are greatly influenced by the surface states. In the arrangement according to Fig. 5, this is indeed the case. The observations correlate qualitatively with investigations on germanium surfaces.[4,5]

Fig. 6(a) shows schematically the conditions which may normally be expected in the case under consideration. The bulk of the semiconductor s is probably of n-type. Adsorbed molecules from the surrounding air, which contains some water vapor, induces donor-like slow states, thus forming an n-type surface.

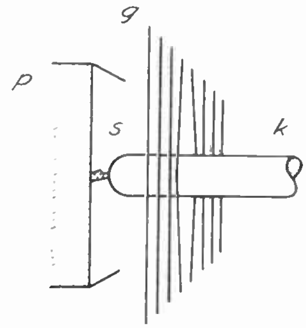

Fig. 5—Evidence of the generation of submillimeter waves is obtained by this arrangement, in which k is a tungsten cathode, diameter 30 microns; s is a particle from an embankment; p is an anode; and g is a grid consisting of gold-plated tungsten wires, diameter 5 microns, stretched with a c-c distance of 25 microns. The grid g may be slid along the cathode k by means of a micromanipulator.

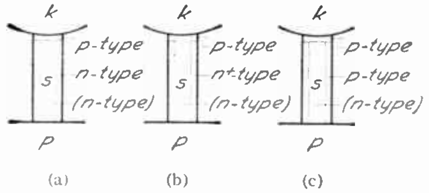

Fig. 6—Variations in surface states by changes of surrounding gas ambients. The embankment particle s is placed between a cathode k and an anode p.

Vapors having an OH radical, *i.e.*, methyl alcohol, acetone, acetic acid etc., will give rise to an increased density of the donor-like slow states as indicated in Fig. 6(b). A corresponding increase of the voltage, necessary to produce an avalanche, is to be expected. Thus, the current through the semiconductor may jump down from values above the jump, when such vapor ambients surround the semiconductor. It is to be expected that an increase of the voltage across the semiconductor will cause a new avalanche. It also appears probable that conditions will relax back to the original, corresponding to surrounding air plus water vapor ambients, when the supply of vapors with an OH radical is stopped. Experiments are in agreement with these expectations. The time constant is around a second in the case of an OH induced n-type slow-state density increase, whereas the relaxation time is of the order of a few seconds.

[3] J. L. Moll, A. Uhler, Jr., and B. Senitzky, "Microwave transients from avalanching silicon diodes," Proc. IRE, vol. 46, pp. 1306–1307; June, 1958.

[4] W. H. Brattain and J. Bardeen, "Surface properties of germanium," *Bell Sys. Tech. J.*, vol. 32, pp. 1–41; January, 1953.

[5] R. H. Kingston, "Review of germanium surface phenomena," *J. Appl. Phys.*, vol. 27, pp. 101–114; February, 1956.

Methyl chloride and carbon monoxide are not expected to influence the conditions prevailing at surrounding air plus water vapor ambients. Experiments have shown that these gases do not interact with the current jumps.

A gas ambient such as ozone induces acceptor-like surface slow states, thus forming a *p*-type surface as indicated in Fig. 6(c). Experiments have shown that the presence of ozone ambients causes an increase of the current through the semiconductor. The change occurs within a few seconds. Under such conditions no jump can be observed as the current is decreased by decreasing the supply voltage. Apparently, the avalanche region is shorted or entirely changed by the *p*-type surface states. When the ozone supply is stopped, a relaxation back to the conditions according to Fig. 6(a) takes place within a few seconds. Current jumps now show up again.

Additional Notes

The negative slope characteristic of the device (Fig. 4) has been used for amplification at frequencies up to around 100 kc. At 1000 c, a voltage amplification of around 15 times has been obtained.

The device is sensitive to changes in contact pressure at current values slightly above the jump value. This has been demonstrated in an experiment using a piece of brass foil, 50 microns thick, as the anode. The foil was fastened to supports about 7 mm apart. The cathode was an ordinary phonograph pickup needle. Normal speech 2 to 3 m from the device causes voice frequency voltages of around 25–50 v across the 5 megohms meter m_l (Fig. 1) in series with the electrode gap.

Acknowledgment

The support of The State Council of Technical Research, Sweden, is gratefully acknowledged. The author is also indebted to Profs. Hannes Alfvén and Erik Rudberg for their interest in the project, and to Dr. Bertil Agdur for several fruitful discussions on a variety of problems.

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Further Notes on Indicated Generation of Submillimeter Waves by an Avalanching Semiconductor*

Alternate Method of Tuning the Cathode

Interaction between a semiconductor avalanche breakdown current and the position of a grid, slid on a cathode lead to the avalanching element, has been reported in the first communication above. The experiment was interpreted as evidence of generation of submillimeter waves. It was mentioned in the same report, however, that the device is sensitive to mechanical vibrations. Therefore, it was considered important to duplicate the experiment under conditions of no mechanical contact between the cathode wire and the laterals of the movable grid.

* Received by the IRE, May 11, 1959.

Fig. 1(a) shows how a tungsten cathode wire *k*, having a diameter of 6 microns, is threaded through a grid *g* with 6 micron tungsten laterals, spaced with a center to center distance of 25 microns. A semiconductor element *s*,[1] having a cross section of around 2 microns and a length of around 10 microns, is placed between the cathode wire and the anode *p*. The grid is kept at cathode potential. By means of a micromanipulator the grid may be moved along the cathode wire without touching it.

Fig. 1(b) shows the relationship between the position of the grid and the current through the device. It is suggested that this relationship is caused by the composition of 1) the curve shown in Fig. 1(c), illustrating the effect of changes in field multiplication at the avalanche region adjacent to the cathode tip, and 2) the curve shown in Fig. 1(d), where the dips are suggested to derive from impedance changes of the cathode wire as seen by a submillimeter wave, generated at the cathode tip. The experiment appears to give additional evidence of generation of submillimeter waves with a wavelength of around 100 microns.

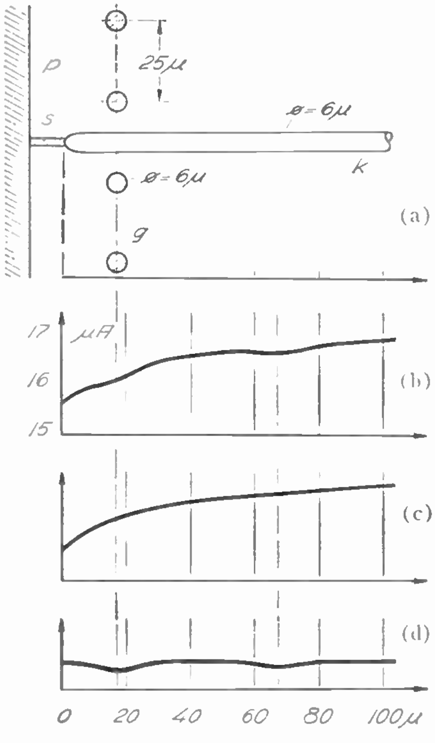

Fig. 1—Electrode arrangement and essential dimensions. Further, the relationship between the avalanche current and the position of the grid is shown.

Frequency Determining Network

Even though the measurements necessarily are lacking in exactness, it appears justified to point out the fact that the apparent wavelength has been in the neighborhood of 100 microns regardless of the size of the semiconductor element (10–40 microns in length), the diameter of the cathode wire (6–30 microns in diameter), and the voltage across the semiconductor, necessary to produce an avalanche breakdown (125–250 volts). The conclusion is drawn that the frequency is determined by factors relating to the immediate neighborhood of the avalanche. It also appears reasonable to draw the conclusion that the avalanche discharge is produced very near the cathode tip and that the resistance between the avalanche region and the cathode tip is comparatively small. Otherwise, the variation in cathode impedance, caused by moving the grid, would hardly be noticeable.

A microscopic investigation of the embankment material has shown that the "bulk" consists of a network of whiskers. These have cross sections of around 0.2 micron. The openings of the mesh are of the order of 0.4–0.8 micron. Fig. 2 shows roughly a typical cross section of an embankment particle.

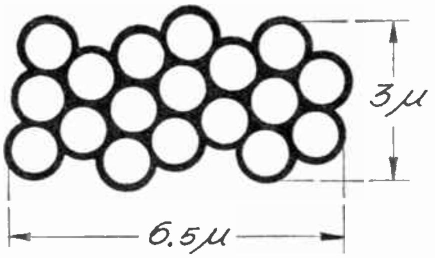

Fig. 2—Section through an embankment particle.

On the basis of the related observations and conclusions, the following hypothesis is suggested. The total capacitance across the junction and between the semiconductor and the cathode in the vicinity of the junction is thought to derive from a great number of extremely small capacitors, having their positive plates coupled in parallel by the resistance of the surrounding bulk material. Besides, each one of these capacitor plates is connected to the anode through the bulk and the bulk-anode interface. It was concluded above that the resistance from the avalanche region to the cathode is low. We will assume that it is low enough to be neglected. As a consequence we will also assume that the negative capacitor plates are coupled in parallel by zero resistance connectors. Fig. 3 visualizes the suggestion. In a semiconductor whisker *w* a diminutive junction *j* is formed adjacent to the tip of the cathode *k*. In addition to the junction capacity other semiconductor-cathode capacitances in the vicinity of the junction are suggested.

Fig. 4 shows the situation diagrammatically. The positive plates of the condensers $c_{j1}, c_{j2}, \cdots, c_{jn}$ are interconnected by the resistors $r_{j1}, r_{j2}, \cdots, r_{j(n-1)}$. Further, these condenser plates are connected to the anode by the resistors $r_{b1}, r_{b2}, \cdots, r_{bn}$. We will assume that breakdown is produced in the condenser c_{j1}. It is suggested that the conditions roughly correspond to the case shown in Fig. 5. The avalanching condenser is here represented by the condenser c_{j1} and the gas discharge tube *v*, the capacitance of which is neglected. One side of the avalanching capacitor is in direct contact with the cathode *k*. The other side

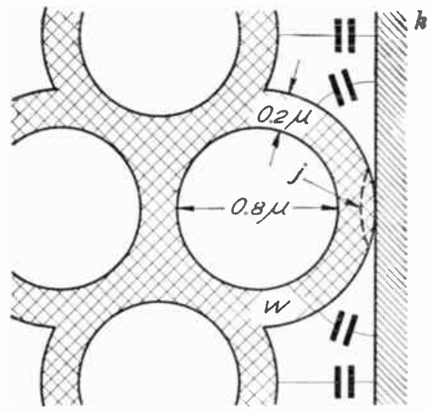

Fig. 3—An embankment whisker w in contact with the cathode k. A junction at j is suggested. At reverse bias this junction gives rise to a capacitance between the whisker and the cathode. Other capacitances between whiskers and cathode in the vicinity of the junction are shown.

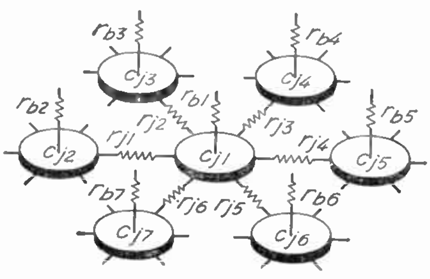

Fig. 4—Semiconductor capacitances and resistances at reverse bias.

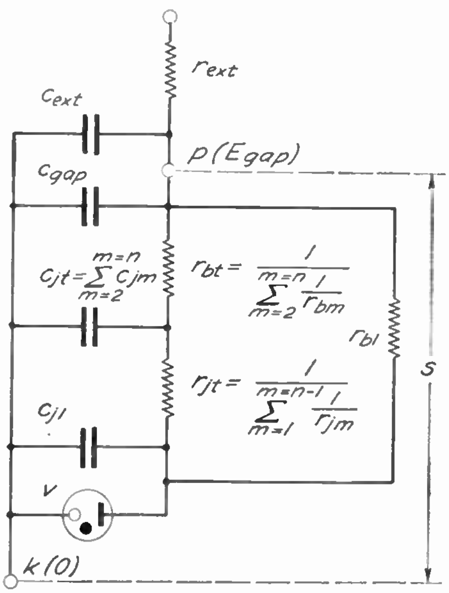

Fig. 5—Suggested RC networks in and outside the semiconductor s at reverse bias.

of the condenser is connected to the condenser

$$c_{jt} = \sum_{m=2}^{m=n} c_{jm}$$

through the resistor

$$r_{jt} = \frac{1}{\sum_{m=1}^{m=n-1} \frac{1}{r_{jm}}}.$$

Further, the condenser c_{j1} is connected to the anode p through the resistor r_{b1}. The condenser c_{jt} is connected to the anode p through the resistor

$$r_{bt} = \frac{1}{\sum_{m=2}^{m=n} \frac{1}{r_{bm}}}.$$

The gap capacitance c_{gap} and the external capacitances c_{ext} are coupled in parallel across the semiconductor element s between cathode and anode. The external resistor r_{ext} completes the picture. It seems reasonable to suggest that $c_{jt} \gg c_{j1}$, and $r_{b1} \gg r_{jt}$. Hence, presupposing an avalanche breakdown formation time shorter than $\tau = r_{jt} \cdot c_{j1}$, oscillations may start. The frequency of these oscillations will be determined by the avalanche breakdown formation time and the time constant of the network $c_{j1}r_{jt}$. The influence of the resistor r_{b1} is neglected both here and in the following discussion, the reason being that $r_{b1} \gg r_{jt}$ and $r_{b1} \gg r_{bt}$. The effect of recombination, of diffusion across the junction, and of current of Zener or avalanche type, not leading to breakdown, is also neglected. Further, the effect of stray capacitances across the resistors r_{jm} and r_{bm} is neglected. It is to be expected that the values of c_{j1} and r_{jt} will vary considerably during a cycle due to the movement of the carriers, produced by the avalanche.

Generation of Low-Frequency Oscillations

The discharges increase the current through the semiconductor. This, again, occasions an increased voltage drop across the resistors r_{bt} and r_{ext}. The effect may be that the voltage across c_{jt} and, consequently, the maximum voltage across c_{j1} assume values, which are too low to produce breakdown. Therefore, the discharges may cease, thereby causing the voltage across c_{jt} to increase until a new series of discharges builds up. Apparently, this condition will result in additional oscillations, the frequency of which is determined or influenced both by conditions in the avalanche region and by the network consisting of c_{jt}, c_{gap}, c_{ext}, r_{bt}, and r_{ext}. It should be borne in mind that r_{bt} probably decreases somewhat with increasing current, due to avalanche-produced carriers. Experimental work has seemingly verified the possibility of obtaining such oscillations. The maximum amplitude and frequency is obtained at supply voltages corresponding to the minimum avalanche breakdown voltage of the device. At somewhat increased supply voltages, the amplitude and frequency is lowered. Only a small increase of the supply voltage is needed to stop the oscillations. The maximum frequency is often around 1000 c. The oscillations can easily be detected by means of the oscilloscope in the basic arrangement described in the first communication.

These oscillations seem to be different from the low-frequency oscillations which were related. Experiments have shown that those oscillations do not stop at a somewhat increased supply voltage. Besides, the oscillation frequency is considerably higher in that case—often of the order of 15 kc. It is suggested that those oscillations are produced when the negative resistance across the semiconductor numerically becomes greater than r_{ext}. Under such conditions heat phenomena, unlinearities, or other factors may be expected to occasion oscillations. Another possibility is that the avalanche breakdown formation time becomes longer than the time constant of the network $c_{j1}r_{jt}$, in which case the network consisting of c_{jt}, c_{gap}, c_{ext}, r_{bt}, and r_{ext} may determine the frequency of generated low-frequency oscillations.

Additional Note

The curve according to Fig. 1(c) appears to indicate a possible method of high impedance control of the current—preferably an avalanche based current—through a semiconductor. Fig. 6 shows a hypothetical example. Changes of the potential of the control electrode g are expected to cause changes of the current through the semiconductor element s, placed between the pointed cathode k and the anode p.

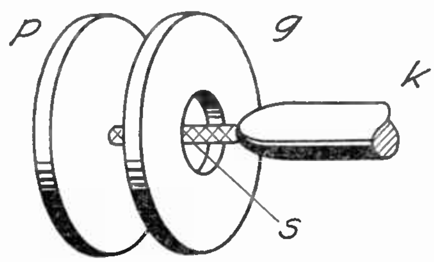

Fig. 6—Suggested arrangement for high impedance control of the current in a small semiconductor element s between an anode p and a pointed cathode k, g being the control electrode.

Acknowledgment

The author is indebted to the State Council of Technical Research, Sweden, for supporting the project, to Prof. J. O. Nielsen for suggesting the reported cathode tuning experiment as a complement to the previous work, and to Prof. H. Hojgaard Jensen and Dr. N. Meyer for several discussions on semiconductor problems.

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Avalanche Controlled Semiconductor Amplifier*

In a recent publication,[1] the author used analog techniques to depict the interaction between two space-charge regions in a semiconductor. This interaction can be used for control in a variety of semiconductor amplifiers, one of which is considered in an approximate theoretical manner herein.

The device to be considered together with related relevant information is shown

* Received by the IRE, January 7, 1959.

[1] L. J. Giacoletto, "Analog solution of space-charge regions in semiconductors," Proc. IRE, vol. 46 pp. 1083–1085; June, 1958.

in Fig. 1. The structure is essentially identical to a conventional transistor, but the mode of operation is considerably different. A *n-p-n* structure is considered for convenience in this analysis which can be easily modified for a *p-n-p* structure. Suppose the collector electrode is biased in the reverse direction until avalanche breakdown occurs. According to S. L. Miller's[2] work, the collector-to-source voltage, V_{CS}, corresponding to avalanche breakdown voltage, V_A, in germanium with a Shottky "abrupt" junction is given by

$$V_{CS} = V_A = \pm 22.2 \times 10^{16}[\pm(N_a - N_d)]^{-0.725}$$
$$= \pm 1980[\pm B]^{-0.725} \text{ volts} \quad (1)$$

where like signs go together and are chosen so that the quantities within the brackets are positive, N_a and N_d are acceptor and donor impurity concentrations, respectively (impurities/meter³), and

$$B = \frac{N_a - N_d}{n_i}. \quad (2)$$

B is the impurity doping of the semiconductor normalized by n_i, the electron (or hole) carrier density in the intrinsic semiconductor ($n_i = 2.4 \times 10^{19}$ carriers/meter³ in germanium at near room temperature, 300°K). The application of the voltage, $V_{CS} = V_A$, causes complete depletion of mobile carriers in a region of the germanium given by the depletion width, W_A,

$$W_A = -38.15 \times 10^{-5}[\pm B]^{-0.862} \text{ meters.} \quad (3)$$

The variation of voltage within the depleted region is parabolic with distance as shown by the right-hand portion of the solid curve shown in Fig. 2. The voltage gradient at the collector, E_c, corresponding to avalanche breakdown field, E_A, is given by

$$E_c = -\left.\frac{\partial V}{\partial x}\right|_{x=0} = E_A$$
$$= \pm 10.37 \times 10^6[\pm B]^{0.138} \text{ volts/meter.} \quad (4)$$

For any collector-to-source voltage, $|V_{CS}| < |V_A|$, Miller[2] has found

$$M = \left[1 - \left(\frac{V_{CS}}{V_A}\right)^n\right]^{-1} \quad (5)$$

where n is a parameter that depends upon the resistivity and resistivity type of the germanium; $n = 4$–6 for "metallic" n on p abrupt diodic junctions, and $n \approx 3$ for "metallic" p on n abrupt diodic junctions. Eq. 5 can also be written as

$$M = \left[1 - \left(\frac{E_C}{E_A}\right)^{2n}\right]^{-1}. \quad (6)$$

It is seen that M is a rapid function of E_C as $E_C \rightarrow E_A$.

Suppose that the semiconductor wafer thickness, W, is larger than W_A. Then, the application of an interaction electrode-to-source voltage, V_{IS}, will cause depletion of mobile carriers from the semiconductor near the interaction electrode diodic junction. When $V_{IS} = V_I$, the two depletion regions just touch at $x = W_A$ as shown by the solid curve in Fig. 2.

[2] S. L. Miller, "Avalanche breakdown in germanium," *Phys. Rev.*, vol. 99, pp. 1234–1241; August 15, 1955.

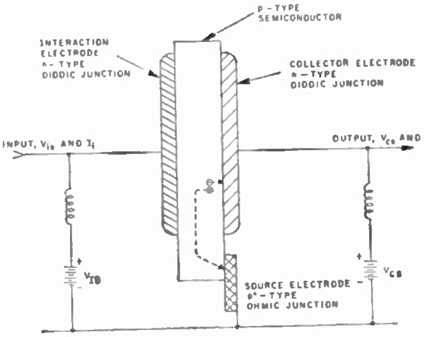

Fig. 1—Structure and circuit arrangement of amplifier.

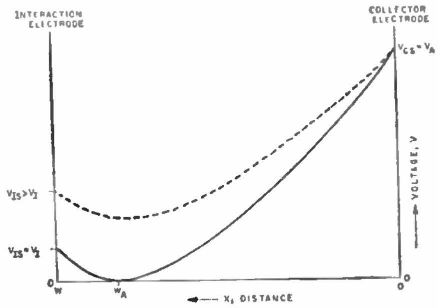

Fig. 2—Variation of voltage with distance within the semiconducter.

$$V_I = \frac{qn_i}{2K\epsilon_0}B(W - W_A)^2$$
$$= 1.36 \times 10^{10}B(W - W_A)^2. \quad (7)$$

In this equation, q is the charge of a hole (1.60×10^{-9} coulombs), ϵ_0 is the permittivity of free space

$$\left(\frac{1}{36\pi} \times 10^{-9} \text{ farads/meter}\right),$$

K is the relative permittivity of the semiconductor (16 for germanium), and the evaluated constant is applicable for germanium. A small contact voltage usually of less than 1 volt has been neglected in (7). If now, V_{IS} is made larger than V_I, a voltage distribution as shown by the dotted line of Fig. 2 is obtained. It is evident that the voltage gradient at the collector is now smaller than E_A and avalanche breakdown is eliminated. By varying V_{IS}, it is thus possible to vary the value of M, and, therefore, control the collector current. The interaction electrode, being a reverse biased diodic junction, will represent a small input conductance. The collector electrode is also a reverse biased diodic junction and because of this will have a small capacitance associated with it. But the output conductance will be large since the multiplied minority carriers will flow out of the collector and the equal majority carriers will flow out of the source.

The collector current, I_C, will be that of a reverse biased diodic junction,

$$I_C = I_{CS}M, \quad (8)$$

where I_{CS} is the saturation current of the junction. M will be a function of V_{IS} and V_{CS} since these voltages determine E_C. Assuming a parallel plane geometry and neglecting the lateral flow of current, the voltage distribution through the semiconductor can be obtained by solving Poisson's equation,

$$\frac{d^2V}{dx^2} = \frac{qn_i}{K\epsilon^0}B, \quad (9)$$

subject to the boundary conditions that 1) $V = V_{CS}$ at $x = 0$ and 2) $V = V_{IS}$ at $x = W$, provided also that

$$(\pm V_{CS})^{1/2} + (\pm V_{IS})^{1/2} > \left(\pm\frac{qn_iB}{2K\epsilon_0}\right)^{1/2} W$$

to insure that (9) is everywhere applicable. The solution for the voltage and the electric field is

$$V = \frac{qn_i}{2K\epsilon_0}Bx^2 - \left(V_{CS} - V_{IS} + \frac{qn_iBW^2}{2K\epsilon_0}\right)\frac{x}{W} + V_{CS}, \quad (10)$$

$$E = -\frac{dV}{dx} = \frac{qn_iB}{K\epsilon_0}\left(\frac{W}{2} - x\right) + \frac{V_{CS} - V_{IS}}{W}. \quad (11)$$

The voltage minimum is located at x_M,

$$x_M = \frac{W}{2} + \frac{K\epsilon_0}{qn_iB}\left(\frac{V_{CS} - V_{IS}}{W}\right), \quad (12)$$

and has the value, V_M,

$$V_M = -\frac{qn_iBW^2}{8K\epsilon_0} - \frac{K\epsilon_0}{2qn_iB}\left(\frac{V_{CS} - V_{IS}}{W}\right)^2 + \frac{V_{CS} + V_{IS}}{2}. \quad (13)$$

The electric field at the collector is

$$E_C = \frac{qn_iBW}{2K\epsilon_0} + \frac{V_{CS} - V_{IS}}{W}. \quad (14)$$

This electric field can be employed in (6) to formulate the dependence of M on V_{CS} and V_{IS}. The device output, g_{cc}, and forward transfer, g_{ci}, small-signal conductances can then be evaluated as

$$g_{cc} = \left.\frac{\partial I_C}{\partial V_{CS}}\right|_{V_{IS}=\text{const.}} = 2n\, I_C \frac{M-1}{E_CW}, \quad (15)$$

$$g_{ci} = \left.\frac{\partial I_S}{\partial V_{IS}}\right|_{V_{CS}=\text{const.}} = -g_{cc}. \quad (16)$$

The device input g_{ii} and reverse transfer, g_{ic} small-signal conductances would be approximately zero. For $g_{ic} \approx 0$ and $g_{ci} = -g_{cc}$, the maximum power amplification is $g_{ci}/4g_{ii}$ and would be large in view of the fact that $g_{ii} \approx 0$. The small-signal conductances are for the idealized device and would be modified significantly by extraneous effects. The most important of these effects would be that associated with lateral current flow to the source electrode.

The preceding equations can be used for carrying out calculations whose results are tabulated below.

1) Choose germanium with $(N_a - N_d) = 2.4 \times 10^{21}$ acceptor impurities/meter³. A smaller value would be desirable for larger W, but greater difficulty would then be encountered with surface avalanche breakdown.

2) $\sigma = 58$ mhos/meter ($\rho \approx 1.7$ ohm cm.).
3) $B = 100$ (2).
4) $V_A = 70$ volts (1).
5) $W_A = 7.22$ microns (3).
6) $E_A = 19.57 \times 10^6$ volts/meter (4).
7) Choose $W = 7.5$ microns, $V_{CS} = 75$ volts, and $V_{IS} = 5$ volts.
8) $E_C = 19.54 \times 10^6$ volts/meter (14).
9) $M = 54.3$ [(6) with $n = 6$ as given in Reference 2].
10) $g_{ei}/I_C = -4.4$ volts (15 and 16).

Larger values of M and g_{ei}/I_C can be obtained by reducing V_{IS}; as $V_{IS} \rightarrow 4.7$ volts, M and g_{ei}/I_C would approach infinity.

Since the movement of both minority and majority carriers is determined almost entirely by electric fields, rather good high-frequency operation should be possible—at least for the idealized device. Impurity grading could be employed to optimize certain operating characteristics.

The avalanche controlled semiconductor amplifier was conceived several years ago while the writer was with the RCA Laboratories, Princeton, N. J.

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A New Very Low-Frequency CW Transmitter for Ionospheric Investigation—KM2XIX*

The California Institute of Technology has recently completed a VLF transmitting station at Shaver Lake, Calif. The transmitter consists of a 20-kw amplifier with a flat frequency response from 4 to 40 kc built by Ling Electronics, Inc. However, propagation experiments will be conducted at 8.4 kc for the present. The signal source is an 8.4-kc crystal oscillator.

The transmitting antenna[1,2] consists of an 8-mile section of a Southern California Edison Co. power line which has been isolated electrically for RF as shown in Fig. 1. The line is approximately one-half wavelength long at 8.4 kc. In order to reduce parasitic effects of the second wire, both wires are driven in phase as shown.

The parallel tuned circuits resonate at transmitted frequency, while presenting negligible impedance to the 60-cps circuit. The series tuned circuits permit coupling the RF energy into the line while preventing the 60-cycle high voltage from appearing across the output transformer of the amplifier.

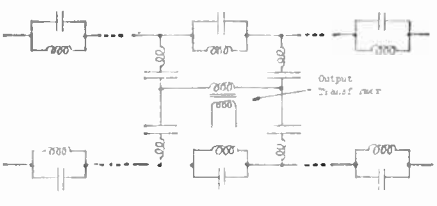

Fig. 1—Schematic diagram of power line used as VLF antenna.

Preliminary experiments have shown that a strong transmitted signal can be easily detected at a distance of 250 km from the transmitter. Measurements beyond this distance have not yet been made.

During station operation, transmission consists of CW on for three minutes and off for one minute, commencing on the hour, except for the period between 28 minutes and 40 minutes past the hour when transmission is one *second* on and 4 *seconds* off. Although time of transmission is still sporadic, a definite transmitting schedule will soon be established and generally will take place on the weekends.

Initial experiments conducted during the afternoon hours and the early morning hours at near vertical incidence have indicated strong fading in the late afternoon until sunset and strong fading at approximately sunrise. The 1-second to 4-second pulsing data are presently being studied for the existence of whistler mode echos.

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R. S. MACMILLAN
W. V. T. RUSCH
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* Received by the IRE, January 23, 1959. This work was supported by the U. S. Air Force, Air Res. and Devel. Command, O.S.R., under Contract No. AF 18(600)-1552.

[1] R. M. Golden, R. S. Macmillan, and W. V. T. Rusch, "A VLF Antenna for Generating a Horizontally Polarized Radiation Field," Pasadena, Calif., AFOSR-TN-57-9 ASTIA Doc. No. AD 115 041; July 1957.

[2] R. M. Golden, R. V. Langmuir, R. S. Macmillan, and W. V. T. Rusch, "Design and Construction of Equipment Used to Operate a Commercial Power Line as a Very Low Frequency Antenna," Pasadena, Calif., AFOSR-TN-58 908, ASTIA Doc. No. AD 204 514; October, 1958.

New Geometrical Properties and their Usefulness for Ionospheric Radio Propagation*

If one chooses an arbitrary point P inside of two concentric circles other than their center, a normal s upon the diameter, both through P, forms a segment Δs which is one-half of the difference between the secants of both circles (Fig. 1). Δs diminishes if s is rotated on P in either sense. For the conditions stated above Δs is a maximum.[1] The proof has been reported elsewhere.[2]

In determining the height of the night airglow the increase of Δs with increasing zenith distance was first utilized by Van Rhijn.[3] Because of the geometrical property stated above, an extension of its utilization for the region below the horizon is possible. If one applies it to propagating radio waves, one arrives at the following conclusion: if a linear radio beam is moved from the zenith to the horizon Δs, the distance inside of a concentric layer of constant thickness increases monotonically and reaches a maximum for zero elevation angle Δ of the beam. For highly elevated antennas, negative elevation angles are possible. Hence, Δs passes through a maximum before the beam is tangential to the earth. Similarly, the angle of incidence ψ of this beam (Fig. 1) upon a spherical concentric layer passes through a minimum for $\Delta \equiv 0$.[4,5] This minimum property of ψ and the maximum property of Δs show symmetry relative to $\Delta = 0$ (Fig. 2). For a radio beam which originates at an antenna height $h_A = 40$ km and for an effective earth radius $R_{eff} = 7972.5$ km, the Δs-distribution as a function of the elevation angle is shown for two absorbing layers, one extending from 60–120 km, the other from 60–90 km. The Δs-distribution has a sharp maximum at $\Delta \equiv 0$. Δs is a minimum for $\Delta = \pm \pi/2$. Δ_{shadow} is the elevation angle for which the radio beam grazes the earth. For elevated antennas it is possible to bring the maximum within the observation range. If Δs is considered the path length of absorption of a radio wave, its maximum absorption will occur at $\Delta \equiv 0$. It is implicit in this discussion that ray paths remain linear and are not refracted inside of the absorbing region. This assumption conflicts less with actual physical conditions the higher the frequency of the radio wave. Since curve 1 (Fig. 2) cannot be normalized to curve 2, it follows by inference that the Δs-distributions contain information from which the unknown thickness of a uniform absorbing layer can be determined. In this case it is assumed that r (Fig. 1) is constant. It can be shown in general that any $\Delta s(\Delta)$-distribution as given by d, C, and r (Fig. 1) is unique. In an experiment C, the elevation of the receiving point as measured from the center of the earth is preselected. By measuring the Δ-distribution of absorption, one is able to determine the height and the thickness of the absorbing region. The measurement of this distribution assumes a radio signal to be transmitted from a satellite.

The maximum property of Δs for linear rays can be generalized to include circular rays as well. In this case it can be shown that Δs between two concentric circles of a circular ray rotating on P is a maximum if the departure angle at P is zero, *i.e.* if the circular ray is tangent to the normal s upon the diameter through P. Moreover, these circular rays can be concave as well as convex (Fig. 3). While Δs_{max} strictly adheres to the condition of $\Delta \equiv 0$, π, Δs_{min} does not occur at $\Delta = \pm \pi/2$. It occurs at values of Δ which depend on the magnitude of the radius of curvature of the ray relative to the parameters of the geometry. For circular ray paths, the $\Delta s(\Delta)$-distribution is symmetrical relative to $\Delta = 0$ at P.

In the above, it was assumed that ray paths pass through the absorbing region without being refracted. If we allow for re-

* Received by the IRE, January 30, 1959.

[1] First stated at the Spring URSI Meeting, Washington, D. C., April 23–26, 1958. A more elaborate report has been presented at the Congres International sur la Propagation des Ondes Radio-Electriques, 1958, Liége, Belgium, October 6–11, 1958.

[2] K. Toman, "A maximum property of two concentric circles," *Math. Gazette*, to be published.

[3] P. J. Van Rhijn, "On the Brightness of the Sky at Night and the Total Amount of Starlight," Astron. Lab., Groningen, The Netherlands, Publ. No. 31; 1921.

[4] K. Toman, "On the earth geometry—a theorem," PROC. IRE, vol. 46, p. 495; February, 1958.

[5] K. Toman, "A minimum property of the circle," *Math. Gazette*, to be published.

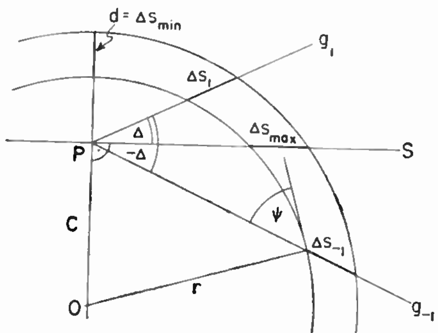

Fig. 1.

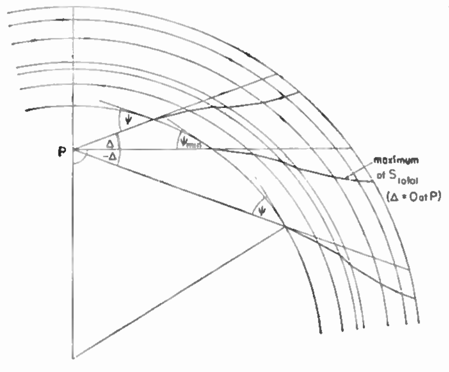

Fig. 4.

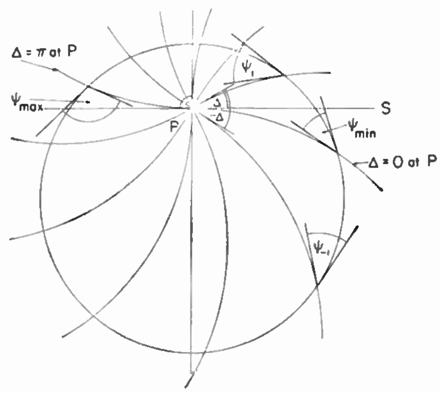

Fig. 5.

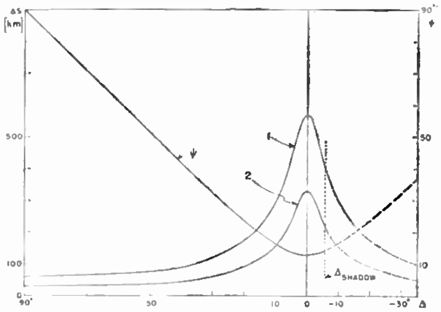

Fig. 2—Absorption path length Δs and reflection angle ψ as a function of the elevation angle Δ; $h_A=40$ km. $h_L=250$ km. $R_{eff}=7972.5$ km. Absorbing layer: 1) 60–120 km. 2) 60–90 km.

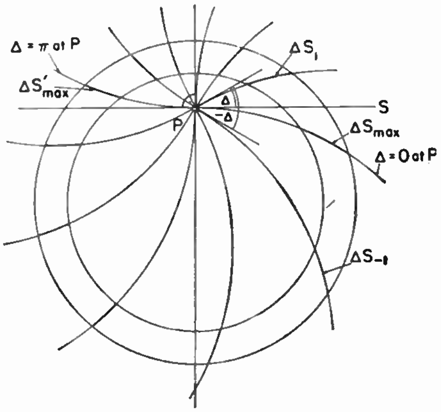

Fig. 3.

fraction it can also be shown that the total geometrical path length of the refracted ray inside the absorbing region reaches a maximum for $\Delta \equiv 0$ (Fig. 4). This is true for any $\mu(h)$-distribution within the ionosphere. Consequently, the maximum of the absorption path length to be obtained at $\Delta=0$ is of general validity. With elevated antennas, it is possible to put the absorption maximum within the observation range. For a homogeneous ionosphere concentric to the earth, one can conclude that the maximum of a nondeviative absorption is strictly obtained at $\Delta=0$. The absorption path length distribution is also in this case symmetrical relative to $\Delta=0$. Actual conditions in the ionosphere complicate the radio-path analysis and any description is approximate.[6] For grounded receiving antennas, the influence of refraction in the ionosphere upon the "radio-rise" and "radio-set" of signals from the first satellite were used in the USSR to determine the electron concentration in the outer ionosphere.[7] The above-stated property regarding the symmetry of the absorption path length distribution relative to positive and negative elevation angles is considered a useful supplement to such investigations.

A similar generalization as for Δs can be made with respect to the minimum property of ψ.[4,5] It can be shown that ψ, the angle of incidence of a circular concave ray upon a layer (Fig. 5) is a minimum for zero departure angle at P. $\Delta=0$ is obtained when the ray is tangential to s through P. s is the normal to the line which connects P with the centers of both ray path and layer respectively. Rotating a circular ray on P in a clockwise sense yields a maximum of ψ for a departure angle at P of $\Delta \equiv 180°$, provided one is consistent about the notation of ψ over a full swing of Δ. The $\psi(\Delta)$-distributions for convex and concave circular ray paths are both symmetrical relative to $\Delta=0$ at P.

Almost circular ray paths are obtained if the refractive index of the atmosphere decreases exponentially with height. In that case circular ray paths are important if an effective earth radius is used.[8,9] The transformation involved does not preserve ψ. If, for a given geometry, one wishes to preserve ψ, one finds an optimum value for the earth-radius modification-factor k.

The minimum property of ψ and its symmetry relative to $\Delta=0$ is important for the MUF-concept. In the past the MUF-concept functioned only because for zero antenna height, a monotonic increase of transmission distance for the ionospheric mode is related to a monotonic decrease of the angle of incidence ψ at the reflecting layer. For elevated antennas, the symmetry of $\psi(\Delta)$ with respect to $\Delta=0$ implies that for increasingly negative elevation angles ($\Delta<0$), ψ increases with an increase of the transmission distance. Consequently, the reflection of radio signals of decreasing frequency is sustained. This behavior calls for an extension of the MUF-concept for highly elevated antennas. In this case the total transmission distance increases up to the limiting condition of a grazing beam, but for $\Delta<0$, the MUF decreases.

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[6] G. H. Millman, "Atmospheric effects on VHF and UHF propagation," Proc. IRE, vol. 46, pp. 1492–1501; August, 1958.

[7] I. L. Al'pert, F. F., Dubriakova, F. F. Chudesenko, and B. S. Shapiro, "On the results of determining the electron concentrations of the outer regions of the ionosphere by means of observations on the radio signals of the first satellite," *Dok. Akad. S.S.S.R.*, vol. 120, pp. 743–746; June, 1958.

[8] G. Millington, "The concept of the equivalent radius of the earth in tropospheric propagation," *Marconi Rev.*, vol. 20, pp. 79–93; August 11, 1957.

[9] E. C. Jordan, "Electromagnetic Waves and Radiating Systems," Prentice-Hall, Inc., New York, N. Y., p. 649, 1950.

WWV Standard Frequency Transmissions*

Since October 9, 1957, the National Bureau of Standards radio stations WWV and WWVH have been maintained as constant as possible with respect to atomic frequency standards maintained and operated by the Boulder Laboratories, National Bureau of Standards. On October 9, 1957, the USA Frequency Standard was 1.4 parts in 10^9 high with respect to the frequency derived from the UT 2 second (provisional value) as determined by the US Naval Observatory. The atomic frequency standards remain constant and are known to be constant to 1 part in 10^9 or better. The broadcast frequency can be further corrected with respect to the USA Frequency Standard, as indicated in the table; values are given as parts in 10^{10}. This correction is *not* with respect to the current value of frequency based on UT 2. A minus sign indicates that the broadcast frequency was low.

The WWV and WWVH time signals are synchronized; however, they may gradually depart from UT 2 (mean solar time corrected for polar variation and annual fluctuation in the rotation of the earth). Corrections are determined and published by the US Naval Observatory.

WWV and WWVH time signals are maintained in close agreement with UT 2 by making step adjustments in time of precisely plus or minus twenty milliseconds

* Received by the IRE, June 26, 1959.

on Wednesdays at 1900 UT when necessary; no time adjustment was made during this month at WWV and WWVH.

WWV Frequency†

1959 May	vs NBS‡ Atomic Standards 30-Day Moving Average Seconds pulses at 15 Mc	Vs Atomichron at WWV Measuring Time 1 Hour 2.5 Mc	Vs Atomichron at NRL Measuring Time 56 Minutes 2.5 Mc
1	−31	−35	−32
2	−32	−35	
3	−32	−35	
4	−33	−35	−31
5	−33	−35	−31
6	−33	−35	−31
7	−34	−35	−31
8	−34	−35	−31
9	−34	−34	
10	−33	−35	
11	−33	−35	−31
12	−34	−35	−30
13	−33	−34	−31
14	−32	−35	−30
15	−33	−35	−31
16	−33	−35	
17	−33	−35	
18	−33	−35	−31
19	−33	−35	−30
20	−33	−35	−31
21	−33	−35	−32
22	−34	−35	−31
23	−35	−35	
24	−35	−35	
25	−36	−34	−31
26	−36	−34	−32
27	−36	−34	−31
28	−36	−34	−31
29	−36	−34	−31
30	−35	−34	
31	−35	−34	

† WWVH frequency is synchronized with that of WWV.

‡ Method of averaging is such that an adjustment of frequency of the control oscillator appears on the day it is made. No adjustment was made during May.

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Boulder, Colorado

Novel Expression for the Relationship Between the Real and Imaginary Parts of the Transfer Function of a Linear Filter*

The relationship between the real and imaginary parts of the transfer function of a linear filter is generally expressed in the following form:

$$X(\omega) = \frac{2\omega}{\pi}\int_0^\infty \frac{R(x)dx}{(x^2-\omega^2)}, \qquad (1)$$

wherein $R(\omega)$ and $X(\omega)$ are, respectively, the real and imaginary parts of the filter's transfer function. This formula contains a singular integrand, and its derivation customarily involves considerable gymnastics in the complex plane. The purpose here is to present the much simpler derivation of a useful and novel formula equivalent to (1) and logically antecedent to (1) in the sense that (1) can readily be derived from the new formula.

The key to the new derivation is the consideration of the impulse-response function $U(T)$ of the filter. It is well known that the physical restriction that $U(T)$ should be zero before application of the impulse enables $U(T)$ to be determined if either $R(\omega)$ or $X(\omega)$ is known. In particular, Guillemin[1] gives (in slightly different notation)

$$U(T) = \frac{2}{\pi}\int_0^\infty R(\omega)\cos\omega T d\omega. \qquad (2)$$

On the other hand, the impulse-response function determines the complex transfer function of the filter; these two functions in fact form a Fourier-Transform pair. The part of the Fourier reciprocal relationship which gives the imaginary part of the transfer function in terms of the impulse-response function is

$$X(\omega) = -\int_0^\infty U(T)\sin\omega T dT. \qquad (3)$$

By eliminating the impulse-response function $U(T)$ between (2) and (3), the following relationship is obtained:

$$X(\omega) = -\frac{2}{\pi}\int_0^\infty\int_0^\infty R(x)\cos xT \cdot \sin\omega T dx dT. \qquad (4)$$

This novel form for the relationship between the real and imaginary parts of the transfer function of a linear filter involves a double integral but features a nonsingular integrand in contrast to the usual formula (1). The derivation of (4) makes use only of the Fourier reciprocal relationship between the transfer function of a filter and its impulse-response function, and of the physical restriction on the latter function mentioned earlier.

The usual formula (1) can be derived from (4) by interchanging the order of the two integrations in (4) and carrying out the evaluation of the resulting indeterminate integral with respect to T by the Cesàro method.

In closing, it should be pointed out that the inverse relationship to (4), giving $R(\omega)$ in terms of $X(\omega)$, can readily be derived by essentially the same logical procedure which led to (4). This inverse relationship is

$$R(\omega) = -\frac{2}{\pi}\int_0^\infty\int_0^\infty X(x)\sin xT \cdot \cos\omega T dx dT. \qquad (5)$$

The highly symmetrical reciprocal relationships (4) and (5) define a type of transformation which appears to be a logical antecedent of the Hilbert transformation insofar as the latter applies to the theory of realizable electrical filters.

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* Received by the IRE, April 6, 1959.

[1] E. A. Guillemin, "Synthesis of Passive Networks," John Wiley and Sons, Inc., New York, N. Y., pp. 281–282; 1957.

Some Notes on Space Communications*

Introduction

Satellite and space-probe telemetry systems which have been extensively used in the past[1] employ audio sub-carriers which are modulated with information signals derived from sensing devices in the vehicle. The modulated sub-carriers are combined additively, and this composite audio signal is then used to phase or frequency modulate the RF carrier. Due to the deviations used in the final modulation process the resulting RF signal is usually characterized by a rather large carrier component with a symmetrical sideband distribution very similar to that which would obtain from amplitude-modulation of the RF carrier. Telemetry reception is accomplished by synchronous detection, employing a local oscillator which is phase-locked to the carrier component of the received signal.

Since SNRs often become critical, especially for space-probe vehicles, the telemetry technique described above poses some rather interesting design problems, for example, determining the proper division of available power between the carrier and the sideband components. Excessive carrier power will result in good receiver-oscillator phase-lock at times when the telemetry subchannel SNRs are so poor as to be useless. Conversely, excessive sideband powers (assuming a carrier-lock scheme is used) will result at times in good telemetry SNRs which will be made useless by the inability of the receiver to achieve an acceptable phase-lock. A bit of reflection on these matters could well lead to the formulation of the following questions:

1) If a carrier-lock scheme is used, what is the proper division of available power between carrier and sidebands?

2) Can a proper division of power be achieved using conventional modulation techniques such as AM, NBFM, or PM?

3) Since sideband energy must be expended in order to transmit information, is it possible to use this sideband energy for phase-lock purposes? If so, is any carrier necessary or may complete carrier suppression be employed?

4) With regard to the telemetry information, what are the relative merits of time-division and frequency-division-multiplex

* Received by the IRE, February 11, 1959.

[1] "Telemetry standards for guided missiles," *Electronics*, vol. 31, pp. 96–98; October 24, 1958.

techniques in a space communication system?

Without knowledge of the specific parameters involved in a given application, exact answers to some of the above questions cannot be given. However, it is believed that the analysis which follows contains results which may be used to obtain definite answers for a given application. Furthermore, it is believed that these results will permit valid conclusions to be drawn for a majority of future space communications systems.

Carrier-Lock System

Shown in Fig. 1 are the fundamental elements of a phase-lock system typically used for receiver local-oscillator phase-control. The incoming carrier and noise are multiplied by the local-oscillator signal in a product detector to produce a control signal which is filtered and used to actuate a phase-control device.

The low-pass filter is assumed ideal with a cutoff frequency of Δb cps. Thus, only noise components falling within $\pm\Delta b$ cycles of the carrier frequency need be considered. We are then able to represent[2] the input noise as two base-band noise voltages DSB-modulating a pair of quadrature carriers at frequency f_0. Thus, the received signal, $e_r(t)$, may be written as

$$e_r(t) = A \cos \omega_0 t + n_i(t) \cos \omega_0 t + n_q(t) \sin \omega_0 t \qquad (1)$$

where $n_i(t)$ and $n_q(t)$ are white, Gaussian, independent variables with highest frequency Δb. Furthermore,

$$\overline{n_i^2(t)} = \overline{n_q^2(t)} = 2a^2\Delta b, \qquad (2)$$

where a^2 is the input noise power density expressed in watts per cycle. The output of the product detector, $e_d(t)$, will be

$$e_d(t) = A \sin \phi + n_i(t) \sin \phi + n_q(t) \cos \phi; \qquad (3)$$

and, since the phase error ϕ is to be kept small,

$$e_d(t) \cong A\phi + n_q(t) \qquad (4)$$

where ϕ is the error angle in radians. Since $n_q(t)$ contains no frequencies higher than Δb, $e_d(t)$ will appear at the input to the phase-control device without filtering effects. Assume for the servo system that

$$\phi(t) = -K_1 e_d(t), \qquad (5)$$

which when combined with (4) yields

$$\phi(t) = -\frac{K_1}{1 + AK_1} n_q(t). \qquad (6)$$

For most servo systems of interest ($AK_1 \gg 1$), (6) simplifies to

$$\phi(t) \cong -n_q(t)/A. \qquad (7)$$

From (7) and (2) we may obtain at once the rms value of phase error for carrier-lock as

$$\Phi_{\text{rms CL}} = \left[\frac{2a^2\Delta b}{A^2}\right]^{1/2} \text{radians.} \qquad (8)$$

Note that the ratio in (8) involves one-half the input noise power divided by the carrier power.

[2] J. L. Lawson and G. E. Uhlenbeck, "Threshold Signals," Rad. Lab. Ser., vol. 24, pp. 59–60; 1950.

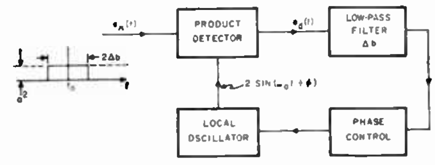

Fig. 1—Carrier-lock system.

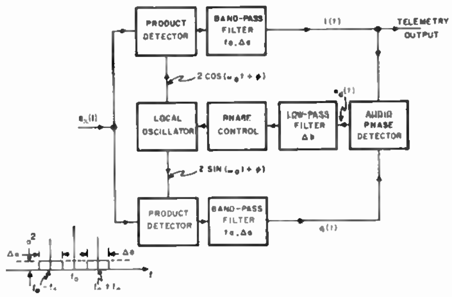

Fig. 2—Sideband (DSB) phase-lock system.

DSB Phase-Lock System

Although carrier power is able to provide only one function, receiver-oscillator phase-lock, sideband power can be used for both the transmission of information and phase-control purposes. One receiving system for obtaining this dual performance has been described in the literature.[3] A block diagram of this system is shown in Fig. 2, as modified for the reception of a telemetry signal using one audio sub-carrier at frequency f_a. It is assumed that a total bandwidth of Δa cycles, centered about the sub-channel frequency f_a, is required to accommodate the sub-carrier modulation, and bandpass filters appear in Fig. 2 accordingly. Consequently, only noise components falling within $\pm\Delta a/2$ cycles of each of the two RF sidebands will be significant. Using the same noise representation as before, we may write for the received signal, $e_r(t)$,

$$e_r(t) = C \cos \omega_a t \cos \omega_0 t + n_1(t) \cos (\omega_0 + \omega_a)t + n_2(t) \sin (\omega_0 + \omega_a)t + n_3(t) \cos (\omega_0 - \omega_a)t + n_4(t) \sin (\omega_0 - \omega_a)t, \qquad (9)$$

where all the noise voltages are white, Gaussian, independent, and with highest frequency $\Delta a/2$ cycles. Further,

$$\overline{n_1^2} = \overline{n_2^2} = \overline{n_3^2} = \overline{n_4^2} = a^2\Delta a \qquad (10)$$

where a^2 has the same meaning as before and Δa is the telemetry sub-channel bandwidth. It may be easily shown that if

$$e_d(t) = i(t) \cdot q(t), \qquad (11)$$

then the products of interest in $e_d(t)$ may be written for small ϕ as

$$e_d(t) = \frac{C^2}{2}\phi + \frac{C}{2}(n_2 + n_4) + n_1 n_4 + n_2 n_3, \qquad (12)$$

where C is the peak sideband amplitude. The first term in (12) is the desired phase-control voltage and the remaining terms are undesired noise voltages. Of special interest here is the noise power, P_n, which appears at the output of the low-pass filter. If $\Delta b \leq \Delta a/2$, a condition easily satisfied in most systems, then some fairly routine operations yield

[3] J. P. Costas, "Synchronous communications." Proc. IRE, vol. 44, pp. 1713–1718; December, 1956.

$$P_n = C^2\Delta b a^2\left[1 + \frac{4a^2\Delta a}{C^2}\left(1 - \frac{\Delta b}{2\Delta a}\right)\right] \qquad (13)$$

as the expression for the noise power at the input to the phase-control device. This equation may be simplified by noting that the SNR in the telemetry sub-channel on an average power basis, $(S/N)_T$, will be given by

$$\left(\frac{S}{N}\right)_T = \frac{C^2}{4a^2\Delta a}. \qquad (14)$$

Then (13) becomes

$$P_n = C^2\Delta b a^2\left[1 + \frac{1}{(S/N)_T}\left(1 - \frac{\Delta b}{2\Delta a}\right)\right], \qquad (15)$$

which for good telemetry sub-channel SNRs may be approximated as

$$P_n \cong C^2\Delta b a^2. \qquad (16)$$

Note that for $(S/N)_T \geq 1$ (0 db), the approximation in (16) is in error by less than 3 db.

From this point, a development identical to that used for the servo loop in the carrier-lock case will give

$$\Phi_{\text{rms DSB}} = [4P_n/C^4]^{1/2} \cong [4a^2\Delta b/C^2]^{1/2} \text{ radians,} \qquad (17)$$

or, more generally, if there are K reasonably spaced telemetry sub-channels,

$$\Phi_{\text{rms DSB}} = \left[\frac{4a^2\Delta b}{KC^2}\right]^{1/2} \text{ radians,} \qquad (18)$$

which simplifies to

$$\Phi_{\text{rms DSB}} = \left[\frac{\Delta b/\Delta a}{K(S/N)_T}\right]^{1/2} \text{ radians} \qquad (19)$$

when (14) is used. Eq. (19) will be quite accurate for $(S/N)_T$ of 10 db or greater, and the approximation error will be less than 3 db if $(S/N)_T$ is greater than 0 db.

Discussion

Although (14) was derived for the DSB phase-lock system, it applies equally well in the carrier-lock case. Thus, by combining (14) and (8), we obtain

$$\frac{A}{C} = \left[\frac{\Delta b/\Delta a}{2(S/N)_T}\right]^{1/2} \Big/ \Phi_{\text{rms CL}} \qquad (20)$$

which determines the ratio of carrier amplitude to peak sideband amplitude (for one sub-channel) required for a specified rms phase error concurrent with a specified telemetry SNR. For example, if the maximum rms phase error is to be 20° and the minimum telemetry channel SNR +3 db, then for $\Delta b/\Delta a = 1/10$, we obtain

$$A/C = 0.45 \quad \text{or} \quad C = 2.2A.$$

Thus an optimum division of power in this case requires that the peak sideband amplitude be over two times the carrier amplitude. Since in AM $A \geq C$, it appears that for this example the use of AM would result in an excessive amount of carrier power in relation to sideband power. Furthermore, as the data rate of the system is increased either by continued use of one sub-channel (which means progressively smaller $\Delta b/\Delta a$ ratios) or by the addition of other sub-channels, (20) shows rather clearly that AM will become progressively poorer in regard to division of available power between carrier and sidebands. When used with phase-lock receivers, NBFM and PM techniques do not appear to offer any improvement over AM with regard to proper carrier-to-sideband power ratio.

Since it has been shown that the sidebands may be used for receiver-oscillator phase control, it is interesting to compare the relative performance of carrier-lock and sideband-lock systems. This may be done by combining (17) and (8) to obtain

$$\frac{\Phi_{\text{rms DSB}}}{\Phi_{\text{rms CL}}} = \left[\frac{A^2/2}{C^2/4}\right]^{1/2}$$

$$= \left[\frac{\text{Ave. Carrier Power}}{\text{Ave. Sideband Power}}\right]^{1/2}. \quad (21)$$

Note that if the telemetry channel SNR is reasonably good, the sideband-lock system is just as efficient as the carrier-lock system from considerations of average power. Even if an unfavorable $(S/N)_T$ is assumed, the sideband-lock system will almost always come within 3 db of the performance of the carrier-lock technique. The above comparison tends to obscure a very important obvious fact: *Since sideband energy may also be used for phase-lock purposes any communications system which obtains receiver lock only from a carrier component is inherently inefficient, at least to some degree.* The fact that average sideband power is equally as effective as average carrier power for phase-lock purposes serves to make more serious the shortcomings of a system which employs carrier lock exclusively.

Since sideband power will normally be as effective as carrier power for phase-lock purposes, it seems reasonable at this point to inquire as to the necessity for any carrier component in the transmitted signal. Eq. (19) is useful in this investigation.

$$\Phi_{\text{rms DSB}} = \left[\frac{\Delta b/\Delta a}{K(S/N)_T}\right]^{1/2} \text{radians.} \quad (19)$$

Choosing $\Delta b/\Delta a = 1/10$, $K = 4$ (4 sub-channels), $(S/N)_T = 4$ (+6 db), we obtain an rms phase error of about 4.5 degrees, which is quite good. In any event, as the data rate requirements are increased, the phase lock will improve either because K is increased or because $\Delta b/\Delta a$ is decreased. Since sideband power is being used for phase lock, the lock system will perform better as the data rate increases since sideband power must be increased along with the data rate; this cannot be avoided. These results are confirmed by our own experience with highly efficient binary data transmission systems using DSB RF techniques. At extreme range, failure occurs because of poor SNRs in the data channel and not because of excessive oscillator phase error.

In the previous discussion, it has been mentioned that increased data rate may be obtained either by increasing the speed of a single channel or by using additional subchannels of a given speed. In effect, we may choose between serial and parallel data transmission or, if you will, between time division and frequency division multiplexing. For HF radio transmission frequency division multiplex has become somewhat traditional and for a very good reason—multipath. Since multipath echoes in HF limit the speed of data transmission on a given channel, a practical way to increase data rate has been to send slowly on many channels.[4] In a space communication system, multipath should be of minor concern so that frequency division multiplexing may be avoided, if desired. Indeed, there are good reasons why frequency division should be avoided if a choice exists. Since peak power is usually the limitation in transmitter design, the RF peak-to-rms factor in parallel data transmission will normally result in significantly less average power per subchannel as compared to serial data transmission under the same peak-power limitations. Also parallel data transmission usually makes rather stringent demands on transmitter linearity; serial data transmission is quite tolerant in this regard. Before the author is accused of being a theoretician,[5] let it be said that in early space vehicles there may well be overpowering practical considerations which force use of frequency-division techniques. In future systems, however, it seems safe to predict that time-division techniques will be found to be the more desirable.

[4] Those of us who have attempted to push the state of the art in HF data transmission must, at times, agree with the British scientist who held that the discovery of the Kennelly-Heaviside layer was unfortunate. Had this discovery not been made, he argued, we would have directed our efforts along paths which, by this time, would have provided us with satisfactory world-wide communications.

Conclusion

We should now be able to answer with some assurance the questions raised at the beginning of this note.

1) If carrier-lock is used, the proper division of power between carrier and sidebands may be determined by setting limits on RMS phase error and telemetry-channel SNR, and substituting these limits into (20).

2) In general, a proper division of transmitter power cannot be obtained by use of AM, NBFM, or PM techniques. In most practical cases of interest, such use will result in excessive carrier power, especially if frequency division multiplex techniques are employed.

3) Since sideband energy must be expended in order to transmit information, it is fortunate that this energy may also be used for receiver phase-lock purposes. In most cases the lock obtained from the sidebands will be more than adequate and, hence, suppressed-carrier transmissions may be used. Consequently, systems which use carrier-lock exclusively are inherently inefficient, at least to some degree.

4) The relative freedom of space communication circuits from multipath permits use of either serial or parallel data transmission. In most cases the choice will be easy to make—serial.

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[5] Theoretician—one who has been trained to assume everything but responsibility.

Contributors

J. B. Chown

John B. Chown (A'53) was born in La Salle, Ill., on March 20, 1927. He received the B.E. degree in electrical engineering from the University of Southern California, Los Angeles, in 1951.

From 1951 to 1954, he was employed as a Research Engineer with Lockheed Aircraft Corporation at Burbank, Calif. He joined the staff of Stanford Research Institute, Menlo Park, Calif., in 1954. He was project leader for the design and development of compatible antenna systems for army rotary and fixed-wing aircraft and has worked on the design and development of antennas for missile guidance systems and investigation of gaseous discharge phenomena as they affect antennas. Presently, he is senior research engineer in the radiation systems group, Electromagnetics Laboratory.

Mr. Chown is a member of the Scientific Research Society of America.

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S. B. Cohn

Seymour B. Cohn (S'41–A'44–M'46–SM'51–F'59) was born in Stamford, Conn., on October 21, 1920. He received the B.E. degree in electrical engineering from Yale University, New Haven, Conn., in 1942, the M.S. degree in electrical engineering from Harvard University, Cambridge, Mass., in 1946, and the Ph.D. degree in engineering sciences and applied physics from Harvard in 1948. From 1942 to 1945 he was a special research associate at the Radio Research Laboratory of Harvard University, where he was engaged in the development of UHF and microwave search receivers for radar countermeasure applications. From 1948 to 1953 he worked in the Microwave Instruments and Components Department of Sperry Gyroscope Co., becoming a research engineer.

He joined the staff of the Stanford Research Institute, Menlo Park, Calif., as head of the Microwave Group of the Antenna Systems (now Electromagnetics) Laboratory in 1953. In 1957, he became manager of that laboratory. His fields of specialty include microwave components and circuits, antennas, and microwave systems.

Dr. Cohn is a member of Tau Beta Pi and Sigma Xi.

Eiichi Goto was born on January 16, 1931, in Tokyo, Japan. He graduated from the University of Tokyo in March, 1953, receiving the "Rigakusi" degree (corresponding to the Master of Science degree) in physics. He completed the postgraduate course in physics in March, 1958.

E. Goto

Since April, 1958, he has been a research assistant in the Department of Physics, Faculty of Science, at the University of Tokyo.

Mr. Goto is presently engaged in the construction of the parametron computer (PC-2) at The University of Tokyo.

❖

Tetsu Morita (S'44–A'49–SM'54) was born in Seattle, Wash., on February 5, 1923. He received the B.S. degree in electrical engineering from the University of Nebraska, Lincoln, in 1944, and the M.S. degree in communications engineering in 1945 and Ph.D. degree in engineering sciences in 1949, both from Harvard University, Cambridge, Mass.

T. Morita

From 1949 to 1953, he was a Research Fellow and Head of the antenna research group at Harvard. From 1951 to 1953, he was a consultant on microwave antennas for Trans-Sonics Inc., Bedford, Mass., and in 1953, for the Sylvania Electric Company in Boston. In 1953, he joined the staff of Stanford Research Institute, Menlo Park, Calif., where he has worked on ECM antennas, missile antenna systems, and an investigation of gaseous discharge phenomena in regard to antennas. He is currently the head of the radio systems group, Electromagnetics Laboratory.

Dr. Morita is a member of the American Physical Society, Sigma Xi, Pi Mu Epsilon, and the Scientific Research Society of America.

❖

Clyde L. Ruthroff (M'56) was born in Sioux City, Iowa, on February 4, 1921. From 1939 to 1946 he served in the U. S. Navy. He received the B.S. degree in 1950 and the M.A. degree in 1952 from the University of Nebraska, Lincoln, Neb.

C. L. Ruthroff

From 1946 to 1952 he worked as a central office craftsman for the Long Lines Department of the American Telephone and Telegraph Company. In 1952, he joined the Bell Telephone Laboratories, Inc., where he has worked on communications systems.

❖

William E. Scharfman (S'50–A'55) was born in New York, N. Y., on May 29, 1932. He received the B.E. degree in electrical engineering from New York University, N. Y., in 1953. He received a Westinghouse Fellowship from The Ohio State University, Columbus, Ohio, obtaining the M.S. degree in electrical engineering in 1954. The subject of his thesis was in the field of radio astronomy.

W. E. Scharfman

In 1954, he joined the staff of Stanford Research Institute, Menlo Park, Calif., where he has been engaged in the development of ECM antennas, ADF input circuits studies, the development of guidance antennas for missiles, and an investigation of gaseous discharge phenomena in regard to antennas. He is currently a research engineer in the radiation systems group, Electromagnetics Laboratory.

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❖

Fred Sterzer (M'56) was born in Vienna, Austria, on November 18, 1929. He received the B.S. degree in physics in 1951 from the College of the City of New York, and the M.S. and Ph.D. degrees in 1952 and 1955, respectively, from New York University.

From 1952 to 1953 he was employed by the Allied Control Corporation, in New York. During 1953 to 1954 he was an instructor in physics at the Newark College of Engineering in New Jersey, and a research assistant at New York University. He joined the RCA Tube Division in Harrison, N. J., in October, 1954, and transferred to the Princeton, N. J., branch in 1956, where he is now group leader in microwave physics.

F. Sterzer

His work has been in the field of microwave spectroscopy, traveling-wave tubes, backward-wave oscillators, solid-state microwave amplifiers and oscillators, and microwave computing circuits.

Dr. Sterzer is a member of Phi Beta Kappa, Sigma Xi, and the American Physical Society.

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Harold A. Wheeler (A'27–M'28–F'35) was born in St. Paul, Minn., on May 10, 1903. He received the B.S. degree in physics from George Washington University, Washington, D.C., in 1925 and did postgraduate studies in physics at The Johns Hopkins University, Baltimore, Md., until 1928.

H. A. Wheeler

He was employed by the Hazeltine Corp. from 1924 to 1945, advancing to vice-president and chief consulting engineer. Since 1946, he has been engaged in independent work as a consulting radio physicist, and since 1947, his principal occupation has been as President of Wheeler Laboratories, Inc. In this capacity, he is directing the Great Neck and Smithtown laboratories, specializing in microwaves and antennas.

His specialization in antennas dates back to "all-wave" antennas for broadcast receivers around 1935, then radar beacon and IFF antennas during World War II, for which he received the Navy Certificate of Commendation. He has published basic studies of "small" antennas and "large" arrays and has directed recent developments in radar antennas for guiding missiles.

Mr. Wheeler has served the IRE in such positions as Director (1934, 1940–1945), chairman of Standards Committee, and chairman of the Long Island Section. He received the Morris N. Liebman Memorial Prize in 1940 for work on some problems of television. He is a Fellow of AIEE and Radio Club of America, associate member of IEE (British), and member of Sigma Xi and Tau Beta Pi.

Scanning the Transactions

We welcome the first issue of the TRANSACTIONS of PGRFI (Radio Frequency Interference) to the growing family of IRE publications, now 32 in number. To illustrate the broad nature of PGRFI interests, all three papers in the issue are discussed below. The papers are concerned with measurement techniques, instrumentation, and suppression.

Control of Microwave Interference. This paper is of a tutorial nature and deals with a topic currently of extended interest. It discusses the nature of radiation from microwave tubes, as distinguished from that at lower frequencies, and special problems arising therefrom. Clearly, the techniques for measuring such radiation are substantially different from "conventional" techniques, largely because of the peculiar characteristics of microwave transmission circuits, and a number of new methods are described in some detail. In controlling interference in this region, filtering and other techniques likewise are unique. The bibliography provides a wealth of source material for those who have not been active in this area. It is expected that this paper will be followed by others in the near future which will go into more detail on some of the techniques now in development. (A. H. Ryan, "Control of microwave interference," IRE TRANS. ON RADIO FREQUENCY INTERFERENCE, May, 1959.)

A quasi-peak detector is included in most present-day noise measuring equipments. Although a number of papers have analyzed it in various ways, this paper pays special attention to its response when a step carrier is applied. This technique is one which is sometimes used to define the detector performance. The objective is to provide a practical method for the design of a detector circuit with specified charge and discharge time constants. It has application to the design of other detector circuits also, since any circuit containing a diode has "charge and discharge" time constants. (Y. Peless, "Design of quasi-peak detectors with specified time constants," IRE TRANS. ON RADIO FREQUENCY INTERFERENCE, May, 1959.)

The development of the feedthrough capacitor was very significant in the control of radio frequency interference. The requirements for miniaturization in modern electronic equipment calls for new concepts in the design and application of such capacitors. An analysis has now been made of an assemblage of such capacitors which make use of a common ferrite wall to provide improved characteristics. Problems arise in this construction due to cross-talk between circuits, but this cross-talk is negligible when a low-cost lossy ferrite is used. The analysis is extended to include several multi-wall structures. The data on performance which are given should be of considerable interest to equipment designers. (I. Melngailis, E. M. Williams and J. H. Foster, "Analysis of through-channel and cross-channel insertion loss in ferrite-wall multiple-circuit feedthrough capacitors," IRE TRANS. ON RADIO FREQUENCY INTERFERENCE, May, 1959.)

If the beat-beat dovap, ullage, and hypergolic sound to you like words from another world, you wouldn't be very far from wrong. Actually, these terms come from the field of astronautics and are in every-day use at U. S. missile test ranges. Members of the 9898th Air Reserve Squadron at Eau Gallie, Florida, recently compiled over 100 such "common" words and their definitions to form a glossary of astronautic terms which gives an excellent insight into the vast extent of missile test operations and the expanding field of space electronics. So the next time you say "Egads," bear in mind that to some people it means "Electronic Ground Automatic Destruct Sequencer." (D. C. Madrid, "Glossary of astronautics terminology," IRE TRANS. ON SPACE ELECTRONICS AND TELEMETRY, June, 1959.)

Circuit theory and information theory, although they are distinctly separate fields, exhibit a number of interesting and significant similarities. Specialists in both fields employ many of the same disciplines: graph theory, statistical theory, binary algebra, matrix algebra, to name a few. The differences are often primarily of interpretation, not of substance. In applications of graph theory, for example, both the circuit and the information theorists deal with flows, but call the flows currents in one case and information in the other. In order to illuminate the large area of interest which they share, the PGCT and PGIT recently held a joint International Symposium on Circuit and Information Theory and jointly published the papers in their respective May issues of TRANSACTIONS—a broadening course of action that is most welcome in an age of narrow specialization.

Sequential transducers. When a large collection of bistable circuit elements is interconnected in a network, the overall configuration can exhibit a "memory." That is, the action of the network will at any given time be influenced not only by the signals which impinge on it then, but also by signals which appeared in the remote past. Even in a network containing a small finite number of memory elements an input signal appearing at one time can influence the behavior of the circuit an indefinite time into the future, in spite of the fact that that input will have long since been replaced by the other input signals which followed it. This kind of "finite-state" logical machine serves as an instructive model for a wide variety of computing, control and coding circuits.

Many important things can be said about a finite-state machine in its role as a transducer between an input and an output stream of digits without referring to the specific technology used in realizing the elements from which it is made. Most of the papers in the "Sequence Transducer" issue of the IRE TRANSACTIONS ON CIRCUIT THEORY, March, 1959, concentrate their attention on the transformations possible on the data streams at the input and output terminals of finite-state machines, some with special emphasis upon a special class of linear transformations. Other papers deal specifically with the internal communication problems of these transducers, with questions of network efficiency, and with the question of the equivalence of machines constructed in a variety of ways to achieve the same ultimate data-processing objective.

Dial jockeys have been struck a mortal blow. Automatic brightness and contrast control circuitry has been developed for color television receivers that eliminates the need for dial adjustments by the viewer. In fact, the automatic circuitry has been found on the average to adjust the set better than a viewer would, especially when the viewer is nontechnical. (L. L. Burns, R. W. Ahrons, and L. B. Johnson, "Simplification of viewer brightness and contrast controls on color TV receivers," IRE TRANS. ON BROADCAST AND TELEVISION RECEIVERS, May, 1959.)

The Medical Electronics Center of the Rockefeller Institute has recently completed a 1959 Supplement to the 1958 Bibliography on Medical Electronics. The Supplement covers 2500 articles which have appeared in journals all over the world and forms a most important addition to the 2200 articles covered by the 1958 edition. The Supplement is truly world-wide in its coverage, having been compiled by 75 correspondents in 10 countries. It has just been published by the

IRE Professional Group on Medical Electronics, and is now available from IRE headquarters at $2.50 per copy. (SUPPLEMENT 1, BIBLIOGRAPHY ON MEDICAL ELECTRONICS, June, 1959.)

Modern weapons and space control systems operate with inputs, outputs, and disturbances which may be characterized as vector quantities. These systems include devices such as coordinate converters, fire control and guidance computers, gyroscopic instruments, and inertial navigation systems. One of the difficulties associated with three-dimensional problems is the physical visualization of the operation. This is especially true in dynamic problems where time as well as space is involved. Intuition and simple calculations often lead to the omission of important design factors related to inobvious dynamic coupling between system variables. To reduce these errors, a systematic vector notation may be used which breaks the continuum of motion into a series of static two-dimensional problems in much the same way that the motion picture camera reduces continuous motion to a series of still pictures. This vector notation is developed and illustrated with several practical design problems in the first of a three part tutorial series. (A. Lange, "Automatic control of vector quantities," IRE TRANS. ON AUTOMATIC CONTROL, May, 1959.)

Books

Semiconductors, edited by N. B. Hannay

Published (1959) by the Reinhold Publishing Co., 430 Park Ave., N. Y. 22, N. Y. 752 pages+15 index pages+xxiii pages. Illus. 6×9. $15.00.

This book on semiconductor materials fills a long felt need for a comprehensive reference to the properties of a wide variety of semiconducting materials. Published as American Chemical Society Monograph #140, it provides a good balance between the chemistry and physics of semiconductors. Most of the chapters were written from the chemical point of view, and thereby will be found more useful by chemists in particular than other existing references written specifically for physicists or other professions.

Although it is not a book on radio engineering, it will be of great value to those members of the radio engineering profession who are concerned with research, development, or production of semiconductor devices.

The scope and organization of the subject matter is indicated by the seventeen chapters, each written by an authority on his subject: 1) Semiconductor Principles, N. B. Hannay; 2) Survey of Semiconductor Chemistry, J. J. Lander; 3) Semiconductor Crystal Growing, M. Tanenbaum; 4) Control of Composition in Semiconductors by Freezing Methods, C. D. Thurmond; 4) Defect Interactions in Semiconductors, C. S. Fuller; 6) Diffusion Processes in Germanium and Silicon, H. Reiss and C. S. Fuller; 7) The Chemistry of Some Compound Semiconductors, D. G. Thomas; 8) Group IV Semiconductors, T. H. Geballe; 9) Properties of Some Covalent Semiconductors, J. M. Whelan; 10) Infrared Absorption of Semiconductors, H. J. Hrostowski; 11) Recombination and Trapping, R. G. Shulman; 12) Effect of Imperfections on Germanium and Silicon, J. N. Hobstetter; 13) Semiconducting Properties of Some Oxides and Sulfides, A. R. Hutson; 14) Oxides of the 3d Transition Metals, F. J. Morin; 15) Organic Semiconductors, C. G. B. Garrett; 16) Semiconductor Surfaces, J. T. Law; 17) Semiconductor Electrodes, J. F. Dewald.

There is some emphasis on germanium and silicon because of the relatively excellent state of our knowledge of these materials as well as their demonstrated usefulness, but the other semiconductors have not been neglected. The text is clearly written and there is a unity of approach which helps tie together the work of the seventeen authors.

In addition to the well illustrated text material, there are many references to the literature (average 90 references per chapter), so that original sources for most of the contents are accessible with a minimum of searching.

The book has been held down to size by keeping its contents closely within its stated scope of semiconductor materials. Junctions and electrolytic contacts are discussed only in their relation to material properties. The authors have discussed bulk semiconductor transport properties, but have not digressed into transistor or rectifier theory. They have discussed certain optical properties, but have avoided almost all discussion of phosphor phenomenon. These necessary limitations have been applied with a high degree of consistency. Of course, the specialist in any field may have some minor quibbles concerning the relative amount of space devoted to the different materials. For example, there are pages of fairly speculative material on certain organic semiconductors, yet there is very limited information on the known properties of such important materials as SiC and ZnS. On the whole, however, the balance of emphasis is excellent.

This book should rapidly become recognized as a comprehensive standard reference of great value in the literature of semiconducting materials.

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Noise in Electron Devices, edited by L. D. Smullin and H. A. Haus

Published (1959) by the Technology Press, M.I.T., Cambridge, Mass. and John Wiley and Sons, Inc., 440 Fourth Ave., N. Y. 16, N. Y. 406 pages+7 index pages +xvi pages. Illus. 5¾×9. $12.00.

Six outstanding contributors to the field of low-noise electronics present, in this volume, seven monographs dealing with noise in space-charge control tubes, electron beam amplifier, and semiconductor devices. The material was adapted from notes prepared for an M.I.T. short course in 1955.

C. F. Quate, in the opening chapter, derives classical shot effect formulas, and describes recent analyses relating to noise near the potential minimum at thermionic cathodes. A. Van der Ziel next discusses, in considerable detail, the flicker effect (which leads to 1/f noise) and various theories of its cause. Following is the generalized noise theory of linear electron beam devices (H. A. Haus), which the mathematically inclined reader will find most intriguing. T. E. Talpey gives a classical treatment of noise in space-charge control tubes, also a good deal of practical information on noise measurements. In the fifth chapter, R. W. Peter discusses noise in traveling wave tubes, largely from a qualitative point of view. Changing the subject to semiconductors, Van der Ziel develops general theories for noise production in semiconductor devices. In the final chapter, W. H. Fonger develops noise theories and equivalent circuits for transistors, and includes a small section on transistor amplifier design.

This book is really a research report up to 1956, rather than a general treatise on its subject. Although the writing of each individual author unifies the work in his area, the book lacks a unified approach and wholly consistent symbolism. This is its major shortcoming. It must also be pointed out that substantial progress in low-noise electronics has been achieved since 1956, especially in the maser and parametric amplifier fields.

Those active in low-noise electron device research will find "Noise in Electron Devices" a useful reference. It might also be used as an advanced text, complementary to Van der Ziel's book entitled "Noise" (Prentice-Hall, 1954).

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Analysis of Linear Systems, by David Cheng

Published (1959) by Addison-Wesley Publishing Co., Inc., Reading, Mass. 382 pages+9 index pages +35 appendix pages. Illus. 6×9. $8.50.

This is a remarkably good text and reference book devoted primarily to the application of linear differential equations with constant coefficients to engineering problems with emphasis on the Laplace transform method of solution. The audience appears to be the advanced undergraduate, the graduate student, and the practicing engineer. Portions of the book can be used as a text or reference for the separate subjects covered. Especially noteworthy are the fine tutorial style and the breadth of coverage.

While reading the book, one gets the feeling of being in a classroom. Each subject starts with a physical problem, leads the student through the process of writing his own equations, and then proceeding to solve them. It is then illuminated through the use of pertinent examples, which are designed either to bring home a point, or to impress an important method of attack on the mind of the reader. A wealth of informative problems are given at the end of each chapter.

The book starts with the general development of the properties of linear differential equations. It then swings into an intensive attack on the classical methods of solution.

Attention then shifts to electric circuit theory. The treatment is surprisingly complete considering the small pagination. Mesh and node analysis, duality, and Thevenin and Norton equivalents are discussed in considerable detail.

The treatment is then broadened to include other analogous systems such as mechanical, acoustic, and electromechanic acoustic systems. It is a pity these analogies were not developed from the basic energy equations by Lagrange's method, since this gives a more basic understanding of what the analogies mean and their limitations.

With this background, attention then shifts to Fourier series, Fourier integrals, and Fourier transforms.

This presentation is particularly fortunate. The book explains to the student just why each step is made. "Sinusoidal functions . . . are the favorite functions of engineers because arbitrary periodic functions with few restrictions can be expanded into Fourier series of harmonic sinusoidal components, and transient nonperiodic functions can be expressed a Fourier integral." A simple statement but one enlightening and comforting to the neophyte in the Fourier world.

The transition to Laplace transforms is then performed. Here again the purpose of the Laplace transform is very carefully explained before plunging into the mathematics. The application of Laplace transforms to the solution of simultaneous differential equations is then detailed including initial and terminal conditions considerations. Finally, additional concepts such as the impulse function, the convolution integral, and the inverse transform of irrational functions such as the gamma function and the error function are covered.

Feedback systems are next discussed. Block diagram and flow graph concepts are introduced. Such concepts as complex plane mapping and stability criteria are included. The Z transformations and the use of Z transforms in solving sampled data systems with feedback are covered in some detail.

Finally, a short survey of Laplace transform solution for distributed parameter circuits is given.

Appendixes include Graeffe's method for numerical solution of algebraic equations, a fairly good table of Laplace transforms, and answers to the chapter problems.

All in all, these reviewers feel that this is a very fine book for the personal library of every engineer and physicist who has need for a ready reference on linear system theory and the use of Laplace and Z transforms. We also recommend it to the instructors in these fields for consideration as a standard text. The main fault we find is the almost complete lack of a bibliography.

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Successful Technical Writing, by T. G. Hicks

Published (1959) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 287 pages+6 index pages+xi pages. Illus. 5¼×8. $5.50.

The growth of publications groups and fruitless search for well-qualified technical writers emphasizes an increasing need for more and better writing by engineers and scientists of the electronics industry. Tyler Hicks makes a strong contribution to meeting this need in a well written text which furnishes both the motivation and the instruction for more and better writing by technical people.

In a book which clearly illustrates his teachings, the author covers the various categories of technical writing and the techniques essential to successful writing in each of these areas. Perhaps of greatest interest to readers of Proceedings are the chapters on technical papers and on illustrations. Nevertheless the treatment of magazine articles, reports, manuals, advertising and catalogs, and technical books all merit reflective and careful reading.

A professional editor and author as well as a mechanical engineer, Mr. Hicks has written a book on technical writing of considerable use to any engineer or scientist who wishes to write for publication. Following a section dealing with the rewards of writing, the author devotes a good portion of the book to articles for technical publications. He describes techniques for developing ideas, outlining, and rewriting and polishing. Coming from an editor, the material on selling articles is of special significance.

To those who write technical papers, the book offers much. Careful study of the section on graphs and illustrations deserves the gratitude of those who struggle to fathom the many overburdened, confusing slides presented at technical meetings. The material on preparing papers and on procedures for submitting them and gaining their acceptance will help engineers and scientists who are beginning to cultivate the writing phase of a professional career. The professional man will find the chapters on technical books both stimulating and helpful. To some extent, they spell out the obvious. Still there is enough material on types of technical books, dealings with publishers, and such practical devices as writing schedules and progress books, to make reading and rereading very worthwhile. In fact, there is some danger that the reader of the chapters on writing technical books will catch the bug himself.

In essence, "Successful Technical Writing" is a useful "do it yourself" book for engineers or scientists who would write. It is logical and well planned. It contains a wealth of useful detail and helpful instructional material. Repeated reading in conjunction with specific writing tasks will prove well worthwhile. Quite helpful are the chapter summaries and the questions which appear at the end of each chapter.

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Transform Method in Linear System Analysis, by John A. Aseltine

Published (1958) by McGraw-Hill Book Co., Inc., 330 W. 42 St., N. Y. 36, N. Y. 269 pages+8 index pages+22 appendix pages+xvi pages. Illus. 6¼×9¼. $8.50.

Almost all new textbooks are hailed at some time or other as models of lucid exposition. Since such statements frequently have little foundation in fact, many readers are inclined to view such descriptions with suspicion. This is unfortunate, because when an author does make a sincere effort to write an easily understandable book and succeeds, the reviewer has no way of adequately calling attention to this achievement. Nevertheless, it should be stated that the main virtue of Dr. Aseltine's book is excellent readability.

According to the preface the book has a threefold purpose: to show what the transform method is, how it is applied, and how it can give understanding of physical phenomena. The mathematical aspects of the Laplace transform are covered in five nonconsecutive chapters. Four chapters are devoted to applications, primarily electrical or mechanical in nature, and to the solution of partial differential equations. There are two-chapter discussions on each of the following topics: systems analysis, Fourier series and transforms, random processes, and special transforms including the Z transform and the Mellin transform.

Although portions of the book have been used in both the undergraduate and graduate curricula, at UCLA, it would appear that it will prove most useful at the undergraduate level or as an introduction to the subject for the practicing engineer. It is definitely not adequate for an engineer who already has a good grasp of the fundamentals, since the range of topics considered is so broad as to preclude any treatment in depth. In fact, the last two chapters on difference equations and Mellin transforms are so insubstantial that one might question including them at all. This superficial treatment of certain topics could be compensated, in part, by providing a more comprehensive list of references.

On the other hand the examples are clearly stated and solved in illuminating detail, and a reasonable number of carefully selected problems are included. In view of the importance to engineers of transform techniques as a basic tool, Dr. Aseltine deserves credit for contributing a carefully prepared addition to the available instructional literature.

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Conductance Design of Active Circuits, by Keats A. Pullen, Jr.

Published (1959) by John F. Rider, Inc., 116 W. 14 St., N. Y. 11, N. Y. 306 pages+7 index pages+2 bibliography pages+15 appendix pages+xiii pages. Illus. 6×9. $9.95.

Conductance design of active circuits as described in this book seems little different from the methods taught in any good engineering college. The difference lies primarily in the vast amount of practical know how included with the design data. A better title might have been "Practical Circuit Design." For example, the first chapter which claims to cover basic principles ends by discussing such things as cathode interface impedance, cathode drift, microphonics, heater cathode leakage, etc. Similarly, the second chapter, entitled "Data Presentation Problem," deals with practical component characteristics. Frequency effects on resistors, losses in iron core coils, self resonance of capacitors, reforming of electrolytic capacitors, and similar topics are covered. The following chapters deal with the design of tube circuits and considers in detail the design problems of keeping all components and tube elements within their voltage, current and power dissipation ratings. How to select the proper tube for a particular application is discussed to the inclusion of tube size and mounting problems. Detection and elimination of parasitic oscillations by tracing with a grid dip meter are described completely, even including an explanation of the principle of the grid dipmeter.

Finally, the last two chapters deal with some elementary transistor circuits, again from a very practical view point. For anyone wanting more information on active circuit design, there are 35 references in the bibliography, 34 of them by the author.

In summary, this is a book that might be helpful to a technician designing equipment for laboratory use or a young engineer just starting product design work. It certainly would be an enlightening book for a college engineering senior to make him aware of some of the engineering difficulties of putting theory into practice.

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The Magneto-Ionic Theory and Its Applications to the Ionosphere, by J. A. Ratcliffe

Published (1959) by The Cambridge University Press, 32 E. 57 St., N. Y. 22, N. Y. 191 pages+2 index pages+12 bibliography pages+1 appendix page+x pages. Illus. 5¼×8½. $7.50.

This book is an authoritative and outstanding contribution to the literature of electromagnetic wave propagation. It is the first concise and complete treatment of the basic theory which underlies all phenomena associated with the propagation of electromagnetic waves through the ionosphere. In addition, it contains material never before published. Its general excellence can be traced to the author's many years of leadership in ionospheric research and his significant personal contributions to the subject of his book.

In Part I the equations are derived rigorously from a macroscopic point of view. A parallel microscopic approach leads to useful physical pictures which are essential to a good working knowledge of the theory. Interpretation of the mathematical equations developed in Part I is considered extensively in Part II. Representative curves of refractive index and absorption together with polarization are presented and clearly explained. The two principle approximations to the magneto-ionic theory, the quasi-longitudinal and the quasi-transverse, are treated extensively with the aid of graphical methods. Applications to the terrestrial ionosphere are considered in Part III; they are illustrated with phenomena observed mainly in vertical incidence sounding of the ionosphere. In addition, the nature of electron motion and related heating effects in the ionosphere are discusssed quantitatively

In the last part of the book, various special topics are considered briefly , such as the controversial Lorentz polarization term, ion effects, propagation through the inhomogeneous media, comparison with crystal optics, and the propagation of wave packets.

The rather brief treatment of applications of the theory, such as ionospheric cross modulation, is compensated to a large extent by the annotated bibliography arranged both by author and by section of the book. More than 130 papers are listed and should provide a complete source of information on any topic related to the magneto-ionic theory.

All ionosphere research workers should have a copy of this book. Anyone interested in electromagnetic theory will find it a useful addition to his library. Workers in the new fields of plasma physics and ion-loaded waveguides should find this book useful as a reference. It appears to this reviewer that Ratcliffe's book would also be useful as a text in a graduate course on ionospheric propagation. Its main disadvantage for course work would be the lack of practice problems.

In the field of technical literature, Ratcliffe's book is an outstanding and scholarly contribution. It will undoubtedly be the standard reference on the magneto-ionic theory for some years to come.

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Abstracts of IRE Transactions

The following issues of TRANSACTIONS have been published recently, and are now available from The Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, N. Y., at the prices indicated. The contents of each issue and, where available, abstracts of technical papers, are given herewith.

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Automatic Control

Vol. AC-4, No. 1, May, 1959

Control Concepts—The Editor (p. 1)

Chairman's Report—J. E. Ward (p. 2)

The Issue in Brief—(p. 4)

The American Automatic Control Council—R. Oldenburger (p. 5)

Comparison of Lead Network, Tachometer, and Damper Stabilization for Electric Servos—G. A. Biernson (p. 7)

Three types of compensation widely used to achieve stable operation in instrument servomechanisms are: the lead network, tachometer feedback, and the viscous-coupled-inertia damper. The paper compares these types of compensation in such matters as servo bandwidth, velocity constant, torque constant, transient response, tolerance to gear-train backlash, noise, and required amplifier gain. The purpose of this comparison is to provide a basis for selection of the most appropriate type of compensation for a particular application.

The paper also serves to illustrate a method of analyzing servo performance in terms of the asymptotic gain-crossover frequency. Although this method may be theoretically trivial, it actually is a powerful tool for analyzing the performance of feedback control systems.

The Analysis of Sampled-Data Control Systems with a Periodically Time-Varying Sampling Rate—E. I. Jury and F. J. Mullin (p. 15)

The z-transform is used to solve sampled-data systems which have a periodically time-varying sampling rate, *i.e.*, systems which have a repetitive sampling pattern in which the time duration between the individual samples is not constant. Such systems are described by linear difference equations with periodic coefficients; however, the difference equation which describes the system at sampling instants corresponding to KN, where N is the period of the coefficients of the difference equation, and $K=0, 1, 2, \cdots$, is a linear difference equation with constant coefficients. Thus by forming a series of difference equations which individually describe the system at sampling instants corresponding to KN, $KN+1$, $KN+2, \cdots$, $(K+1)N-1$, the time varying features of the system are in essence removed from the analysis and the z-transform can be used to solve the resulting constant coefficient difference equations. Also, the response between the sampling instants can be found using the solutions of these difference equations.

The method presented is straightforward and can be used to analyze any linear sampled-data system with a periodic sampling pattern. Such a condition could occur, for example, when a computer is time shared by more than one system or in some telemetering devices which periodically give to control systems information on quantities being monitored but in which the desired information is not available at equally spaced intervals of time. This method can also be used to obtain an approximate solution for the output of any linear system which is excited by a periodic but non-sinusoidal forcing function and, because of the flexibility of the sampling pattern, should give more accurate results than an approximation which uses equally spaced samples.

In this analysis, only periodicity of the sampling pattern is assumed, and no relationship between the individual sampling intervals is required. A few examples have been introduced to illustrate the analytical procedure and the features of the response of a system to sinusoidal inputs is indicated in one of the examples.

Automatic Control of Vector Quantities—A. S. Lange (p. 21)

A method is presented for synthesizing a feedback system under the constraints that the open-loop transfer function must have specified K_v and contain real poles at prescribed locations. The method is based on examination of the inverse root-locus plot for the closed-loop poles and zeros. Algebraic equations are obtained for the open-loop pole and zero locations. Examples are given for systems through fourth order in which the resulting *linear* algebraic equations are readily solved for the required compensation poles and zeros.

On the Synthesis of Feedback Systems with Open-Loop Constraints—J. A. Aseltine (p. 31)

This is primarily a tutorial paper written to acquaint control engineers with mathematics pertaining to important sub-systems in modern weapons and space control systems. It is intended to minimize basic design errors often made when attempting to visualize the processes involved, particularly those involving dynamics where time as well as three-dimensional space is involved.

Complex-Curve Fitting—E. C. Levy (p. 37)

The mathematical analysis of linear dynamic systems, based on experimental test results, often requires that the frequency response of the system be fitted by an algebraic expression. The form in which this expression is usually desired is that of a ratio of two frequency-dependent polynomials.

In this paper, a method of evaluation of the polynomial coefficients is presented. It is based on the minimization of the weighted sum of the squares of the errors between the absolute magnitudes of the actual function and the polynomial ratio, taken at various values of frequency (the independent variable).

The problem of the evaluation of the unknown coefficients is reduced to that of the numerical solution of certain determinants. The elements of these determinants are functions of the amplitude ratio and phase shift, taken at various values of frequency. This form of solution is particularly adaptable to digital computing methods, because of the simplicity in the required programming. The treatment is restricted to systems which have no poles on the imaginary axis; *i.e.*, to systems having a finite, steady-state (zero frequency) magnitude.

Characteristics of the Human Operator in Simple Manual Control Systems—J. I. Elkind and C. D. Forgie (p. 44)

The characteristics of simple pursuit and compensatory manual control systems were measured with a family of gaussian input signals having power-density spectra that covered a range of bandwidths, center frequencies, and some variety of shapes. The experimental results, presented in the form of graphs, show the nature of the dependence of human operator characteristics upon input-signal characteristics. The superiority of pursuit systems over compensatory systems is clearly demonstrated.

Simple analytic models that approximate these measured results are derived for both systems. The compensatory model is highly developed and relations among its parameters and those of the input have been obtained. The pursuit model is not so well developed and only approximate relations among its parameters and the input parameters have been found. The measured results and the analytic models together provide a description of manual control systems that should be useful in design of control systems that should be useful in design of control systems.

Transportation Lag—An Annotated Bibliography—R. Weiss (p. 56)

This bibliography is an attempt to survey the writings, in various fields of study, which deal with functions with retarded argument. This problem is characterized by a response to a stimulus which is identical to a normal response except that it is delayed in time. Some situations in which this transportation lag occurs include process control (distance-velocity lag), control of thermal systems (including control of nuclear reactors), rocket motor combustion (ignition and combustion lags), traveling waves, magnetic amplifiers, human link in control systems (reaction time), high-speed aero-dynamic control, and economic systems (period of gestation or production lag). A bibliography is presented which lists and abstracts a number of the references dealing with this problem. Relevant references in two major categories have been omitted. Foreign language works and pure mathematical treatments have not been listed. A comprehensive list of these references may be found in an excellent bibliography on the subject.

The format of the reference listings is an adaptation of standard bibliographical format convenient to the type of material presented. References are lettered according to the author's surname, rather than numbered, to facilitate future additions without breaking the continuity of the reference notation.

Adaptive of Self-Optimizing Control Systems—A Bibliography—P. R. Stromer (p. 65)

Adaptive, self-adjusting, or self-optimizing servos are designed for operation in a slowly-changing environment as opposed to servos intended for a fixed environment. Optimalizer controls and similar services which hunt for and adjust to a pre-set optimum condition are considered as adaptive servos. The references which follow are a selective sampling of the latest material on this subject taken from the open literature and technical reports. Servos which are designed to operate at some pre-set optimum based on pre-filtering of input signals evolved from Wiener's optimum filter theory, and, accordingly, references to the latter topic have also been included.

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Broadcast and Television Receivers

Vol. BTR-5, No. 2, May, 1959

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Minutes of Administrative Committee Meeting, March 25, 1959 (p. 1)

Chapter News (p. 4)

Awards (p. 5)

Design of Transistor Vertical Deflection Output and Driver Stages—M. J. Hellstrom (p. 7)

Television vertical deflection circuits using transistors and direct coupling to the deflection yoke have been described. Although techniques for compensation for the large average flux in the yoke are known, they suffer from difficulties with linearity, raster distortion and power consumption. A circuit which uses direct coupling to the yoke requires approximately twice as much power from the battery as does one using ac coupling to the yoke. This is illustrated in a figure which shows graphically the relative power consumption and its division between the yoke and output transistor. Since power is a prime consideration in a portable television receiver which is to be operated from a battery, ac coupling is considered an important design objective. To aid in understanding some of the problems involved, the circuit requirements of the output and driver stages are studied.

Improving Vertical Synchronization—H. W. Proudfoot (p. 18)

A continuous 31.5 kcs pulse-train, derived from the stabilized horizontal deflection waveform, is added to the integrated vertical sync pulse. The gating action of the integrated vertical sync wave limits triggering to a single 31.5 kcs pulse in each field, thereby stabilizing the repetitive trigger-phase of the vertical oscillator in the presence of noise and/or crosstalk from the horizontal sweep circuits.

Experimental results are included which demonstrate that the minimum signal-to-noise ratio tolerance of a television monitor was extended more than 15 db by employing the proposed stabilizing method.

Double-Tuned Transistor IF Amplifiers for TV Receivers—H. C. Lee (p. 25)

A transistor television picture IF double-tuned amplifier strip using three transistors is described. The over-all power gain at 44 mc is 70 db bandwidth equal to 3.6 mc. The over-all pass band is substantially flat from 43 mc to 45 mc. The AGC range is 45 db. The first part of this paper covers 1) the pole configuration for a double-tuned network for the case of unequal primary and secondary circuit Q's, and 2) the design of the double-tuned transformer based on maximum power transfer. The second part of this paper deals with the practical aspects of designing a transistor double-tuned IF strip. The choice of transistors, the design of the output stage, AGC consideration as well as traps used for the transistor amplifier are discussed.

Hold Range and Pulse Interference Immunity of Triggered Deflection Oscillators for Television Receivers—E. Luedicke (p. 33)

It is shown that formulas can be derived which describe the property of pulse triggered saw-tooth oscillators if interference pulses are in the synchronizing signal.

To synchronize a free-running oscillator it is necessary that the free-running frequency of the oscillator be in a certain range, the hold range. If interference pulses are in the synchronizing signal the position of the free-running frequency in this range describes whether the oscillator will be triggered by interference pulse or not and how many cycles pass before the oscillator will regain synchronization. The derived formulas and supporting experiments show that it is advantageous to operate the oscillator at the lower frequency part of the hold range to get the best interference immunity. A chart is presented which gives the relationship between hold range, interference immunity and how many cycles will pass before the oscillator will regain synchronization.

Modification of U.S. Television Receivers for Operation in 50-Cycle Power Areas—R. C. Auriema and R. J. Farber (p. 50)

Conventional television receivers designed for operation in continental United States can be operated, after some modification, in other environments. The most likely of these are: 1) the 525-line 60-field standard, as in the United States, but with 50-cps nominal primary power; and 2) the 625-line 50-field systems with 4.5 mc or 5.5 mc inter-carrier spacing. This report describes the nature of the modifications that have been employed under these various conditions.

Simplification of Viewer Brightness and Contrast Controls on Color TV Receivers—L. L. Burns, R. W. Ahrons, and L. B. Johnston (p. 54)

Automatic brightness and contrast control circuitry has been developed for color television receivers that eliminates the need for viewer adjustment of these functions. This circuitry prevents spot blooming and ultor power supply overload and results in a picture that is on the average superior to the picture obtained when a nontechnical viewer adjusts the sets. Inherent in this circuitry is some variation in the background brightness level.

Two versions of this automatic circuitry have been built. One has both viewer brightness and contrast controls removed while the other retains a single picture knob. Both versions use a high-impedance diode circuit to sense the point where spot blooming begins. The signal from this circuit is amplified, rectified, and then fed back to turn down the overall set gain so as to reduce the amount of spot blooming. Another circuit uses the boosted B plus as a gate signal to gate through a signal proportional to the ultor power supply load. This signal is also amplified and rectified, and is then used to control picture brightness.

Circuit Theory

Vol. CT-6, No. 1, March, 1959

Sequential Transducer Issue

Abstracts (p. 2)

Buyer's Guide—D. A. Huffman, Guest Editor (p. 4)

Transistion Matrices of Sequencial Machines—S. Seshu, R. E. Miller, and G. Metze (p. 5)

In this paper a matrix technique is introduced for the analysis of state diagrams of synchronous sequential machines. The matrices introduced are closely related to the relation matrices of the calculus of relations and provide a formal tool for discussing state diagrams. It is shown that several of the well-known theorems on state diagrams are consequences of properties of transition matrices, which remain invariant under matrix multiplication. A reduction procedure for state diagrams, based on transition matrices, which is similar to Moore's technique, is given. A method of extending the results to asynchronous machines is also included.

Hazards and Delays in Asynchronous Sequential Switching Circuits—S. H. Unger (p. 12)

This paper is concerned with asynchronous, sequential switching circuits in which the variables are represented by voltage levels, not by pulses. The effects of arbitrarily located stray delays in such circuits are analyzed, and it is shown that, for a certain class of functions, proper operation can be assured regardless of the presence of stray delays and without the introduction of delay elements by the designer. All other functions require at least one delay element in their circuit realizations to insure against hazards. In the latter case it is shown that a single delay element is always sufficient. The price that must be paid for minimizing the number of delay elements is that of greater circuit complexity.

A Note on Memory Aspects of Sequence Transducers—J. M. Simon (p. 26)

This paper defines several classes of sequence transducers whose operations exhibit simple forms of memory. Some of the special properties and interrelationships for these classes of transducers are established.

Equivalent Sequential Circuits—W. J. Cadden (p. 30)

Three types of sequential circuits are defined, two of which are synchronous and one of which is asynchronous. The concept of equivalent sequential circuits as discussed by Huffman, Mealy, and Moore is extended to circuits of different types. Transformation procedures are given for transforming a state table of one type into state tables of the other types. One of these transformations can also be used to introduce unit delay between corresponding inputs and outputs for a synchronous circuit. The transformation methods allow a comparison of circuits, or state tables of different types to be made for a given sequential circuit problem. A few general conclusions are drawn about the different types of sequential circuits.

Analysis of Bilateral Iterative Networks—F. C. Hennie (p. 35)

In the usual iterative switching circuit, which may be considered the space analog of a synchronous sequential transducer, the output of any cell is dependent only upon the inputs of the cells to its left. This paper describes a more general type of one-dimensional iterative network in which the output of each cell may be a function of the inputs of all the cells in the network, both to the left and to the right of the given cell. Starting from a table of combinations which specifies the behavior of an individual cell, a means of describing the steady-state behavior of the entire network is developed. This description is readily reduced to a fairly simple canonic form, so that equivalent networks can be recognized. Certain types of redundancy which do not occur in an ordinary iterative or sequential network are discussed, and a means of detecting these redundancies is described. Examples are presented which indicate that the process of removing redundancies is more complex than the corresponding process in the sequential case. Finally, one method of synthesizing a stable bilateral iterative network is described, and some of the problems of transient behavior are indicated.

The Theory of Autonomous Linear Sequential Networks—B. Elspas (p. 45)

Analysis and synthesis techniques for a class of sequential discrete-state networks are discussed. These networks, made up of arbitrary interconnections of unit-delay elements (or of trigger flip-flops), modulo-p adders, and scalar multipliers (modulo a, prime p), are of importance in unconventional radar and communication systems, in automatic error-correction circuits, and in the control circuits of digital computers. In addition, these networks are of theoretical significance to the study of more general sequential networks.

The basic problem with which this paper is concerned is that of finding economical realizations of such networks for prescribed autonomous (excitation-free) behavior. To this end, an analytical-algebraic model is described which permits the investigation of the relation between network logical structure and state-sequential behavior. This relation is studied in detail for nonsingular networks (those with purely cyclic behavior). Among the results of this investigation is the establishment of relations between the state diagram of the network and a characteristic polynomial derived from its logical structure. An operation of multiplication of state diagrams is shown to correspond to multiplication of the corresponding polynomials.

A criterion is established for the realizability of prescribed cyclic behavior by means of linear autonomous sequential networks. An effective procedure for the economical realization of such networks is described, and it is shown that linear feedback shift registers constitute a canonical class of realizations. Examples are given of the realization procedure. The problem of synthesis with only one-cycle length specified is also discussed. A partial solution is obtained to this "don't care" problem.

Some special families of feedback shift registers are investigated in detail, and the state-diagram structures are obtained for an arbitrary number of stages and an arbitrary (prime) modulus.

Mathematical appendixes are included which summarize the pertinent results in Galois field theory and in the factorization of cyclotomic polynomials into irreducible factors over a modular field.

The relation of the theory developed in this paper to Huffman's description of linear sequence transducers in terms of the D operator is discussed, as well as unsolved problems and directions for further generalization.

Linear Modular Sequential Circuits—B. Friedland (p. 61)

Sequential circuits comprising 1) modulo-p (p = prime) summers, 2) amplifiers whose gains are integers $< p$, and 3) unit delays are considered in this paper which constitutes an extension of earlier work by Huffman. Such circuits are characterized in terms of the modular field

$GF(p)$ and vectors and matrices defined thereover. A summary of the properties of $GF(p)$ is given.

A linear sequential circuit is defined in terms of

$$\vec{y}(n) = C\vec{s}(n) = D\vec{x}(n)$$

$$\vec{s}(n+1) = A\vec{s}(n) + B\vec{x}(n)$$

where A, B, C, and D are $k \times k$ matrices defined over $GF(p)$. The latter equations constitute a canonical representation of any circuit comprising the above listed components. It is shown that circuits of this type meet the usual additivity criterion of linear systems.

The behavior of the circuit is described in a finite state space of k dimensions and p^k states. The autonomous circuit (A, B, C, D = constant and $\vec{x}(n) \equiv \vec{0}$, all n) is characterized by the matrix A. If A is nonsingular all initial states are either finite equilibrium points or lie in periodic sequences of length $T_r \leq T_{max} = p^k - 1$. If the minimum polynomial of A^r has distinct roots, T_r divides $r(p-1)$. If A is singular, there are some singular initial states to which the circuit cannot return in the absence of excitation.

The use of Z transforms for linear modular sequential circuits is demonstrated. Inputs and outputs are represented by their "transforms" and the circuit by its "transfer function." The transform of the output is the product of the transfer function and the transform of the input. Several illustrative examples are included.

Linear Multivalued Sequential Coding Networks—J. Hartmanis (p. 69).

Linear multivalued sequential coding networks are circuits whose input and output are synchronized sequences of non-negative integers less than some fixed number m. The output depends linearly on the present input and a finite number of previous inputs and outputs. The transfer characteristics of such a network are described by a ratio of polynomials in the delay operator, where the multiplication and addition are performed with respect to the fixed modulus m. An algebraic theory of the delay polynomials is obtained. It is shown that a polynomial has a complete set of null sequences if, and only if, its first and last coefficients are prime to the modulus m. The polynomials with no null sequences are characterized. It is shown when common null sequences imply that the polynomials have common factors and that a complete set of null sequences defines the polynomials.

It is also shown that a transfer function can be realized if the denominator contains a constant term prime to m and explicit constructions are given. A network is stable if the polynomial in the denominator of the transfer junction has no null sequence. Thus any nontrivial polynomial or its inverse is unstable if we are working modulo a prime. If the modulus is not prime, stable networks with stable inverses are constructed. Finally it is indicated how polynomials with no null sequences can be used to simplify the construction of coding networks.

Equivalent Ladder Networks by the Use of Signal Flow Graphs—C. F. Simone (p. 75)

Signal flow graphs of ladder networks have properties that make them convenient for determining impedances and transfer ratios. Because of the symmetry of these flow graphs it is possible to recognize equivalent flow graphs, and hence equivalent networks, with respect to some desired characteristic. In particular, the output-input voltage ratio is the characteristic that is used as the basis for equivalence. Evaluation of elements in the equivalent circuits results from relating coefficients in the transfer voltage ratio to the element values.

Using 4-branch ladder networks, examples are given of distributing resistance, determining when networks must use active elements for certain transfer functions, and finding the number of equivalences that exist.

A particular equivalence is derived between a bridged-T and ladder, and between a lattice and ladder. In each case, three of the branches of the ladder are the same as in the bridged-T or lattice, while the fourth branch of the ladder is a function of all the impedances. These equivalences are derived by recognizing the flow graph configuration for a ladder within the flow graph of each of the other circuits and then reducing these flow graphs to the one for the ladder.

Identification of Certain Networks with Reflection Coefficient Zero Locations—D. C. Fielder (p. 81)

In this paper, the coefficients of return loss expansions are found for certain low-pass, LC ladder networks which have n lossless elements and which exhibit Tchebycheff (or equal ripple) pass band and monotonic stop band transmission behaviors. The return loss expansion is the Taylor expansion of $\ln(1/\rho_1(s))$ about s equal to infinity, the variable s being the familiar complex frequency variable $s=\sigma+j\omega$, and ρ_1 being the reflection coefficient between a resistive termination and the remainder of the network. The return loss coefficients are tabulated according to reflection zero locations for odd and even n.

Methods for synthesizing low-pass, LC ladder networks from return loss coefficients are available. A presentation of the modifications necessary to adapt these methods for use with the particular coefficients discussed above is given. Thus, it is possible to synthesize certain Tchebycheff networks through use of return loss coefficients which are, in turn, directly identified with reflection zero locations.

The paper concludes with brief discussion of the extension of existing tables of Tchebycheff network element values for finding the element values for several reflection zero distributions and LC ladder arrangements.

The Degrees of Freedom in RLC Networks—A. Bers (p. 91)

It is shown here that the number of degrees of freedom, or what is equivalent—the number of natural frequencies—of any RLC network can readily be determined from the number of energy-storing elements and the topology of the network. The effect of loss (resistance) in altering the number of degrees of freedom is explained.

Pole Migration in Coupled-Resonator Filters—R. La Rosa (p. 95)

The narrow-band, coupled-resonator filter is analyzed by giving a vector interpretation to the transfer function. The significant parameters are the natural frequencies of the complete filter and the natural frequencies of the individual resonators. It is shown that insertion loss is related to the migration of the natural frequencies (poles) as the coupling coefficients between resonators are increased from zero. A vector construction is described for the pole migration of three coupled resonators.

Bounded Real Scattering Matrices and the Foundations of Linear Passive Network Theory—D. Youla, L. Castriota, and H. J. Carlin (p. 102)

In this paper the most general linear, passive, time-invariant n-port (*e.g.*, networks which may be both distributed and nonreciprocal) is studied from an axiomatic point of view, and a completely rigorous theory is constructed by the systematic use of theorems of Bochner and Wiener. An n-port Φ is defined to be an operator in H_n, the space of all n-vectors whose components are measurable functions of a real variable t, $(-\infty < t < \infty)$ (and as such need not be single-valued). Under very weak conditions on the domain of Φ, it is shown that linearity and passivity imply causality. In every case, Φ_a, the n-port corresponding to ϕ augmented by n series resistors is always causal (Φ_a is the "augmented network,"). Under the further assumptions that the domain of Φ_a is dense in Hilbert space and ϕ is time-invariant, it is proved that Φ possesses a frequency response and defines an $n \times n$ matrix $S(z)$ (the scattering matrix) of a complex variable $z=\omega+i\beta$ with the following properties: 1) $S(z)$ is analytic in Im $z>0$; 2) $Q(z) = 1_n - S^*(z)S(z)$ is the matrix of a non-negative quadratic form for all z in the strict upper half-plane and almost all ω. Conversely, it is also established that any such matrix represents the scattering description of a linear, passive, time-invariant n-port Φ such that the domain of Φ_a contains all of Hilbert space. Such matrices are termed "bounded real scattering matrices" and are a generalization of the familiar positive-real immittance matrices.

When Φ and Φ^{-1} are single-valued, it is possible to define two auxiliary positive-real matrices $Y(z)$ and $Z(z)$, the admittance and impedance matrices of Φ, respectively, which either exist for all z in Im $z>0$ and almost all ω or nowhere. The necessary and sufficient conditions for an $n \times n$ matrix $A_n(z)$ to represent either the scattering or immittance description of a linear, passive, time-invariant n-port Φ are derived in terms of the real frequency behavior of $A_n(\omega)$.

Necessary and sufficient conditions for Φ_a to admit the representation

$$i(t) = \int_{-\infty}^{\infty} dW_n(\gamma)e(t-\gamma)$$

for all integrable $e(t)$ in its domain are given in terms of $S(z)$. The last section concludes with a discussion concerning the nature of the singularities of $S(z)$ and the possible extension of the theory to active networks.

A New Operation for Analyzing Series-Parallel Networks—K. E. Erickson (p. 124)

The operation * is defined as $A*B = AB/A + B$. The symbol * has algebraic properties which simplify the formal solution of many series-parallel network problems. If the operation * were included as a subroutine in a digital computer, it could simplify the programming of certain network calculations.

Abstracts of Articles on Circuit Theory (p. 127)

Correspondence (p. 129)

PGCT News (p. 139)

Circuit Theory

Vol. CT-6, Special Supplement, May, 1959

Transactions of the 1959 International Symposium on Circuit and Information Theory, Los Angeles, Calif., June 16–18, 1959.

This material also appears as a special supplement to the IRE Trans. on Information Theory, Vol. IT-5, May, 1959.

Optimum Filter Theory

Nonstationary Smoothing and Prediction Using Network Theory Concepts—S. Darlington (p. 1)

Nonstationary signal and noise statistics are assumed, such that ensembles with the same covariances can be generated by passing white noise through finite networks of linear, time-variable, positive elements. Linear least-squares smoothing and prediction operations are to be found. This paper may be regarded as an extension, to nonstationary systems, of methods applied to stationary systems by Bode and Shannon, using primarily circuit theory concepts. Analogous results are obtained by examining analogous operations in frequency domain, and differential equations terms.

A New Kind of Matched Filter—H. P. Debart (p. 14)

In this article, an attempt is made to bring together the method of frequency filters, designed to separate signals whose spectra are nonoverlapping without regard to the statistical properties of the signals being separated, and the method of "optimum filters" (Wiener, Zadeh-Ragazzini) where the desired signal and the interference are specified by their power spectral densities or their autocorrelation functions.

Thus a class of new filters is defined; their fundamental properties are studied and a number of examples are furnished. Finally, a comparison is made, referring to a particular case, with the method of Zadeh and Ragazzini.

Nonlinear System Characterization and Optimization—A. G. Bose (p. 30)

The characterization and optimization of nonlinear systems is considered from the function space point of view. The design of nonlinear systems is regarded as the problem of mapping the function space of the past of the input onto a line that corresponds to the amplitude of the filter output. An orthogonal functional representation for a system is shown to result from any mapping which partitions this space into nonoverlapping cells. The complication of solving for optimum systems in terms of measured higher order statistics is circumvented by formulating the problem so that particular statistical measurements directly yield the optimum systems.

Coding Theory

Canonical Forms for Information-Lossless Finite-State Logical Machines—D. A. Huffman (p. 41)

An important class of finite-state machines transforms input sequences of digits into output sequences in a way such that, after an experiment of any finite length on the machine, its input sequences may be deduced from a knowledge of the corresponding output sequence, its initial and final states, and the set of specifications for the transformations by which the machine produces output sequences from input sequences. These machines are called "information-lossless."

Canonical circuit forms are shown into which any information-lossless machine may by synthesized. The existence of inverses tor these circuits is investigated; and circuits for their realization are derived.

Group Code Equivalence and Optimum Codes—A. B. Fontaine and W. W. Peterson (p. 60)

This paper describes a search for optimum group codes using the IBM 704 computer. Some theory of the relationship between equivalent codes used in narrowing the search is described, and the method of searching is outlined. The newly found optimum codes are listed, along with a number of counter-examples to typical conjectures on binary group codes.

Multi-Error Correcting Codes for a Binary Asymmetric Channel—W. H. Him and V. Freiman (p. 71)

Many binary channels currently in use exhibit highly asymmetric transmission characteristics. In such a channel, it may be sufficient to correct only those errors which result from incorrect transmission of one of the two code elements. The minimum distance requirement for a pair of i-tuple, error correcting code characters in such a case is weaker than in the case of a symmetric channel. This weaker requirement is used to generate codes which generally contain more code characters for a given length than codes designed for use in a symmetric channel. The resulting code is symbol-correcting rather than message-correcting.

A Class of Binary Systematic Codes Correcting Errors Occurring at Random and in Bursts—L. Calabi and H. G. Haefeli (p. 79)

Presentation of results concerning the performance of a family of binary systematic codes of arbitrary size, correcting bursts of considerable length and/or random errors. The basic idea of these codes is due to C. Hobbs of the Air Force Cambridge Research Center.

For the codes of two sub-families, practical decoding schemes are given. Also formulated are results concerning the use of these codes with erasure channels.

Graph and Matrix Theories

Graph Theory and Electric Networks—F. Harary (p. 95)

In this discussion, we mention the following topics concerning electric networks in graph theoretic terms: Kirchhoff's Laws, mesh and node equations, and matrix tree theorem; flow problems and Menger's theorem; Boolean functions and enumeration and synthesis problems; information theory and Markov chains; cut sets and incidence matrices; the "crummy relay" results of Moore and Shannon; and the treatment using electrical concepts of the dissections of rectangles into squares by Brooks, Smith, Stone, and Tuttle. The treatment is expository, but introduces the unifying framework of graph theory for these various considerations.

How to Grow Your Own Trees from Cut-Set or Tie-Set Matrices—E. A. Guillemin (p. 110)

The method recognizes that construction of a tree (and hence the pertinent graph) from a given matrix can be done by inspection once the pattern of its growth has been established. To this end it is only necessary that we have a mechanism, applicable to a given cut-set matrix which sorts out those rows that correspond to the outermost twigs or tips of the tree, for we can then form an abridged cut-set matrix corresponding to what is left of the total graph after the tree tips with their uniquely attached links are pruned away. This remainder again has tips which can be found and eliminated in the same way. Continuation thus reveals the desired growth pattern.

Since the method cannot fail to yield a graph if its existence is compatible with the structure of the given matrix, it may be regarded as a constructive test for fulfillment of necessary and sufficient conditions.

Applications of Matrix Algebra to Network Theory—I. Cederbaum (p. 127)

The role of unimodular (E), paramount (M) and dominant matrices in network theory is described. A distinction is made between the unimodular matrices which represent the transformations of the current coordinates and those representing the voltage coordinates of a network. A similar distinction can be made between the cut-set to branch and the loop to branch incidence matrices for adequate systems of node-pair voltages and link currents, respectively.

Some new results concerning the synthesis of a resistive n-port from its admittance or impedance matrix are given.

Reliability of a Physical System—H. Mine (p. 138)

This paper presents the general concept of the reliability of a complex physical system which consists of a number of unreliable components. Such a system may be analyzed systematically by means of algebraic and topological theory. Various properties concerning the system reliability are established. A numerical procedure for finding the necessary topological quantities is developed to facilitate computations. The optimization of the reliability of the basic system under given restricted conditions can be accomplished by the application of the theory described.

Switching Theory

The Theory of Switching Nets—M. Yoeli (p. 152)

The paper develops a strictly mathematical unified theory of combinational switching networks of various types, with the aid of linear graph theory and lattice algebra. The *switching net* serves as the basic concept; it is defined as a directed, linear graph, the branches of which are weighted by elements of a distributive lattice.

Similarly to the application of Boolean matrix theory to the study of relay-contact networks, the theory of switching nets makes use of a more general lattice matrix calculus.

The paper includes, besides some new results, suitably modified, purely mathematical versions of known theorems on electrical contact networks.

Irredundant and Redundant Boolean Branch-Networks—L. Löfgren (p. 158)

Certain Boolean functions can be generated by irredundant branch-networks, *i.e.*, with networks with only one branch for each variable (literal) of the function. A simple solution (based on graph theory) is given to the realizability problem for irredundant 2- and n-terminal networks. The theory of irredundant networks is significant for the design of redundant networks, *i.e.*, networks generating functions with a certain protection against temporary branch errors. A few examples on redundant networks are given and the method of design is compared with coding theory.

On the Classification of Boolean Functions—S. W. Golomb (p. 176)

Two Boolean functions which differ only by permutation and complementation of their n input variables belong to the same symmetry class. Methods are described for determining the number of symmetry classes for functions of n variables, and for ascertaining whether or not two functions belong to the same class. This classification is achieved via a complete set of invariants, characteristic of the class, and easily computable from any function in it. The invariants also provide information concerning the size and symmetry properties of the class. Analogous techniques apply to other symmetry classifications of Boolean functions, and to more general categories of discrete mappings.

A Limit of Crosspoint Number—N. Ikeno (p. 187)

This paper describes a theoretical limitation on the number of crosspoints in large scale switching networks. The conclusion is as follows: given any blocking rate ($\neq 0, 1$), and any $\epsilon > 0$, we can construct a network with less crosspoints than $X_A(1+\epsilon)$, where $X_A = 10.90\ A \log_e A$, and cannot with less crosspoints than X_A, when the size of the network, as well as the total traffic A, becomes sufficiently large.

Signal, Noise and Detection Theories

The Representation of Signals—R. M. Lerner (p. 197)

A conceptually clear and computationally simple method of representing complicated signals is described. A signal of high time-bandwidth product is represented as the sum of a collection of simple elementary signals. As in the work of Gabor, these elementary signals are spaced at equal intervals in "time" and "frequency." It is shown that any convenient elementary signal may be used as the basis for the collection of elementary signals. A matrix algebra appropriate to these representations is discussed.

Some Results on Noise Through Circuits—W. M. Brown (p. 217)

The object of this paper is to give some novel analyses of noise statistics. Specifically, the zero crossing problem is analyzed for nonstationary noise, and some features of the envelope of noise are established. The theory underlying the formulation of the average number of times a noise, possibly not stationary, attains some specified value is given in some detail. The crossing rate for the nonstationary noise consisting of the sum of a stationary Gaussian noise and a determinate signal is found in terms of a rather simple integral. The integral is evaluated and approximated for such determinate signals as video pulse trains and sine waves.

The following two properties of the envelope of noise are proved: 1) the mean square output of an envelope detector is twice the mean square input (independent of the statistics of the input), and 2) the derivative of the envelope of Gaussian noise has a Gaussian first probability distribution.

The Probability Density of the Output of a Filter When the Input is a Random Telegraphic Signal: Differential-Equation Method—J. A. McFadden (p. 228)

By the method of Darling and Siegert, a differential equation is obtained for the characteristic function of the output of a linear system when the input is a random telegraphic signal. For the ideal integrator with finite memory and for the RC low-pass filter, the solutions agree with previous results. For a truncated exponential weighting function, the characteristic function is obtained in terms of Bessel functions. For a particular ratio of the constants, the probability density of the output is rectangular except for delta functions. The applicability of this rectangular solution to other systems is investigated.

A Comparison of Random and Periodic Data Sampling for the Detection of Signals in Noise—D. Middleton (p. 234)

Threshold coherent and incoherent detection of signals in normal noise is examined when random data sampling is employed at the receiver. The resulting optimum system and its threshold performance are compared with the corresponding cases where periodic sampling is used. Expressions for the system structure the error probabilities, and the Bayes risk are obtained; for the specific examples examined it is found that periodic sampling gives better performance than random sampling. A discussion of the generality of these results is given in the concluding section.

Random, Adaptive and Unilateral Systems

On the Mean Square Stability of Random Linear Systems—J. C. Samuels (p. 248)

The theory of random linear systems is extended to systems containing one or more nonindependent parameters under the assumption that the parameter processes and the solution process have very widely separated spectra. It is shown that the second product moment of the solution satisfies a linear integral equation which can be solved in closed form in some important special cases.

The mean square stability theory of equations containing one purely random coefficient initiated by Samuels and Eringen is developed further and extended to systems containing one narrow-band random parameter. Specific mean square stability criteria are worked out for an RLC circuit with capacity variations that are a narrow-band stochastic function.

Stability of Circuits with Randomly Time-Varying Parameters—J. E. Bertram and P. E. Sarachik (p. 260)

This paper is concerned with the stability, in a stochastic sense, of circuits or systems described by ordinary differential equations with randomly time varying parameters. Sufficient conditions for stability in the mean square are obtained by an extension of "Lyapunov's Second Method" to stochastic problems. The general result while applicable to nonlinear as well as linear systems, presents formidable computational difficulties except for a few special cases which are tabulated.

The linear case with certain assumptions concerning the statistical independence of parameter variation is carried out in detail.

Functional Equations in Adaptive Processes and Random Transmission—R. Bellman and R. Kalaba (p. 271)

By imbedding a given complex physical process within an appropriate class of processes and expressing the functional relationships among the members of the class, it is possible to obtain insights into the structure of the original process which would not be possible by considering this process alone. Not only may analytic expressions be obtained, but frequently computational tools are forged which make possible the exploitation of modern digital computing machines.

By way of illustration, this paper is devoted to a discussion of the functional equation techniques of dynamic programming and invariant imbedding in the study of some problems arising in the theory of adaptive control processes and in the transmission of signals through random media. Still other applications which have been made are briefly sketched.

On Passive One-Way Systems—H. Gamo (p. 283)

The passivity or positive real condition of passive linear two-terminal-pair networks is introduced. The formulas for thermal noise voltages of these networks are derived by using the Nyquist theorem. A relation between the passivity condition and thermal noise voltages is discussed.

From these results, several interesting features of passive one-way systems are derived. For instance, any physically realizable passive one-way system must contain a resistive component dissipating energy. It is not unidirectional with respect to the transmission of heat energy.

A method of synthesis for passive linear one-way systems unilateral at all frequencies is treated. Several examples such as electromechanical one-way systems are shown.

Component Parts

Vol. CP-6, No. 2, June, 1959

Information for Authors (p. 47)

Who's Who in PGCP—J. T. Brothers, Member Administration Commiteee (p. 48)

A Comparison of Thin Tape and Wire Windings for Lumped-Parameter, Wide-Band, High-Frequency Transformers—T. R. O'Meara (p. 49)

This paper considers the problem of optimum design of the impedance matching, lumped-parameter, wide-band transformer model with all transmission zeros at infinity. The spiral-tape-winding transformer is compared with the wire-winding transformer with an electrostatic screen, and it is shown that the former has no advantage over the latter except (perhaps) at quite low impedance levels. The low-pass-filter model of the transformer is considered in more detail than is customary, and it is shown that the HF performance of any lumped-parameter wide-band transformer may be extended in proportion to the number of branches selected for the ladder network model of the transformer; building out the transformer-coupling network to include additional inductor and capacitors thus extends the frequency response.

For a given network model and a given low-end cutoff frequency, it is shown that the high-end cutoff frequency is a function of the peripheral distance around the winding, the mean impedance level of the source and load, and the turns ratio. From this relation it is shown that the most favorable turns ratio is unity and that the most favorable impedance levels are low ones.

A Comparison of the Noise and Voltage Coefficients of Precision Metal Film and Carbon Film Resistors—T. R. Williams and J. B. Thomas (p. 58)

Measurements of the current noise and voltage coefficient are given for metal film and carbon film resistors. In general, the noise power in the metal resistors was less than that in the carbon by a factor of 10^3, although a few of the former type were very noisy. For many typical applications in and below the audio spectrum the current noise in a large fraction of the metal resistors will be smaller than thermal noise even at rated dissipation. The voltage coefficients of the metal resistors were less than those in the carbon by a factor of about 10; in most units of the former type the coefficients were less 3×10^{-5} per cent/volt, and in a few units they were less than 1×10^{-6} per cent/volt. Voltage coefficients of both signs were found in the metal resistors, while all of them were negative in the carbon resistors.

Problems in Long-Term Component Reliability—K. E. Latimer (p. 62)

The motion of submerged repeaters during laying and pick-up in deep water has been investigated and the results are presented.

An attempt has been made to gather together in a systematic way the very scattered references to long-term deterioration problems affecting the choice of materials of which components are made.

Component testing procedure is discussed and special features of individual components which affect long-term deterioration are mentioned.

The Physics of the Solid-State Maser—J. D. Howarth (p. 81)

Since the demonstration of the possibility of achieving very low noise amplification of signals in the centimetric wavebands, a great deal of work has been carried out in various laboratories with a view to producing and testing devices. The major part of the present article focuses attention on one particular device, the three-level solid-state maser. The physical principles underlying the process of stimulated emission of radiation are in many cases unfamiliar to electronic engineers, and study of the growing literature on the subject can be confusing without a clear understanding of the physics involved.

The present article outlines the general theory of emission and radiation processes, particularly as they apply to the microwave spectrum. A quantum mechanical description is employed throughout, and a brief and not very rigorous account is given of the relevant portions of this theory as it applies to the investigation of transistors between energy levels.

Well-known expressions are derived for the operating characteristics of a three-level maser, particular attention being given to the significance of the various factors involved and their relationship to easily measured quantities. Little information is included concerning practical maser amplifiers; at the time of writing, few practical devices had been constructed. A survey of recent literature indicates the rapid progress which has since been made, and shows the interest in the development of masers.

Magnetism and the Rare-Earth Metals—J. M. Lock (p. 93)

After a brief outline of the history of the discovery and separation of the rare-earth elements, the modern theory of paramagnetism is summarized, and its applications to these metals is discussed, with particular attention paid to the way in which deviations from the simple laws of paramagnetism at low temperatures can yield information on the types of magnetic interaction which exist in them. The present state of experimental knowledge about the rare-earth metals is described, and its interpretation for each element is discussed.

Metal and Oxide Film Potentiometers—G. V. Planer (p. 105)

Recent developments in resistors and potentiometers of the noble metal and metal oxide film types are described. Photographic methods of producing "meandered" resistance paths in the two types have been developed, as well as means of rhodium reinforcing the track portions to improve the wear characteristics, and in the case of oxide films, to reduce the contact resistance against the wiper. The relation between resistance, temperature coefficient, and film thickness has been determined for oxide films on glass comprising tin oxide as the major constituent, and from these, the conditions to result in low temperature coefficients over a relatively wide resistance range are deduced. The characteristics in respect of wear, noise, temperature coefficient, and electrical load for either type of element are briefly discussed.

Recent Developments in Fixed Resistors—R. H. W. Burkett (p. 109)

The commoner types of resistor used in electronic apparatus are discussed in terms of recent developments. In most cases developments have been largely progressive improvements without fundamental changes in the component. Some of the more interesting of recently developed types are also considered, these being metal films and metal oxide films and combinations. Their potentialities are outlined. The paper concludes with some account of resistors that are in the process of development and may be available soon. Improvement and development in pyrolytic carbon resistors is foreseen and wider availability and use of metal and metal oxide films are predicted.

Development of Plastic Dielectric Capacitors—J. H. Cozens (p. 114)

The salient characteristics of capacitors having dielectrics of polystyrene, polythene, polytetrafluorethylene, and polyethylene terephthalate are enumerated, and the current trends are indicated. Test results on experimental capacitors made with the new polycarbonate film are also quoted.

Some Recent Developments in Magnetic Alloys—C. E. Richards (p. 119)

The magnetic properties and use of some conventional and new alloys are discussed. The control which can be exercised on the switching properties by varying composition and treatment is indicated and a very fast switching alloy described.

The abnormally low permeability of very thin strip is explained; it can be avoided by keeping material and furnace atmosphere pure.

The latest aluminum-iron and cobalt-iron alloys, and permanent magnets, are briefly described.

Contributors (p. 123)

Electronic Computers

Vol. EC-8, No. 1, March, 1959

The Chairman's Column (p. 1)

Absolute Minimal Experssions of Boolean Functions—S. Abhyankar (p. 3)

In this paper we make a beginning in the hitherto unexplored problem of finding absolute minimal expressions of Boolean functions. We shall adhere to the notations and terminology introduced in our previous paper, which will be referred to as *S*. In the present paper, we shall find absolute minimals for Boolean functions whose point set complex consists of either one or two points. The case of one point is in Theorem 1, Section I. The case when the two points form a 1-cell is covered by Theorem 4, Section I which discusses an arbitrary dimensional cell. The case when the cell complex consists of two isolated points, the main theme of this paper, is dealt with in Section II.

A Generalized Resistor-Transistor Logic Circuit and Some Applications—S. S. Chao (p. 8)

This paper discusses a generalized resistor-transistor logic circuit; *i.e.*, the output produces a signal when any *m* out of the *n* inputs are "on." Practical limitations such as using precision power supplies and components are discussed. However, for smaller values of *n* and *m*, circuits could be designed such that no special precision component and supplies would be required. Several practical circuits are worked out, including a two-transistor binary full adder, a three-transistor comparator and a one-transistor-per-bit-ring counter. These circuits, especially the first two, are uniquely simple and low in cost. They can be incorporated with other circuits to simplify a digital system. It is felt that with ordinary supplies (less than 5 per cent voltage variation) and 1 to 5 per cent resistors, these circuits can be designed to be very reliable as one would expect from conventional circuits. The slight increase in cost of power supplies and components, if any, is, in many cases, over compensated by the simplicity of these circuits.

Experimental circuits employing germanium alloy junction transistors operate successfully at pulse rates up to 500 kc and an ambient temperature of 55°C.

A Synthesis Technique for Minimal State Sequential Machines—S. Ginsburg (p. 13)

A method is presented which always yields a minimal state sequential machine satisfying a prescribed finite set of input-output sequences. An application is made to the case where a given sequential machine is to be reduced, by the merging technique, to a machine having the smallest number of states possible. Numerous examples are given.

A Ring Model for the Study of Multiplication for Component Codes—H. L. Garner (p. 25)

A model is presented which, when modulo addition is used, can be used to derive multiplication correction schemata for operands expressed in either the radix complement or the diminished radix complement code.

A High Speed Analog to Digital Converter—D. Savitt (p. 31)

An electronic voltage encoder has been developed which converts analog voltages to their corresponding parallel seven binary-digit representations at a 50-kc encoding rate. The encoder is capable of being time-shared by any number of 0–50-volt range inputs. Performance tests indicate that the present design may be capable of eight binary-digit conversions at encoding rates as high as 80 kc. Either more precise conversions or higher encoding rates may be obtained at the expense of the other by cascading more or less of the identical one-digit encoder stages which constitute the analog to digital converter.

A Non-Real-Time Simulation of SAGE Tracking and BOMARC Guidance—D. W. Ladd and E. W. Wolf (p. 36)

The addition of facilities to the SAGE system for control of a new defensive weapon, such as the BOMARC missile, requires extensive modifications to the SAGE computer program. To obtain a better understanding of BOMARC control problems, a program has been written for the IBM Type 704 computer to simulate the proposed employment of BOMARC in the SAGE system. Such a simulation is flexible enough to optimize and evaluate a large range of parameters. On three separate passes through the 704 (with tape storage of intermediate results) the program simulates radar, target, and missile performance, as well as SAGE tracking and missile guidance. A fourth program presents the desired output data in the form of frequency distributions and detailed results pertaining to selected target or missile tracks.

Time Multiplexing as Applied to Analog Computation—E. Rawdin (p. 42)

This multiplexer can perform a common dynamic operation upon several sets of inputs utilizing equipment for one dynamic operation. The result of the multiplexing will yield the corresponding several sets of outputs as though each set of inputs were operated upon separately by the dynamic operation. This device is useful when the dynamic operation to be shared involves relatively expensive equipment such as electromechanical gear and/or electronic computing or measuring circuits. It is particularly useful to reduce the number of components required when implementing problems in a simulation laboratory.

A Figure of Merit for Single-Pass Data Recording Systems—J. H. Mulligan, Jr. (p. 48)

The problem of the interference caused by eddy current transients to the reproduction of recorded data is studied for single-pass magnetic recording systems of both the write-read and read-write variety. Signal-to-interference ratios are introduced for both modes of operation, and their variation is studied in detail. It is found convenient to introduce a dimensionless parameter a as a figure of merit for single-pass systems. This factor is a function of the velocity of the magnetic medium, the number of pulses that can be recorded per unit length, and the permeability, conductivity, and dimensions of the laminations of the recording head; it is equal to $a=\pi^2/6Nv\mu\sigma d^2$. Brief consideration is given to the effect of certain practical system factors on the conclusions reached from the theoretical analysis.

Simulation to Obtain a Systems Measure of an Air Duel Environment—A. A. B. Pritsker, R. C. Van Buskirk, and J. K. Wetherbee (p. 55)

A combined analog-digital simulation of an air battle between an attacking bomber aircraft and a ground controlled interceptor, including the intermediate human radar operator, has been designed for the purpose of evaluating the effects of airborne electronic countermeasures upon a ground-based radar operator.

Both real and nonreal time simulation are used in the experimental setup. The simulation encompasses as much as possible of the system as affected by the operators' performance in the hope that a systems measure could be obtained. It is hypothesized that probable success of the bomber is the systems measure of the effectiveness of the countermeasures.

1958 PGEC Membership Survey Report—K. W. Uncapher (p. 60)

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Abstracts of Current Computer Literature (p. 69)

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Information Theory

Vol. IT-5, Special Supplement, May, 1959

Transactions of the 1959 International Symposium on Circuit and Information Theory, Los Angeles, Calif., June 16–18, 1959. See this material listed under Circuit Theory.

Military Electronics

Vol. MIL-3, No. 2, April, 1959

Frontispiece (p. 25)

Guest Editorial—K. A. Ehricke (p. 26)

Some Problems in Ionic Propulsion Systems—E. Stuhlinger and R. Seitz (p. 27)

Some of the problems and applications of ionic propulsion systems are discussed. Three different systems' optimization criteria are considered: the maximization of the initial acceleration of a space vehicle; the minimization of the total mass-to-payload mass ratio; and the minimization of the propellant mass required to refuel the vehicle. The production, accleleration, and neutralization of beams of singly-ionized cesium ions is also discussed in limited detail. A hot tungsten contact-catalyst type of ion source is assumed and some experimental results with such a source are reviewed. Finally, a simplified treatment of the space charge neutralization of a positive ion beam in the region behind the space vehicle is presented. In this treatment, the positive ion beam is replaced by an infinitely long cylinder of uniformly distributed positive charge. Electrons are emitted from an annular filament encircling the perimeter of the beam. It is shown that this approximation leads to radial oscillations of the electrons through the positive column.

Plasma Propulsion Devices for Space Flight—M. Camrac, A. Kantrowitz, and H. E. Petschek (p. 34)

An analysis of some of the more immediate space missions indicates that a large increase in payload can be achieved when electrical propulsion is used instead of chemical propulsion. For missions in the gravitational field of the Earth and to the Moon, the optimum specific impulse range for electrical propulsion is from about 1500 to 5000 seconds. Electrical propulsion with neutral plasma devices operates well in this specific impulse range as well as at higher specific impulses. Three different chambers have been described as examples of devices using neutral plasmas. Some of the factors which limit the range of efficient operation of such devices have been discussed.

Plasma Propulsion Possibilities—W. Rayle (p. 42)

Plasma propulsion systems are arranged in three categories according to the cyclic nature of the jet produced: 1) steady, 2) alternating or wave-accelerated, and 3) pulsed. Typical systems within each category are described with emphasis on work being done at the NASA Lewis Research Center. The criteria for evaluating the relative merits of these systems are listed and the advantages and disadvantages pointed out. Such parameters as energy efficiency and propellant utilization must be measured before conclusions can be reached as to the eventual applicability of any of these systems.

A Brief Survey of Direct Energy Conversion Devices for Possible Space-Vehicle Application—A. E. von Doenhoff and D. A. Premo (p. 46)

A brief review is given of various types of devices for converting heat or radiant energy directly into readily available electrical form. These devices include the thermoelectric generator, the photovoltaic cell, the thermionic converter, and the photoemissive converter. The discussion is from the point of view of possible space-vehicle application. An attempt is made to indicate in a general way the present state of development, the advantages and difficulties associated with each device, and to suggest general lines of future research.

Fusion for Space Propulsion—S. H. Maslen (p. 52)

The possible role of a controlled thermonuclear reactor in space missions is discussed. Although such a reactor is many years from reality, some of its properties are understood well enough to indicate problems which will appear and which are peculiar to space flight. It appears that it will have a deliver electric power or thrust at a weight of about one pound per kw in order to represent significant improvement over other systems, notably the fission-electric one. One attractive feature of a fusion reactor, as now envisioned, is that it may lend itself to the direct production of electricity or even thrust, without an intermediate heat cycle. It is essential to avoid such a cycle if the weight is to be kept low.

Astronautics and Propulsion—K. A. Ehricke (p. 58)

Contributors (p. 65)

Radio Frequency Interference

Vol. RFI-1, No. 1, May, 1959

Control of Microwave Interference—A. H. Ryan (p. 1)

Three types of spurious signals generated by microwave transmitters are discussed: splatter, harmonic radiation and anharmonic radiation. The interference potentials and measurement problems of these types of radiation are discussed. Possible corrective measures in the form of receiver and transmitter filters are presented.

Analysis of Through-Channel and Cross-Channel Insertion Loss in Ferrite-Wall Multiple-Circuit Feedthrough Capacitors—I. Melngailis, E. M. Williams, and J. H. Foster (p. 11)

Through channel and cross-channel insertion losses of a new type of multiple-circuit feed-through-capacitors, comprising ferrite walls and multiple ceramic-tubes, have been calculated to aid in determining means for optimizing in design the characteristics in the VHF-UHF range. Units designed on the basis of the analytical results are shown to have considerable advantages over earlier feedthrough units in their economic feasibility and improved characteristics.

Design of Quasi-Peak Detectors with Specified Time Constants—Y. Peless (p. 18)

The paper describes a method for designing a quasi-peak detector for given charge and discharge time constants, assuming that the rectifying element has a linear forward characteristic. Some constants, useful in relating charge time and the physical parameters of the circuit, are computed for a wide range of charge to discharge time constant ratios. Special attention is paid to such circuits with standard charge to discharge ratios as used in noise meters.

Biographies of Authors (p. 24)

Reliability and Quality Control

Vol. RQC-16, June, 1959

Address to the Fifth National Symposium on Reliability and Quality Control—W. T. Thurman (p. 1)

Making a Multiplant Supplier Rating System Produce—P. J. Goldin (p. 7)

The Heart of a Reliability Program—A. Mood (p. 16)

The heart of a reliability program for a complex mechanism is early detection of design weaknesses by the performance and analysis of environmental test experiments on prototype or pilot models of major parts of the mechanism. Such a program must be carried out jointly by design engineers, experts in environmental testing, and statisticians thoroughly versed in the practice of experimental design; it must be completed before the onset of scheduled production.

The Relation Between Sample Size and Confidence in Test-to-Failure Reliability Programs—H. C. Jones (p. 24)

A Reliability Analysis of Recoverable Missiles—G. G. den Broeder, Jr., and W. E. Kane (p. 34)

Missiles with built-in recoverability features have been of interest to most missile firms and many related firms for some time. In order to evaluate the adequacy of recoverable missile performance, it is frequently necessary to answer such questions as, "With what probability will m such missiles yield a total of N or more successful flights?" or, "How many missiles should be allocated to a test program in which N or more successful flights must be realized with probability Q?" Answers to these questions are obtained in terms of three basic reliability characteristics: 1) probability of a successful flight, 2) probability of recovering after a successful flight, and 3) probability of recovering after an unsuccessful flight. In addition, a decision rule is derived for selecting the "best" reliability program.

The Employment of Failure Rate Data in Logistic Planning—J. B. Heyne and L. Brotman (p. 41)

Module Prediction—G. Hauser (p. 53)

An Approximate Method of Forming a Confidence Interval on Predicted System Reliability—R. E. Warr, J. A. Navarro, R. Schwartz, and R. D. Turner (p. 64)

Increased System Worth Through Reliability Design Review—R. Cazanjian and D. Ehrenpreis (p. 70)

It is the purpose of this paper to present the results, conclusions and recommendations of the analysis of electronic equipment to provide the optimum system worth, with regard to reliability and performance. Additional parameters set up in the three mathematical regimes are minimum weight, minimum geometric space envelope, schedule time delays, and cost trade-offs.

This paper further proposes a methodical engineered system which attaches numerical quantities and mathematical relationships which may be measured and compared to parameters determining electronic equipment system worth. Value engineering concepts are thus generalized for electronic equipment to include many significant parameters for optimum system worth—with probability of success and performance replacing cost reductions as the prime yardstick for anlaytical trade-off comparisons.

Forcing function inputs include transportation and handling loads, gunfire, takeoff, landing, flight maneuvers and catapult dynamic loads. These are mathematically treated as random vibrations, random shock, sustained acceleration, steady-state sinusoidal vibrations at resonance, sweep-cycle sinusoidal vibrations, and sudden impulse shock.

The electronic equipment is analyzed under all probable conditions of the true environment plus the requisite conditions of the governing military specifications. Critical deflections, rotations, stresses and deformations are determined at all key substations of each dynamic subsystem of the electronic equipment. Each electronic tube is subdivided into the significant subsystems: 1) cantilevered gun and assembly; 2) cantilevered heater and button assembly; 3) ceramic rods and helix; 4) outer envelope; 5) collector end; and 6) longitudinal tube framework.

Mathematical regimes are set up to determine the dynamic properties and characteristics of the electronic equipment. Natural frequencies, responses, internal and external rotations, deflections, shears, bending moments, thrusts, torsional shears and moments, stresses, deformations and margins of safety are determined.

A discussion is presented of the method of analysis, the setting up of the mathematical model, reasons for selection of this approach, basic relationships and equations. Definitions are given of regime, dynamic subsystem, substation, recursion equation, dynamic matrixes, error function, and margin of safety.

Test results for the electronic equipment demonstrated the effect of the recommendations to improve reliability and simultaneously reduce weight. Nonlinear vibration theory and nonviscous damping are the refinements included in the analysis of the electronic tubes to improve reliability and system worth.

An Evaluation of Torque-Rated Ball Bearings to Establish Specification Limits—L. G. Rado and J. P. Tuggle (p. 77)

One of the most difficult tasks of a standards group is the selection of specification limits for instrument precision ball bearings (Grade ABEC-5, or better). This paper presents a method of establishing these limits. Prior to this evaluation, the Ordnance Department had several procurement drawings with out-of-date torque specification. Engineering would have preferred tighter specifications, but the standards group objected on the ground that vendors might not be able to meet the specifications. The analysis of an experiment which was used to help resolve this problem is presented.

Announcement (Back Cover)

Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these papers, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

The Index to the Abstracts and References published in the PROC. IRE from February, 1958 through January, 1959 is published by the PROC. IRE, May, 1959, Part II. It is also published by *Electronic and Radio Engineer*, incorporating *Wireless Engineer*, and included in the March, 1959 issue of that journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534.143-8:537.228.1 **2078**
The Generation of Very Short Ultrasonic Pulses by means of Piezoelectric Resonators—J. Koppelmann, R. Frielinghaus, and F. J. Meyer. (*Acustica*, vol. 8, no. 4, pp. 181-187; 1958. In German.) The possibilities are discussed of using thickness vibrations of $BaTiO_3$ resonators for generating very short pulses and single pressure waves, and experimental methods are described.

534.15.087.352 **2079**
A Stroboscopic Method of Making Frequency Response Measurements on Small Electromechanical Devices—M. Shepherdson and R. Walters. (*Electronic Engrg.*, vol. 31, pp. 220-221; April, 1959.) A simple pulse amplifier and phase-shifting network are used with a stroboscopic lamp and travelling microscope. No loading of the test component occurs and amplitudes below 0.001 inch can be measured.

534.2+538.566 **2080**
Guided Propagation in a Slowly Varying Medium—Weston. (See 2204).

534.21:534.6 **2081**
Instrumentation for Study of Propagation of Sound over Ground—F. M. Wiener, K. W. Goff, and D. N. Keast. (*J. Acoust. Soc. Am.*, vol. 30, pp. 860-866; September, 1958.)

534.21:534.88 **2082**
Sound Absorption at 50 to 500 kc/s from Transmission Measurements in the Sea—S. R. Murphy, G. R. Garrison, and D. S. Potter. (*J. Acoust. Soc. Am.*, vol. 30, pp. 871-875; September, 1958.) The absorption coefficient, in decibels per thousand yards for sea water at 10°C and with a salinity of 30 parts per thousand, is: 14.4 ±0.3 at 60 kc, 35.7 ±0.7 at 142 kc, 57 ±3 at 272 kc and 101 ±3 at 467 kc. The equipment and the method of measurement are described.

534.26 **2083**
An Experimental Study of the Scattering of Sound in a Turbulent Atmosphere—M. A. Kallistratova. (*Dokl. Ak. Nauk SSSR*, vol. 125, pp. 69-72; March 1, 1959.) A graph shows the dependence of the scattering of sound on the turbulence of the atmosphere for scattering angle of 25° when the distance between the emitter and receiver is 40 meters.

534.6-8:621.385.83:537.228.1 **2084**
Results Obtained in the Construction of an Electronic Ultrasonic Image Converter—W. Freitag and H. J. Martin. (*Acustica*, vol. 8, no. 4, pp. 197-200; 1958. In German.) In the ultrasonic image converter described, the sound waves impinge on a piezoelectric plate which is scanned by an electron beam. The resulting signal is amplified and applied to a crt where it is displayed as an image of the object under test in the ultrasonic field.

534.6-8:621.395.625.3 **2085**
A Magnetic-Tape Recorder for Ultrasonic Frequencies—H. Lennartz. (*Elektron. Rundschau*, vol. 12, pp. 170-172; May, 1958.) An adaptor unit for tape recorders is described which is capable of recording or reproducing frequencies in the range 0.5-120 kc at a tape speed of 30 inches per second.

534.76:061.3 **2086**
Convention on Stereophony—(*Wireless World*, vol. 65, pp. 239-241; May, 1959.) A report of some of the papers read and equipment demonstrated at the IEE Convention held in London, March 19-20, 1959.

534.782:621.396.41 **2087**
Simple Multiplex Vocoder—Billings. (See 2394.)

534.784 **2088**
Measurements of Pitch Distribution in the German Language—W. Rappaport. (*Acustica*, vol. 8, no. 4, pp. 220-225; 1958.) Report on statistical measurements made with a specially-developed pitch recorder.

534.839 **2089**
Analysis of Impact Noise—F. M. Savage. (*Electronic Engrg.*, vol. 31, pp. 200-203; April, 1959.) An instrument is described for measuring electronically the peak intensity of dangerous impact noises. The time taken to do this is 50 μsec.

534.845 **2090**
Investigations of the Influence of Self Resonances of Measurement Chambers on the Results of Sound Insulation Measurements—M. Heckl and K. Seifert. (*Acustica*, vol. 8, no. 4, pp. 212-220; 1958. In German.)

534.88:534.15 **2091**
Portable Instrument for Locating Noise Sources in Mechanical Equipment—D. A. Gilbrech and R. C. Binder. (*J. Acoust. Soc. Am.*, vol. 30, pp. 842-846; September, 1958.) A description of a direction finder sensitive to the correlation between signals received by two microphones of a directional array.

621.395.61 **2092**
The Theory of the Cardioid Microphone—I. P. Valkó. (*Hochfreq. und Elektroak.*, vol. 66, pp. 185-188; May, 1958.) The combined pressure-type and differential microphone is represented by a three-pole network consisting of three mechanical or acoustic impedances.

621.395.61.089.6 **2093**
Equipment for the Absolute Calibration of Microphones of the Acoustics Department of C.N.E.T.—P. Riety. (*Ann. Télécommun.*, vol. 13, pp. 16-34; January/February, 1958.) Thermophone, reciprocity, electrostatic-grill, Rayleigh-disk and pistonphone methods are described.

621.395.614 **2094**
The Gradient Receiver for Intercommunication Installations—C. Smetana. (*Hochfreq. und Elektroak.*, vol. 66, pp. 179-185; May, 1959.) The suppression of acoustic feedback by means of differential microphones is discussed (see also 1757 of June). A first-order gradient crystal microphone is described and details are given of the suitable positioning of loudspeaker and microphone; results of tests under operating conditions in an intercommunication network are summarized.

621.395.623.7+621.395.625.3]:061.4 **2095**
London Audio Fair—(*Wireless World*, vol. 65, pp. 225-227; May, 1959.) A review of some of the new equipment on show in London, April 2-6, 1959.

621.395.625:681.84.081 **2096**
New Electromechanical Two-Component Transducer for Stereophonic Recording by the Sound-on-Disk Method—H. Redlich and H. J. Klemp. (*Telefunken Z.*, vol. 31, pp. 75-81; June, 1958. English summary, p. 135.) The design of a cutter head for single-groove stereophonic recording on disks is described.

ANTENNAS AND TRANSMISSION LINES

621.372 2097

An Investigation of the Excitation of Radiation by Surface Waves—K. P. Sharma. (*Proc. IEE*, pt. B, vol. 106, pp. 116–112; March, 1959.) The excitation of radiation at a discontinuity in surface reactance, and at the edge of a metallic strip above a reactive surface, is studied by a graphical method. Both discontinuities cause appreciable radiation, but the radiation from a change in surface reactance is confined to a narrower angle above the surface than that excited at the edge of a metallic strip.

621.372 2098

The Power Radiated by a Surface Circulating around a Cylindrical Surface—H. E. M. Barlow. (*Proc. IEE*, pt. B, vol. 106, pp. 180–185; March, 1959.) An analysis of the radiation from a wave on a highly-reactive supporting surface of cylindrical form. When the surface has a finite loss, there is a particular radius of curvature for which the surface wave progresses for a limited distance without attenuation.

621.372.029.6:535.8 2099

Optical Techniques at Microwave Frequencies—A. F. Harvey. (*Proc. IEE*, pt. B, vol. 106, pp. 141–157; March, 1959.) A summary of optical techniques applied in radiation and diffraction, artificial dielectrics, surface reflection, and instruments which are especially useful at millimeter wavelengths. 162 references.

621.372.2 2100

The Influence of the Dielectric on the Phase Constants of the Spatial Harmonics of a Helix—V. P. Kiryushin. (*Radiotekh. Elektron.*, vol. 2, pp. 901–911; July, 1957.) An approximate theory of the tape helix is derived from the dispersion equation for a helix surrounded by a dielectric cylinder of finite thickness. Good agreement is obtained between the calculated values of the dielectric effect for the first inverse harmonic and the measured values for a twin helix made of round wire and secured by means of a quartz tube.

621.372.2–419 2101

Nonuniformities in Laminated Transmission Lines—G. Raisbeck. (*Bell Sys. Tech. J.*, vol. 38, pp. 477–516; March, 1959.) The effect of certain nonuniformities has been calculated by a perturbation method. These include variation of radius of curvature, systematic variation of effective dielectric constant and random variation in layer thickness.

621.372.2–419 2102

An Experimental Clogston 2 Transmission Line—R. A. King. (*Bell Sys. Tech. J.*, vol. 38, pp. 517–536; March, 1959.) The construction and termination of a laminated conductor of 100 concentric layers are described. Measurements of the mode pattern and attenuation as a function of frequency up to 25 mc were made.

621.372.8 2103

Propagation in Discontinuous Periodic Structures and its Application to Waveguides—M. Jouguet. (*Câbles & Transm.*, vol. 12, pp. 23–36; January, 1958.)

621.372.8:537.56 2104

Wave Propagation in a Plasma Cable with External Magnetic Field—G. Bittner. (*Z. angew. Phys.*, vol. 10, pp. 117–122; March, 1958.) Phase velocity and attenuation of em waves at frequencies in the range 30–1000 mc, and the characteristic impedance between 30 and 300 mc, were measured in a coaxial system consisting of the plasma in a gas-discharge tube as center conductor and a brass outer conductor slotted to accommodate a sliding probe. Tests were made with and without a magnetic field applied parallel to the direction of wave propagation.

621.372.8.001.4(083.74) 2105

IRE Standards on Antennas and Waveguides: Waveguide and Waveguide Component Measurements, 1959—(Proc. IRE, vol. 47, pp. 568–582; April, 1959.) Standard 59 IRE 2.S1.

621.372.81.09 2106

Propagation around Bends in Waveguides—H. E. M. Barlow. (*Proc. IEE*, pt. C, vol. 106, pp. 11–15; March, 1959.) The use of an inhomogeneous dielectric to minimize mode changes at bends, previously worked out for the circular H_{01} guide (3037 of 1957), is extended to the rectangular H_{01} guide bent in either the H plane or the E plane, and to the dielectric-coated single-wire waveguide. General requirements for smooth propagation are also discussed.

621.372.81.09 2107

Use of Circular Waveguides for Long-Distance Transmission of Centimetre and Millimetre Waves—G. Comte, F. de Carfort, A. Ponthus, and M. Paris. (*Câbles & Transm.*, vol. 11, pp. 342–355; October, 1957.) The attenuation of Te_{01} waves in guides with isotropic and aeolotropic conductivity is studied theoretically and experimentally.

621.372.821 2108

Parallel-Plate Transmission Systems for Microwave Frequencies—A. F. Harvey. (*Proc. IEE*, pt. B, vol. 106, pp. 129–140; March, 1959.) A survey of the various types of parallel-plate or strip lines and their basic characteristics. A photo-etching process for manufacture is outlined. 67 references.

621.372.821 2109

Propagation in Ferrite-Filled Microstrip—M. E. Brodwin. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 150–155; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1328; June, 1958.)

621.372.826 2110

The Launching of Radial Cylindrical Surface Waves by a Circumferential Slot—J. Brown and K. P. Sharma. (*Proc. IEE*, pt. B, vol. 106, pp. 123–128; March, 1959.) The launching efficiency is investigated theoretically and experimentally. The radius of the slot has a small effect on the efficiency. An optimum value of 68 per cent is found with a slot of 2-cm radius above a 58-Ω reactive surface.

621.372.83 2111

The Transformation of Admittance through a Matching Section and Lossless Waveguide Junction—J. R. G. Twisleton. (*Proc. IEE*, pt. B, vol. 106, pp. 175–179; March, 1959.)

621.372.832.43 2112

Properties and Design of Long-Slot Directional Couplers—E. Schuon. (*Arch. elekt. Übertragung*, vol. 12, pp. 237–243; May, 1958.) The coupler is considered as a single waveguide in which two types of field distribution exist, and the boundary conditions at the input of the coupler are satisfied by superimposing the two types of field. Coupling and directivity factors are obtained in terms of cutoff wavelengths determined by analog measurements.

621.372.832.8:538.632:537.311.33 2113

The Hall-Effect Circulator—a Passive Transmission Device—W. J. Grubbs. (Proc. IRE, vol. 47, pp. 528–535; April, 1959.) Three-part nonreciprocal Hall-effect devices have been made which circulate dc and ac signals in either a clockwise or anticlockwise sense. Forward losses of 17 db and reverse losses of 61 db have been obtained, giving a transmission ratio of 44 db. It is shown that the minimum possible forward loss for a Hall-effect circulator is 8.4 db.

621.372.852.2 2114

A New Class of Broad-Band Microwave 90-Degree Phase Shifters—B. M. Schiffman. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 232–237; April, 1958. Abstract, Proc. IRE, vol. 46, pp. 1329–1330; June, 1958.)

621.372.852.22 2115

Calculation of Phase Shifts of Gyrotropic Inhomogeneities in a Waveguide using a Perturbation Method—V. V. Nikol'skiĭ. (*Radiotekh. Electron.*, vol. 2, pp. 833–842; July, 1957.) A mathematical analysis of waveguides of rectangular and circular cross section containing ferrite rods, ferrite spheres or diaphragms. Inhomogeneities in a coaxial line are also examined.

621.372.852.22 2116

Circular Waveguide Partially Filled with Ferrite as a Slow-Wave Structure—R. G. Mirimanov and Yu. V. Anisimova. (*Radiotekh. Electron.*, vol. 2, pp. 843–855; July, 1957.) A theory is evolved for a waveguide with ideally-conducting walls covered on the inside by a layer of a gyromagnetic material of arbitrary thickness. A dispersion equation is derived which can be applied to a wide range of waveguides. The physical properties of a waveguide and its delay system are examined and some of their characteristics are determined.

621.372.86 2117

Rotating-Loop Reflectometer for Waveguide—P. J. Houseley. (Proc. IRE, vol. 47, pp. 585–586; April, 1959.)

621.396.67:537.226 2118

Some Investigations on Dielectric Aerials: Part 3—B. R. Rao, R. Chatterjee, and S. K. Chatterjee. (*J. Indian Inst. Sci.*, sect. B, vol. 39, pp. 143–155; October, 1957.) Two theories for the radiation of a dielectric rod antenna excited in the He_{11} mode have been verified experimentally using a perspex rod of length $2\lambda_0$–$10\lambda_0$ and diameter $0.5\lambda_0$. Part 2: *ibid.*, vol. 39, pp. 134–140; July, 1957. See 1030 of 1958 (Chatterjee and Chatterjee).

621.396.67.029.63:621.372.51 2119

A Quadruplexer Allowing the Simultaneous Transmission of Two Complete Television Stations using a Common Antenna—G. B. MacKimmie. (*Commun. and Electronics*, no. 40, pp. 787–791; January, 1959.) Shows how sound- and vision-frequency signals of two television transmitters, on bands 4 and 5 respectively, were combined and made to radiate from a single antenna originally designed for band 4.

621.396.677:621.396.933.2 2120

A New Method of Generating a Rotating Radiation Polar Diagram—H. W. Hawkes. (*Proc. IEE*, pt. B, vol. 106, pp. 158–169; March, 1959.) A rotating antenna array of small dimensions is coupled electrically to a static array of large dimensions acting as the final radiator. The application of the technique in a new and more accurate form of VHF omnirange system (Vorac) is described.

621.396.677:621.396.965.4 2121

A Microwave Antenna with Rapid Sawtooth Scan—J. S. Foster. (*Can. J. Phys.*, vol. 36, pp. 1652–1660; December, 1958.) An account of the development of the Foster antenna. Two systems are described, one with maximum angular scan of 45° and the other 80°. See also 1331 of 1957 (Honey and Jones).

621.396.677:621.397.62 2122
A Second Band-III Programme?—The Aerial Problem—F. R. W. Strafford. (*Wireless World*, vol. 65, pp. 235–238; May, 1959.) Continuation of 1775 of June. The efficiency of conventional Yagi arrays used in primary or fringe areas is shown to be poor when the operating frequency is separated by two or three channels from the optimum frequency. Stacked-dipole and corner-reflector wide-band antennas are shown to have satisfactory electrical characteristics, but have attendant mechanical problems due to their large size.

621.396.677.85 2123
Theory of Reflection from the Rodded-Type Artificial Dielectric—A. Carne and J. Brown. (*Proc. IEE.*, pt. B, vol. 106, pp. 107–114; March, 1959. Discussion, pp. 114–115.) An artificial dielectric having a wave impedance equivalent to that of free space is described in which an array of thin conducting wires is located parallel to the electric field of the incident wave. Results are given which show good agreement with theory.

621.396.677.852:621.396.965.4 2124
The Use of Dispersive Artificial Dielectrics in a Beam-Scanning Prism—J. S. Seeley and J. Brown. (*Proc. IEE*, pt. B, vol. 106, pp. 93–102; March, 1959. Discussion, pp. 114–115.) Beam scanning is achieved by using an FM signal and two types of dispersive dielectric. One consists of an array of rods, and the other of an array of sheets containing a pattern of resonant slots. Experimental values of the electrical constants of the arrays are given with details of the design of the prism.

621.396.677.852:621.396.965.4 2125
The Quarter-Wave Matching of Dispersive Materials—J. S. Seeley. (*Proc. IEE*, pt. B, vol. 106, pp. 103–106; March, 1959. Discussion, pp. 114–115.) "Reflections from the surfaces of dispersive materials used in broad-band antenna systems are highly frequency-dependent. A technique for matching such materials is described, and results are included of a successful application to the input surface of a dispersive prism."

AUTOMATIC COMPUTERS

681.142 2126
A New Concept in Computing—R. L. Wigington. (Proc. IRE, vol. 47, pp. 516–523; April, 1959.) The phase of a sine-wave signal is used as an information-bearing medium which, together with majority logic, permits the realization of logic operations. Nonlinear reactances are employed. Computing can be carried out more rapidly than by present techniques if microwave frequencies are used.

681.142 2127
A New High-Speed Digital Technique for Computer Use—D. Eldridge. (*Proc. IEE*, pt. B, vol. 106, pp. 229–236; March, 1959. Discussion, pp. 237–239.) Square-loop ferrite cores and transistors are used, operating at digit rates of 500 kc. Only two low-voltage dc supplies are required and the system is not critically dependent on voltage and component variations.

681.142 2128
The Automatic Computing Engine at the National Physical Laboratory—J. H. Wilkinson and D. W. Davies. (*Nature*, (*London*), vol. 183, pp. 22–23; January 3, 1959.)

681.142 2129
Digital Memory System keeps Circuits Simple—T. C. Chen and O. B. Stram. (*Electronics*, vol. 32, pp. 130–135; March 13, 1959.) A magnetic disk memory of 50- to 100-words capacity using simple control and selection circuits.

681.142 2130
A General Approach for Obtaining Transient Response by the use of a Digital Computer—P. E. Lego and T. W. Sze. (*Commun. and Electronics*, no. 40, pp. 1031–1036; January, 1959.) Adaptation of digital computers to the inverse Laplace transformation process and the Fourier integral method is shown to have major advantages in determining the transient response of linear control systems.

621.142:538.632 2131
The Use of Hall Generators in Analogue Multipliers—J. Oxenius. (*Nachrichtentech. Z.*, vol. 11, pp. 263–268; May, 1958.) Experimental equipment incorporating an InAs-crystal Hall generator is described.

681.142:621.314.7 2132
Operating Experience with a Transistor Digital Computer—R. C. M. Barnes and J. H. Stephen. (*Proc. IEE*, pt. B, vol. 106, pp. 222–228; March, 1959. Discussion, pp. 237–239.) A description of the performance of a small laboratory-model digital computer over a period of a year, with analyses of serviceability and transistor failures. The failure rate of point-contact transistors was higher than expected, but was of the same order as that quoted by other workers for standard thermionic tubes in digital computers.

681.142:621.317.79 2133
Quadratic Interpolation in Tapped-Potentiometer Function Generators—E. M. Deeley. (*Proc. IEE*, pt. C, vol. 106, pp. 102–107; March, 1959.) The quadratic variation of the resistance to ground from the slider of an auxiliary potentiometer interpolating between the tapping points on the function-generating potentiometer is utilized to achieve quadratic interpolation.

621.142:621.318.57:621.395.4 2134
Verification of the Logic Structure of an Experimental Switching System on a Digital Computer—D. C. Leagus, C. Y. Lee, and G. H. Mealy. (*Bell Sys. Tech. J.*, vol. 38, pp. 467–476; March, 1959.) "The verification problem is concerned with the construction on a computer of a logical program which satisfies all the design specifications prescribed for an experimental switching system and with the process of putting calls through the computer simulation to evaluate the system's logical structure."

681.142:621.385.832 2135
Stable High-Speed Digital-to-Analogue Conversion for Storage-Tube Deflection—C. F. Ault. (*Bell Sys. Tech. J.*, vol. 38, pp. 445–465; March, 1959.) Discussion of the design of access circuitry for a barrier-grid-tube temporary storage system which converts a 14-bit binary address into the analog voltage necessary to deflect the electron beam to a specific storage area defined by the address. A special feedback circuit and raster reference tube control the size and centering of the array of storage spots.

CIRCUITS AND CIRCUIT ELEMENTS

621.319.4.011.21 2136
Study of the Impedance of Capacitors as a Function of Frequency—J. P. Mayeur. (*Câbles & Transm.*, vol. 11, pp. 22–31; January, 1957.) Strip, stacked and disk-type capacitors have been studied. The natural resonant frequency is almost entirely dependent on the capacitance value and the connections.

621.319.45 2137
Solid-Electrolyte Tantalum Capacitors—R. Aries. (*Electronic Engrg.*, vol. 31, pp. 230–231; April, 1959.) The manufacturing process is described and the temperature characteristics and results of life tests are given.

621.372.01 2138
Elements of Electronic Circuits: Part 2—Clamping or D.C. Restoration—J. M. Peters. (*Wireless World*, vol. 65, pp. 231–232; May, 1959.) **Part 1: 1795 of May.**

621.372.2.029.6:512.831 2139
The Physical Realizability of a Microwave Junction—G. C. Corazza and G. Zoland. (*Note Recensioni Notiz.*, vol. 7, pp. 445–449; July/August, 1958.) The conditions are derived which must be satisfied by a matrix to represent the admittance, impedance or scattering matrix of a junction at a given fixed frequency. See also 1060 of 1958 (Corazza and Serracchioli).

621.372.41:621.318.424 2140
The Ferroresonant Circuit—G. E. Kelly, Jr. (*Commun. and Electronics*, no. 40, pp. 843–848; January, 1959. Discussion, p. 1061.) A theoretical and experimental treatment of the resonance obtained by varying the voltage applied to a circuit containing an iron-cored inductance.

621.372.41:621.318.424 2141
Behaviour of the Ferroresonant Series Circuit containing a Square-Loop Reactor—R. H. Dennard. (*Commun. and Electronics*, no. 40, pp. 903–911; January, 1959.)

621.372.412.002 2142
The Present State of Crystal-Resonator Techniques—H. Awender. (*Nachrichtentech. Z.*, vol. 11, pp. 225–237; May, 1958.) Review of production techniques with details of performance obtained in recent applications of crystal resonators in frequency standards, filters and delay lines. 112 references.

621.372.413 2143
The Expansions of Electromagnetic Fields in Cavities—K. Kurokawa. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 178–187; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1329; June, 1958.)

621.372.414:621.372.8 2144
Travelling-Wave Resonators—L. J. Milosevic and R. Vautey. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 136–143; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1328; June, 1958.) See also 1325 of 1956 (Sferrazza).

621.372.5 2145
Gyrators and Nonreciprocal Systems—M. Prudhun. (*Câbles & Transm.*, vol. 11, pp. 66–73; January, 1957.) Discussion of the conditions necessary for a linear four-terminal network containing only passive elements and gyrators, to have different attenuations in either direction.

621.372.5 2146
A New Synthesis Procedure for Two-Terminal-Pair Networks using the Symmetrical Lattice Structure—S. S. Forte. (*Proc. IEE*, pt. C, vol. 106, pp. 112–114; March, 1959.)

621.372.5 2147
Synthesis of *LC* Networks—J. T. Allanson. (*Electronic Radio Engrg.*, vol. 36, pp. 182–184; May, 1959.) "A method is outlined for the synthesis of certain voltage transfer functions by means of asymmetrical, balanced *LC* networks terminated at the load end by a resistance."

621.372.5:621.376.3 2148
A Simplified Analysis of Transients in Linear Circuits caused by the Frequency Modulation of an Input Signal—V. G. Segalin. (*Radiotekh. Electron.*, vol. 2, pp. 856–869; July, 1957.) A simplified method of investigation of transients is described with the intro-

duction of the concept of the transmission frequency coefficient. An explanation is provided for the mechanism of dependence of the time constant of the frequency transient on the frequency of modulation of the input signal. The frequency coefficients of transmission for aperiodic and differentiating circuits are also considered.

621.372.5.029.64 2149
Wave Matrices of a Quadripole—L. P. Yavich. (*Radiotekh. Electron.*, vol. 2, pp. 870–882; July, 1957.) The use of scattering and transmission matrices for cm-wave quadripoles is considered and the essential properties of these wave matrices are determined. The method is illustrated by a practical example in which an examination is made of the modulus and phase of the reflection coefficient of a waveguide filter consisting of two equal inhomogeneities and separated by a section of waveguide propagating an H_{10} wave

621.372.54 2150
Interchange of Infinite-Attenuation Elements in Ladder Filter Structures—J. E. Colin. (*Câbles & Transm.*, vol. 12, pp. 10–22; January, 1958.) Formulas are given for interchanging series antiresonant and shunt resonant circuits.

621.372.54 2151
Branched Filters—J. Oswald. (*Câbles & Transm.*, vol. 12, pp. 37–39; January, 1958.) The theories of Cauer and Piloty relating to constant-impedance branched networks are supplemented and applied using image-attenuation functions instead of Cauer's insertion-loss function. An eight-terminal network using two low-pass and two high-pass filters without a differential transformer is described.

621.372.54 2152
The Reactance Transformation of Low-Pass into Band-Pass Ladder Networks—A. Alaćić. (*Arch. elekt. Übertragung*, vol. 12, pp. 203–208; May, 1958.) The low-pass network is subdivided into quadripole elements which are then combined to form the band-pass network.

621.372.54 2153
Development of Filter Technique in France during the Last Ten Years—J. E. Colin. (*Câbles & Transm.*, vol. 11, pp. 302–313; October, 1957.)

621.372.54:534.1 2154
Flexural Vibrations in Mechanical Filters—M. Börner. (*Telefunken Z.*, vol. 31, pp. 115–123, 188–196; June and September, 1958. English summary, pp. 137–138, 206.) Matrix methods are used for calculating the characteristics of flexural vibrations in rods, and the results are compared with those measured by an experimental method described. The design of mechanical filters with torsional and longitudinal vibrations and free from flexural waves is discussed.

621.372.543.2:538.652 2155
Mechanical Filters for Communications Technique—M. Börner, E. Kettel, and H. Ohnsorge. (*Telefunken Z.*, vol. 31, pp. 105–114; June, 1958. English summary, p. 137.) The principle of operation and the design of filters consisting of magnetostrictive transducers and mechanical resonators are described. Details are given of a 525-kc IF band filter and a SSB filter for a carrier frequency of 200 kc.

621.372.543.3:621.375.4 2156
Transistor Active Filters using Twin-T Rejection Networks—A. E. Bachmann. (*Proc. IEE*, pt. B, vol. 106, pp. 170–174; March, 1959.)

621.372.6 2157
A Topological Investigation of Network Determinants—P. R. Bryant. (*Proc. IEE*, pt. C, vol. 106, pp. 16–22; March, 1959.) The main result gives the determinant of the nodal admittance matrix of an RLC network without mutual inductance or ideal transformers.

621.372.6:621.3.018.1 2158
The Practical Design of Two-Phase Networks—G. Wunsch. (*Nachrichtentech Z.*, vol. 8, pp. 154–158; April, 1958.) An example illustrating the theory given in 395 of 1958.

621.372.62:621.317.727:681.142 2159
Linear Multitapped Potentiometers with Loaded Outputs—K. C. Garner. (*Electronic Engrg.*, vol. 31, pp. 192–199; April, 1959.) "An analysis of multitapped linear potentiometers is given for the type in which shunt resistors are connected between adjacent tapping points and in the presence of an output load resistance."

621.373.42.029.4 2160
A Simple Very-Low-Frequency Oscillator—J. F. Young. (*Electronic Engrg.*, vol. 31, pp. 218–220; April, 1959.) Amplitude limitation is effected by a Zener diode and a selective circuit filters out the resulting harmonics, giving amplitude stabilization that is not frequency-selective.

621.373.52:621.374 2161
Transistorized Generator for Pulse Circuit Design—L. Neumann. (*Electronics*, vol. 32, pp. 47–49; April 3, 1959.) The generator produces pulses of 25–35-mμsec duration at repetition frequencies from 3 to 20 mc. The maximum amplitude is 2 volts into a 50-Ω load. Type-2 N501 switching transistors are used.

621.373.52:621.396.66 2162
Transistor Phase-Locked Oscillators—K. A. Edwards, O. Golubjatnikov, and D. J. Brady. (*Commun. and Electronics*, no. 40, pp. 1043–1051; January, 1959.) An analysis followed by detailed design data for two systems, one operating at 10.5 kc and the other at 30 mc.

621.374.3 2163
Greater Gain Bandwidth in Trigger Circuits—M. Brown. (*Rev. Sci. Instr.*, vol. 30, pp. 169–175; March, 1959.) A special series connection of two tubes produces a gain-bandwidth product per stage of up to three times that of a conventional amplifier without introducing the unwanted time delay associated with a distributed amplifier.

621.374.34 2164
Cathode-Follower for a D.C. Reference Level—S. Krishnan. (*Electronic Radio Engr.*, vol. 36, pp. 192–193; May, 1959.) Describes the use of a cathode follower to provide a variable reference-voltage source with a low output impedance.

621.375.024:621.318.43 2165
Design Criteria for Low-Level Second-Harmonic Magnetic Modulators—E. J. Kletsky. (*Commun. and Electronics*, no. 40, pp. 1013–1019; January, 1959.) Detailed analysis of a device suitable for low-level dc amplification.

621.375.121.2 2166
How to Design Pulsed Distributed Amplifiers—S. K. Meads. (*Electronics*, vol. 32, pp. 56–58; March 20, 1959.) Principles of operation are discussed and basic design equations are listed. Details of design procedure and performance of a power amplifier operating around 200 mc are given.

621.375.13.01:517.93 2167
The Effect of Reaction on the Gain of Nonlinear Amplifiers—I. Gumowski. (*Ann. Télécommun.*, vol. 13, pp. 45–47; January/February, 1958.) An analysis in which it is shown that in certain conditions, the nonlinear differential equation may be reduced to a linear equation of infinite order with constant coefficients.

621.375.2.029.3 2168
Performance of Class-B Audio Amplifiers with Random Noise Signals—T. Usher, Jr. (*Commun. and Electronics*, no. 40, pp. 939–943; January, 1959.) Two basic limitations on performance are considered; average anode dissipation is the same as that for sinusoidal modulation, but the positive-grid operation permitted is slightly different.

675.221 2169
Construction of a Logarithmic Wide Band Amplifier—H. Schwahn. (*Nachrichtentech Z.*, vol. 8, pp. 158–167; April, 1958.) The equipment described has a gain of about 1000. Amplification is linear for input voltages up to 1 mv, and proportional within ±0.5 db to the logarithm of the input voltage from 1 mv to 10 volts. Frequency response is linear from 50 cps to 100 kc.

621.375.3 2170
"Variable-μ" Magnetic Amplifier—C. C. Whitehead. (*Wireless World*, vol. 65, pp. 219–224; May, 1959.) A method is described for varying the current gain by means of a variable impedance in parallel with the feedback rectifiers.

621.375.3 2171
Volt-Second Transfer Efficiency in Fast-Response Magnetic Amplifiers: Part 1—N^2/R and Control—T. J. Pula. (*Commun. and Electronics*, no. 40, pp. 861–867; January, 1959.) Analysis for the case of finite control-circuit resistance and nonideal core characteristics. N^2/R, defined as the summation of the quotients of the square of the number of turns and the circuit resistance for all control circuits, is shown to be a basic reactor parameter.

621.375.3 2172
On Feedback in Magnetic Amplifiers: Part 1—Single Feedbacks—L. A. Finzi and J. J. Suozzi. (*Commun. and Electronics*, no. 40, pp. 1019–1030; January, 1959. Discussion, pp. 1030–1031.) Feedback configurations associated with two-core full-wave self-saturating amplifiers are analyzed and compared.

621.375.3:621–526 2173
Magnetic Amplifiers for Servo Systems—S. Davis. (*Electronics*, vol. 32, pp. 134–135; March 13, 1959.) Tabulated comparison of seven different combinations of push-pull magnetic-amplifier units.

621.375.3:621.318.57:621.314.7 2174
Linear Power Amplifiers using Dynistors or Trinistors—F. J. Hierholzer, Jr. (*Commun. and Electronics*, no. 40, pp. 892–898; January, 1959.) The use of two-or three-terminal semiconductor switching devices with a pulse network in series with the output of a magnetic-amplifier transducer, acting as an amplitude/phase converter, is described. These amplifiers are much smaller than conventional magnetic amplifiers of comparable maximum output power. Resistive or inductive loads can be used.

621.375.4:621.395.625.3:621.3.087.9 2175
Transistor Amplifier for Magnetic Tape and Drum Playback—A. E. Bachmann. (*Electronic Engrg.*, vol. 31, pp. 213–217; April, 1959.) The amplifier operates from a 2-mv input over the range 2–400 kc and from 0°C to +70°C. Rise

time of the output pulse is less than 1 μsec. Details are given of the design and full performance.

621.375.4.024:621-526 2176
A Stable Direct-Coupled Transistor Servo Preamplifier—A. N. DeSautels. (*Commun. and Electronics*, no. 40, pp. 943–947; January, 1959.) Capable of dc operating-point stability and high gain at >125°C.

621.375.9:538.569.4.029.6 2177
The Three-Level Solid-State Travelling-Wave Maser—R. W. DeGrasse, E. O. Schulz-DuBois, and H. E. D. Scovil. (*Bell Sys. Tech. J.*, vol. 38, pp. 305–334; March, 1959.) Theoretical comparison is made between the characteristics of the traveling-wave maser and those of the cavity maser and the general requirements for slow-wave structures are discussed. Theoretical analysis and experimental results are presented for the comb-in-waveguide slow-wave structure.

621.375.9:538.569.4.029.6 2178
A U.H.F. Ruby Maser—C. K. Wessel. (Proc. IRE, vol. 47, p. 590; April, 1959.) The maser is tunable over the range 380–450 mc and consists of a ruby crystal at the center of a teflon-loaded cavity which is excited in a TE_{011} pump mode.

621.375.9:538.569.4.029.6:536.8 2179
Three-Level Masers as Heat Engines—Scovil and Schulz-DuBois. (See 2212.)

621.375.9:538.569.4.029.6:621.317.3 2180
Calculation and Measurement of the Noise Figure of a Maser Amplifier—Helmer and Muller. (See 2343.)

621.375.9:538.569.4.029.63 2181
Stimulated R.F. Amplifiers Working on Hyperfine Levels of Paramagnetic Atoms—K. A. Valiev and Sh. Sh. Bashkirov. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 302–303; July, 1958.) A note on the possibility of obtaining signal amplification in the frequency range 100 mc – 1 kmc using crystals of salts containing bivalent ions of the Cu^{64} isotope. With $Ho=5000$ oersteds, $T=2$ to 4°K and $N=10^{19}$ (number of paramagnetic ions) the stored energy for one pair of hyperfine levels will be of the order of 1 to 2 ergs. For a pulse duration of 10^{-7} second the output power may reach 10^{-3} w.

621.375.9.029.6:621.3.011.23 2182
Parametric Devices Tested for Phase-Distortionless Limiting—F. A. Olson, C. P. Wang and G. Wade. (Proc. IRE, vol. 47, pp. 587–588; April, 1959.) Tests on two devices are described: one is a 100-mc amplifier and the other an *S*-band converter; both use variable-capacitance diodes.

621.375.9.029.6:621.3.011.23:621.314.63 2183
Directional-Bridge Parametric Amplifier—L. U. Kibler. (Proc. IRE, vol. 47, pp. 583–584; April, 1959.) A description is given of the operation and performance of a directional bridge system using variable-reactance diodes.

621.375.9.029.64:538.221 2184
Gain Measurements on a Pulsed Ferromagnetic Microwave Amplifier—R. D. Haun, Jr. and T. A. Osial. (Proc. IRE, vol. 47, pp. 586–587; April, 1959.) The amplifier operates in the "quasi-degenerate" mode in which one cavity serves as the resonant circuit for both the signal and the idle frequency fields. A second cavity is used for the pump signal which is pulsed.

621.375.9.029.64:621.3.011.23 2185
Low-Noise Parametric Amplifier—R. C. Knechtli and R. D. Weglein. (Proc. IRE, vol. 47, pp. 584–585; April, 1959.) A note of preliminary analytical and experimental results obtained with a cavity-type amplifier for the *S* band in which, through variable coupling, the effect of diode losses on noise figure can be minimized at the expense of pump power.

621.376.2/.3 2186
A Comparison of the Transient Response of Amplitude-Modulated and Frequency-Modulated Signals—S. J. Cotton. (*Proc. IEE*, pt. C, vol. 106, pp. 91–96; March, 1959.) The performance of RC and RL circuits, filters, and transmission lines is analyzed.

621.376.3:621.385.2 2187
The Diode Reactance Modulator—G. F. Montgomery. (*Commun. and Electronics*, no. 40, pp. 980–983; January, 1959.) A detailed analysis of the control of current through a capacitor by one or more diodes.

621.376.56:621.375.3:621.398 2188
A Magnetic-Amplifier Commutating and Pulse-Width Encoding Circuit—W. H. Lucke. (*Commun. and Electronics*, no. 40, pp. 884–892; January, 1959.) Description of a circuit designed for telemetry applications.

GENERAL PHYSICS

534.2:537.3 2189
Acoustoelectric Effect—R. H. Parmenter. (*Phys. Rev.*, vol. 113, pp. 102–109; January 1, 1959.) Three general approaches to the theory of the effect are discussed, and a development of the phenomenological approach is given in detail for metals and semiconductors. See 2281 of 1953.

535.223:538.566.029.65 2190
A New Determination of the Free-Space Velocity of Electromagnetic Waves—K. D. Froome. (*Proc. Roy. Soc. A.*, vol. 247, pp. 109–122; September 9, 1958.) A full description of the experiments briefly described in 2048 of 1958.

535.33-1 2191
The Theory of Interference Modulation for Double-Beam Interference—L. Genzel and R. Weber. (*Z. angew. Phys.*, vol. 10, pp. 127–135; March, 1958.) Infrared interferometry is discussed. See also 88 of 1958 (Strong).

535.33-1 2192
Spectroscopy in the Far Infrared by means of Interference Modulation—L. Genzel and R. Weber. (*Z. angew. Phys.*, vol. 10, pp. 195–199; April, 1958.) Practical application of the principle discussed in 2191 above.

537.21 2193
A Simple Method of Calculating Electrostatic Capacity—C. J. Bouwkamp. (*Physica*, Special Issue, vol. 24, pp. 538–542; June 16, 1958.) Attention is drawn to a simple theorem for evaluating the capacitance of certain conductors in free space such as a system of two spheres in contact with each other or a "ring without hole."

537.311.1 2194
Diamagnetism of Conduction Electrons in Metals—J. E. Hebborn and E. H. Sondheimer. (*Phys. Rev. Lett.*, vol. 2, pp. 150–152; February 15, 1959.) Calculation made by using a reasonably simple form for the field-independent part of the susceptibility.

537.312.62 2195
A Superconductor in a High-Frequency Field—A. A. Abrikosov, L. P. Gor'kov, and I. M. Khalatnikov. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 265–275; July, 1958.) An equation is derived which describes the behavior of a superconductor in an HF field, and the frequency and temperature dependence of the impedance of a bulk superconductor are evaluated.

537.5:061.3 2196
Electrical Discharges—J. Dutton and E. Jones. (*Nature, (London)*, vol. 183, pp. 91–93; January 10, 1959.) Report of a Conference held by the Physical Society in Swansea, September 17–20, 1958.

537.533 2197
Theoretical Total-Energy Distribution of Field-Emitted Electrons—R. D. Young. (*Phys. Rev.*, vol. 113, pp. 110–114; January 1, 1959.)

537.533 2198
Experimental Measurement of the Total-Energy Distribution of Field-Emitted Electrons—R. D. Young and E. W. Müller. (*Phys. Rev.*, vol. 113, pp. 115–120; January 1, 1959.)

537.533.73:621.317.42 2199
Magnetic Analysis with Electron Beams—S. Yamaguchi. (*Z. angew. Phys.*, vol. 10, pp. 138–140; March, 1958.) A device based on the Lorentz effect is used to estimate remanent magnetism. See also 3041 of 1958.

537.56 2200
An Extension of Townsend's Approximation Formula for Ionization in a Homogeneous Electric Field—H. Neu. (*Z. Phys.*, vol. 152, pp. 294–305; September 5, 1958.) The use of an additional parameter improves the approximation and extends the range of validity for lower field strengths. A general approximation formula is proposed for ionization dependent simultaneously on both field strength and voltage.

537.56:538.56 2201
On the Damping of Electromagnetic Waves in a Plasma Situated in a Magnetic Field—K. N. Stepanov. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 283–284; July, 1958.) Using expressions derived by Sitenko and Stepanov (2418 of 1957) for the components of the permittivity tensor, an expression for the damping coefficient is obtained.

537.56:538.566.029.6 2202
Conductivity of Plasmas to Microwaves—P. H. Fang. (*Phys. Rev.*, vol. 113, pp. 13–14; January 1, 1959.) Plasma conductivities for electrons with a Maxwellian energy distribution are evaluated for the cases in which the collision cross section is (a) independent of the velocity, and (b) inversely proportional to the velocity. The corresponding distribution functions of relaxation times are discussed.

537.56:538.569.4.029.64 2203
Microwave Investigation of Disintegrating Gaseous Discharge Plasmas—H. J. Oskam. (*Philips Res. Rep.*, vol. 13, pp. 335–400, 401–457; August and October, 1958.) The phenomenon of afterglow is investigated both theoretically and experimentally by considering the shift of the resonance frequency of a microwave cavity enclosing the plasma. Measurements using binary gas mixtures show the production of a considerable number of atomic ions of the admixture even at low concentrations. The process concerned in helium-neon is a charge-transfer one between a He_2^+ ion and a neon atom, the relevant cross section being $Q_{er}\approx 1.5\times 10^{-15}\text{cm}^2$. In other mixtures, the atomic ions are produced by the Penning effect and possibly the charge transfer process.

538.566+534.2 2204
Guided Propagation in a Slowly Varying Medium—D. E. Weston. (*Proc. Phys. Soc.*, vol. 73, pp. 365–384; March 1, 1959.) Formulas are derived for the propagation of elastic or em waves in a variable stratified medium, with particular application to underwater sound transmission.

538.566 2205
Absorption of Electromagnetic Waves by means of Lossy Resonant Slots—F. Wieckhorst. (*Z. angew. Phys.*, vol. 10, pp. 173–178; April, 1958.) Very thin microwave absorbers can be constructed by using a sheet of resistive material with tuned slots at a distance $\ll\lambda/4$ in front of a metal plate. The bandwidth can be increased by the insertion of a grid of dipoles, and the effects of polarization are minimized if circular slots are used. See also 1846 of June (Schmitt and Futtermenger).

538.566:535.42 2206
Phase Object Diffraction Patterns in Microscopes and Microwave Fields—O. Bryngdahl and E. Ingelstam. (*Physica*, Special Issue, vol. 24, pp. 445–456; June 16, 1958.) Optical phase diffraction patterns are interpreted by analogy with patterns obtained by a microwave technique at 5.15 cm λ.

538.567.4 2207
Velocity Modulation of Electromagnetic Waves—F. R. Morgenthaler. (IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-6, pp. 167–172; April, 1958. Abstract, PROC. IRE, vol. 46, p. 1329; June, 1958.)

538.569.3 2208
Propagation of an Electromagnetic Impulse in a Medium with Dielectric Losses—M. Cotte. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1324–1327; October 27, 1958.)

538.569.4:535.34:621.372.413 2209
High-Q Stark Cavity Absorption Cell for Microwave Spectrometers—A. Dymanus. (*Rev. Sci. Instr.*, vol. 30, pp. 191–195; March, 1959.) Design, description and performance data are given of a large pillbox-shaped Stark cavity absorption cell for the 1.25-cm λ region. The cavity can be used in any TE_{0m1} mode with m ranging from about 5 to 12.

538.569.4:538.221 2210
Theory of the Anisotropy of the Width of Ferromagnetic Resonance Absorption Lines—G. V. Skrotskiĭ and L. V. Kurbatov. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 216–220; July, 1958.) The dependence of the width of an RF resonance absorption line on the internal field is derived from the Landau-Lifshitz equation, and examples of ferrites with single-axis and cubic symmetry are examined.

538.569.4.029.6:535.33 2211
Microwave Spectrometer tests Electron Resonance—R. R. Unterberger. (*Electronics*, vol. 32, pp. 142–144; March 13, 1959.) A method of measuring the absorption properties of paramagnetic materials in which a sample is immersed in a dc field whose strength is varied to determine the value at which RF energy is absorbed by the sample.

538.569.4.029.6:621.375.9:536.8 2212
Three-Level Masers as Heat Engines—H. E. D. Scovil and E. O. Schulz-DuBois. (*Phys. Rev. Lett.*, vol. 2, pp. 262–263; March 15, 1959.) It is shown that a three-level maser can be regarded as a heat engine, and its limiting efficiency is that of a Carnot engine. The possibility of treating masers as heat engines represents a fundamental difference between masers and parametric amplifiers.

538.569.4.029.65 2213
Absorption and Refraction of Ammonia as a Function of Pressure at 6-mm Wavelength—F. W. Heineken and A. Battaglia. (*Physica*, vol. 24, pp. 589–603; July, 1958.) Description of measurements made using a resonant-cavity technique.

539.2:538.221 2214
Exact Foundations of the Theory of Spin Waves—F. Boop and E. Werner. (*Z. Phys.*, vol. 151, pp. 10–15; April 9, 1958.) The validity of equations of the type of Bloch's spin-wave equations is proved for the multi-electron problem, disregarding spin interactions.

539.2:548.0 2215
Theory of Electron-Phonon Interactions—G. D. Whitfield. (*Phys. Rev. Lett.*, vol. 2, pp. 204–205; March 1, 1959.) The theory has been formulated for nonpolar crystals in terms of a new set of basic states whose wave functions are essentially Bloch functions that deform with the lattice. A result of this is a generalization of the deformation potential theorem [3032 of 1950 (Bardeen and Shockley)].

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 2216
Possible Mechanism by which Terrestrial Corpuscular Radiation Arises in Response to the Action of Cosmic Rays—S. N. Vernov, N. L. Grigorov, I. P. Tvanenko, A. I. Lebedinskiĭ, V. S. Murzin, and A. E. Chudakov. (*Dokl. Ak. Nauk SSSR*, vol. 124, pp. 1022–1025; February 11, 1959.) Expressions are derived giving the total number of protons and electrons generated per second at the equator in a tube of 1 cm² cross section. The dependence of the intensity of the earth's corpuscular radiation on height and latitude is shown graphically. Experiments show that the intensity near the equator is approximately 100 times less than that calculated, which indicates the existence of supplementary leaks from "magnetic traps" especially noticeable at high latitudes.

523.16:550.389.2:629.19 2217
Possible Explanation of the Radiation Observed by Van Allen at High Altitudes in Satellites—P. J. Kellogg. (*Nuovo Cim.*, vol. 11, pp. 48–66; January 1, 1959. In English.) The possibility is considered that the radiation is due to the decay electrons and protons from neutrons produced by cosmic rays and stored in the earth's magnetic field.

523.164 2218
Radiation Transfer and the Possibility of Negative Absorption in Radio Astronomy—R. Q. Twiss. (*Aust. J. Phys.*, vol. 11, pp. 546–579; December, 1958.) Conditions are discussed under which negative absorption can arise at radio wavelengths, when the medium will behave like an amplifier to the incident radiations. The necessary conditions can be met in cases where the dominant radiation process is due to (a) the Cherenkov effect, (b) gyro radiation, or (c) synchrotron-type radiation.

523.164 2219
Radio Interferometry at Three Kilometres Altitude above the Pacific Ocean—G. Reber. (*J. Geophys. Res.*, vol. 64, pp. 287–303; March, 1959.) A Lloyd's mirror type of interferometer using the surface of the sea as a mirror is described whose effective spacing changes in a continuous manner from zero to 6 km during about one half hour. The fluctuations caused by the ionosphere are discussed and the measurements of the fine structure details of Cassiopeia, Cygnus, Hydra, the sun and Jupiter are described.

523.164.3 2220
A Pencil-Beam Survey of the Galactic Plane at 3.5 m—E R. Hill, O. B. Slee, and B. Y. Mills. (*Aust. J. Phys.*, vol. 11, pp. 530–549; December, 1958.) "A survey has been made of the galactic plane region from $l=223°$ through the galactic center to $l=13°$ between $b=+4°$ and $-6°$, using the 3.5-meter-λ cross-type antenna (beamwidth 50 minutes of arc) near Sydney. Contour diagrams of brightness temperature have been prepared. The preparation of contours is described in detail, and a detailed discussion of the accuracy of the temperatures is given."

523.164.3 2221
Radio Emission from the Vela-Puppis Region—H. Rishbeth. (*Aust. J. Phys.*, vol. 11, pp. 550–563; December, 1958.)

523.164.4 2222
The Radio Emission from Centaurus-A and Fornax-A—C. A. Shain. (*Aust. J. Phys.*, vol. 11, pp. 517–529; December, 1958.)

523.164.4 2223
A Search for Radio Emission at 3.5 m from the Local Supergalaxy—E. R. Hill. (*Aust. J. Phys.*, vol. 11, pp. 580–583; December, 1958.)

523.5 2224
Approximations for the Electron Density in Meteor Trails—A. A. Weiss. (*Aust. J. Phys.*, vol. 11, pp. 591–594; December, 1958.) Improved approximate expressions for describing conditions near the point of maximum electron density for both fast and slow meteors are compared with Herlofsen's exact solution (see 3401 of 1948).

523.5:621.396.9 2225
Oblique Echoes from Over-Dense Meteor Trails—L. A. Manning. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 82–93; April, 1959.) Ray paths are computed for waves refracted by meteor trails. Curves are derived showing how the echo duration depends on the trail orientation; these curves show that the $\sec^2 \phi$ law applies for overdense trails only if the plane of propagation contains the trail axis. If not, the effective secant exponent may be as small as 0.3. The theory is in agreement with duration measurements of McKinley and McNamara (923 of 1957) and gives results similar to the more complex wave solutions of Keitel (see 234 of 1956).

523.5:621.396.9 2226
Investigation of the Drifts of the Effective Point of Radio Reflection along a Meteor Train—M. S. Rao and R. L. Armstrong. (*Can. J. Phys.*, vol. 36, pp. 1601–1623; December, 1958.) Experimental evidence is given to support the postulate of the drift of the effective point of reflection along a meteor train towards the maximum echo duration level. Drift velocities tend to have higher values in the case of shorter echo durations and vice versa. From theoretical considerations, it is predicted that maximum echo durations always occur at about 2.46 km below the height of maximum ionization. The degree of turbulence is considered to be slightly greater than that suggested by Manning (2720 of 1958) but less than that by Booker and Cohen (1417 of 1957). See also 3798 of 1958 (Rao).

523.53:621.396.9 2227
The Limitations of Narrow-Beam Radio Equipments in the Detection of Weak Meteor Showers—A. A. Weiss. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 19–30; April, 1959.) Fluctuations in background activity, diffuseness of shower radiants and the short interval over which some showers are active are the chief limitations. A significance test for use as a search method for weak showers is developed.

550.384.4 2228
First Results on the Lunar-Dirunal Variation of the Horizontal Component of the Geomagnetic Field at Tamanrasset—F. Duclaux and R. Will. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1220–1222; October 20, 1957.)

550.385:551.513 2229
An Apparent Relationship between Geomagnetic Disturbances and Changes in Atmospheric Circulation at 300 Millibars—D. D. Woodbridge, N. J. Macdonald, and T. W. Pohrte. (*J. Geophys. Res.*, vol. 64, pp. 331–341; March, 1959.) "Contour length" and "trough" indexes were used as measures of atmospheric disturbance over North America and the eastern Pacific Ocean. These features were studied for periods following geomagnetic disturbances from October, 1956 to March, 1957. There appears to be a significant relation between geomagnetic activity and the development some days later of wave phenomena at the 300-mb level.

550.389.2:629.19 2230
Radio-Electronics and Cosmic Flight—(*Radiotechnika, Moscow*, no. 2, pp. 6–7; February, 1959.) A brief description of the flight of the Russian cosmic rocket launched on January 2, 1959. The scientific equipment carried in the 361. 3-kg last stage and the possibilities open to these rockets for interplanetary space investigation are also examined.

550.389.2:629.19 2231
Study of Cosmic Rays and Terrestrial Corpuscular Radiation by Cosmic Rocket—S. N. Vernov, A. E. Chudakov, P. V. Vakulov, and Yu. I. Logachev. (*Dokl. Ak. Nauk SSSR*, vol. 125, pp. 304–307; March 11, 1959.) A preliminary examination of data obtained by the cosmic rocket at distances between 8 and 150×10^3 km from the center of the earth. Graphs show that a maximum intensity of terrestrial corpuscular radiation is found at a distance of 26×10^3 km, and that at 55×10^3 km, this intensity falls to zero. The density of cosmic rays was found by Geiger counter to be 2.3 ± 0.1 particles/cm² second by scintillation counter to be 1.9 particles/cm² second.

550.389.2:629.19 2232
Methods for Predicting the Orbits of Near Earth Satellites—D. G. King-Hele and D. M. C. Walker. (*J. Brit. Interplanetary Soc.*, vol. 17, pp. 2–14; January/February, 1959.) "Methods are described for predicting the times and positions of the daily transits of a satellite and the geometry of its orbit. The methods depend upon maintaining an accurate record of the period of revolution, from which the other orbital elements are deduced theoretically."

550.389.2:629.19 2233
The Effect of the Earth's Oblateness on the Orbit of a Near Satellite—D. G. King-Hele. (*Proc. Roy. Soc. A*, vol. 247, pp. 49–72; September 9, 1958.) "The equations of motion of a satellite in an orbit over an oblate earth *in vacuo* are solved analytically, by a perturbation method. The solution applies primarily to orbits of eccentricity 0.05 or less. The accuracy of the solution for radial distance should then be about 0.001 per cent, and the error in angular travel about 0.001 per cent per revolution. A brief comparison is made between theory and observation for Sputniks 1 and 2."

550.389.2:629.19 2234
Earth Oblateness in terms of Satellite Orbital Periods—L. Blitzer. (*Science*, vol. 129, pp. 329–330; February 6, 1959.) An equation relating the earth's oblateness to the anomalistic and nodical periods and orbit parameters of a satellite is given.

550.389.2:629.19 2235
Changes in the Inclination of Satellite Orbits to the Equator—R. H. Merson, D. G. King-Hele, and R. N. A. Plimmer. (*Nature, (London)*, vol. 183, pp. 239–240; January 24, 1959.) An extension of earlier investigations [792 of March (Merson and King-Hele)], taking into account the spread of atmospheric resistance around perigee. See also 1542 of May (Bosanquet).

550.389.2:629.19 2236
Vanguard Measurements give Pear-Shaped Component of Earth's Figure—J. A. O'Keefe, A. Eckels, and R. K. Squires. (*Science*, vol. 129, pp. 565–566; February 27, 1959.) Calculations indicate that the periodic variations in the eccentricity of orbit of satellite 1958β2 can be explained by the presence of a third zonal harmonic in the earth's gravitational field.

550.389.2:629.19 2237
Radio Observations at 20 Mc/s of the First Russian Earth Satellites—H. K. Paetzold and H. Zschörner. (*Telefunken Z.*, vol. 31, pp. 100–104; June, 1958. English summary, p. 137.) Report on observations in Germany of satellites 1957α and β. The various types of amplitude and bearing fluctuations are interpreted and the wave propagation mechanism is discussed.

550.389.2:629.19 2238
Radio Observations with Satellite 1958ϵ—J. A. Van Allen, C. E. McIlwain, and G. H. Ludwig. (*J. Geophys. Res.*, vol. 64, pp. 271–286; March, 1959.) The earlier discovery of the great radiation belt around the earth has been confirmed and extended by the use of improved detector equipment. This preliminary report suggests that visible auroras and other geophysical phenomena are closely related to the reservoir of charged particles trapped by the earth's magnetic field.

550.389.2:629.19 2239
Space Vehicles, Satellites, and Missiles—a Symposium—(*Elect. Engrg., N. Y.*, vol. 77, pp. 1077–1095; December, 1958.) Verbatim report of a symposium sponsored by the Feedback Control Systems Committee of the *AIEE*, Buffalo, N. Y., June 22–27, 1958.

551.510.52:621.396.9 2240
Radio Echoes from some Invisible Objects in the Troposphere—A. G. Gorelick and V. V. Kostarev. (*Dokl. Ak. Nauk SSSR*, vol. 125, pp. 59–61; March 1, 1959.) A regular scanning of the troposphere was carried out by the Central Aerology Observatory of the USSR from 1956 to 1958 at 3.2 cm λ using a 20-meter parabolic reflector and a 100-kw pulse transmitter. During the investigation, radio echoes at heights up to 7 km were recorded. Film recordings show the distribution of echo sources as functions of height and time.

551.510.535 2241
Variations in Ionospheric F-Region Characteristics—N. M. Brice. (*Aust. J. Phys.*, vol. 11, pp. 587–591; December, 1958.) Analysis of $h'f$ records obtained at Macquarie Island (geomagnetic latitude 60°S) since 1950.

551.510.535 2242
Study of Horizontal Drifts in the F_1 and F_2 Regions of the Ionosphere at Waltair (17°43′N, 83°18′E, mag. lat. 9°30′N)—B. R. Rao and E. B. Rao. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 94–106; April, 1959.) The diurnal and seasonal changes of drifts in the F_2 region are given in detail. The reversal of direction relative to movements at high latitudes is consistent with Martyn's drift theory.

551.510.535 2243
Some Measurements of Horizontal Movements in Region F_2 using Widely Spaced Observing Stations—L. Thomas. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 123–137; April, 1959.) Vertical-incidence recordings at stations some 200 km apart were compared. The results show a correlation between velocity magnitude and the degree of magnetic activity, and a positive height gradient of velocity.

551.510.535 2244
Investigation of the Inhomogeneous Structure of the F Region of the Ionosphere—E. G. Proshkin and B. L. Kashcheev. (*Radiotekh. Elektron.*, vol. 2, pp. 819–825; July, 1957.) Results of vertical incidence soundings at Khar'kov from June 1954 to May 1956 have shown that in 90 per cent of cases, the reflection from the ionosphere has a static character and that the regular diurnal and seasonal variation of the degree of inhomogeneity of the F region does not arise.

551.510.535:523.745 2245
Geomagnetic Influence on the F_1 and F_2 Regions of the Ionosphere—Effect of Solar Activity—R. G. Rastogi. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 31–40; April, 1959.) Noon critical frequencies for the F_1 and F_2 layers are examined for different seasons and levels of solar activity. It is found that the F_1 layer exhibits a geomagnetic control at periods of high solar activity only, while the equatorial trough in f_0F_2 is most marked during periods of low solar activity.

551.510.535:550.385 2246
Geomagnetic Distortion of Region E—W. J. G. Beynon and G. M. Brown. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 138–166; April, 1959.) An analysis of the behavior of the normal E region suggests that departures from the classical Chapman theory can be attributed to vertical drift of ionization resulting from the interaction of the geomagnetic field and the Sq-current system flowing in or near the E region. Perturbations of f_0E under magnetically-disturbed conditions and near the auroral zone are also discussed.

551.510.535:550.385.2 2247
On the Seat of the L Currents causing Geomagnetic Tides—K. S. Rajo Rao. (*J. Geophys. Res.*, vol. 64, pp. 384–385; March, 1959.) A note on some ionospheric and geomagnetic data which support the view that the seat of the L current system is situated in the F_2 layer.

551.510.535:550.385.4 2248
A Study of the Morphology of Ionospheric Storms—S. Matsushita. (*J. Geophys. Res.*, vol. 64, pp. 305–321; March, 1959.) A study of variations of the maximum electron density in the F_2 layer for the period 1946–1955 at 38 stations between 60.4°N and 60.4°S geomagnetic latitude. Storm-time variations and disturbance daily variations during each six-hour period were obtained and the changes of these with latitude were examined.

551.510.535:621.3.087.4 2249
A Rapid Method of Obtaining Accurate Virtual Heights from an Ionogram—W. R. Piggott. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 175–177; April, 1959.) The variation of apparent vertical height with the amplitude of the reflected signals depends on constants of the equipment. These constants are used to construct a transparent slider which corrects for this variation and enables virtual heights to be obtained accurately.

551.510.535:621.396.11 2250
The Reflexion of Radio Waves from a Stratified Ionosphere Modified by Weak Irregularities—M. L. V. Pitteway. (*Proc. Roy. Soc. A*, vol. 246, pp. 556–569; August 26, 1958.) "Consideration is given to the scattered wave which accompanies reflexion from a stratified ionosphere in which there are weak irregularities. By considering these irregularities to be confined to a thin layer near a given height, the possibility is examined that they might produce considerably enhanced scattering if they were situated near the reflexion level calculated on the basis of geometrical optics. It is found that they would not have a very much

greater effect at this level. It is also shown that, if the electron collision frequency is of the order likely to be encountered in the real ionosphere, there would be little enhancement by "resonance" effects of the kind suggested by Herlofson (403 of 1952)."

551.510.535:621.396.11 2251

Irregularities in Refraction of Radio Waves and Large Inhomogeneities in the Ionosphere—V. V. Vitkevich and Yu. L. Kokurin. (*Radiotekh. Elektron.*, vol. 2, pp. 826–832; July, 1957.) Description of the method and results of measurements of the vertical refraction of radio waves at 4 mλ in the ionosphere. The irregularities of refraction are produced by inhomogeneities of dimensions about 200 km in the F region. The diurnal variation of inhomogeneities is analyzed and it is shown that their presence is related to solar activity.

551.510.535:621.396.11 2252

Ionospheric Self-Demodulation and Self-Distortion of Radio Waves—J. W. King. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 41–49; April, 1959.) Demodulation was observed only at low modulation frequencies. The magnitude of the effect agreed with that predicted by theory and was also what would have been expected from results obtained in cross-modulation experiments.

551.594.21 2253

Preliminary Results of an Experiment to Determine Initial Precedence of Organized Electrification and Precipitation in Thunderstorms—B. Vonnegut, C. B. Moore, and A. T. Botka. (*J. Geophys. Res.*, vol. 64, pp. 347–357; March, 1959.) It is shown that electrification of clouds begins before any radar echo is observed; this raises doubts about the assumption that precipitation is the primary cause of charge generation.

551.594.5:621.396.9 2254

Determination of the Angle of Arrival of Auroral Echoes—L. Harang and J. Tröim. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 107–110; April, 1959.) An interference method is used at Kjeller to measure the angle of arrival, θ, of auroral echoes. As θ varies from 15° to 6.5°, the range increases from 400 to 730 km and it is shown that the height of the reflection area must be 100–120 km.

551.594.5:621.396.96 2255

Horizontal Motions in Radar Echoes from Aurora—G. F. Lyon and A. Kavadas. (*Can. J. Phys.*, vol. 36, pp. 1661–1671; December, 1958.) Observations at Saskatoon at 48.2 mc show a systematic motion of echoes toward the west before midnight and toward the east after midnight, the mean velocity in either direction showing a statistical relation to variations in the earth's magnetic field.

LOCATION AND AIDS TO NAVIGATION

621.396.93 2256

The Physical Properties of Various Cathode-Ray Direction Finders for Short Waves—A. Troost. (*Telefunken Z.*, vol. 31, pp. 84–89; June, 1958. English summary, pp. 135–136.) A comparison of the five basic df systems in present-day use. The answers to questions on suitability and operational facilities are given in tabular form, showing the relative advantages of the two-channel system.

621.396.93 2257

The Telefunken Short-Wave Cathode-Ray Direction Finder—G. Schmucker. (*Telefunken Z.*, vol. 31, pp. 90–97; June, 1958. English summary, p. 136.) The equipment described operates in the range 1.35–25.2 mc.

621.396.93 2258

Evaluation Improvement with the Two-Channel Cathode-Ray Direction Finder—K. Baur. (*Telefunken Z.*, vol. 31, pp. 97–99; June, 1958. English summary, p. 136.) An integrating method of eliminating errors in evaluating df bearing indications is described.

621.396.932/.933:061.3 2259

Convention on Radio Aids to Aeronautical and Marine Navigation—(*Proc. IEE*, pt. B, vol. 105, suppl. no. 9, pp. 193–198; 1958.) The following papers were included among those read at the IEE Convention held in London, March 27–28, 1958.

a) **A Review of Radio Aids to Aeronautical and Marine Navigation**—C. Williams (pp. 196–212). Discussion (pp. 212–215).

Medium and Long-Range Aids:

b) **Survey of Long-Range Radio Navigation Aids**—J. C. Farmer (pp. 216–224).

c) **The Decca Navigator System for Ship and Aircraft Use**—C. Powell (pp. 225–234).

d) **Doppler Navigation**—J. E. Clegg and T. G. Thorne (pp. 235–247).

e) **An Airborne Doppler Navigation Equipment**—G. E. Beck and T. G. Thorne (pp. 248–257).

f) **Low-Power C.W. Doppler Navigation Equipment**—J. E. Clegg and J. W. Crompton (pp. 258–265).

g) **The Combination of Inertial Navigation and Radio Aids**—A. Stratton (pp. 266–276). Discussion (pp. 277–283).

Range and Bearing Systems:

h) **General Aspects of Short-Range Rho-Theta Systems**—C. E. Strong (pp. 284–297).

i) **TACAN: A Navigation System for Aircraft**—W. L. Garfield (pp. 298–306).

j) **Current Direction-Finding Practice**—H. G. Hopkins and B. G. Pressey (pp. 307–316).

k) **The Practical Evolution of the Commutated Aerial Direction-Finding System**—C. W. Earp and D. L. Cooper-Jones (pp. 317–325). Discussion (pp. 326–332).

Airfield and Harbor Approach:

l) **A Survey of Approach and Landing Aids**—W. J. Charnley (pp. 333–343).

m) **Precision Approach Radar**—G. J. Moorcroft (pp. 344–350).

n) **A Survey of Harbor Approach Aids**—A. L. P. Milwright (pp. 351–357).

o) **The Application of Radio Altimeters to Aircraft Approach and Landing**—M. P. G. Capelli, A. E. Outten, and K. E. Bücks (pp. 358–364). Discussion (pp. 365–369).

Marine and Ground Radar:

p) **Advances in Ground Radar for Civil Aviation**—E. Eastwood and C. D. Colchester (pp. 370–379).

q) **Survey of Recent Developments in Marine Radar**—A. L. P. Milwright (pp. 380–384).

r) **A Mathematical Analysis of Collision-Course Prediction by Doppler Radar**—H. R. Whitfield and C. M. Cade (pp. 385–391). Discussion (pp. 392–398).

621.396.933.2:621.396.677 2260

A New Method of Generating a Rotating Radiation Polar Diagram—Hawkes. (See 2120).

621.396.96.089.6:621.317.7 2261

Precision Generator for Radar Range Calibration—Broderick, Hartke, and Willrodt. (See 2353.)

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 2262

Grades of Vacuum in Electronic and Ionic Tubes—A. I. Vishnievsky. (*J. Indian Inst. Sci.*, sect. B, vol. 40, pp. 139–144; July, 1958.) The most important factor that qualifies the grade of vacuum is not the pressure of the residual gases but the ratio of the mean free path of the molecules to the distance between the cathode and the anode of the device.

535.215:537.311.33 2263

Quenching of Photoconductivity and the Lifetime of Conduction Electrons—F. Matossi. (*Z. Phys.*, vol. 151, pp. 5–9; April 9, 1958.) A simple general model is considered with a minimum number of assumptions including that of monomolecular transitions. See also 3486 of 1957.

535.215:546.431–3 2264

Exciton-Induced Photoemission from BaO near 80°K—E. Taft, H. Philipp, and L. Apker. (*Phys. Rev.*, vol. 113, pp. 156–158; January 1, 1959.)

535.215:546.482.21 2265

Analysis of Mixed Ambipolar and Exciton Diffusion in CdS Crystals—G. Diemer, G. J. van Gurp, and W. Hoogenstraaten. (*Philips Res. Rep.*, vol. 13, pp. 458–484, October, 1958; vol. 14, pp. 11–28, February, 1959.) A detailed report of photodiffusion experiments and of the various effects interfering with the interpretation of the results. In crystals having special photoconduction and fluorescence properties, excitons can contribute to the diffusion of photoconduction over distances of several millimeters into nonexcited parts of the crystal.

535.376:546.472.21 2266

Particle Size and Efficiency of Electroluminescent Zinc Sulphide Phosphors—W. Lehmann. (*J. Electrochem. Soc.*, vol. 105, pp. 585–588; October, 1958.) Experimental data show that efficiency, *i.e.*, the ratio of brightness to electrical power absorption, increases with decreasing particle size.

535.37:[546.482.21+546.472.21 2267

Polarization of Fluorescence in ZnS and CdS Single Crystals—A. Lempicki. (*Phys. Rev. Lett.*, vol. 2, pp. 155–157; February 15, 1959.) The fluorescence was excited by filtered 3650 Å radiation incident perpendicularly to the plate-like surface of the crystals. Simple dipole theories fail to account for the results.

535.37:[546.482.21+546.472.21 2268

Polarization of Fluorescence in CdS and ZnS Single Crystals—J. L. Birman. (*Phys. Rev. Lett.*, vol. 2, pp. 157–159; February 15, 1959.) The 6200 Å emission in CdS and 4500 Å emission in ZnS are interpreted on the basis of the Lambe-Klick model (3274 of 1955).

535.37:546.482.21 2269

Nature of Blue Edge Emission in CdS—G. Diemer and A. J. Van der Houven van Oordt. (*Physica*, vol. 24, pp. 707–708; August, 1958.) See also 3106 of 1958 (Diemer, *et al.*).

535.37:621.317.39:531.76 2270

The Measurement of Extremely Short Afterglows of Electronically Excited Luminophores—Heine. (See 2350.)

537.226:537.311.6 2271

Impedance of Dielectric Layers—P. Winkel and D. G. de Groot. (*Philips Res. Rep.*, vol. 13, pp. 489–498; October, 1958.) Experimental results are given to confirm that a correlation exists between the real and imaginery components of the impedance of a dielectric layer as indicated by the general theory on amorphous dielectrics of Gevers and du Pre (2798 of 1947). Oxide layers of Al, Ta and Al-oxide layers containing boehmite have been investigated.

537.226.2:549.514.51 2272

The Dielectric Properties of Quartz Sands at High and Ultra High Frequencies—E. Löb. (*Z. angew. Phys.*, vol. 10, pp. 178–185; April, 1958.) Measurements were made in the wavelength range 3 cm–800 meters.

537.227 2273
Radiation Damage Effect in Ferroelectric Triglycine Sulphate—A. G. Chynoweth. (*Phys. Rev.*, vol. 113, pp. 159–166; January 1, 1959.)

537.227:546.431.824-31 2274
Effect of Space-Charge Fields on Polarization Reversal and the Generation of Barkhausen Pulses in Barium Titanate—A. G. Chynoweth. (*J. Appl. Phys.*, vol. 30, pp. 280–285; March, 1959.) Further experimental investigation (see also 3488 of 1958) indicates that the rate of nucleation of new domains is determined by the field near the electrodes which, in turn, is the resultant of the applied field and a relaxing space-charge field. This result follows directly if the Barkhausen pulses represent individual nucleations.

537.227:546.431.824-31:621.318.57 2275
Pulse Width Dependence of the Switching Velocity in $BaTiO_3$ Crystal—K. Husimi and K. Kataoka. (*J. Appl. Phys.*, vol. 30, pp. 323–324; March, 1959.) The maximum switching velocity is discussed as a function of the applied pulse field and the pulse width.

537.227:546.48.882.5 2276
The Preparation of Cadmium Niobate by an Anodic Spark Reaction—W. McNeill. (*J. Electrochem. Soc.*, vol. 105, pp. 544–547; September, 1958.)

537.228.1:534.133:621.3.029.64 2277
Piezoelectric Production of Microwave Phonons—E. H. Jacobsen. (*Phys. Rev. Lett.*, vol. 2, pp. 249–250; March 15, 1959.) Propagation of elastic waves along a quartz rod at a frequency of 9.270 mc has been observed at temperatures below 77°K.

537.228.1:546.482.21 2278
Some Elastic Properties of Hexagonal Cadmium Sulphide—H. Gobrecht and A. Bartschat. (*Z. Phys.*, vol. 152, pp. 417–424; September 26, 1958.) The resonance frequencies for the thickness-shear mode as a function of thickness were determined on synthetic single crystals of CdS which are piezoelectric (see 1814 of 1954). The temperature coefficient of the resonance frequency for this mode is negative in the temperature range +20°C to −180°C.

537.311.33 2279
Correlation between Mobility and Effective Mass in Semiconductors—R. W. Keyes. (*J. Appl. Phys.*, vol. 30, p. 454; March, 1959.)

537.311.33 2280
Theory of Transport Phenomena on a Semiconductor Surface—G. M. Avak'yants. (*Izv. Ak. Nauk. Uz. SSR, ser. Fiz. Mat. Nauk*, no. 5, pp. 23–41; 1958.) Mathematical treatment of electrical and thermal conduction and different thermal and magnetic effects at the surface of a semiconductor. Formulas derived are generalized for the case of charge transfer when collisions of carriers with the "walls" of channels are more frequent than collisions with impurities or with lattice vibrations. See also 3519 of 1954.

537.311.33 2281
Properties of a Semiconductor Surface as Determined from a Modified Drift-Mobility Experiment—N. J. Harrick. (*Phys. Rev. Lett.*, vol. 2, pp. 199–200; March 1, 1959.) Information may be obtained on the type, barrier potential, relaxation effects, and possibly mobility of the surface.

537.311.33 2282
Nonequilibrium Processes in Impurity Semiconductors—V. P. Shabanskiĭ. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 143–153; July, 1958.) Analysis is presented of the kinetic equations which describe transitions from impurity levels to conduction band including the effect of recombination and ionization. Expressions are derived for the energy and kinetic coefficient for cases when the lifetime of electrons in conduction bands is determined by photo-recombination and triple-collision recombination processes. The equation obtained can be used to calculate the electron temperature and number of electrons in the conduction band in various nonequilibrium processes.

537.311.33:538.615 2283
Zeeman-Type Magnetio-optical Studies of Interband Transitions in Semiconductors—E. Burstein, G. S. Picus, R. F. Wallis, and F. Blatt. (*Phys. Rev.*, vol. 113, pp. 15–33; January 1, 1959.) In the presence of a magnetic field, the quasi-continuous levels of simple energy bands coalesce into one-dimensional sub-bands and the "time reversal" degeneracy of the levels is split. The energy levels are characterized by three quantum numbers, details of the theoretical treatment being given. The selection rules, polarization effects, and the character of the absorption spectra for interband transitions in the presence of a magnetic field are discussed and illustrated by experimental data for Ge and InSb.

537.311.33:539.2 2284
Vibration Spectra and Specific Heats of Diamond-Type Lattices—J. C. Phillips. (*Phys. Rev.*, vol. 113, pp. 147–155; January 1, 1959.)

537.311.33:546.23:537.226 2285
The Dielectric Behaviour of Hexagonal Selenium in the Decimetre Wave Range—J. Jaumann and E. Neckenbürger. (*Z. Phys.*, vol. 151, pp. 72–92; April 9, 1958.) Impedance measurements were made in the range 312–4300 mc and the dielectric constant was determined as a function of frequency, temperature, and annealing time. Results are compared with those of other authors.

537.311.33:[546.28+546.289 2286
Lattice Vibrations in Silicon and Germanium—B. N. Brockhouse. (*Phys. Rev. Lett.*, vol. 2, pp. 256–258; March, 15 1959.) Dispersion curves for lattice waves traveling in the [001] directions in a Si single crystal are given for the various modes of vibration. The results are discussed with reference to those of other workers, and to similar data on Ge.

537.311.33:[546.28+546.289 2287
Specific Heat of Germanium and Silicon at Low Temperatures—P. H Keesom and G. Seidel. (*Phys. Rev.*, vol. 113, pp. 33–39; January 1, 1959.) The specific heats of several samples of Si have been measured between 1.2°K and 4.2°K. The Debye characteristic temperature θ_0 at 0°K is estimated to be 636°K. Measurements on Ge between 0.5°K and 4.2°K yield θ_0=363°K. From knowledge of the electronic specific heat and carrier concentration of several degenerate samples of Ge and Si, information is deduced concerning the energy band structure of the crystals.

537.311.33:546.28 2288
Technique for Preserving Lifetime in Diffused Silicon—S. J. Silverman and J. B. Singleton. (*J. Electrochem. Soc.*, vol. 105, pp. 591–594; October, 1958.) Lifetimes improved by a factor of ten can be obtained if, prior to diffusion, a metal-silicon liquid phase, acting as a getter, is formed on the surface of the material. Ni, Ag and Bi have been applied independently with comparable results.

537.311.33:546.28 2289
Precipitation on a Dislocation—R. Bullough, R. C. Newman, J. Wakefield, and J. B. Willis. (*Nature, (London)*, vol. 183, pp. 34–35; January 3, 1959.) A study of the effect of heat treatment on Si crystals containing up to 10^{17} Al atoms/cm^3.

537.311.33:546.28 2290
Gold in Silicon—G. Bemski and J. D. Struthers. (*J. Electrochem. Soc.*, vol. 105, pp. 588–591; October, 1958.) Experimental results indicate that changes in electrical characteristics after heat treatment in excess of 900°C are due to the introduction of gold concentrations. These can be removed, preferably by a Ni-Si liquidus on the surface of the sample (see 2290 above) or by vacuum heat treatment.

537.311.33:546.28 2291
Lattice Vibrations in Silicon by Scattering of Cold Neutrons—H. Palevsky, D. J. Hughes, W. Kley, and E. Tunkelo. (*Phys Rev Lett*, vol. 2, pp. 258–259; March 15, 1959.)

537.311.33:546.28 2292
Density Change in Silicon upon Melting—R. A. Logan and W. L. Bond. (*J. Appl. Phys.*, vol. 30, p. 322; March, 1959.)

537.311.33:546.28 2293
Impurity Compensation and Magnetoresistance in *p*-Type Silicon—D. Long, C. D. Motchenbacher, and J. Myers. (*J. Appl. Phys.*, vol. 30, pp. 353–362; March, 1959.) A new method is proposed for determining the separate concentrations of acceptor and donor impurities in crystals of *p*-type Si. The method involves finding the total concentration of impurities in a sample from a measurement of the weak-field magnetoresistance and combining this result with the excess of acceptors over donors.

537.311.33:546.28 2294
Some Effects of Oxygen on Resistiv'ty in Silicon—D. H. Roberts and B. L. H. Wilson. (*J. Appl. Phys.*, vol. 30, pp. 447–448; March, 1959.) Oxygen concentration has been determined from measurements of the absorption coefficient and the effect of heat treatment has been investigated.

537.311.33:546.28 2295
Strain-Optic Coefficient of Silicon for Infrared Light—S. Prussin and A. Stevenson. (*J. Appl. Phys.*, vol. 30, pp. 452–453; March, 1959.) The coefficient has been found for birefringent patterns in a nonisotropic plate.

537.311.33:546.28:621.793 2296
Bonding Materials for Making Contacts to *p*-Type Silicon—D. R. Mason and J. C. Sarace. (*J. Electrochem. Soc.*, vol. 105, pp. 594–598; October, 1958.) A technique is described for bonding a Si wafer to a molybdenum base plate using Al or Al-Si eutectic, applied by rolling, as a bonding agent.

537.311.33:546.281.26 2297
Infrared Properties of Hexagonal Silicon Carbide—W. G. Spitzer, D. Kleinman, and D. Walsh. (*Phys. Rev.*, vol. 113, pp. 127–132; January 1, 1959.)

537.311.33:546.281.26:539.23 2298
Infrared Properties of Cubic Silicon Carbide Films—W. G. Spitzer, D. A. Kleinman, and C. J. Frosch. (*Phys. Rev.*, vol. 113, pp. 133–136; January 1, 1959.)

537.311.33:546.289 2299
Fine Structure in the Zeeman Effect of Excitations in Germanium—K. J. Button, L. M. Roth, W. H. Kleiner, S. Zwerdling, and B. Lax. (*Phys. Rev. Lett.*, vol. 2, pp. 161–162; February 15, 1959.) A discussion of the results of an experimental study of exciton formation in Ge, based on the transmission of infrared radiation at 1.5°K at field strengths up to 38,900 oersteds.

537.311.33:546.289 2300

Magnetic Susceptibility of Photogenerated Current Carriers in Germanium—J. O. Kessler and A. R. Moore. (*Phys. Rev. Lett.*, vol. 2, pp. 247–249; March 15, 1959.) A new method is described for measurement of the susceptibility of free carriers. The change in magnetism of the crystal due to photogenerated hole-electron pairs is measured, and requires a much higher detection sensitivity than previously achieved.

537.311.33:546.289 2301

Influence of Atomic Hydrogen on the Conductivity of Cleaned Germanium Surfaces—G. Heiland and P. Handler. (*J. Appl. Phys.*, vol. 30, pp. 446–447; March, 1959.) Atomic hydrogen increases the *p*-type conductivity of a Ge surface cleaned by argon bombardment and annealing.

537.311.33:546.289 2302

Microwave-Induced Carrier Multiplication in Germanium—K. Seeger. (*J. Appl. Phys.*, vol. 30, pp. 443–444; March, 1959.) The microwave breakdown of Ge at low temperatures has been investigated.

537.311.33:546.289 2303

Recombination Centres on Ion-Bombarded and Vacuum Heat-Treated Germanium Surfaces—S. Wang and G. Wallis. (*J. Appl. Phys.*, vol. 30, pp. 285–290; March, 1959.) It was confirmed that after annealing of the bombardment damage, a large number of acceptor-type surface states essentially fixed the surface potential. Two types of recombination centers were identified: type 1, located near the middle of the gap, and type 2, located near the valence band.

537.311.33:546.289 2304

Lattice Vibrations in Germanium by Scattering of Cold Neutrons—A. Ghose, H. Palevsky, D. J. Hughes, I. Pelah, and C. M. Eisenhauer. (*Phys. Rev.*, vol. 113, pp. 49–52; January 1, 1959.) The dispersion relations for the optical and acoustical vibrations in the [100] and [110] directions in Ge have been determined. An improved experimental method is described.

537.311.33:546.289 2305

Thermal and Radiation Annealing of Ge—J. W. Mackay, E. E. Klontz, and G. W. Gobeli. (*Phys. Rev. Lett.*, vol. 2, pp. 146–148; February 15, 1959.) It was found that about 50 per cent of the defects produced by 1.10-mev electron irradiation of Ge at 10°K could be annealed either by heating or by irradiation at lower energies.

537.311.33:546.289 2306

Length and Resistivity Changes in Germanium upon Low-Temperature Deuteron Irradiation and Annealing—F. L. Vook and R. W. Balluffi. (*Phys. Rev.*, vol. 113, pp. 62–69; January 1, 1959.) Simultaneous measurements of the length change and resistivity of high-purity Ge single crystals were made upon irradiation and annealing. The specific length expansion was $\Delta L/L=(1.5\pm0.3)\times10^{-21}/$(deuteron/cm^2). The annealing showed a gradual recovery of the expansion which was observable only after warming to above 200°K.

537.311.33:546.289 2307

Lattice Parameter Changes in Deuteron-Irradiated Germanium—R. O. Simmons. (*Phys. Rev.*, vol. 113, pp. 70–71; January 1, 1959.) A lattice expansion of 3×10^{-5} was measured in Ge irradiated by 1.5×10^{17} 9-mev deuterons/cm^2 at low temperature and annealed to 320°K. The results provide confirmatory evidence that structural damage in deuteron-irradiated Ge consists of well-localized centers of dilatation.

537.311.33:546.289 2308

Structure of Deuteron-Irradiated Germanium—F. L. Vook and R. W. Balluffi. (*Phys. Rev.*, vol. 113, pp. 72–78; January 1, 1959.) Discussion in the light of recent experiments (2306 and 2307 above) together with low-angle X-ray scattering measurements at liquid-nitrogen temperatures. A model of the damage at liquid-nitrogen temperature consisting of separated clusters of vacancies and interstitials is proposed.

537.311.33:546.289 2309

Anomalous Transmission of X-Rays by Single-Crystal Germanium—L. P. Hunter. (*Proc. kon. ned. Akad. Wetensch.*, *B*, vol. 61, no. 3, pp. 214–219; 1958. In English.)

537.311.33:546.289 2310

The Reaction of Germanium with Nitric Acid Solutions—M. C. Cretella and H. C. Gatos. (*J. Electrochem. Soc.*, vol. 105, pp. 487–496; September, 1958.)

537.311.33:546.621.86 2311

Preparation and Properties of Aluminium Antimonide—A. Herczog, R. R. Haberecht, and A. E. Middleton. (*J. Electrochem. Soc.*, vol. 105, pp. 533–540; September, 1958.) The known properties of AlSb are compared with those of other high-energy-gap semiconductors and features which suggest its suitability for use in high-temperature devices are discussed. Techniques are described for growing AlSb crystals by the Czochralski method. The resistivity of *p*-type crystals can be decreased by doping with C or increased by adding small amounts of Se or Te. Various surface treatments are described and brief data on point-contact and *p-n* junction diodes are given.

537.311.33:546.682.24 2312

Indium Monotelluride—H. C. Wright and J. C. Brice. (*Nature*, (*London*), vol. 183, pp. 27–28; January 3, 1959.) A report of measurements which reveal the anomalous properties of the compound. Certain electrical properties indicate a metallic nature, but the large value of the thermal emf, the computed Wiedemann-Franz ratio and the large variation of resistivity are more characteristic of a semiconductor.

537.311.33:621.317.3 2313

Technique for Measuring Particle Drift Mobilities in Near-Intrinsic and Narrow-Band-Gap Semiconductors—N. J. Harrick. (*J. Appl. Phys.*, vol. 30, pp. 451–452; March, 1959.)

537.311.62:537.312.62 2314

The Variation with Frequency of the Resistance of Superconducting Tin and Indium—M. D. Sturge. (*Proc. Roy. Soc. A.*, vol. 246, pp. 570–581; August 26, 1958.) The ratio of the superconducting to the normal resistance of tin has been measured calorimetrically at frequencies between 220 and 8500 mc, as a function of temperature, crystal orientation and purity. Some approximate measurements on indium indicate that the superconducting resistance varies as the square of the frequency up to 5 kmc.

537.323 2315

Effect of Oxide Impurities on the Thermoelectric Powers and Electrical Resistivities of Bismuth, Antimony, Tellurium, and Bismuth-Tellurium Alloys—R. A. Horne. (*J. Appl. Phys.*, vol. 30, pp. 393–397; March, 1959.) The thermoelectric properties of Bi and Sb are only slightly changed by the presence of oxide, but small concentrations of TeO_2 greatly increase the thermoelectric power of Te.

537.533.8 2316

Secondary Electron Emission from MgO Thin Films—N. R. Whetten and A. B. Laponsky. (*J. Appl. Phys.*, vol. 30, pp. 432–435; March, 1959.) The properties of MgO films have been measured by pulse and dc methods. The high yields observed are due primarily to the properties of bulk crystalline MgO.

538.22:538.569.4 2317

Spin-Phonon Interaction in Ruby—N. S. Shiren and E. B. Tucker. (*Phys. Rev. Lett.*, vol. 2, pp. 206–207; March 1, 1959.) An experiment is described which shows that "hot phonon" theories of paramagnetic relaxation are inapplicable to ruby.

538.221 2318

Ferromagnetic Granular Structures—P. M. Prache. (*Câbles & Transm.*, vol. 11, pp. 32–65, 128–166; January and April, 1957.) 83 references.

538.221 2319

Domain Boundary Configurations during Magnetization Reversals—J. J. Becker. (*J. Appl. Phys.*, vol. 30, pp. 387–390; March, 1959.) The signal produced by applying an alternating field while a magnetization reversal is occurring is a measure of the total domain boundary area. The technique is used for measurements on 65 Permalloy tape cores and $3\frac{1}{4}$-per-cent silicon-iron crystal.

538.221 2320

Ferromagnetic After-Effect in Mumetal—L. Castelliz and W. W. H. Clarke. (*Brit. J. Appl. Phys.*, vol. 10, pp. 142–147; March, 1959.) Measurements of the response of crt deflection yokes with thin mumetal laminations to a step-function current have revealed a magnetic after-effect in addition to that caused by eddy currents. It is suggested that the new phenomenon is similar to nuclear magnetic time delay.

538.221 2321

Magnetic Moments of Alloys and Compounds of Iron and Cobalt with Rare-Earth Metal Additions—E. A. Nesbitt, J. H. Wernick and E. Corenzwit. (*J. Appl. Phys.*, vol. 30, pp. 365–367; March, 1959.) Data on the Co-Gd system indicate that antiferromagnetic exchange coupling exists in this system.

538.221:538.632 2322

Hall Effect in Pure Nickel at Helium Temperatures—N. V. Volkenshteĭn, G. V. Fedorov, and S. V. Vonsovskiĭ. (*Zh. Eksp. Teor. Fiz.*, vol. 35, pp. 85–88; July, 1958.) Investigations carried out on 99.99-per-cent-pure Ni in the temperature range 300°–14°K show that the the ferromagnetic constant drops sharply with temperature showing a minimum at 20°–30°K. Experimental results are shown graphically.

538.221:621.3.042.15 2323

Iron Powders for Cores—(*Electronics*, vol. 32, p. 141; March 13, 1959.) Typical properties of pressed and sintered cores are tabulated.

538.221:621.318.124 2324

Magnetic Materials with Perminvar Effect: Part 3—The Relation between Overstochiometric Oxygen Content and Perminvar Effect in Ferrites containing Cobalt—A. V. Kienlin. (*Z. angew. Phys.*, vol. 10, pp. 167–169; April, 1959.) **Parts 1 and 2: 1284 of April.**

538.221:621.318.134 2325

Magnetic Viscosity Displayed on Hysteresis Loop Traces—R. G. George. (*Nature, (London)*, vol. 183, p. 245; January 24, 1959.) Results are given of measurements on a polycrystalline Mg-Mn ferrite, using superposed pulse and ac magnetizations. They are in agreement with those obtained by Galt (175 of 1955).

538.221:621.318.134 2326

Calculation of the Square Hysteresis Loop of Ferrites—K. Ganzhorn. (*Z. angew. Phys.*, vol. 10, pp. 169–172; April, 1958.) Evaluation of a hysteresis loop, by means of an electronic computer, on the basis of a theory founded on pure spin processes and a statistical distribution of crystal orientations. A comparison with experimental results is made.

538.221:621.318.134 2327

Relation between Disaccommodation and Magnetic Properties of Manganese Ferrous Ferrites—U. Enz. (*Physica*, vol. 24, pp. 609–624; July, 1958.) Initial permeability, crystalline anisotropy, and magnetostriction have been measured on a single crystal and compared with corresponding measurements for polycrystalline material. See 3179 of 1958.

538.221:621.318.134 2328

Variation of the g-Factor of Yttrium Garnet in which Cr^{3+} Ions have been Substituted for Fe^{3+} Ions—R. Vautier and A. J. Berteaud. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1322–1324; October 27, 1958.) The value of g, measured in the 3-cm-λ band and extrapolated to a specimen diameter of zero, increases with the percentage of chromium, but in a nonuniform manner. See 3181 of 1958 (Villers and Loriers) for study of saturation moment.

538.221:621.318.134 2329

Variation of the Width of the Absorption Curve of Yttrium-Iron Garnet with the Substitution of Cr^{3+}—R. Vautier and A. J. Berteaud. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1574–1577; November 10, 1958). The variations can be explained by a variation of density with the percentage of chromium.

538.221:621.318.134:538.569.4 2330

Line Widths in Polycrystalline Yttrium-Iron Garnet—L. G. Van Uitert, F. W. Swanekamp, and S. E. Haszko. (*J. Appl. Phys.*, vol. 30, pp. 363–365; March, 1959.) Measurements at 16 kmc show the dependence of resonance line width upon iron content in dense samples.

538.221:621.318.134:548.0 2331

Some Properties of Mixed Dysprosium-Yttrium, Dysprosium-Gadelinium and Dysprosium-Erbium Garnets—G. Villers and J. Loriers. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1101–1104; October 13, 1958.)

538.569.4 2332

High-Frequency Susceptibilities of some Paramagnetic Alums at Liquid-Hydrogen Temperatures—J. C. Verstelle, G. W. J. Drewes, and C. J. Gorter. (*Physica*, vol. 24, pp. 632–638; August, 1958.) Samples of Cr and Fe alum were studied at frequencies between 1 and 20 mc.

538.569.4:538.222:546.824–31 2333

Fine Structure, Hyperfine Structure, and Relaxation Times of Cr^{3+} in TiO_2 (Rutile)—H. J. Gerritsen, S. E. Harrison, H. R. Lewis, and J. P. Wittke. (*Phys. Rev. Lett.*, vol. 2, pp. 153–155; February 15, 1959.) Resonances observed at 23,800 mc and 9520 mc in the paramagnetic spectrum are shown as a function of field and crystal orientation.

549.514.51 2334

The Anelasticity of Natural and Synthetic Quartz at Low Temperatures—J. C. King. (*Bell Sys. Tech. J.*, vol. 38, pp. 573–602; March, 1959.)

549.514.51:534.133 2335

Multiple-Beam Interferometric Studies on Oscillating Quartz Crystals—S. Tolansky and A. F. B. Wood. (*Physica*, Special Issue, vol. 24, pp. 508–518; June 16, 1958.) Multiple-beam interferometry is used to study the displacements perpendicular to the surface associated with the longitudinal vibrations of a circular Z-cut quartz disk.

621.315.61:537.529 2336

Corona Discharge—the Failing of Dielectrics—C. D. Nail. (*Electronic Ind.*, vol. 17, pp. 74–77; September, 1958.) Experimental and theoretical evidence indicates that breakdown is caused primarily by high-energy electron bombardment.

669.046.54/.55 2337

Improvement in Floating-Zone Technique—W. G. Pfann, K. E. Benson, and D. W. Hagelbarger. (*J. Appl. Phys.*, vol. 30, pp. 454–455; March, 1959.) A note on the use of different stationary zone forms.

MEASUREMENTS AND TEST GEAR

531.76:621.374.32 2338

Vernier Chronotron—H. W. Lefevre and J. T. Russell. (*Rev. Sci. Instr.*, vol. 30, pp. 159–166; March, 1959.) The instrument is a multichannel time-interval analyzer with digital output for use in the millimicrosecond region. The analyzer consists of two transmission-line circulators of slightly different periods with a single fast coincidence circuit between them and associated gating circuits. Linearity, stability and time resolution are discussed.

531.76:621.376.5 2339

Encoder measures Random-Event Time Intervals—R. J. Kelso and J. C. Groce. (*Electronics*, vol. 32, pp. 48–51; March 20, 1959.) The transistorized encoder stores and reads out the elapsed time between consecutive but randomly occurring events. Read-out data are converted to traces on a cro and recorded photographically.

621.3.018.41(083.74) 2340

Circuits employed in the N.P.L. Caesium Standard—L. Essen, E. G. Hope, and J. V. L. Parry. (*Proc. IEE*, pt. B, vol. 106, pp. 240–244; March, 1959.) A description of the circuits used to excite the caesium resonance and to measure the resonance frequency to an accuracy within ±1 part in 10^{10}. The excitation frequency is derived by multiplication of a 5.0069-mc signal from a quartz oscillator. An alternative, simpler system is described and some comments are made on the problem of frequency synthesis.

621.317.3:621.314.63 2341

A Method for Testing and Establishing the Rating of Semiconductor Rectifiers under Dynamic Conditions—J. I. Missen. (*Proc. IEE*, pt. C, vol. 106, pp. 3–10; March, 1959.) Junction temperature is monitored under working conditions at mains frequency, using a synchronous commutator to separate forward and reverse half-cycles. The method is particularly useful for life-testing, and a circuit suitable for testing large quantities is given.

621.317.3:621.375.2.024 2342

Zeroing of Direct-Current Amplifiers—R. W. Tolmie. (*Rev. Sci. Instr.*, vol. 30, pp. 205–206; March, 1959.)

621.317.3:621.375.9:538.569.4.029.6 2343

Calculation and Measurement of the Noise Figure of a Maser Amplifier—J. C. Helmer and M. W. Muller. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 210–214; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1329; June, 1958.)

621.317.3:621.385.1:621.396.822 2344

A Filament Noise Source for 3 Gc/s—E. W. Collings. (*Proc. IEE*, pt. C, vol. 106, pp. 97–101; March, 1959.) The construction of an incandescent filament lamp and tuned-waveguide mount is described. The filament temperature and losses in the lamp mounting have been measured. The noise source is useful as a standard in the determination of the noise temperature of gas discharges.

621.317.3:621.396.822:621.397.8 2345

The Measurement of Random Noise in the Presence of a Television Signal—L. E. Weaver. (*BBC Engrg. Div. Monographs*, no. 24, pp. 5–14; March, 1959.) A substitution method is described, based upon sampling the random noise in the minimum-energy regions of the spectrum. Accuracy of measurement is within ±1 db.

621.317.3.089.6:621.318.42 2346

The Calibration of Inductors at Power and Audio Frequencies—G. H. Rayner. (*Proc. IEE*, vol. 106, pp. 38–46; March, 1959.) Methods of inductance measurement at the National Physical Laboratory are described.

621.317.334:621.397.62 2347

Video Output Stage with Wire-Wound Anode Resistor for Television Receivers—K. Hecker. (*Elektron. Rundschau*, vol. 12, pp. 191–193; June, 1956.) A method of measuring accurately the inductance of wire-wound resistors with high resistance is described.

621.317.335.029.65 2348

Measurement of the Dielectric Properties of Low-Loss Materials at Millimeter Wavelengths—A. C. Mungall. (*Can. J. Phys.*, vol. 36, pp. 1672–1677; December, 1958.) A free-space technique involving the measurement of the Brewster angle for the determination of the dielectric constant, and a measurement of the transmission loss at this angle for the determination of the loss tangent.

621.317.35:519.272.119 2349

Technique for Measurement of Cross-Spectral Density of Two Random Functions—M. S. Uberoi and E. G. Gilbert. (*Rev. Sci. Instr.*, vol. 30, pp. 176–180; March, 1959.)

621.317.39:531.76:535.37 2350

The Measurement of Extremely Short Afterglows of Electronically Excited Luninophores—K. Heine. (*Elektron. Rundschau*, vol. 12, pp. 164–167; May, 1958.) The equipment described covers the range 10^{-3} to about 10^{-8} second; the afterglow decay function is displayed on a cro screen.

621.317.441 2351

Improvement in the Magnetic Detecting Power of Iron-Cored Search Coils—D. F. Walker. (*Nature, (London)*, vol. 183, pp. 173–174; January, 1959.) An eight-fold increase in detecting power may be obtained by fitting permeable collector cones to the ends of the rod on which search coils are wound. The increase is related almost linearly to the diameter of the cone.

621.317.7:621.396.96.089.6 2352

Precision Generator for Radar Range Calibration—D. Broderick, D. Hartke, and M. Willrodt. (*Electronics*, vol. 32, pp. 58–60; April 3, 1959.) Two delayed pulses are produced with separations of 1–10,000 μsec, adjustable in 1-μsec steps. The oscillator is crystal-controlled to 1 part in 10^5 from −10° to +50° C.

621.317.789.029.64:621.316.72 2353

Amplitude Stabilization of a Microwave Signal Source—G. F. Engen. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 202–206; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1329; June, 1958.)

621.317.715.083.5:621.383 2354

The Measurement Limit of Photocell Compensators—H. G. Pohl. (*Z. angew. Phys.*, vol. 10, pp. 125–127; March, 1958.) The improvement of the performance of photoelectric compensating circuits used for measurements with mirror galvanometers is discussed. This can be achieved by lengthening the time constant of the grid circuit of the amplifying tube at the expense of a somewhat slower system response. See also 2064 and 2065 of 1955 (Kelen).

621.317.725 2355
Digital Voltmeter—H. Sutcliffe. (*Electronic Radio Engr.*, vol. 36, pp. 160–166; May, 1959.) Voltages in the ranges 0–1 and 0–10 V can be measured with a maximum error of ±0.02 per cent of full scale reading.

621.317.729 2356
Space-Charge Simulation in an Electrolytic Tank—T. Van Duzer and G. R. Brewer. (*J. Appl. Phys.*, vol. 30, pp. 291–301; March, 1959.) A description is given of the theory and design of a system for simulating space-charge effects by means of electric currents injected into the electrolyte through probes in the tank floor.

621.317.75 2357
The Recording and Collocation of Waveforms: Part 2—R. J. D. Reeves. (*Electronic Engrg.*, vol. 31, pp. 204–212; April, 1959.) A detailed description of an instrument for the permanent recording of waveforms is given. The vertical scale accuracy is within 0.5 per cent and the range covered is 50 v/inch–0.5 v/inch on time scales ranging from 500 μsec/inch to 0.1 μsec/inch on paper 10 inches×77 inches. The pen is driven by a bowed tape that can transmit thrust as well as tension forces and requires no return loop. Part 1: 1650 of May.

621.317.789.029.6 2358
Broad-Band Calorimeters for the Measurement of Low- and Medium-Level Microwave Power—(IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 188–202; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1329; June, 1958.)
Part 1—Analysis and Design—M. Sucher and H. J. Carlin (pp. 188–194).
Part 2—Construction and Performance—A. V. James and L. O. Sweet (pp. 195–202).

621.317.789.029.64 2359
A Wide-Band Double-Vane Torque-Operated Wattmeter for 3-cm Microwaves—A. L. Cullen, B. Rogal, and S. Okamura. (IRE Trans. on Microwave Theory and Techniques, vol. MTT-6, pp. 133–136; April, 1958. Abstract, Proc. IRE, vol. 46, p. 1328; June, 1958.)

551.508:629.19 2360
'Moons' aid Weather Research—(*Electronics*, vol. 32, pp. 26–27; March 20, 1959.) Current research using artificial satellites includes cloud-cover mapping and measurement of heat-balance of the earth. Instrumentation covers infrared sensors, television cameras and radar.

615.84:621.396.677.7.029.6 2361
A Wide-Band Radiator of Variable Wavelength with Continuously Adjustable Matching in the Range λ=30 to 70 cm—A. Sander. (*Elektron. Rundschau*, vol. 12, pp. 155–159; May, 1958.) A microwave radiator for heat therapy is described which is suitable for treatment at close range or at a distance.

621.3.087.4:621.385.832 2362
System Design of the Flying-Spot Store—C. W. Hoover, Jr., G. Haugk, and D. R. Herriott. (*Bell Sys. Tech. J.*, vol. 38, pp. 365–401; March, 1959.) The factors which control speed, capacity, number of channels, physical size and probability of error in read-out are discussed.

621.3.087.4:621.385.832 2363
Optics and Photography in the Flying-Spot Store—M. B. Purvis, G. V. Deverall, and D. R. Herriott. (*Bell Sys. Tech. J.*, vol. 38, pp. 403–424; March, 1959.) A discussion of the optical and photographic problems to be considered in the construction of a flying-spot store.

621.3.087.4:621.385.832 2364
Beam-Positioning Servo System for the Flying-Spot Store—L. E. Gallaher. (*Bell Sys. Tech. J.*, vol. 38, pp. 425–444; March, 1959.) The characteristics of the basic servo loop and its components are discussed.

621.3.087.9:621.374.5 2365
Digital Recorder holds Data after Shock—C. P. Hedges. (*Electronics*, vol. 32, pp. 60–62; March 20, 1959.) A recorder memorizes the instantaneous magnitude of parameters when triggered by a predetermined set of conditions. Ferrite cores store data and subsequent interrogation releases the stored information for processing.

621.3.087.9:621.395.625.3 2366
Sampling Discriminators for Data Reduction—P. S. Bengston. (*Electronics*, vol. 32, pp. 70–72; March 27, 1959.) The data are recorded as FM signals on one channel of a magnetic tape. The second channel contains a constant reference signal which allows wow and flutter to be eliminated in the playback.

621.362:621.385.2 2367
Thermionic Diode as a Heat-to-Electrical-Power Transducer—Nottingham. (See 2434.)

621.362:621.385.2 2368
Addendum Remarks on a Diode Configuration of a Thermo-Electron Engine—Nottingham. Hatsopoulos, and Kaye. (See 2435.)

621.383.2:778.37 2369
Shutter Image Converter Tube for Multiple Frame Photography—W. O. Reed and W. F. Niklas. (*J. Soc. Mot. Pic. Telev. Engrs.*, vol. 68, pp. 1–5; January, 1959.) The tube described has a Cs-Sb photocathode, es focusing and em deflection, and is capable of exposure times of about 1 mμsec.

621.384.611 2370
Stability and Isochronism in Cyclotrons with a Star-Shaped Field—F. Fer. (*Compt. rend. Acad. Sci., Paris*, vol. 247, pp. 1097–1098; October 13, 1958.)

621.397.3:681.142 2371
Pattern Recognition by means of Automatic Analogue Apparatus—W. K. Taylor. (*Proc. IEE*, pt. B, vol. 106, pp. 198–209; March, 1959.) The problem of pattern recognition is discussed. Analog circuits, rather than digital switching circuits, provide the simpler solution. The results indicate the possibility of recognition of the alphabet and numerals in a variety of styles and sizes, typed or handwritten.

621.397.3:681.142 2372
A System for the Automatic Recognition of Patterns—R. L. Grimsdale, F. H. Sumner, C. J. Tunis, and T. Kilburn. (*Proc. IEE*, pt. B, vol. 106, pp. 210–221; March, 1959.) The pattern is presented to a flying-spot scanner connected to a digital computer which prepares a statement describing the basic features of the pattern. The latter is then recognized by comparing this statement with a number of others already stored and which relate to named patterns.

621.398:621.314.7 2373
Transistors Improve Telemeter Transmitter—D. Enemark. (*Electronics*, vol. 32, pp. 136–137; March 13, 1959.) Battery weight of balloon-borne units is reduced and better frequency stability and modulation consistency are obtained.

621.398:621.387 2374
Telemetering employing the Principle of the Gas-Fitted Stepping Tube—Y. Hatta. (*Electronic Engrg.*, vol. 31, pp. 227–229; April, 1959.) Rotational displacement can be telemetered, without slip, by a digital device using a small frictionless transmitter of low inertia.

PROPAGATION OF WAVES

621.396.11 2375
A Comparison of Millington's Method and the Equivalent Numerical Distance Method with the Theory of Ground-Wave Propagation over an Inhomogeneous Earth—Z. Godziński. (*Proc. IEE*, pt. C, vol. 106, pp. 62–69; March, 1959.) Millington's method (1758 of 1949) is sufficiently accurate for most practical problems; errors are very small for overland paths, and land-sea paths involve errors of 2.7 db and 5.5 db for 2- and 3-section paths respectively. In most cases, the "equivalent numerical distance" method shows considerable errors, and is reliable only for small numerical distances or for longer paths with little inhomogeneity. See also 3949 of 1958.

621.396.11 2376
Long-Distance Propagation—(*Wireless World*, vol. 65, p. 234; May, 1959.) General information concerning forthcoming tests between Ascension Island and Slough to investigate modes of propagation and associated aerial design. The frequency of the transmitter in Ascension Island can be stepped by increments of 20 kc from 5.5 to 50 mc in about 15 minutes; the receiver tuning is automatically synchronized.

621.396.11:551.510.535 2377
Ray Paths in The Ionosphere. Approximate Calculations in the Presence of the Earth's Magnetic Field—J. E. Titheridge. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 50–62; April, 1959.) The approximate ionospheric ray paths are derived for both linear and parabolic electron-density/height distributions. From these paths, values of the horizontal displacement of the reflection point are estimated, and are found to be less than 10 km for all angles of propagation, provided the transmission frequency is greater than 5 mc.

621.396.11:551.510.535 2378
Further Results of Sweep-Frequency Oblique-Incidence Pulse Transmissions—W. Dieminger, H. G. Möller, and G. Rose. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 179–180, Plate; April, 1959.) Attention is drawn to the importance of the F_1 layer in oblique-incidence circuits. For summertime European circuits over 2000 km, the F_1-layer MUF is greater than the F_2-layer MUF by about 2 mc for 14 hours of the day.

621.396.11.029.6 2379
The Propagation of Ultra Short Waves along Rough Layers—R. Schünemann. (*Hochfreq. und Elektroak.*, vol. 66, pp. 171–173; May, 1958.) Theoretical investigation of the propagation mechanism for various types of scattering surface in the atmosphere in relation to field-strength measurements (see 3235 of 1958). Field-strength fluctuations with time can be determined using the probability distribution discussed by Norton, *et al.* (197 of 1956).

621.396.11.029.62:523.164 2380
Observations of Abnormal V.H.F. Radio Wave Absorption at Medium and High Latitudes—G. C. Reid and C. Collins. (*J. Atmos. Terr. Phys.*, vol. 14, pp. 63–81; April, 1959.)

Absorption of cosmic noise at 30 mc has revealed two distinct types of abnormal event: a) a night-time phenomenon closely associated with auroral and geomagnetic disturbances; it is suggested that this is due to an increase in the electron collision frequency; b) a daytime phenomenon confined to the auroral zone and occurring several days after a solar flare; this may be due to an increase in the low-level electron density.

621.396.11.029.64 2381
Radio Attenuation at 11 kMc/s and some Implications affecting Relay System Engineering—S. D. Hathaway and H. W. Evans. (*Commun. and Electronics*, no. 40, pp. 930–938; January, 1959.) Measurements of attenuation have been related to amounts of rainfall; agreement with theory is quite good.

RECEPTION

621.376.23:517.512.2 2382
Multiple Fourier Analysis in Rectifier Problems—R. L. Sternberg, J. S. Shipman, and S. R. Zohn. (*Quart. Appl. Math.*, vol. 16, pp. 335–360; January, 1959.) Theory of a cutoff power-law rectifier with up to three signals of different frequency applied simultaneously. The main functions required are shown in graphs and are available in tabular form.

621.396.621.2 2383
The Influence of the Top-End Capacitance in Inductive Aerial Couplings—H. Röbel. (*Elektron. Rundschau*, vol. 12, pp. 194–196; June. 1958.) The design of receiver antenna input stages is considered, taking account of stray capacitance.

621.396.8:551.510.535:621.317.373 2384
Phase Characteristic of Radio Signals Received via the Ionosphere—D. W. Morris and C. J. Hughes. (*Nature*, (*London*), vol. 183, pp. 310–311; January 31, 1959.) A brief description of a phase-measurement system using two spaced antennas and a gate-operated analyzer which indicates on counters the phase difference distribution.

621.396.8:621.396.666 2385
Simplified Frequency-Diversity Method—H. Völz. (*Elektron. Rundschau*, vol. 12, pp. 200–202; June, 1958.) The double-diversity system described is particularly suitable for VHF FM reception; the IF and subsequent stages are common to both channels.

621.396.823.029.6:621.317.3 2386
Radio Interference in the Ultra-Short-Wave Range, its Propagation, Forms of Appearance and Measurement—W. Knopf. (*Nachrichtentech Z.*, vol. 8, pp. 167–173; April, 1958.) Test arrangements and specifications of equipment suitable for interference field-strength measurements are discussed.

STATIONS AND COMMUTATION SYSTEMS

621.391 2387
Binary Communication Feedback Systems—B. Harris, A. Hauptschein, K. C. Morgan, and L. S. Schwartz. (*Commun. and Electronics*, no. 40, pp. 960–969; January, 1959.) Discussion of different types of decision-feedback and information-feedback systems.

621.391 2388
Binary Channels in Cascade—J. Loeb. (*Ann. Télécommun.*, vol. 13, pp. 42–44; January/February, 1958.) A method is described for resolving ambiguities.

621.391 2389
Error Probability of Binary Coded Message with Interference by White Noise—H. J. Held. (*Nachrichtentech. Z.*, vol. 11, pp. 244–249; May, 1958.) The effect of error-correcting codes on the reliability of binary-code transmission systems is investigated.

621.391:621.372.54 2390
Finite-Duration Signals with Maximum Filtered Energy—J. A. Ville and J. Bouzitat. (*Câbles & Transm.*, vol. 11, pp. 102–127; April, 1957.) A study of the maximum value of power efficiency which can be obtained in the transmission of a signal of finite duration through an ideal low-pass filter having a sharp cutoff at a given frequency. See also 1206 of 1956.

621.391:621.362.54 2391
On the Interpolation and Prediction of Signals plus Noise for Infinite and Finite Smoothing Times—C. McDonnell and R. W. Perkins. (*Proc. IEE*, pt. C, vol. 106, pp. 47–54; March, 1959.) Laplace transformations are used to solve the Wiener-Hopf integral equation for the lagging (nonprediction) case. The solution of the optimum filter for minimum error at a given time after switch-on is also derived, the averaging being taken over an ensemble.

621.394.3:621.376.3 2392
A Frequency-Modulation Digital Subset for Data Transmission over Telephone Lines—L. A. Weber. (*Commun. and Electronics*, no. 40, pp. 867–872; January, 1959.) The subset converts digital information to AF tones and reconverts incoming information.

621.396.41 2393
A 6000-Megacycle Radio System for Toll Telephone Service—M. H. Kebby and A. F. Culbertson. (*Commun. and Electronics*, no. 40, pp. 969–979; January, 1959.) Gives details of construction and performance of a 240-channel (1200-kc base-band) system with frequency division multiplexing and facilities for space or frequency diversity. RF channel separation is achieved by a ferrite circulator.

621.396.41:534.782 2394
Simple Multiplex Vocoder—A. R. Billings. (*Electronic Radio Engr.*, vol. 36, pp. 184–188; May, 1959.) Describes a time-division vocoder with a common rectifier for all channels.

621.396.41:621.395.665.1 2395
A Transistorized Compandor—J. C. Perkins, Jr., D. A. Perreault, and A. F. Perkins. (*Commun. and Electronics*, no. 49, pp. 791–797; January, 1959.) An instrument for general use in speech transmission circuits.

621.396.41:621.396.82 2396
Echoes Cause F.M. Intermodulation—H. E. Curtis. (*Electronic Ind., Electronic Operations Sect.*, vol. 17, pp. 06–07; September, 1958.) A method is described for calculating the degree of intermodulation introduced by mismatched transmission lines in multichannel FM systems. See also 3089 of 1955 (Bennett, *et al.*).

621.396.5:534.76 2397
Recent Developments in Stereo Broadcasting—J. M. Carroll. (*Electronics*, vol. 32, pp. 41–46; April 3, 1959.) Some details, including block diagrams, are given for twelve different stereophonic broadcast systems and methods that have been used or proposed as compatible systems. See also (*ibid.*, vol. 32, p. 78; April 10, 1959.)

621.396.65:621.396.41 2398
The Expansion of the Pacific Coast Microwave Network—R. G. Kuck. (*Commun. and Electronics*, no. 40, pp. 898–903; January, 1959.)

SUBSIDIARY APPARATUS

621.311.69:629.19 2399
New Power Sources for Space-Age Electronics—D. Linden and A. F. Daniel. (*Electronics*, vol. 32, pp. 43–47; March 20, 1959.) Developments are described in chemical, nuclear and solar energy sources which are expected to fulfill requirements for portable electrical power in space. Output characteristics of different types are summarized.

621.314.63:621.317.3 2400
A Method for Testing and Establishing the Rating of Semiconductor Rectifiers under Dynamic Conditions—Missen. (See 2341.)

621.316.722.078.3 2401
Regulated Power Supplies—D. J. Collins and J. E. Smith. (*Electronic Engrg.*, vol. 31, pp. 222–226; April, 1959.) A brief review is made of various types of stabilized power supply leading to the closed-loop series regulator for which design details are given.

621.352.7 2402
Dry Cells containing Various Aromatic C-Nitrose Compounds as Cathode Materials—C. K. Morehouse and R. Glicksman. (*J. Electrochem. Soc.*, vol. 105, pp. 619–624; November, 1958.) The cells have a Mg anode and an aqueons $MgBr_2$ solution as electrolyte. Performance characteristics compare favorably with those of commercial Leclanché-type cells.

621.355.2 2403
Self-Discharge Reactions in Lead-Acid Batteries—P. Rüetschi and R. T. Angstadt. (*J. Electrochem. Soc.*, vol. 195, pp. 555–563; October, 1958.) In a theoretical and experimental analysis, the rates of seven different reactions which contribute to the self-discharge process have been determined. 54 references.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5:535.623 2404
On the Quality of Colour-Television Images and the Perception of Colour Detail—D. H. Schade, Sr. (*J. Soc. Mot. Pic. Telev. Engrs.*, vol. 67, pp. 801–818; December, 1958. Discussion, pp. 818–819.) A theoretical and experimental examination of the NTSC color system shows that contrast range and color saturation obtained with commercial tricolor kinescopes provide a larger color space than that provided by color motion pictures.

621.397.611.2 2405
Standards Converter using a Vidicon Camera—W. Dillenburger. (*Arch. elek. Übertragung*, vol. 12, pp. 209–224; May, 1958.) A special vidicon tube has been developed for use in equipment for the conversion of television standards. Results obtained in converting from 819 to 625 and from 405 to 625 lines are reproduced and discussed and special circuit features are described.

621.397.62:621.317.334 2406
Video Output Stage with Wire-Wound Anode Resistor for Television Receivers—Hecker. (See 2347.)

621.397.621.2:535.623 2407
Afterglow Problems in Colour-Television Picture Tubes—I. Bornemann. (*Elektron. Rundschau*, vol. 12, pp. 204–206; June, 1958.) Methods of modifying the afterglow characteristics of phosphors to improve the performance of color-television tubes are discussed. See also 2251 of 1958.

621.397.8 2408
Subjective Impairment of Television Pictures—L. E. Weaver. (*Electronic Radio Engr.*, vol. 36, pp. 170–179; May, 1959.) Flat and triangular noise waveforms of known levels were superimposed upon accurately-standardized television 405-line and 605-line pictures; a number of observers recorded their opinions

of the displays on a 5-point scale of assessment. The results are analyzed and discussed.

621.397.8:621.396.822:621.317.3 2409

The Measurement of Random Noise in the Presence of a Television Signal—Weaver. (See 2345.)

TUBES AND THERMIONICS

621.314.63 2410

D.C. Characteristics of a Junction Diode—I. Ladany. (Proc. IRE, vol. 47, p. 589; April, 1959.) Theoretical expressions are derived for the characteristics taking account of the field in the base region.

621.314.63:546.289 2411

The Influence of Geometrical and Physical Factors at the Point Contact of Germanium Diodes on the Characteristic—E. Hofmeister and E. Groschwitz. (*Z. angew. Phys.*, vol. 10, pp. 109–114; March, 1958.) Closer agreement between theory and experiment is obtained by the introduction of form factors which allow for the shape of the *p-n* junction formed at the point contact of the diode.

621.314.63:546.289 2412

High-Speed Switching Diodes from Plastically Deformed Germanium—G. L. Pearson and R. P. Riess. (*J. Appl. Phys.*, vol. 30, pp. 311–312; March, 1959.) The degradation of minority-carrier lifetime caused by dislocations generated during plastic deformation greatly reduced the minority-carrier storage effect and permitted fabrication of diodes with turnoff times of the order of 10^{-9} second.

621.314.63+621.314.7]:621.396.822 2413

Theory and Experiments on Shot Noise in Silicon *p-n* Junction Diodes and Transistors—B. Schneider and M. J. O. Strutt. (Proc. IRE, vol. 47, pp. 546–554; April, 1959.) New theoretical expressions are derived on the basis of recombination-generation in the depletion layer. They are shown by experiment to be satisfactory for silicon in the case of low-level current injection; at high-level injection, deviations occur.

621.314.63:621.372.632 2414

Proposed Microwave Mixer Diode of Improved Conversion Efficiency—L. B. Valdes. (*J. Appl. Phys.*, vol. 39, pp. 436–439; March, 1959.) The conversion efficiency can be improved by using a spherically-symmetrical convergent flow of minority carriers in a semiconductor. The admittance will be small, and over a limited frequency range it may be possible to have a negative conductance.

621.314.632 2415

The Determination of the Characteristic Parameters of the Barrier Layer in Metal/Semiconductor Junction Diodes—V. Andresciani, D. Sette, and S. Tiberio. (*Note Recensioni Notiz.*, vol. 7, pp. 418–433; July/August, 1958.) Capacitance and thermal methods are compared in investigations of Cu/Cu_2O and Au/Ge junctions.

621.314.7 2416

Theory of Transient Build-Up in Avalanche Transistors—W. Shockley and J. Gibbons. (*Commun. and Electronics*, no. 40, pp. 993–998; January, 1959.) When biased into the negative resistance range, the transistor initially delivers an exponentially-increasing current into a capacitor connected between emitter and collector. Finally, the current rises abruptly and nearly reaches its peak value before the capacitor is substantially discharged.

621.314.7 2417

Stored-Charge Method of Transistor Base Transit Analysis—L. J. Varnerin. (Proc. IRE, vol. 47, pp. 523–527; April, 1959.) The transit time, defined as the stored-charge-per-unit emitter current, is particularly applicable to HF transistor performance. Analysis of a *p-n-p* transistor shows that shorter transit times can be achieved with retarding fields, since smaller base thicknesses are possible.

621.314.7:546.28:621.318.57 2418

Silicon-Controlled Rectifiers from Oxide-Masked Diffused Structures—R. W. Aldrich and N. Holonyak, Jr. (*Commun. and Electronics*, no. 40, pp. 952–954; January, 1959.) Description of a two-impurity simultaneous-diffusion process for producing structures suitable for two- or three-terminal signal and power *p-n-p-n* switches (controlled rectifiers). Gallium and phosphorus impurities are used.

621.314.7:546.289 2419

Alloyed Germanium Transistor has Symmetrical Characteristics—O. Stavik. (*Canad. Electronics Engrg.*, vol. 2, pp. 28–31; November, 1958.) The problems encountered in the production of symmetrical *n-p-n* transistors are discussed and characteristics for normal and reverse operation are given. Specially-matched units have deviations <10 per cent for f_α, α_{cb} and I_{co} between normal and reverse operation.

621.314.7:621.318.57 2420

The Deplistor, a Semiconductor Switching Device—O. W. Memelink. (*Philips Res. Rep.*, vol. 13, pp. 485–488; October, 1958.) A device on near-intrinsic Ge is described which makes use of the depletion region surrounding an alloy contact biased in the reverse direction. Appropriate circuit conditions allow the deplistor to be used as a switching element with a negative differential resistance. Switching times of 5–20 μsec have been measured.

621.314.7:621.318.57 2421

The Controlled Rectifier: Key to the Continuing Control Renaissance—J. D. Harnden, Jr. (*Commun. and Electronics*, no. 40, pp. 1006–1012; January, 1959. Discussion.) A discussion of the principles and applications of the new *p-n-p-n* switching devices. Very high operating voltages and current ratings are obtainable.

621.314.7+621.385]:621.396.822 2422

On the Noise Generated by Diffusion Mechanisms—K. M. Van Vliet and A. Van der Ziel. (*Physica*, Special Issue, vol. 24, pp. 415–421; June 16, 1958. Correction, *ibid.*, vol. 24, p. 556; July, 1958.) A restatement of Richardson's theory of contact noise (1391 of 1950) and a discussion of later theories.

621.314.7.012.8 2423

Experimental and Theoretical Investigations of the Equivalent Circuit of Modern High-Frequency Transistors, in particular Drift Transistors—W. Guggenbühl and W. Wunderlin. (*Arch. elekt. Übertragung*, vol. 12, pp. 193–202; May, 1958.) The transport factor of the base of a drift transistor is derived and compared with experimental results. The HF behavior of a transistor with uniform base resistivity is discussed for high-level injection. Measurements of drift transistor parameters and methods of evaluating transit time through the base layer are given.

621.385.029.6 2424

The Integral Energy Distribution of Electrons beyond the Output Resonator of a Transit Type Klystron—I. R. Gekker. (*Radiotekh. Elektron.*, vol. 2, pp. 895–900; July, 1957.) The energy distribution of electrons in a double- and triple-resonator klystron is examined. An experiment was devised making use of a glass model of a double-resonator klystron, in order to verify the theoretical results. Good agreement between the theoretical and experimental results was obtained.

621.385.029.6 2425

Electronic Conductance of a Space-Charge Cloud in a Magnetron—V. P. Tychinskiĭ. (*Radiotekh. Elektron.*, vol. 2, pp. 912–924; July, 1957.) An examination of small distrubances for a single-flow condition of an electron stream in a plane magnetron with partially-filled interaction space. A differential equation for the tangential field component is derived and a formula for the insertion of electron conductivity in the resonator system is deduced. Results of calculations of conductance, field and energy flux are given.

621.385.029.6 2426

Nonlinear Theory of a Travelling-Wave Valve: Part 1—Equations and Laws of Conservation—L. A. Vaĭnshteĭn. (*Radiotekh. Elektron.* vol. 2, pp. 883–894; July, 1957.) Two laws can be deduced from the derived equations for the conservation and transformation of energy. The first law is based on a fixed system of coordinates, the second on a system moving uniformly with the initial velocity of the electrons. Different methods for evaluating the forces of space-charge repulsion of electrons in a beam are also examined.

621.385.029.6 2427

Theory of the Crestatron: a Forward-Wave Amplifier—J. E. Rowe. (Proc. IRE, vol. 47, pp. 536–545; April, 1959.) A voltage gain is obtained by means of a beating effect between the three small-signal forward waves of traveling-wave-tube theory as they travel along the slow-wave structure. Maximum achievable gain is determined by the injection velocity. A crestatron, embodying this principle, has been constructed and found to give moderate gain (10–20 db) and high operating efficiency, together with very short length (4–6 λ).

621.385.032.213.13 2428

The Conductivity of Oxide Cathodes: Part 6—Conductivity in a Magnetic Field—G. H. Metson. (*Proc. IEE*, pt. C, vol. 106, pp. 55–61; March, 1959.) The oxide-cathode matrix in an *S*-type tube exhibits a powerful magneto-resistance effect, but only when electron transfer occurs by free flight through the matrix pores and when the magnetic field is transverse. Part 5: 4019 of 1958.

621.385.032.26:537.533 2429

Large Perturbations in Electron Beams from Shielded and Immersed Guns—T. W. Johnston. (*J. Electronics Control*, vol. 6, pp. 75–78; January, 1959.) The assumption made by Chen (4020 of 1958) of laminar flow in electron beams is examined.

621.385.032.269.1 2430

Electron Guns for Producing Solid and Hollow Cone-Type Beams with High Current—S. N. Treneva. (*Radiotekh. Elektron.*, vol. 2, pp. 925–934; July, 1957.) The apparatus is described and calculations and graphs are given for the determination of the size of the electrodes in the gun in terms of the stipulated parameters of the electron beam. The guns operate at zero potential on the cathode. 98 per cent to 100 per cent of the total beam current passes through the anode aperture. These guns may be used in traveling-wave tubes, klystrons, and other devices where a high-power solid or hollow electron beam is required.

621.385.1.001.4:534.1:621.396.934 2431

Electron-Tube Evaluation for Guided-Missile Applications—H. G. Chandler. (*Elect. Engrg., N. Y.*, vol. 77, pp. 690–692; August, 1958.) A note on vibration tests of subminiature tubes.

621.385.2 2432
Space-Charge Neutralization by Positive Ions in Diodes—P. L. Auer and H. Hurwitz, Jr. (*J. Appl. Phys.*, vol. 30, pp. 161–165; February, 1959.) Analysis is given with curves for the potential as a function of position for a series of values of the ratio of ion to electron density at the potential minimum.

621.385.2 2433
Azimuthal Electron Flow in a Spherical Diode—W. E. Waters. (*J. Appl. Phys.*, vol. 30, pp. 368–373; March, 1959.) Solutions of Poisson's equation for a space-charge-limited spherical diode, in which electron trajectories are great circles rather than radial lines, are developed. It is shown how Poisson's equation may be separated to yield ordinary differential equations. The radial equation is solved analytically and accurate numerical solutions of the azimuthal equation are given. A method of truncating the flow to produce a "bowl-shaped" electron gun, leading eventually to an annular electron beam, is presented.

621.385.2:621.362 2434
Thermionic Diode as a Heat-to-Electrical-Power Transducer—W. B. Nottingham. (*J. Appl. Phys.*, vol. 30, pp. 413–417; March, 1959.) A vacuum diode can convert heat to electrical power when it has a low-work-function collector, small electrode spacing, and sufficient temperature difference. Conversion efficiency lies between 3 per cent and 4 per cent.

621.385.2:621.362 2435
Addendum Remarks on a Diode Configuration of a Thermo-electron Engine—W. B. Nottingham, G. N. Hatsopoulos, and J. Kaye. (*J. Appl. Phys.*, vol. 30, pp. 440–441; March, 1959.) See 3592 and 4024 of 1958 (Hatsopoulos and Kaye) and 2434 above.

621.385.2/.3].029.6 2436
The Noise of Space-Charge Diodes in the Transit-Time Region allowing for the Maxwellian Velocity Distribution of Electrons—K. H. Löcherer. (*Arch. elekt. Übertragung*, vol. 12, pp. 225–236, 265–270; May and June, 1958.) The fundamental equations for shot noise of planar space-charge diode are deduced, and the quadripole noise parameters of the ideal triode are calculated. See also 1615 of 1957 (Paucksch).

621.385.3.029.6 2437
The Influence of Penetration-Factor Fluctuations on the Input Conductance and Slope of the Triode Type 2c40 in the Transit-Time Region—H. Fiedler. (*Nachrichtentech. Z.*, vol. 11, pp. 269–275; May, 1958.) Measurements on a disk-seal triode were made at 1.5 and 2.4 kmc using a tunable cavity resonator in the anode circuit. An approximation method for calculating the parameters is given.

621.385.832 2438
Surface Phenomena associated with Application of Organic Films to Phosphor Screens—R. W. Dudding and D. J. Finnett. (*J. Electrochem. Soc.*, vol. 105, pp. 388–392; July, 1958.) "The production of aluminized screens for cathode-ray tubes involves the formation of a temporary organic barrier film on the phosphor coating on which the aluminium may be deposited. Defects in this film produce undesirable blemishes on the finished screen. Certain inherent defects encountered when employing a 'flow filming' technique are described, and the fundamental factors governing their formation and prevention are considered."

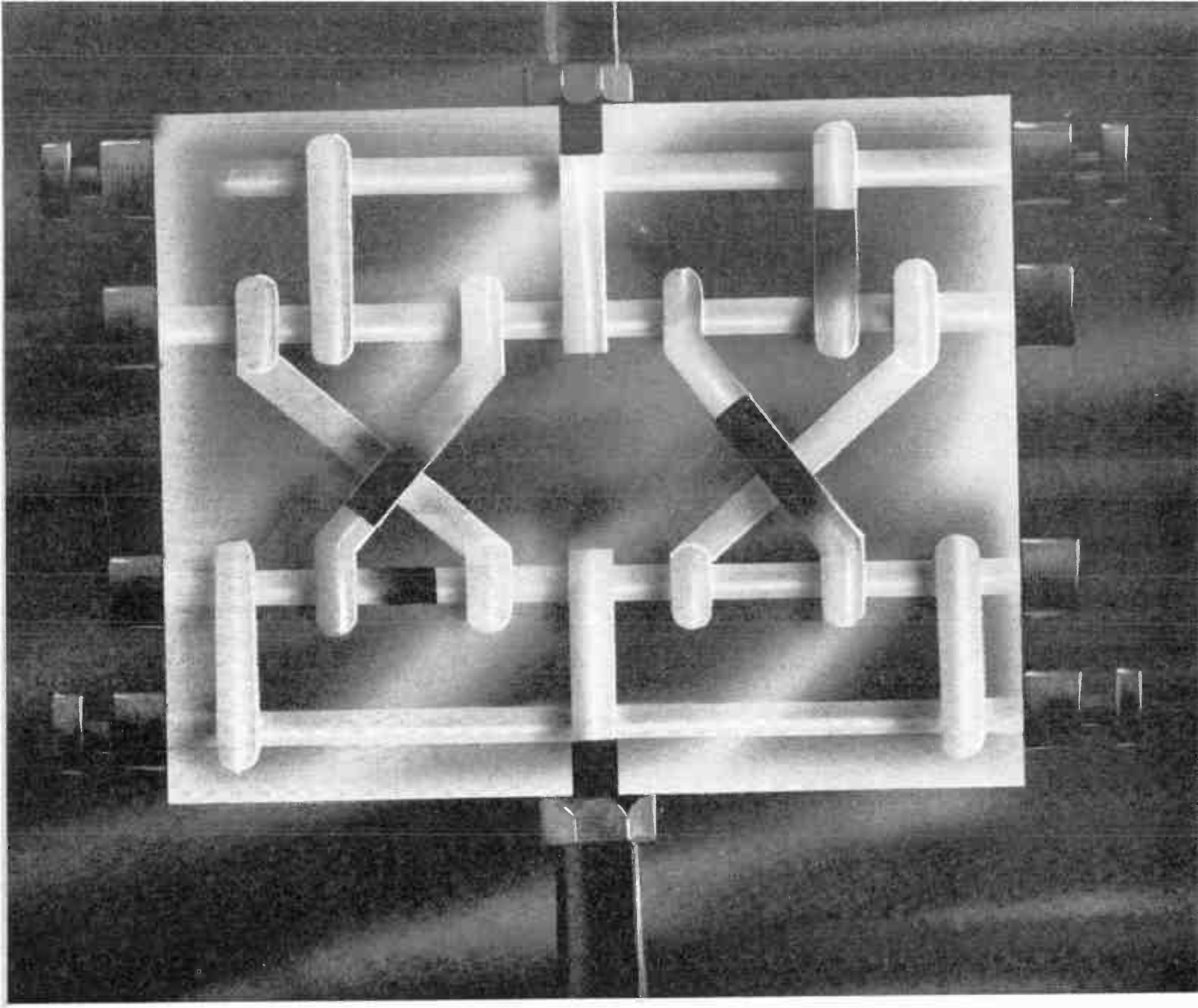
621.385.832:681.142 2439
Stable High-Speed Digital-to-Analogue Conversion for Storage-Tube Deflection—Ault. (See 2135.)

621.385.832.032.366 2440
The Effect of Temperature on the Resistance of Long-Persistence Cathode-Ray-Tube Screens—R. Feinberg. (*Proc. IEE*, pt. C, vol. 106, pp. 77–81; March, 1959.) Increasing temperature reduced the persistence time. The temperature coefficient followed no general rule, being peculiar to the particular type of phosphor used.

621.387 2441
Discharge Modes using Thermionic Cathodes—R. B. Cairns and G. C. McCullagh. (*J. Electronics Control*, vol. 6, pp. 65–69; January, 1959.) "New observations have been made on the structure of discharges from hot cathodes and the relation between different forms, and information obtained about the roles of diffusion and oscillations."

621.387:621.316.722 2442
Effects of Argon Content on the Characteristics of Neon-Argon Glow-Discharge Reference Tubes—F. A. Benson and P. M. Chalmers. (*Proc. IEE*, pt. C, vol. 106, pp. 82–90; March, 1959.) The argon content in specially constructed tubes was varied between 0.001 per cent and 10 per cent. Optimum characteristics were obtained using 1 per cent argon.

621.387:621.318.57:621.395.34 2443
Cold-Cathode Voltage-Transfer Circuits—J. H. Beesley. (*J. Brit. IRE*, vol. 19, pp. 149–161; March, 1959. Discussion, pp. 161–163.) A new method of operating cold-cathode triode switching tubes is described. The departure from conventional operating methods results in some unusual features in the logical design of switching equipment which are discussed



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Any logic unit requires an interchange of signals. In transmitting the signals hydraulically, complex flow phenomena are brought into play. The study of hydraulic logic has led to extensive theoretical investigations into turbulence, response time, inertia and cavitation in a moving fluid. Hydraulic "multivibrators" have been constructed in which one valve sets a second, and motion of the second resets the first. This creates an oscillator in which flow transients may be observed by stroboscopic means. Measurement of flow characteristics is yielding important data on the speed, logical flexibility and optimum size of possible hydraulic logic devices.

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Bennett, L., South Sudbury, Mass.
Bergner, V. D., Buffalo, N. Y.
Berkstresser, R. W., West Glenview, Ill.
Blackerby, C. H., Fairhope, Ala.
Blair, L. L., Los Angeles, Calif.
Boggie, R. A., Fort Huachuca, Ariz.
Boncer, J. J., Elmira, N. Y.
Bond, J. M., Ludington, Mich.
Boor, S. B., Baltimore, Md.
Bratge, J. R., Rome, N. Y.
Breggin, A., Littleton, Colo.
Brooks, J. E., Redwood City, Calif.
Brooks, L. E., Midwest City, Okla.
Brown, D. L. J., Montreal, P.Q., Canada
Brumley, G., Addis Ababa, Ethiopia
Burbridge, H. K., Hampton, Va.
Burgess, J. Q., Columbus, Ohio
Burke, F. P., Jr., Conoga Park, Calif.
Burns, F. P., Somerville, N. J.
Cambey, L. A., Kensington, N.S.W., Australia
Canchola, J. M., Pomona, Calif.
Carlson, W. K., Lexington, Mass.
Carter, S. A., Cincinnati, Ohio
Cheadle, H. R., Fairborn, Ohio
Clark, C. K., San Jose, Calif.
Clark, H. E., Rochester, N. Y.
Clements, D. A., Jr., DeWitt, N. Y.
Cogar, G. R., Philadelphia, Pa.
Conrad, D. A., Tucson, Ariz.
Davidson, J. B., Ft. Walton Beach, Fla.
DeCicco, J., Chicago, Ill.
Dominiak, K. E., Ann Arbor, Michigan
Elias, H. J., Syracuse, N. Y.
Emery, L. T., Fort Worth, Tex.
Engquist, S. T., Bedford, Mass.
Erlandsen, E. K., Auburn, Wash.
Ernstene, M. P., Pasadena, Calif.
Espersen, G. C., Arlington, Va.
Estes, J. R., Silver Spring, Md.
Ettenhofer, K. L., Hatboro, Pa.
Ewy, M. D., San Mateo, Calif.
Fainberg, J., Baltimore, Md.
Farmer, R. H., Redstone Arsenal, Ala.
Friedman, R. F., Melbourne, Fla.
Fulk, L. A., Candor, N. Y.

(*Continued on page 110A*)

Membership

(Continued from page 108A)

Gehring, D. E., Arcadia, Calif.
Glazer, I., Philadelphia, Pa.
Goudy, P. R., Milwaukee, Wis.
Grace, J. W., Northlake, Ill.
Gray, J. F., Minneapolis, Minn.
Greilich, A. L., Livermore, Calif.
Greystone, S. R., Seattle, Wash.
Griffee, L. V., Marion, Iowa
Gross, W. C., Endicott, N. Y.
Hammer, W. F., Dayton, Ohio
Henegar, H. B., Detroit, Mich.
Herget, C. J., Sherman Oaks, Calif.
Heston, J. L., Cedar Rapids, Iowa
Hicks, C. L., Liverpool, N. Y.
Hightower, S. G., Copiague, L. I., N. Y.
Hodges, R. R., Jr., Cedar Rapids, Iowa
Hoecker, N. L., San Pedro, Calif.
Horchos, L. A., Poughkeepsie, N. Y.
Hunt, J. H., San Fernando, Calif.
Huss, J. P., New York Mills, N. Y.
Ida, E. S., Milmont Park, Pa.
Jansen, J. F., Wakefield, Mass.
Jones, W. T., Jr., Waltham, Mass.
Karr, A. L., North Syracuse, N. Y.
Keenan, M. G., Redwood City, Calif.
Kotoucek, W. R., Detroit, Mich.
Kumagai, N., Berkeley, Calif.
Laios, S. C., Adelphi, Md.
Landgraf, R. C., Rochester, N. Y.
Lantto, E. S., Fairborn, Ohio
Laws, J. D., Baltimore, Md.
Leever, W. E., La Mirada, Calif.
Leland, H. R., Buffalo, N. Y.
LeMoine, W. R., Houston, Tex.
Levitt, L., Seattle, Wash.
Lovelace, R. E., Binghamton, N. Y.
MacKenzie, K. R., Burlington, Mass.
Mark, R. C., Syracuse, N. Y.
Marrott, E. V., Kingston, N. Y.
Mawdsley, D. M., Hamilton, Ont., Canada
Maxwell, J. A., Niles, Calif.
Mazzagatti, R. D., Beaumont, Tex.
McDonough, J. J., Hampton, Va.
Meredith, R. P., Orlando, Fla.
Michel, A., Brooklyn, N. Y.
Miller, B. P., Wauwatosa, Wis.
Miller, M., Chicago, Ill.
Morgulis, I. A., Toronto, Ont., Canada
Morris, C. R., Santa Monica, Calif.
Morton, C. T., Towson, Md.
Mueller, E. H., Bethpage, L. I., N. Y.
Naismith, E. G., Montreal, Que., Canada
Narayanan, M. A., New Delhi, India
Neilson, F. W., Albuquerque, N. Mex.
Nepveux, D. L., Ithaca, N. Y.
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Nilson, L. H., Red Bank, N. J.
Novak, A. J. W., Timonium, Md.
Nye, H. A., Jr., Arlington, Va.
Oliver, J. L., Beaumont, Tex.
Olson, F. W., Endicott, N. Y.
Olson, G. O., Denver, Colo.
O'Regan, M. E., Chicago, Ill.
Palumbo, C. J., Astoria, L. I., N. Y.
Parke, S. A., Northbrook, Ill.
Paris, D. A., Springfield, Mass.
Pavelka, C. F., Towson, Md.
Pinsley, R. S., Chicago, Ill.
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Ramachandran, C. V., Mysore State, South India
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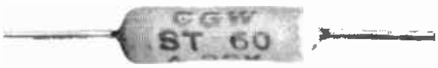
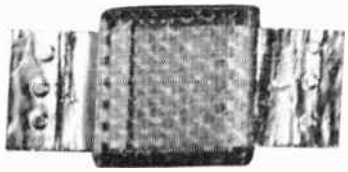
Rhodes, J. S., Boston, Mass.
Ricker, J. A., Washington, Pa.
Robinson, L. M., Long Beach, Calif.
Roesch, B. D., Orange, N. J.
Salkeld, E. M., Jr., San Diego, Calif.
Sanders, B. T., Jr., Santa Fe, N. Mex.
Sandler, G. H., Waltham, Mass.

(Continued on page 112A)





350°C. ST resistors Highest wattage to volume ratio in metallic oxide field. 2½, 5, and 10 W at 25°C., derating to 350°C. Achieves its specs through new resistance film and insulation coating developed at Corning. 2% and 5% tolerances.

High temperature capacitor New high temperature dielectric. Up to 10,000 uuf, DCWV of 300 V at 300°C. Q better than 500 at 300°C. Especially suitable for missiles and aircraft. Highly resistant to nuclear radiation.

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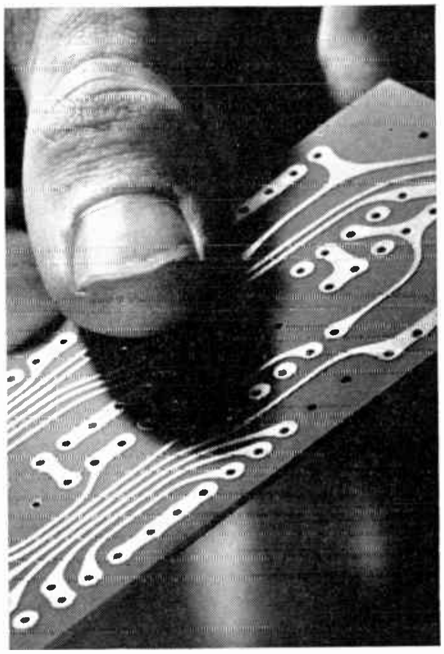

Epoxy coated resistors Exceptional moisture resistance. 1.5% max. resistance change after military moisture tests. Beats demands of MIL-R-10509C, Char. B. Tin oxide film fused to glass. ⅛, ¼, ½ W. 10 ohms to 1 megohm at 70°C., derating to 150°C.

FOTOCERAM,® an unusual new printed circuit board We've resoldered more than fifty times on this board without damage to circuit runs or through-plate holes. No adhesives needed to bond copper to board. Bond strength between Fotoceram and metal is 15 to 20 lbs., when 1" strip is pulled perpendicular to board. Takes over 60 *g* vibration shock. All electrical properties equally outstanding.

Fusion-sealed resistors For *ultra* specs. Glass-enclosed, tin oxide resistance element. Impervious to moisture because of fusion seal. 10 ohms to 360 K at 70°C., derating to 160°C. Well in excess of MIL-R-10509C, Char. B.

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Membership

(*Continued from page 110A*)

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Sickles, L., II, Philadelphia, Pa.
Smith, D. R., Utica, N. Y.
Smith, E. F., Jr., Orlando, Fla.
Spinks, J. M., Newton, Mass.
Stevens, E. E., Ottawa, Ont., Canada
Stewart, H. G., Fort Wayne, Ind.
Stulac, R. J., Steelton, Pa.
Tamir, U., Tel Aviv, Israel
Tamres, L., Mountain View, Calif.
Tanne, S., New York, N. Y.
Thayer, G. E., Santa Ana, Calif.
Thornton, W. G., Poughkeepsie, N. Y.
Tippe, S., Clifton, N. J.
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Veith, W., Littleton, Mass.
Virva, J. J., Chicago, Ill.
Voegtlen, H. D., Rome, N. Y.
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Warthen, C. M., Albuquerque, N. Mex.
Wilker, L. B., Cheyenne, Wyo.
Williams, D. R. W., Berkeley, Calif.
Williams, E. H., Sydney, N.S.W., Australia
Wilson, W. H., Fairfax, Va.
Wood, A. F., Reading, Mass.
Woodward, B. A., Melville, L. I., N. Y.
Wrzepski, J. E., Chicago, Ill.
Yonemitsu, M. K., San Diego, Calif
Yuba, Y., Osaka, Japan
Zanger, H. H., Brooklyn, N. Y.
Zawada, D. F., Detroit, Mich.
Zimmer, K. J., Paoli, Pa.

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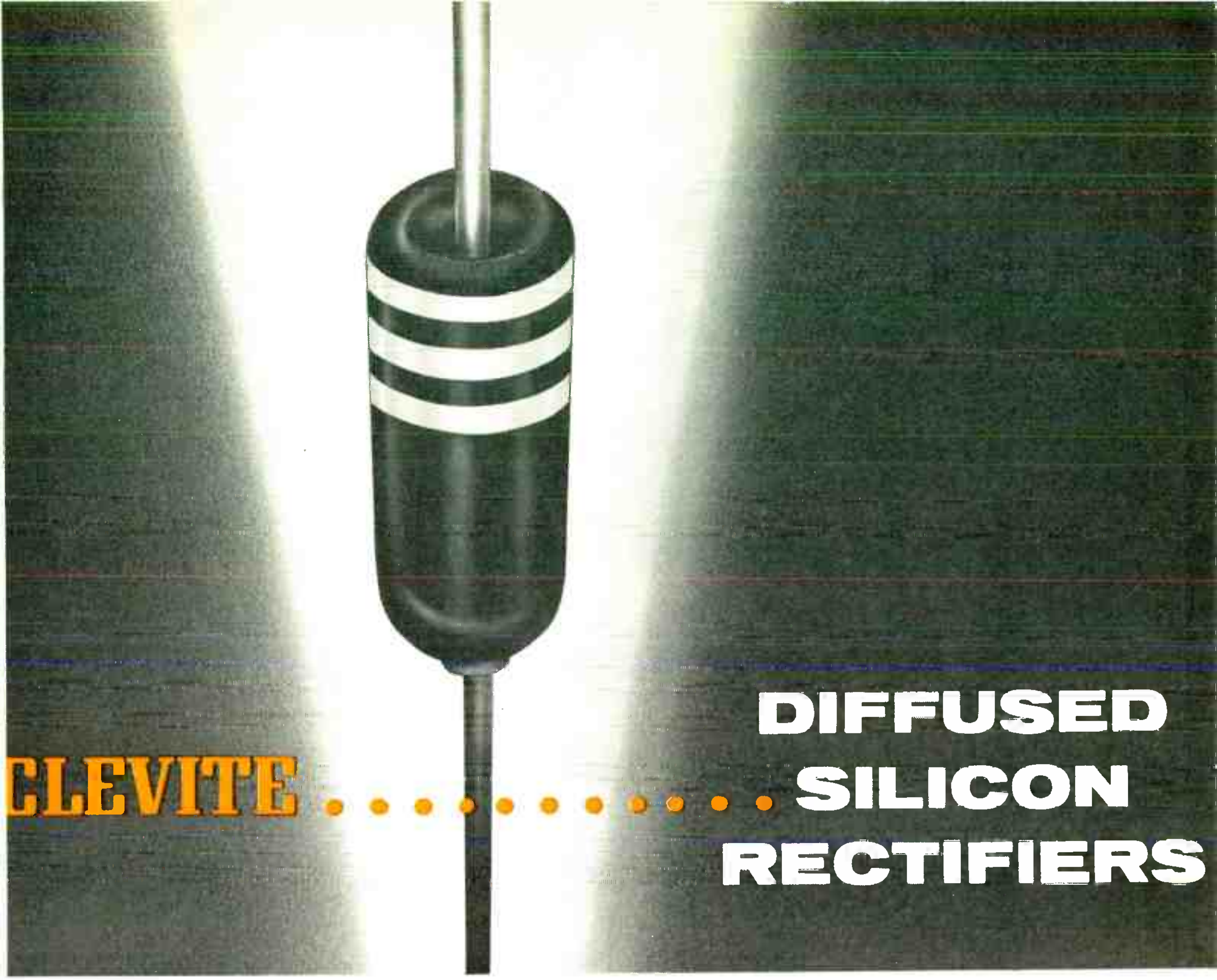

TECHNICAL DATA:			
Diode Type	Maximum DC Inverse Operating Voltage (volts)	Maximum Average Forward Current @ 25°C (ma)	Maximum Forward Voltage Drop @ 25°C (volts @ ma)
1N645	225	400	1.0 @ 400
1N647	400	400	1.0 @ 400
1N649	600	400	1.0 @ 400
1N677	100	400	1.0 @ 400
1N681	300	200	1.0 @ 200
1N683	400	200	1.0 @ 200
1N685	500	200	1.0 @ 200
1N687	600	200	1.0 @ 200

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(Continued from page 112A)

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Briscoe, O. G., Washington, D. C.
Broman, P. R., La Canada, Calif.
Bryan, A. R., Streator, Ill.
Buohl, E. A., Dobbs Ferry, N. Y.
Carl, R. E., Oaklyn, N. J.
Cohen, M., New York, N. Y.
Cote, P., Quebec, Que., Canada
Daniels, C. M., Dana, Ill.
Davidson, R. C., Rochester, N. Y.
De Martino, J. P., San Francisco, Calif.
Dewing, J. B., Needham, Mass.
Di Blasio, G., Rome, Italy
Duquette, D. T., San Gabriel, Calif.
Eichacker, P. G., Boston, Mass.
Enslow, R. M., Jr., New York, N. Y.
Esposito, V. R., New Haven, Conn.
Ferguson, C. A., Colorado Springs, Colo.
Fischer, D. A., Royal Oak, Mich.
Fisher, S. R., Lake Charles, La.
Folsom, J. A., Seattle, Wash.
Fox, G. F., Woodville, Mass.
Gallagher, R. B., Cedar Rapids, Iowa
Galway, P. T., East Syracuse, N. Y.
Golembiewski, A. J., Warren, Mich.
Giacomelli, A., Rome, Italy
Gold, S. D., New York, N. Y.
Guiorguiev, M., Riverside, R. I.
Harigae, S., Tokyo, Japan
Harris, H., Dolton, Ill.
Hatt, H. J., East Palo Alto, Calif.
Hiney, R. A., New York, N. Y.
Hurd, R. G., Haddonfield, N. J.
Jaeger, W. S., Dallas, Tex.
Judd, V. T., Old Bridge, N. J.
Kendall, R. W., Torrance, Calif.
Kougias, G. C., Williamsport, Pa.
Lannamann, R. J., Roslyn, Pa.
Lawler, R. A., Shalimar, Fla.
Letvenko, W., Richmond Hills, L. I., N. Y.
Lieske, R. W., Baltimore, Md.
Looney, V. C., Albuquerque, N. M.
Martinez, F. G., Havana, Cuba
McCloskey, A., Toronto, Ont., Canada
Miller, P. M., Beaumont, Tex.
Morgan, C. L., Cincinnati, Ohio
Morgan, M. J., Jr., Haddonfield, N. J.
Mundy, M. E., Fort Worth, Tex.
Murdock, A. E., New York, N. Y.
Navot, I., Brooklyn, N. Y.
Newland, B. F., Phoebus, Va.
Ohlendorf, W. T., Morton Grove, Ill.
Older, H., Arlington, Va.
Otradovec, J. E., Berkeley, Mo.
Otto, G., Beaumont, Tex.
Reggiani, M., Rome, Italy
Rempel, R. H., Swift Current, Sask., Canada
Roberts, B. J., Oklahoma City, Okla.
Rychtytzkyj, G. G., Angola, Ind.
Saitz, A., Milano, Italy
Sanchez-Finistauri, M., Caracas, Venezuela
Sasso, E. F., Calgary, Alta., Canada
Schiller, A. E., Bellevue, Wash.
Scotch, N., Waban, Mass.
Shepard, R. H., Baltimore, Md.
Stevens, D. F., Pasadena, Calif.
Stoehr, F., Bancroft, Ont., Canada
Stuart-Donathan, W. E., Washington, D. C.
Sullivan, J. L., Burlington, Mass.
Takach, R. V., Huntington, L. I., N. Y.
Teofilato, A. V., Rome, Italy
Thornton, M. Z., State College, Pa.
Vadala, C. J., Jamaica Plain, Mass.
Van Der Oord, S. M., Beirut, Lebanon
White, R. L., Los Alamitos, Calif.
White, W. O., Los Angeles, Calif.
Wilkinson, C. G., Toronto, Ont., Canada
Womelsduff, R. E., Albuquerque, N. M.
Wren, B. W., Fort Worth, Tex.
Yang, T. N. H., Wahiawa, Oahu, Hawaii

Section Meetings

AKRON

"Computers in Decision Making," K. F. Powell, IBM, 5/19/59.

ALBUQUERQUE-LOS ALAMOS

"Nuclear Magnetic Resonance Apparatus & Applications," Drs. Rogers & Schoolery, Varian Associates; 3/9/59.

"Scintillation Detectors," Mr. Van Dilla, Los Alamos Scientific Lab.; 4/10/59.

ATLANTA

"Predictor Control for a Positioning Servomechanism," R. C. Carden, III, Ga. Inst. of Tech.; 5/29/59.

BAY OF QUINTE

"Parametric Amplifiers," E. D. Read, Bell Tel. Labs.; Nominations for '59-60; 5/25/59.

BEAUMONT-PORT ARTHUR

Annual Meeting and Election of Officers; 5/25/59.

CEDAR RAPIDS

"Design and Performance of Deep Space Tracking and Telemetering Systems," R. Stevens, Calif. Inst. of Tech.; "Osprey II" Electronic Installation, a description, P. McKinley; 4/22/59.

CINCINNATI

Spring Technical Conference; 4/21/59 & 4/22/59.

U.C. Student Papers: "Missile Trajectory Determination Using IBM 650," C. H. Witsken; "Semi-Conductor Static Switching Control," R. A. Colclaser; "A DC Transistor Amplifier," R. G. Rikeard; "A Three Megacycle Square Wave Generator," J. A. Walter; 5/19/59.

CLEVELAND

"The Beginning of Radio Broadcasting," C. M. Jansky, Jr., Jansky & Bailey, Inc.; Election of Officers for '59-60; 5/21/59.

DALLAS

"Reliability Programming in the Army Ordnance Missile Command," G. A. Henderson, AOMC; 6/2/59.

"Bell Helicopter Simulator," H. W. Upton, Bell Helicopter Corp.; Jt. with PGEC & PGAC local chapters; 5/5/59.

DAYTON

"Let's Discover the Real Problem," J. R. Shirley, Booz Allen Applied. Res. Inc.; 1/8/59.

"The Four-Layer Transistorized Diode," W. B. Shockley, Shockley Transistor Corp.; 3/5/59.

"Utilization of Scientists and Engineers," R. P. Crago, IBM; 4/2/59.

DENVER

"Plasmas and Semiconductor Diodes in Parametric Amplification," G. Wade, Stanford Univ.; 5/15/59.

Presentation of Student Papers and Prize Awards: "Photo Electric Cells," 1st Prize, R. Waln & R. Stephen, Jt. paper; "NIMAC Computer," 2nd Prize, R. Richmond; "Magnetostrictive Delay Lines," 3rd Prize, J. Davis; "Wanderings of a Radio Engineer," R. S. Kirby, Natl. Bur. of Standards; 5/22/59.

EGYPT

"Time and Frequency Standards," E. M. El Kharadly, Prof. Faculty of Engineers; 4/22/59.

ELMIRA-CORNING

"Educational Television," H. las Jackim, Corning City Sch. District; 6/3/59.

Election of Officers, '59-60; 6/3/59.

(Continued on page 116A)

Section Meetings

(Continued from page 115A)

Emporium

"Crystals—An Introduction," film, Bell Labs.; "Brattain Lecture on Semiconductor Physics," film, Bell Tel. Labs.; 5/19/59.

Evansville-Owensboro

Annual Picnic Meeting; 6/7/59.

Florida West Coast

"Solid State Amplifiers and Detectors," G. P. Rodrigue, Jr., Sperry Microwave; 5/20/59.

Fort Huachuca

"Range Instrumentation," G. Meredith, White Sands Missile Range; 4/27/59.

"Role of IRE, Past, Present, and Future," Dr. Ernst Weber, IRE President; 5/9/59.

Fort Wayne

"Applications of 'Hall Effect' in Semiconductors," A. P. Jerencsik, Ohio Semiconductor; 6/4/59.

Houston

"Stereo Speaker Systems," W. C. Wrye, Jr., Wrye Co., Ltd.; Report and Greetings from REGION VI Director: C. E. Harp, Univ. of Okla.; Election of Officers '59-60; 5/22/59.

Huntsville

"Scientific Engineering & The IRE," Dr. Ernst Weber, IRE President; 1/22/59.

"The Influence of the Ionosphere on Radio Signals," G. Swenson, Jr., Univ. of Illinois; 3/19/59.

"Frontiers of Space Research," R. M. Page, Naval Res. Lab.; 4/17/59.

"Where is The Limit?," Dr. Ernst Stuhlinger, ABMA; 4/30/59.

"Development of Printed Cables," W. Angele, ABMA; 5/26/59.

Ithaca

"Circular Waveguide for Long Distance Communication," H. E. Rowe, Bell Tel. Labs.; Election of Officers '59-60; 5/14/59.

Little Rock

"Communication System, Arkansas Game and Fish Commission," J. P. McRae, Ark. Game & Fish Commission; Election of Officers '59–60; 5/19/59.

Long Island

Annual Fellow Awards: W. A. Higinbotham, J. W. Griemsmann, H. Horn, and M. V. Kiebert, H. Rothe, Y. Watanabe, A. H. Beck; Speaker: Dr. Ernst Weber, IRE President; 3/22/59.

"Environmental Problems in Future Electronic Design," R. A. DiTaranto and J. J. Lamb, Defense Products Div., RCA; 4/9/59.

"Electroluminescence," W. H. Garrett, Jr.; Awards Presentation: R. P. Burr and C. Dean by PGBTR; Election of '59-60 Officers; 4/14/59.

"Electromagnetic Sensors in Future Electronic Systems," D. Peck, Sprague Electric Co.; 4/16/59.

"Display Methods for Future Equipment Designs," W. L. Gardner, MIT Lincoln Labs.; 4/23/59.

"Packaging Techniques for Future Electronic Hardware," J. Staller, ARMA; 4/30/59.

"Electronic Components of the Future," H. R. Lewis, RCA; 5/7/59.

Farmingdale Field Trip, Republic Aviation Company Plant; 5/16/59.

"Recent Developments in Flight Safety," J. C. Bailey, Norton Air Force Base; Gavel Awards Presentation: Subsection Chairman (past); 5/28/59.

"WEMA (Western Electronic Manufacturers Association) IRE Relations," E. H. Lockhart, Radiatronics; Installation of New Officers; Section Award Presentations; 6/13/59.

(Continued on page 118A)

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Section Meetings

(Continued from page 116A)

LUBBOCK

"Communications Problems in Space Travel," J. R. Bradford, Texas Technological College; 3/3/59.

"An Amateur Radioteletype System." Winning Paper. Award: L. Smith; "Some Properties of Superconductors," P. Griffith, both, Texas Technological College; 4/7/59.

"Masers and Parametric Amplifiers," C. F. Davis, Texas Instruments Inc.; Election of '59–60 Officers; 5/5/59.

MIAMI

Tour and Lecture, Milgo Manufacturing Co., L. L. Gordon. Milgo; 3/18/59.

"Art Lynch Road Show," J. Dashiel and others, Lynch Enterprises; 6/4/59.

NEW ORLEANS

"M-33 Fire Control Radar System," a Demonstration Lecture, Capt. Vangilder, La. Natl. Guard; 5/23/59.

NORTH CAROLINA

"High Reliability Transistor Amplifier Design," W. Greatbatch, Tabor Instrument Corp.; Jt. with Eastern N. C. Subsection; 5/15/59.

NORTHERN NEW JERSEY

"Sonar Instrumentation," R. Lafferty, J. Schroeder, Daven Co.; "Nuclear Instrumentation," R. Brown, A. B. DuMont Labs.; 4/8/59.

"Project Matterhorn," G. Warfield, Princeton Univ.; 5/13/59.

OKLAHOMA CITY

Annual Banquet Meeting, Jt. with AIEE and Jt. Student Branches; Student Prize Awards; 5/15/59.

"Engineering Education in Russia," E. Keonjian, American Bosch Arma Corp.; Election of '59–60 Officers; 5/20/59.

"Around the World with Radio Astronomy," P. M. Millman, National Research Council of Ottawa; Ladies Night; 4/9/59.

"Recent Developments of the Thermo Electron Engine," G. N. Hatsopoulis, MIT; Annual Meeting, National Research Council; 5/21/59.

PHOENIX

"The Healing Art and The Changing Times," P. B. Jarrett; Election of Officers '59–60; 6/5/59.

PORTLAND

"First Quick Frozen Foods—Now Quick Frozen Transients," L. Bride, W. Schmitt, Tektronix, Inc.; 4/16 59.

"Can Individual Molecules be Seen in the Field Emission Microscope?" J. A. Becker, Bell Tel. Labs; 5/4/59.

"Transistor Curve Tracer," D. Leuphold, Oregon State College; "Proof of the Niquest Criterion," D. Bem, Reed College; 5/14/59.

"Party Lines to Space Vehicles," L. Hedrick, Tektronix, Inc.; 5/21/59.

PRINCETON

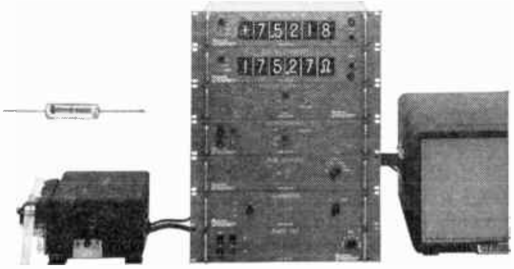
"Parametric Amplifiers; Historical Background and Recent Results with U.H.F. Traveling Wave Diodes," R. S. Englebrecht and W. W. Mumford, Bell Tel. Labs.; 5/14/59.

Annual Banquet; 5/15/59.

(Continued on page 138A)

Low cost, versatile DIGITAL SYSTEMS

for automatic testing of transistors  resistors  diodes and capacitors 



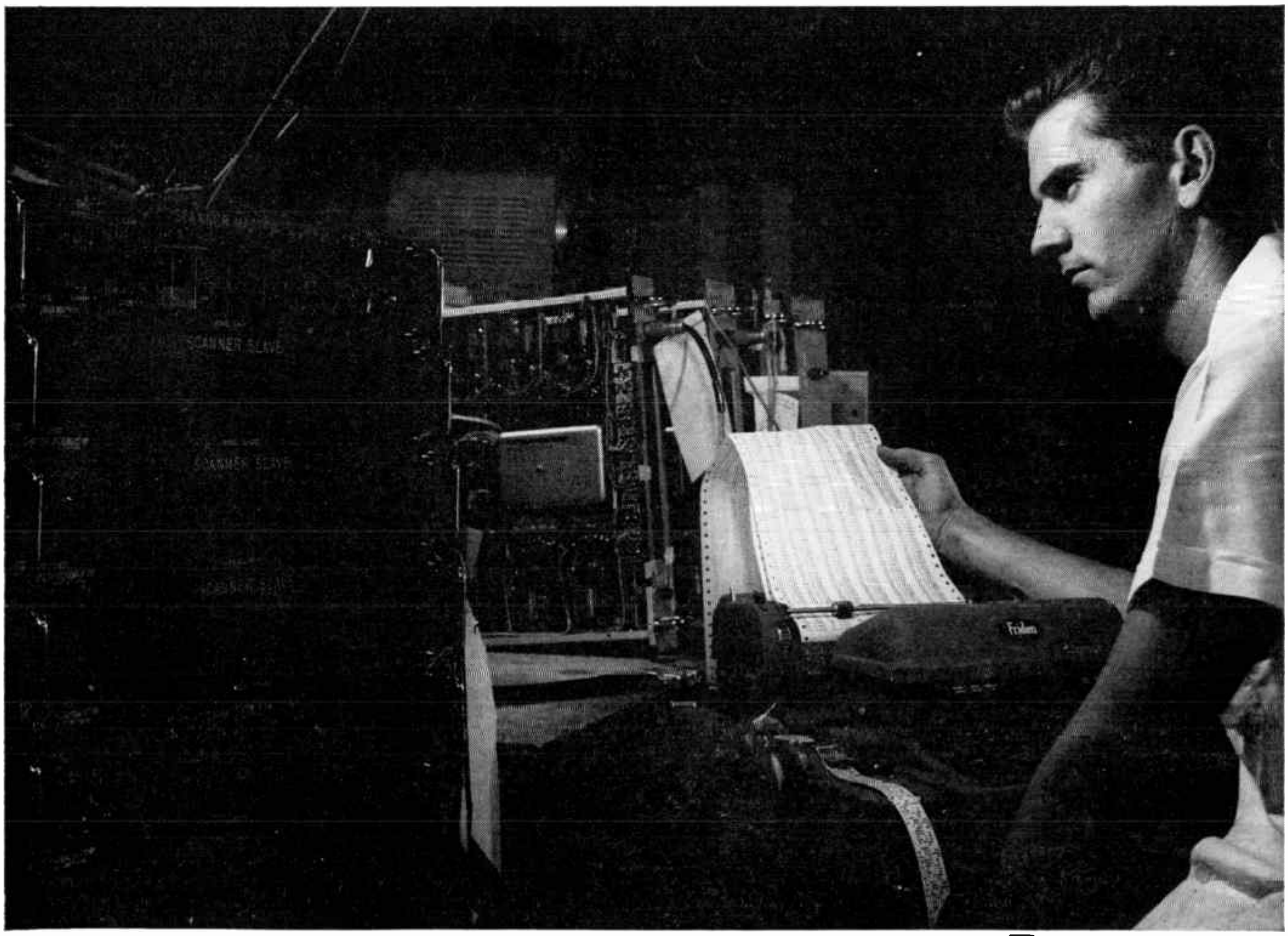
Small E-I automatic digital systems provide many advantages. First, they cost less. This is primarily the result of large-quantity manufacture of modules which make up the E-I system. Cost is almost a linear function of performance capabilities desired in the system.

Second, they are exceptionally versatile. The E-I system can be expanded simply by adding appropriate modules. Typical systems presently in use measure resistance, capacitance, DC and AC voltages, DC/DC ratios, AC/DC ratios, AC/AC ratios and combinations of these. Measurements to four or five digits can be visually displayed and printed out at rates up to five readings per second. Operation can be semi- or totally automatic with go/no go comparison of values and programmed readout at periodic intervals. Scanners can be provided for scanning thousands of single and multi-wire input channels. In brief, the E-I system has an extensive scope of operating capability.

Third, E-I systems provide unmatched reliability. Where practicable, circuits are totally transistorized. The use of etched, plug-in circuit boards, and modular internal construction make maintenance checks and in-plant repairs easy.

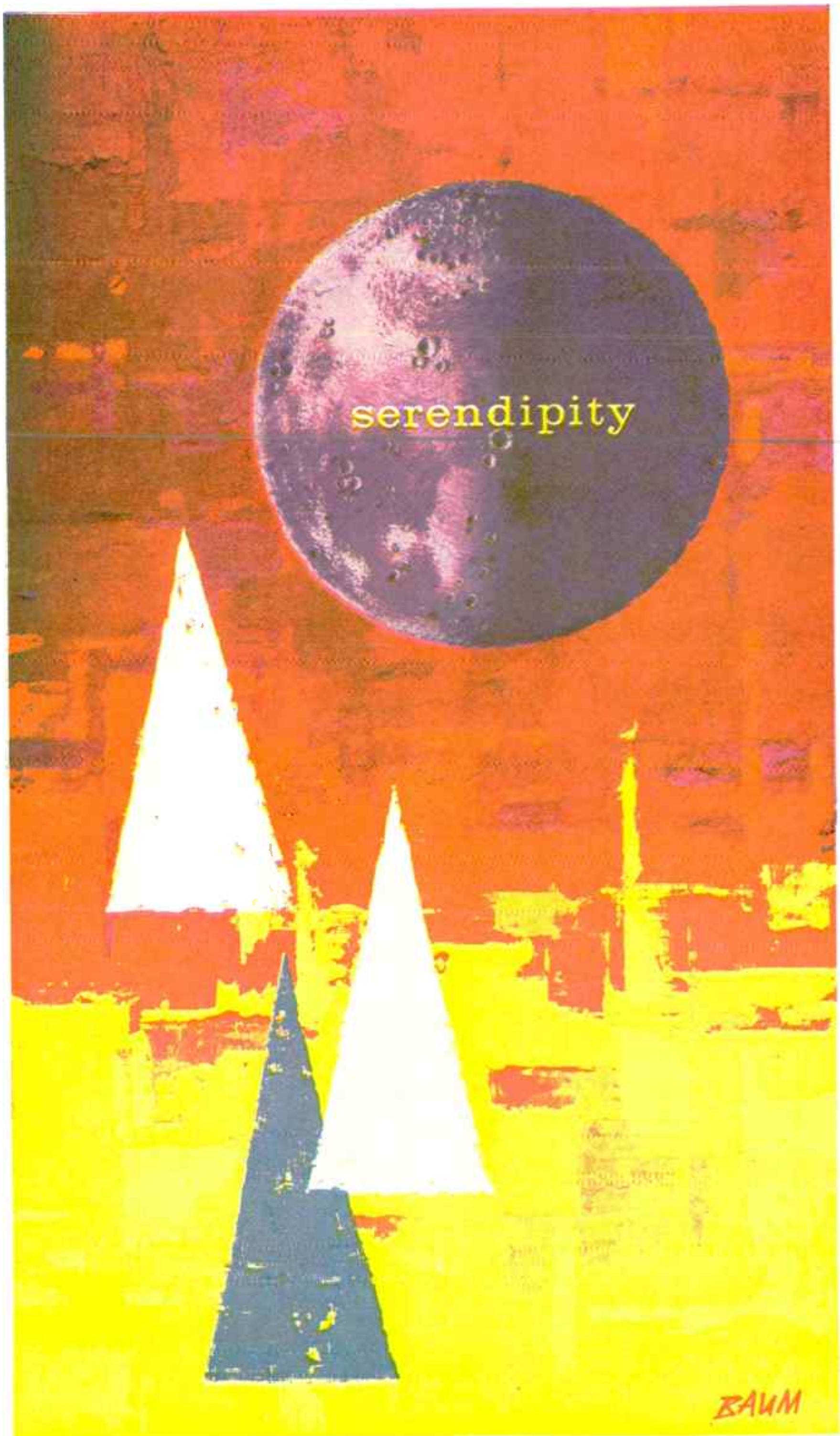
Typical E-I system for evaluating components—includes 100 channel input signal scanner. Can digitize DC voltage, resistance, AC voltage and DC/DC voltage ratio analogs. Digital equivalents are recorded on strip printer for "quick look" data and on punch paper tape for additional data reduction by digital computer.

Lower cost, maximum versatility and greater reliability—if you want these advantages in your component test system, contact your nearest E-I representative. He can give you complete information or answer any specific questions you may have.



Electro Instruments, Inc.

3540 AERO COURT
SAN DIEGO 11, CALIF.



Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

ELECTRONIC INSTRUMENTS SALES ENGINEER

Graduate E.E. with 2-5 years engineering experience and desire for technical sales, or graduate E.E. currently active in engineering sales. For field engineering position in metropolitan New York area. Compensation guaranteed base salary plus bonus. Interesting opportunity. Apply by letter only. Include resume. RMC Associates, 236 East 75 St., New York, N.Y.

ENGINEER

Teaching faculty is needed by Electrical Dept. of one of New York state's expanding community colleges. Salary range $5450.00 and up for B.S., $7190.00 and up for M.S. Completely new campus is under construction and will be completed in 1960. Apply to W. R. Pulhamus, Head, Electrical Dept., Mohawk Valley Technical Institute, Utica, N.Y.

PROJECT ENGINEER

Project Engineer to supervise complete projects in design and development of automatically sequencing, self checking test equipment used to evaluate complex airborne guidance systems and components. E.E. plus 5-7 years experience. Apply Kearfott Co., Inc., 1500 Main Ave., Clifton, New Jersey, Att: C. J. Weinpel.

ASSISTANT OR ASSOCIATE PROFESSOR

Evansville College has an opening beginning Sept. 1959 for an Assistant or Associate Professor of Electrical Engineering. It is considering a salary range of $5000 to $5900. It is located in an industrial city of approximately 150,000. Its student body of 2800 contains a large number of engineering students both on the regular program and on the co-op program. Anyone interested, please address Dean E. M. McKown, Evansville College, Evansville 4, Ind.

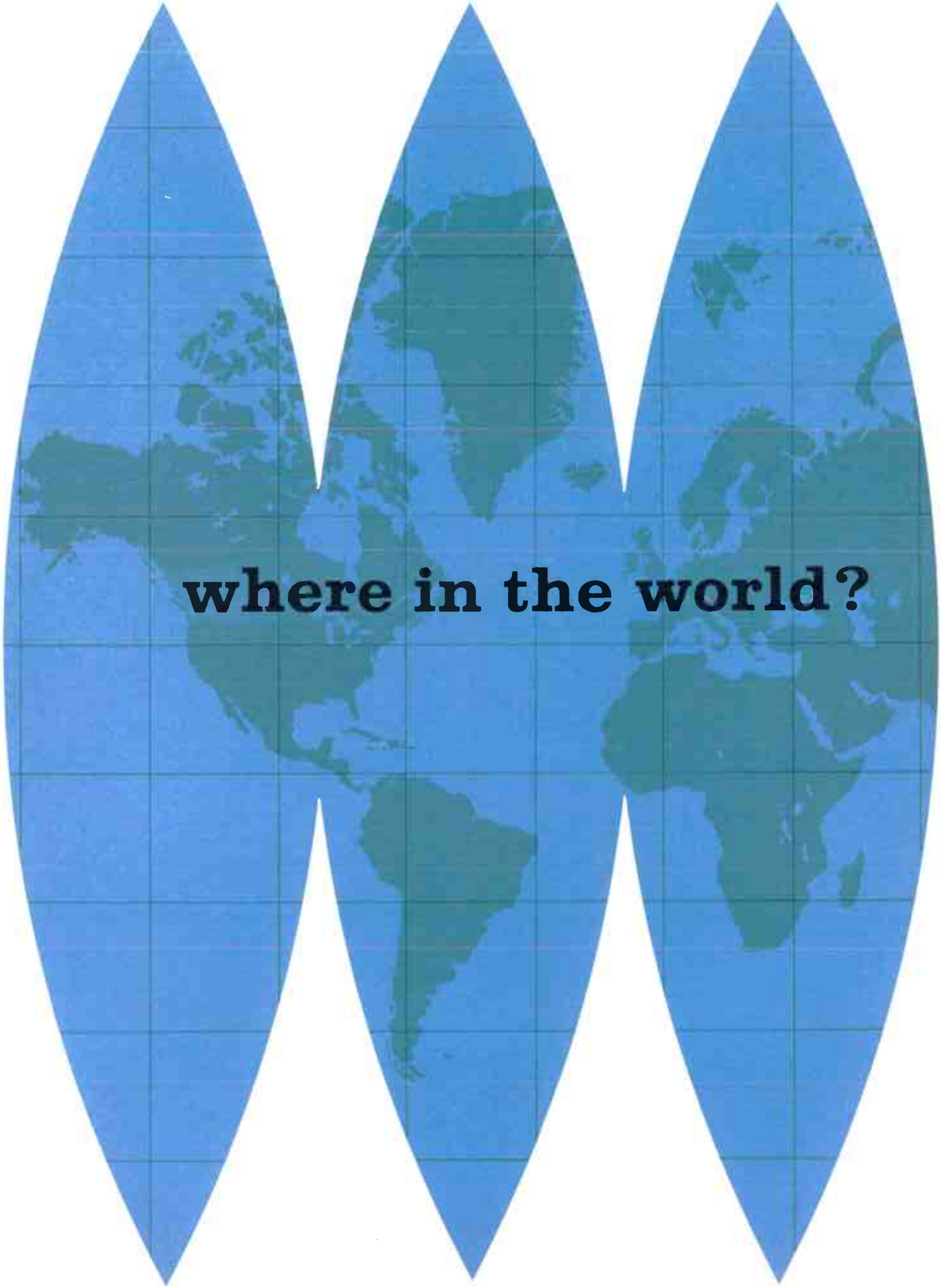
TECHNICAL DIRECTOR

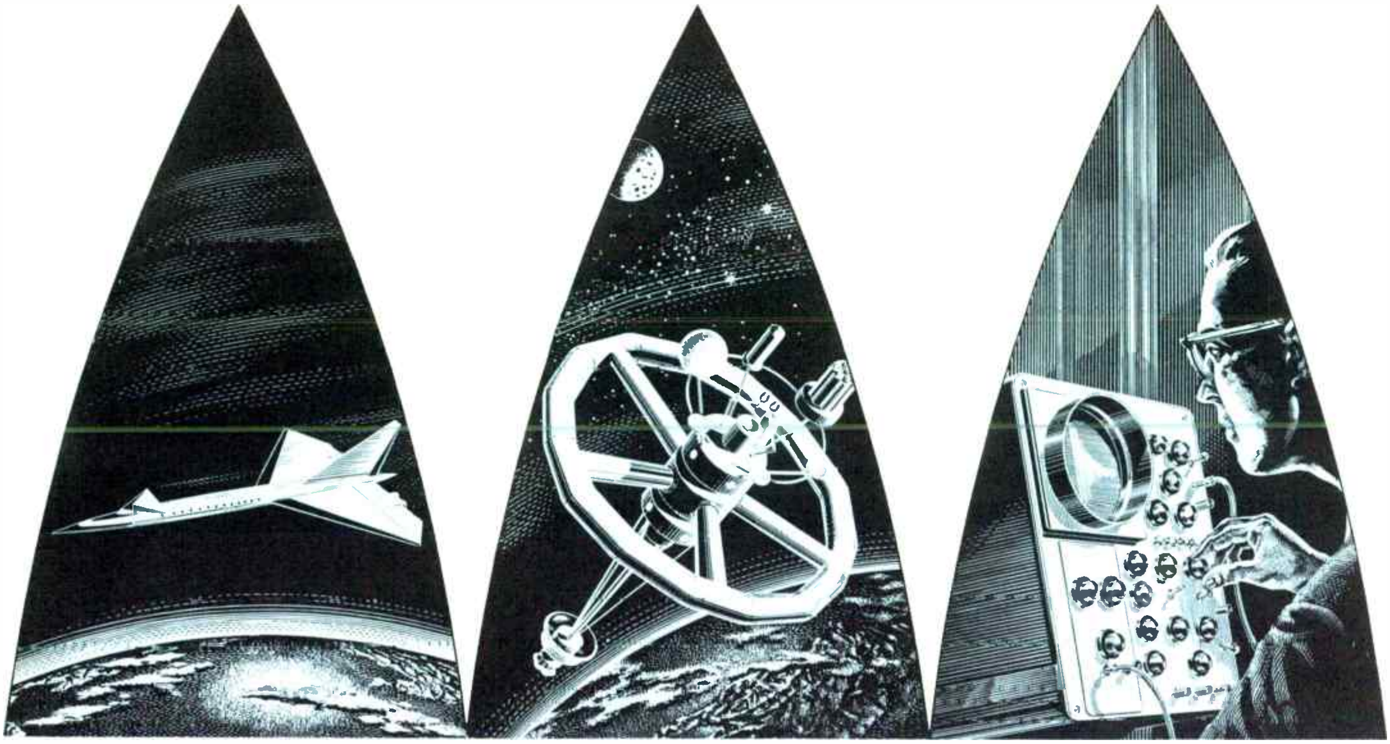
Experienced science-administrator (Ph.D) to direct and stimulate research program of small midwestern contract research laboratory. Research fields are electronics, ceramics, metallurgy, and chemistry, with emphasis on new electronic materials and techniques. Ability to lead and encourage personnel of various scientific disciplines important. Please send resume to Box 1096.

ELECTRONICS ENGINEER

Opening for young (25-30) electrical engineer with advanced degree or equivalent experience in computers and automatic control or semiconductor circuits. As project leader on staff of small midwestern contract research laboratory, will have responsibility for proposal preparation and planning and direction of research projects in his subject area. Please send resume to Box 1097.

(Continued on page 127A)


where in the world?



where in the world...

California Division

Forty-passenger, vertical-rising "commuter" planes, 2000-mph supersonic transports, "Limocopter" 12-passenger helicopters, monorail transportation systems, space ferries to transport men and materials to space stations, anti-submarine warfare research, telescopic cameras for photographing sun spots ...these are just some of the exciting projects now underway. Developments in the future include a five-million-dollar research center in Saugus, California.

Missiles and Space Division

Among this division's projects now gaining world-wide attention are the Polaris Fleet Ballistic Missile, launched from submerged submarines; Project Midas, an early warning system against ballistic missile attack; Project Sentry, development of an advanced satellite reconnaissance system; Project Discoverer, an "open-end" research program for the development of advanced space vehicles and systems; and the Kingfisher ramjet target missile. Studies now in development include a 10-man laboratory satellite for outer space.

Electronics and Avionics Division

Formed just a few months ago, this new division is now staffing in all areas. The division has been established to conduct research, engineering and manufacture of electronic components, equipment and systems. New as this division is, production has already started on such products as FM/FM telemetry, magnetic recorders, command destruct systems, miniaturized television and navigation equipment.

Who in the world is working in so many different areas? Lockheed last year spent nearly 350 million dollars on research and development... in all fields of electronics, supersonic aircraft, nucleonics, vertical take-off airliners, manned space stations, data processing, ionic propulsion, avionics, sun-powered space ships, space communications, computer development.

Where in the world, except at Lockheed, do you find such scope of work at so many different places? San Francisco Peninsula, Vandenberg AFB, Saugus, San Fernando Valley, Los Angeles, Newport Beach, Alamogordo, Cape Canaveral, and many others.

What in the world is your field of interest? Lockheed has requirements in all fields of engineering and science... in fundamental and applied research, electronic systems, advanced development, design, manufacturing, quality assurance, test and service—the entire gamut of your profession!

except at Lockheed

do you find such scope of work at so many different places!

AT WESCON...

members of the technical staffs will be available for interview: Telephone: EXbrook 7-5171.

Positions Open

(Continued from page 122A)

RADIO OR ELECTRONICS ENGINEER

Graduate 23-35. Experience in planning and design of VHF radio systems and controls. Will be responsible for design, specification of system wide VHF radio facilities on trains and wayside stations, including centralized control systems. Supervise technicians in construction and field maintenance including operation system radio repair shops. Headquarters Chicago. Salary commensurate with experience. Send resume including recent picture and salary requirements to Assistant Chief Engineer, Signals & Communications. The Milwaukee Road, Room 836, Union Station, Chicago 6, Ill.

ELECTRONIC ENGINEER

Electronic Engineer to teach lecture and laboratory courses. Up-to-date knowledge of the field required. Working and living conditions excellent; salary and opportunity very attractive. Write to Dean of Engineering, California State Polytechnic College, San Luis Obispo, Calif.

SALES MANAGER

Sales Manager to direct all marketing activities of small manufacturer of VHF television distribution equipment, low noise and specialized amplifiers. Must have engineering education and substantial successful sales management experience. Considerable travel. Located in small academic community in mountains of central Pennsylvania for delightful living and family raising. Growth opportunity. Salary and stock option. Apply to Community Engineering Corp., Box 824, State College, Pa.

GEOPHYSICAL INSTRUMENT MAN

Position available for high-level electronic technician or BS.E.E. to work on instrumentation for mining geophysical prospecting and to develop research apparatus pertaining to same. Must have at least 5 years experience, preferably in audio and sub audio frequencies. Must be capable of independent work. Laboratory located in country near Danbury, Conn. Salary commensurate with ability. Write: Newmont Exploration Ltd., RFD 1, Danbury, Conn., Att: W. M. Dolan.

ELECTRONIC ENGINEERS

Career electronic positions for graduate engineers open with Federal Aviation Agency in Alaska. Employee, dependents, household goods moved at Government expense. Paid vacation travel each 2 years. Requires minimum 2 years technical electronic engineering experience. Salary $6285 and up plus 25% living allowances. Travel per diem $13 to $21. Airmail Federal application or qualifications resume to Box 440, Anchorage, Alaska.

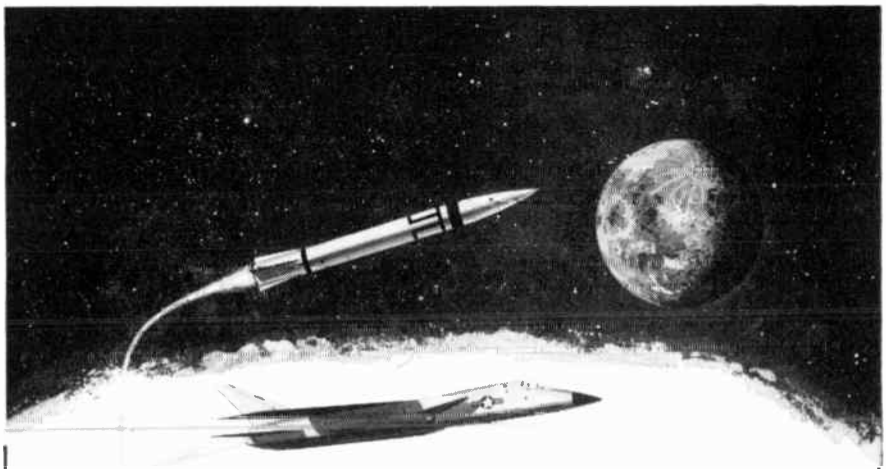
DIRECTOR OF ELECTRONICS

Director of electronics R and D with aeronautical applications. Suburban location near New York City. Salary $30,000. plus. Doctor's degree desirable. Box 1098.

TEACHING—RESEARCH

America's first engineering school now expanding its Electrical Engineering staff. Electrical Engineers experienced in teaching or research (preferably both) are urged to investigate opportunities at Rensselaer Polytechnic Institute. Faculty positions, including full professorships, are open to qualified individuals. Experts in the

(Continued on page 128A)



Electronic Systems Engineers

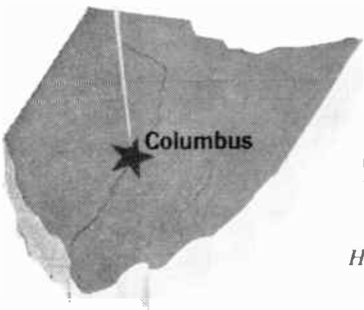
If you are an engineer with a yen to move up from component development to systems management, consider the current openings in the Electronics Section at NAA-Columbus.

We have immediate openings for men qualified to work in the areas of:

Data Processing and Computing
Pictorial and Textural Data Handling
Advanced Radar Antenna Systems
Systems Synthesis and Integration
Physics of Electromagnetic Scattering
High Resolution Radar Applications

These represent but a few of the many fields of electronics being investigated and developed in Columbus for aircraft and missiles of the future.

There is no longer any reason to work 50 hours for a 40 hour salary. The extra 10 hours of commuting can be eliminated living in pleasant Columbus suburbs. And nearby Ohio State University provides you with an opportunity to complete that M.S. or PhD. (on the NAA tuition refund plan) you may have been considering. Write Engineering Personnel, Box PI-130. North American Aviation, Inc., Columbus, Ohio.



THE COLUMBUS DIVISION OF NORTH AMERICAN AVIATION, INC.

Home of the T2J Buckeye and the A3J Vigilante

Positions Open

(Continued from page 127A)

areas of control, computers, and physical electronics will find particularly challenging opportunities. Write, including resume to W. R. Beam, Head, Dept. of E.E., Rensselaer Polytechnic Institute, Troy, N.Y.

ELECTRONIC ENGINEER

Electronic Engineer, experienced in circuit design to do medical instrumentation. Will carry projects from design to finished products. Non military, diverse work. Company in Philadelphia area. Opportunity to rise with small, growing company. Box 1099.

ELECTRICAL ENGINEERS

Electrical Engineers desired for solution of challenging, broad instrumentation design problems. Nuclear instrumentation design involves digital techniques in data processing; wide band linear amplifier design; analog computer techniques; servomechanisms applications and systems design, and many physical measurement techniques. Full responsibility and credit given with considerable technical freedom for competent design engineers. Write Phillips Petroleum Co., Atomic Energy Div., P.O. Box 2067-EM, Idaho Falls, Idaho.

SALES ENGINEERS

For Control Systems Sales to the Petroleum and Gas Industry. Applicants must have an E.E. degree or equivalent and at least 2 years experience in the instrumentation and control field. Salary commensurate with experience. You will be working for a well established organization, recognized world-wide as a leader in its field with headquarters in the Renaissance City of Pittsburgh. If interested contact Mr. Harold Myers at WESCON Booth #2613-15 or send resume to Mr. Geo. Frye, Union Switch & Signal, Div. of Westinghouse Air Brake Co., Pittsburgh 18, Pa.

SYSTEMS DESIGN ENGINEERS

Challenging opportunities for ambitious electrical engineers to work with a leading company in a new branch of systems engineering. You will be trained to design systems for industrial and pipeline transportation control and data-handling equipment to meet customer requirements. Relay or solid-state circuity knowledge helpful but not necessary. Junior positions also are available for training program. If interested contact Mr. Harold Myers at WESCON Booth #2613-15 or send resume to Mr. Geo. Frye, Union Switch & Signal, Div. of Westinghouse Air Brake Co., Pittsburgh 18, Pa.

Positions Wanted

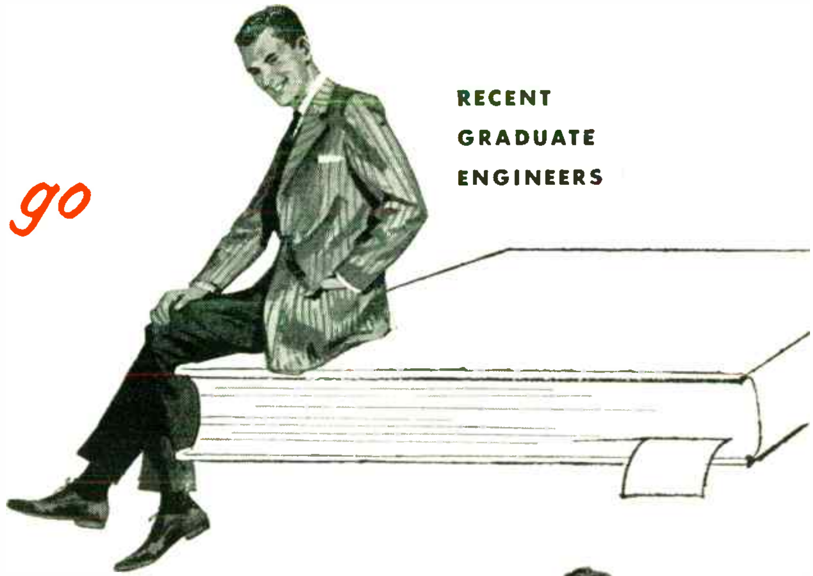
By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have

(Continued on page 132A)

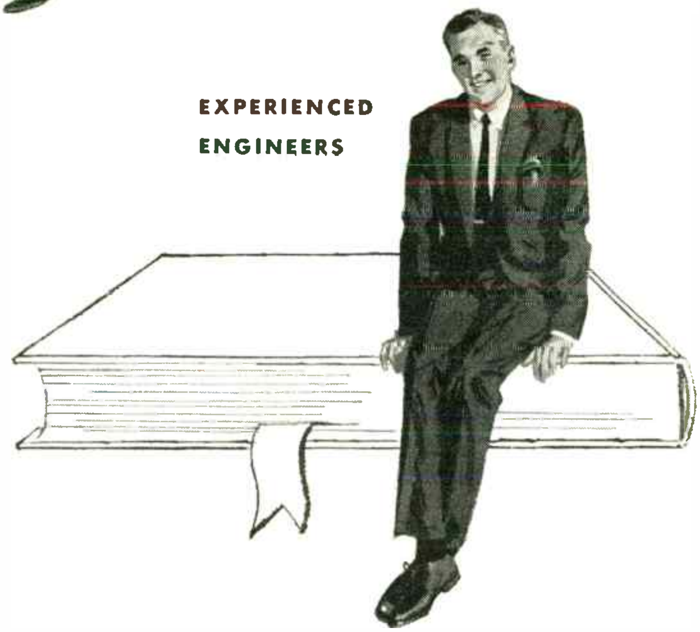
How far can an engineer go at AC?



Free education for the space age

Three levels of special advanced training that can help you prepare for promotion and enhance your professional status. That's what you'll find when you go to work in AC's instrumentation business.

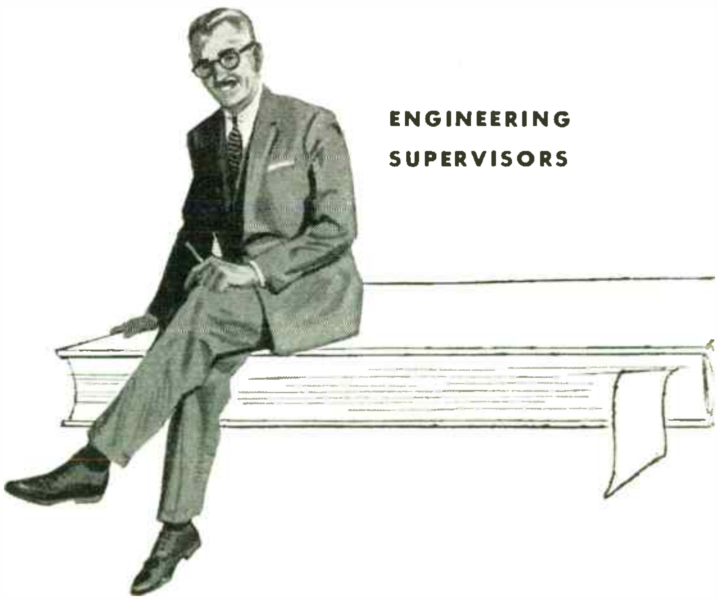
Program A—for recent graduate engineers—gives you a solid foundation in the theory and application of inertial guidance systems and servomechanisms.



Program B—for experienced engineers—consists of upgrading studies in inertial guidance, servomechanisms, environmental problems, engineering math and physics, plus advanced state-of-the-art courses.

Program C—for all engineering supervisors—involves management training developed by a team of AC executives and University of Chicago industrial relations experts.

Comparison will prove these are the finest "in house" programs available anywhere. And they are educational "extras," for AC offers them in addition to their educational assistance programs for men who wish to study for advanced degrees in nearby universities.



You may be eligible for training . . .

if you are a graduate engineer in the electronics, electrical or mechanical fields, or if you have an advanced degree in mathematics or physics. You'll study while you work on the renowned AChiever inertial guidance system or a wide variety of other electromechanical, optical and infra-red devices.

For more information, write the Director of Scientific and Professional Employment: Mr. Robert Allen, Oak Creek Plant, Dept. E, Box 746, South Milwaukee, Wisconsin.

AC SPARK PLUG ⚛ THE ELECTRONICS DIVISION OF GENERAL MOTORS

INERTIAL GUIDANCE SYSTEMS • AFTERBURNER FUEL CONTROLS • BOMBING NAVIGATIONAL COMPUTERS • GUN-BOMB-ROCKET SIGHTS • GYRO-ACCELEROMETERS • GYROSCOPES SPEED SENSITIVE SWITCHES • SPEED SENSORS • TORQUEMETERS • VIBACALL • SKYPHONE

Checking Einstein with

Purity Plus—*Hughes Products Division engineer checks semiconductor materials to insure purity.*

Exit cones *capable of withstanding temperatures of 6000° F. represent one example of advanced engineering being performed by the Hughes Plastics Laboratory.*

an atomic clock in orbit

To test Einstein's general theory of relativity, scientists at the Hughes research laboratories are developing a thirty pound atomic maser clock *(see photo at left)* under contract to the National Aeronautics and Space Administration. Orbiting in a satellite, a maser clock would be compared with another on the ground to check Einstein's proposition that time flows faster as gravitational pull decreases.

Working from the new research center in Malibu, California, Hughes engineers will develop a MASER (Microwave Amplification through Stimulated Emission of Radiation) clock so accurate that it will neither gain nor lose a single second in 1000 years. This clock, one of three types contracted for by NASA, will measure time directly from the vibrations of the atoms in ammonia molecules.

Before launching, an atomic clock will be synchronized with another on the ground. Each clock would generate a highly stable current with a frequency of billions of cycles per second. Electronic circuitry would reduce the rapid oscillations to a slower rate in order to make precise laboratory measurements. The time "ticks" from the orbiting clock would then be transmitted by radio to compare with the time of the clock on earth. By measuring the difference, scientists will be able to check Einstein's theories.

In other engineering activities at Hughes, research and development work is being performed on such projects as advanced airborne systems, advanced data handling and display systems, global and spatial communications systems, nuclear electronics, advanced radar systems, infrared devices, ballistic missile systems...just to name a few.

The variety and advanced nature of the projects at Hughes provides an ideal environment for the engineer or scientist who wishes to increase his professional stature.

Newly instituted programs at Hughes have created immediate openings for engineers experienced in the following areas:

Communications	Environmental Engineering
Thin Films	Logical Design
Electron Tubes	Radar Circuit Design
Field Engineering	Material & Component Eng.
Semiconductors	Systems Analysis
Test Equipment Eng.	Nuclear Electronics

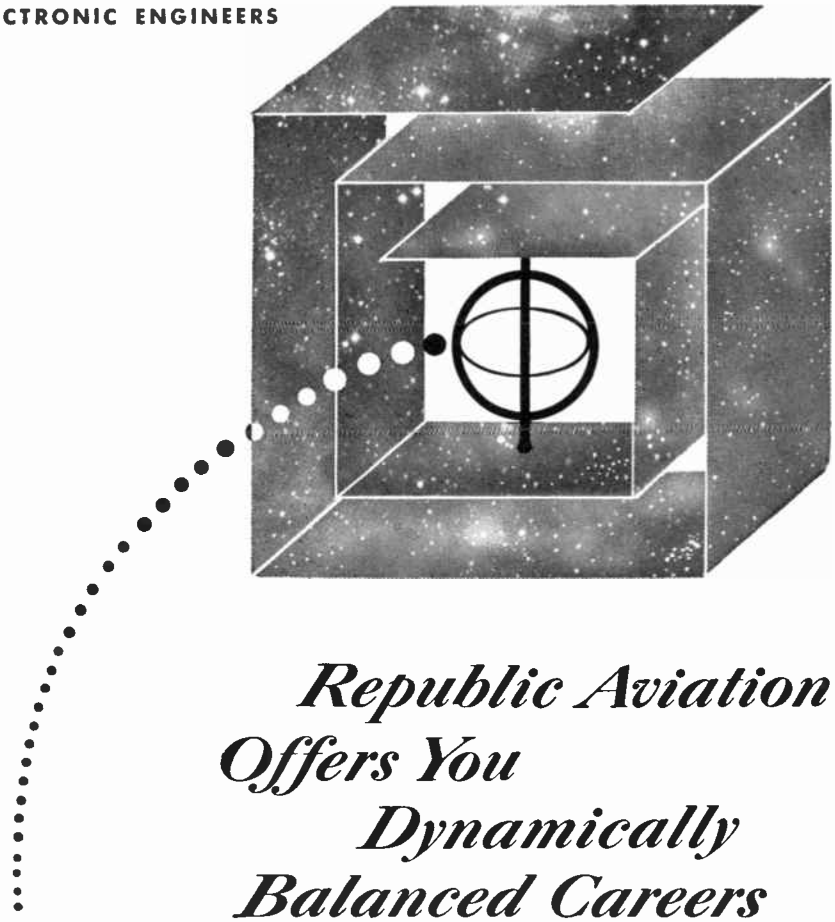
Write in confidence to Mr. Don Eikner, Hughes General Offices, Bldg. 6-E8, Culver City, Calif.

The West's leader in advanced ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY

Culver City, El Segundo, Fullerton, Newport Beach, Malibu and Los Angeles, California; Tucson, Arizona



Positions Wanted

By Armed Forces Veterans

(Continued from page 128A)

received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

TECHNICAL CONSULTING

Ph.D. MIT. 1953. Assignments in microwave heating, other electronic applications to biological and food problems, technical surveys, diversification studies, and information research. Registered professional engineer, inventor, teacher and author. Box 2011 W.

SCIENTIFIC RUSSIAN TRANSLATOR

Computer scientists with 17 years general electronics experience. Large experience in translation of Russian electronics literature. Will accept single-shot or steady outside translation work up to 75,000 words per month. Box 2012 W.

ENGINEER

Engineer with BS. degree wishes to relocate to small town or suburb on west coast. 10 years design and development experience including television, Airborne VHF communication and RF and AF transistor circuit design. Top 10% of graduation class. Now located with A-1 manufacturer in midwest. Box 2013 W.

ENGINEERING MANAGER OR ADMINISTRATOR

BSEE., MSEE., MBA., PE. 12 years of microwave and television design, systems and administration experience. Presently Engineering Director. Seeking high level responsible position. Location secondary to opportunity. Box 2014 W.

ADVERTISING AND PUBLIC RELATIONS

12 years intensive experience in program planning, budgeting and administration; product, market and media analysis; technical advertising, sales promotion and publicity copy; company-agency liaison, Government, industry, community and press relations. Licensed radio operator/mechanic with marketing background in electronic, nucleonic, aviation and allied industries. BS.—Engineering Management, MBA.—Industrial Marketing, Ph.D. candidate—Advertising. Age 39. Desires company or agency affiliation with broader responsibilities leading to marketing management. Box 2016 W.

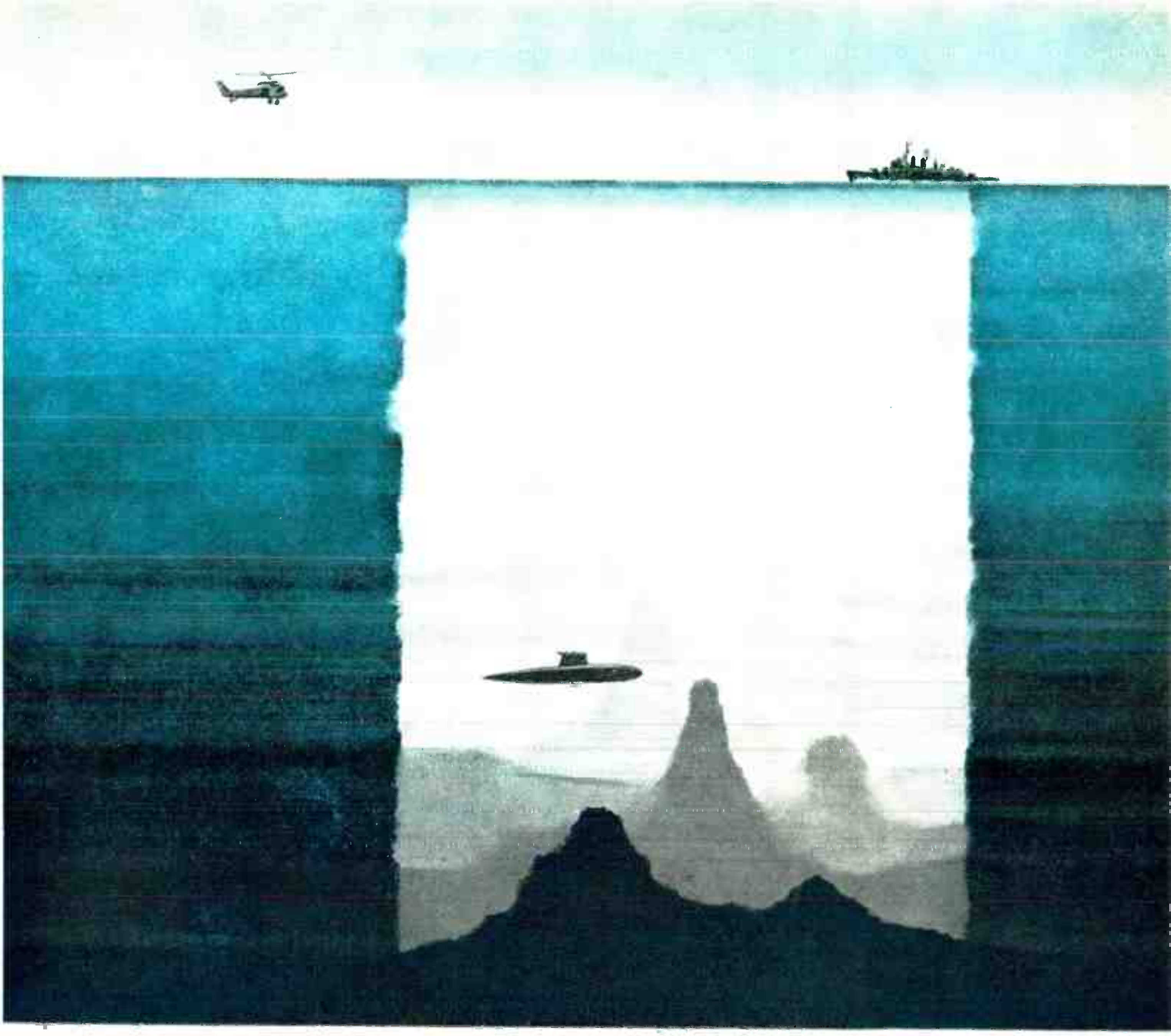
MANAGEMENT—ENGINEER

Broad background in operational requirements for military systems, particularly in airborne electronics. Also in organization and management. Desires challenging position of responsibility preferably in mid-west. BS. (USMA), MS. in engineering electronics. Naval aviator. Age 38. Box 2018 W.

PROFESSIONAL ENGINEER

Broad experience in management and engineering, seeks interesting, remunerative and challenging association. Reg. Washington prof. eng; BS. FCC licenses, etc. 14 years in broadcast,

(Continued on page 136A)



No hiding place for underseas prowlers

Raytheon sonar is as far-reaching as the sea itself. From the air, the surface and the depths, underwater vision is eliminating the hiding places of underseas prowlers. Development of sonars for the highly diversified vehicles and environments necessary to achieve complete surveillance requires a highly adaptable engineering staff.

PROFESSIONAL ASSOCIATION WITH A FUTURE is open to qualified engineers and scientists with BS or advanced degrees. Positions are available in systems, development, design or manufacturing engineering of a wide range of complex equipments. Please write Donald H. Sweet, Government Equipment Division, Raytheon Company, 624 Worcester Road, Framingham, Massachusetts.

Engineering Laboratories: *Wayland, Maynard, Sudbury, Mass.; Santa Barbara, Calif.*
Manufacturing Facilities: *North Dighton, Waltham, Mass.*

RAYTHEON

Excellence in Electronics

GOVERNMENT EQUIPMENT DIVISION

LAND SEA AEROSPACE

TEXAS INSTRUMENTS
INCORPORATED

DALLAS 9, TEXAS

TI's new semiconductor solid circuits measure less than ¼ x ⅛ x 1/32 of an inch and incorporate up to 12 integral electronic components. Complete multivibrator circuit shown. In addition to extreme size and weight reduction, reliability also has been greatly increased.

join TI engineers in such challenging programs as micro-miniaturization

TI develops new semiconductor solid circuit with component densities up to 34 million per cubic foot!

From one of many stimulating research and development programs at Texas Instruments comes another major "first" . . . new semiconductor solid circuits! Born from TI-sponsored research studies, the basic concept was carried through to reality by the Semiconductor-Components division. Utilizing TI developments in semiconductor manufacturing techniques (controlled masking, etching, diffusion), TI has formed diode and transistor elements, as well as passive elements of resistance and capacitance, to provide a complete circuit function normally requiring up to 12 components!

Such significant developments naturally result from TI's great emphasis on creative ability and freedom of professional expression. *You'll find many challenging opportunities at Texas Instruments where such technological advances are a frequent occurrence.* At the Apparatus division, weight and size are critical factors in its missile and aircraft electronic and electromechanical systems. You may explore new possibilities for making these systems even smaller and more reliable using the new semiconductor solid circuits. Or, with the GeoSciences and Instrumentation division, you may exercise this new concept in circuitry to create new and more compact commercial and industrial instrumentation.

A rewarding opportunity awaits you in one of the many programs now in progress at TI's Central Research Laboratory, Semiconductor-Components, Apparatus, and GeoSciences and Instrumentation divisions.

You will also benefit from TI's up-to-date personnel policies which include profit sharing plan (in 1958, 15% of base earnings), semi-annual salary and advancement reviews, educational assistance, insurance, hospitalization, and retirement programs. You will enjoy the temperate Southwestern climate and the many year-round recreational, amusement and cultural activities.

To join this fast-moving company at the forefront of scientific technologies, please write to activity of interest shown at right, enclosing a short resume.

SEE US AT WESCON

interviewing

August 17 thru 21

St. Francis Hotel

specific career opportunities now open at Texas Instruments

SEMICONDUCTOR-COMPONENTS DIVISION

DEVICE DEVELOPMENT — Develop new semiconductor devices; conduct experimental and theoretical studies on the effects of nuclear radiation on semiconductor materials and devices; evaluate experiments in the analysis of gases and electro-chemistry; conduct physical measurements on semiconductor surfaces; determine the effects of chemical reaction on semiconductor surfaces; studies in device stability, reliability and characterization; materials research and development including crystal growth and crystallography.
CIRCUIT DEVELOPMENT — Transistor circuit design and application; design automatic and semi-automatic test equipment.
MECHANIZATION — Design and develop high speed automatic machinery.
Please write to H. C. LAUR, Dept. 1102, P. O. Box 312, Dallas, Texas

APPARATUS DIVISION

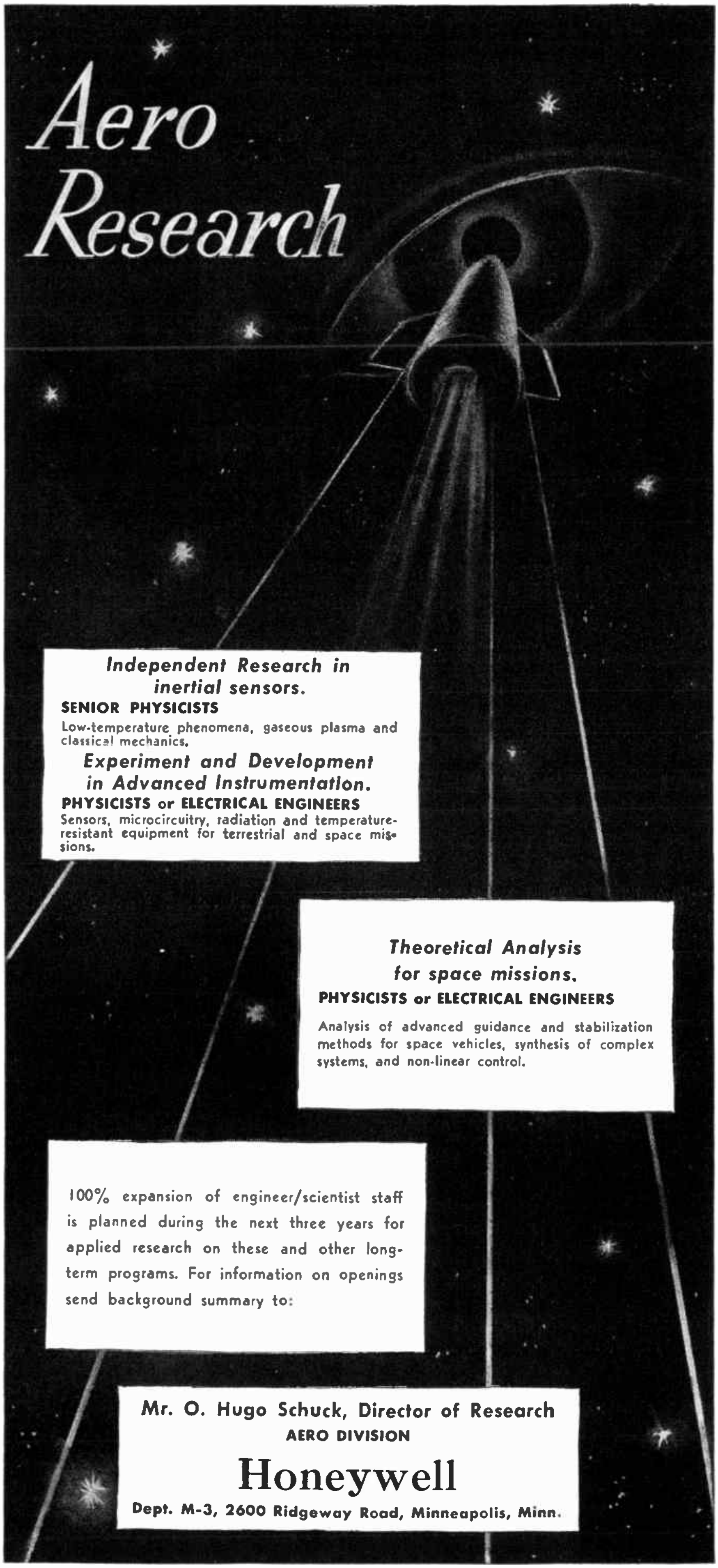
ELECTRICAL DESIGN AND DEVELOPMENT ENGINEERS (minimum 3 years experience) To apply technologies of radar, sonar, infrared, magnetics, microwave, telemetry, special-purpose computers, and servos to submarine detection, missile guidance and instrumentation, combat surveillance and reconnaissance, and aerial object detection and tracking. Conduct studies and analyses, and circuit development, electronic and electromechanical component design, transistorization, and miniaturization. Educational requirements: MSEE, BSEE, or BS Physics.
MECHANICAL DESIGN AND DEVELOPMENT ENGINEERS (minimum 3 years experience) Design and develop servo systems, X-Y plotters, strip recorders, optical systems, vibration damping and isolation packages, antenna structures and drives, sonar reels, cooling and heating systems and electronics packaging. Guide drafting, environmental testing, and model making; give consultation to manufacturing engineers to solve project production problems. Environmental studies. Educational requirements: MSME or BSME.
MANUFACTURING ENGINEERS (minimum 1 year experience) Production planning, tooling, and guidance and control of all phases of general production activity, or of an assigned project. Mechanization for short-run equipment manufacture. Educational requirements: BSME, BSEE, or BSIE.
COST ESTIMATING ENGINEERS (minimum 3 years experience) Estimate or supervise estimation of material, labor, tooling, and indirect costing factors on unusual electronic and electronic and electromechanical systems and equipments. Electromechanical manufacturing experience desired. Educational requirements: BSEE or BSIE.
QUALITY CONTROL ENGINEERS (minimum 3 years experience) Establish and maintain standards of quality and inspection methods for all raw materials and manufactured products. Three years experience in statistical methods, manufacturing processes, equipment inspection and/or design with minimum of 1 year in electronics industry. Educational requirements: BSEE or BSIE.
RELIABILITY ENGINEERS (minimum 3 years experience) Assist project engineers during design phase for maximum electronic or electromechanical reliability. Evaluation, selection, and application of components. Estimate system reliability; analyze and recommend corrective action. Experience in equipment design and component application. Educational requirements: MSEE or BSEE.
Please write to JOHN PINKSTON, Professional Placement, Dept. 1102, 6000 Lemmon Avenue, Dallas 9, Texas

GEOSCIENCES AND INSTRUMENTATION DIVISION

MANUFACTURING ENGINEER—EE or ME with 2 years or more similar experience in production planning and control.
ELECTRICAL ENGINEER — EE with 3 to 5 years experience in electronic design.
ENGINEER — EE or Physics sustaining engineering of seismic products.
SALES ENGINEER, SEISMIC — Science degree with seismic crew experience, with minimum of 5 years experience.
SENIOR ENGINEER — EE with 5 years in electronic circuitry design and development.
INDUSTRIAL ENGINEER — IE with 3 to 5 years experience in Industrial Engineering or related work.
SENIOR ENGINEER — EE or ME with experience in electrical products, particularly in commercial and industrial areas.
MECHANICAL ENGINEERS — ME with instrument field experience.
Please write to DAVE TURNER, Dept. 1102, 3609 Buffalo Speedway, Houston, Texas

CENTRAL RESEARCH LABORATORY

HEAD—PHYSICS SECTION— 4 to 5 years experience in semiconductor physics and proven ability to direct a variety of technical projects. Responsible for directing work on the measurement and understanding of electrical, thermal, magnetic, optical, and transport properties of semiconductors. Educational requirement is PhD in Physics.
HEAD—DEVICE SECTION— 4 to 5 years experience in semiconductors plus experience in group leadership and proven ability to supervise a variety of technical projects. Will be responsible for directing work on design, fabrication and evaluation of new solid state devices. Educational requirement is MS or PhD in either Physics or EE.
SOLID STATE THEORIST — Responsible for the understanding and interpretation of the physical properties of semiconductors and other solid state materials. Educational requirements: PhD in Physics with concentration in quantum mechanics. Solid state experience desirable but not necessary.
DEVICE THEORIST — Responsible for the design of new solid state devices and interpretation of their characteristics in terms of physical and fabrication parameters. Educational requirement is PhD in Physics or EE, or MS with 2 to 3 years experience in solid state device theory.
SEMICONDUCTOR TECHNOLOGY — Responsible for the design and interpretation of experiments on the technology of semiconductors, including impurity diffusion and alloying. Educational requirement is PhD in Physical Chemistry or Metallurgy. Experience requirement: 3 to 4 years experience in semiconductor technology.
THEORETICAL PHYSICIST — 2 to 3 years experience in electron or nuclear magnetic resonance with interest and background to perform theoretical analysis of EMR and NMR to develop possible new types of magnetometers or to make significant improvement in present types. Sufficient experimental background and interest to assist in translating theoretical results into experimental projects.
PHYSICISTS — Either MS or PhD with 1 year minimum experience in the fields of superconductivity and low temperature physics. Should be acquainted with conventional techniques of transferring and handling liquid helium and designing circuits and instrumentation for studies in this area.
Please write to A. E. PRESCOTT, Dept. 1102, 6000 Lemmon Avenue, Dallas 9, Texas



Positions Wanted

By Armed Forces Veterans

(Continued from page 124A)

communications, FCC and management engineering. Senior Member, active on IRE technical committees; NTSC., etc. author 6 books, over 100 articles. Present contract expires shortly, do not wish to stay overseas. Prefer a southwest state. Washington D.C. fine; well known in industry. Excellent references. Box 2023 W.

ELECTRONIC ENGINEER

BSEE. 1955, MSEE. 1957; Eta Kappa Nu, Tau Beta Pi, Phi Kappa Pi. 3 years experience on radar simulators, UHF aircraft radio and circuit development. At present Army Officer (Signal Corps.), available August 1959. Prefer Phila. area but will relocate for outstanding opportunity. Box 2024 W.

PHYSICIST

34 years experience in communication laboratory, desires position in southwest U.S. BA., MA., Ph.D. Member American Physical Society. Member IRE. Has worked in loudness studies, sound recording, network and filter design. Interested in statistical problems. Security clearance Married. Box 2025 W

MANAGER—ENGINEER

6 years diversified experience as corporate manager and engineering director with additional experience encompassing corporate organization, sales, advertising, publicity, public speaking and technical writing, 17 years electronics background in communications, instrumentation, radio and TV development and design. Registered professional engineer. BSEE. Purdue University; Senior Member IRE; Age 37; married; 3 children. Box 2026 W.

EDUCATOR—EDITOR—ENGINEER

BA., BSEE., MA., MS.; Major USAF Res. 15 years experience training, writing and supervising engineering projects. Knowledge Spanish, Portuguese, Italian, French, German, Russian. International relations and Military Intelligence. Desires responsible position overseas. Box 2027 W.

DIGITAL SYSTEMS ENGINEER

BEE.; Tau Beta Pi, Eta Kappa Nu; graduate work in digital techniques. 6 years broad experience, logical design, systems integration, transistorized circuit design, systems evaluation. Married. 2 children. Desires position in Japan or other opportunity of unusual interest. Box 2031 W.

ELECTRICAL ENGINEER

Age 23. BEE. Georgia Tech. September 1957. 1/Lt. U.S. Army Ordnance Corps 1½ years as project coordinator at White Sands. Desires position in missile instrumentation or allied field with management opportunities. Location southeast or southwest. Available November 1959. Box 2032 W.

ELECTRONIC TECHNICIAN

Signals Officer 15½ years service in HF communication work. Age 37. Associate Brit. IRE. Associate Member IRE (USA). Graduate H.R.T. Institute, Los Angeles. Desires suitable position, willing to undergo preparatory training if necessary. Non-U.S. citizen, at present residing outside USA. Location any part of the world, preferably U.S. or possessions. Box 2033 W.

(Continued on page 158A)

Positions Wanted

By Armed Forces Veterans

(Continued from page 136A)

EDITOR—PUBLICATIONS MANAGER

BS. in physics; 10 years technical writing experience including 4 years as supervisor; 3 years teaching radio and television repair, laboratory and theory; holder of first class radiotelephone license; excellent mathematician; expert typist and stenographer. Desires position as editor of electronics periodical or as supervisor in publications section of manufacturer of electronic equipment. New York City area preferred. Box 2034 W.

TECHNICAL REPRESENTATIVE

Assistant to Technical Director in Europe desires position of broad responsibility by September in Europe. University training in eng. and administration; 10 years Comm. & Mil. Elec. Member IRE; FCC 1st. Age 40. Married. Box 2035 W.

ENGINEER

Graduate mechanical engineer with electronic experience. LL.B. August 1959. Age 28. Seeks position to encompass both fields. Desires small to medium company. Married. Location immaterial but favors overseas. Box 2036 W.

PATENT ATTORNEY

BEE., B.Aero.E., LL.B. New York Bar. 3 years patent prosecution for electronics corporation. 6 years engineering experience including transistor circuitry and aircraft instruments. Desires position with New York City firm. Box 2037 W.

ADVERTISING—MARKETING—SELLING—WRITING

B.S.; Age 39. Salary $8,000 to $11,000. Box 2038 W.

ELECTRONIC ENGINEER

Completing Ph.D. in E.E. this fall at large midwestern university. 6 years broad experience in ECM, communication, and control systems. Strong background in applied mathematics. Former Fulbright Scholar. Desires long term position in continental Europe. Age 29, married. U.S. citizen, languages. Box 2039 W.

Section Meetings

(Continued from page 118A)

QUEBEC

"Microwave Facilities," Inspection Tour, O. L. Oakes, Bell Tel. Co. of Canada; Election of Officers; 5/25/59.

ROCHESTER

"Medical Electronics," L. B. Lusted, Univ. of Rochester; Jt. with Rochester Engineering Society; 5/21/59.

ROME-UTICA

"Line of Sights Shibboleths, Scatter Propagation and Radio History," T. Carroll, Bendix Radio; 2/25/59.

"Fuel Cells," W. R. Carson, Jr., Gen. Electric Co.; 4/22/59.

(Continued on page 140A)

Section Meetings

(Continued from page 138A)

"Space Technology," K. Stebling, Naval Research Lab.; 5/21/59.

"Silicon Solar Cell," J. Kalman, Hoffman Electronics Corp.; 6/12/59.

Sacramento

"Television Test Techniques," a Symposium, D. Anderson, KRON, H. Brown, KGO, H. Dover, RCA; 5/5/59.

St. Louis

Student Papers Contest Awards; "A Digit Reader," 1st Prize, R. A. Ellis, & J. L. Tobin, Wash. Univ.; "The Entropy Concept in Information Theory"—2nd Prize, R. F. David, St. Louis Univ.; "A Proposed Application of the Electrets"—3rd Prize, D. A. Lee, Univ. of Mo.; "Sequence Determination from Electrical Relay Circuits"—4th Prize, W. K. Hammond, Mo. School of Mines & Metallurgy; Jt. with AIEE; 5/12/59.

Salt Lake City

"Recent Developments in Microwave Tubes," D. A. Dunn, Stanford Electronics Lab.; 11/19/58.

"Fundamental Research in the Upper Atmosphere," O. C. Haycock, Univ. of Utah; "Measurement of Electron Density," B. Hulet & K. Baker, Univ. of Utah; 12/11/58.

"Modern Developments in InfraRed," B. Howell, Sperry Utah Eng. Labs.; 1/8/59.

"Study of the Ionosphere with Low Frequency Radar," C. Clark, Utah State Univ.; 2/12/59.

"Career Development and the Engineering Student's Responsibility in Industry," H. Boehmer, Utah Power & Light Co.; R. O. Evans, Sperry Utah Eng. Labs., 3/10/59.

"Amplifier Analysis Using Log Modulus and Phase," J. Johnsson, Brigham Young Univ.; 4/7/59.

San Antonio-Austin

"Some Observations on Satellite Experimentation," W. J. Hamm & C. R. Graf, St. Mary's Univ.; 5/21/59.

San Diego

"What Reliability Means to the Department of Defense," C. M. Beyer, Office of the Secretary of Defense; 5/6/59.

"Recent Studies of the Sun by Radio," R. N. Bracewell, Stanford Univ.; 6/3/59.

Schenectady

"Satellite Tracking," R. O. Anderson, G.E. Co.; 4/7/59.

"Optimum Noise Performance of Linear Amplifiers," H. A. Haus, MIT; 5/5/59.

Seattle

"Isotopes in Medical Research," R. Huff, Univ. of Washington School of Medicine; 3/26/59.

Annual IRE-AIEE Student Paper Contest; Placed: 1st, "The Logical Design of a Transistorized Direct-Coupled Amplifier," R. L. Everet, Seattle Univ.; 2nd, "Thermal Electric Power for the Pacific Northwest," T. O. Keefe, Univ. of Wash.; 3rd, "Electrocution—The Industrial Hazard," K. Billingsley, Univ. of Wash.; 4th, "The Radio Telescope," M. Dormann, Seattle Univ.; 5th, "Parametric Amplifiers," D. L. Albright, Seattle Univ.; Contest Judges: A. G. Thompson, Pac. Tel. Co., L. C. Perkins, Boeing Airplane Co.; and A. E. Stewart, Seattle City Light; 4/21/59.

"Life in India," W. R. Hill, Univ. of Wash.; Election of '59 60 Officers; 5/21/59.

Field Trip, North Bend Repeater Station, Pac. Telephone Co.; 6/6/59.

(Continued on page 142A)

Section Meetings

(*Continued from page 140A*)

SOUTH BEND-MISHAWAKA

"Semi-Conductors," A. M. Christian, Westinghouse Electric Corp.; 3/26/59.

Third Annual Dinner Meeting, C. Hoffman, Master of Ceremonies; Student Awards to R. Kentrille and W. McAdam, Notre Dame Univ.; 4/30/59.

WASHINGTON

"Radio Frequency Hazards," I. Roman, International Electronics Co.; 6/1/59.

WICHITA

"Principles of Microwaves," D. E. Wendland, Boeing Airplane Co.; Jt. with AIEE; 5/5/59.

"Microwave Measurements," C. Mathis, Boeing Airplane Co.; Jt. with AIEE; 5/12/59.

TULSA

Annual Meeting, Introduction of New Officers; 5/28/59.

TWIN CITIES

"Management Planning," Panel Discussion: H. E. Weyrauch, Maico; J. H. Rogers, Honeywell, H. Baller, Gen. Mills, R. Clark, Telex, Mr. McKenzie, M.M.M., H. E. Thompson, Rem. Rand; 5/27/59.

VIRGINIA

"Trends in Infrared Detection," G. L. Harvey, Sperry Piedmont; 4/24/59.

"Design and Operation of Miniature Ionization Gages," Winning Paper, J. D. Hamlin, University of Virginia; "Factors Affecting Contact Noise of Sliding Metal Contacts," Runner-up Paper, A. Kuun, Virginia Polytechnic Institute; 5/8/59.

SUBSECTIONS

EASTERN NORTH CAROLINA

"High Reliability Transistor Amplifier Design Construction," W. Greatbatch, Taber Instrument Corp.; Students Recognized: W. T. Easter, IRE Award, L. K. Monteith, H. T. Gnuse, N. C. Section IRE Award; R. Melvin, S. Rudisill, R. Clinard, W. Peters, Student State Sectional Contest winners; J. Wallace, C. W. Kelly, Student State Sectional Contest winner; 5/15/59.

FAIRFIELD COUNTY

"System Considerations in Data Processing Systems," B. Levine, Teleregister; 2/26/59.

"Analog Computer Techniques Applied to Industrial Instrumentation," B. Seddon, G. A. Philbrick Researches, Inc.; 4/30/59.

"Stereophonic Sound Reproduction," B. Raver, CBS Lab.; 5/28/59.

GAINESVILLE

"TACAN Air Navigation Aid System," J. D. Swearingen, Sperry Electronic Tube Div.; 5/13/59.

KITCHENER-WATERLOO

"Stereo—Past, Present and Future," F. Gordon, Dominion Electrohome Industries, Ltd., and J. Buhr, Dominion Electrohome Industries Ltd.; 5/25/59.

LANCASTER

Tour of Bendix Aviation Corporation, York Division; 5/27/59.

(*Continued on page 144A*)

Dear Engineer,

If you are a fortune-hunter, turn the page; this is not for you. But if you are one of the great majority of professional men who is primarily interested in a satisfying job and attractive working and living conditions with reasonable security and good promise for the future, read on!

Sure, this is a sales pitch - but different, since it aims to be honest! We need engineers, just like every other leading company. You've seen the screaming ads promising Utopia, or Nirvana, to anybody with any semblance of engineering qualifications. We're different! At York, we cling to the belief that you will be more impressed with a frank statement of the pros and cons.

First, we are in the electronics business. Most of our work is military. Since we are working with five or six government agencies, our activities are diverse. We are a small, but full-fledged division of the Bendix Aviation Corporation, which conveys the security and stability of a large company. On the other hand, Bendix operates its divisions on a practically autonomous basis, so that we also have the flexibility and healthy atmosphere of a small, independent company. Nobody gets buried!

Our plants contain a total of 130,000 square feet, are about 7 years new and are excellently equipped with machinery and test equipment. They are located about five miles east of York, Pa., on the Lincoln Highway, in what the real estate dealers describe as a "beautiful suburban area". (And it is.) You can live (as I do) within three minutes drive of the plant. For $10,000 you can have a 2-bedroom house (cheaper if you buy a run-down farm house).

The town (of about 75,000) has at least one of everything you could find in a bigger city, including a symphony orchestra of some note. (Sorry, the pun was unintentional.)

Here in our plant, we believe that engineers are people, individuals yet, and not hired hands. We exercise some care in hiring, because we want them to stick; and, in fact, our turn-over rate is negligible. The work and status of each individual is reviewed every six months. This doesn't mean that he gets a raise every time, but 10% a year isn't far from the average. As an engineer, it's possible to make over $12,000 a year, but you have to be good.

We operate basically by a project system, with a great deal of responsibility vested in each Project Engineer. The supporting departments - Drafting, Mechanical Engineering, Model Shop (you should see our model shop), technical publications and the like - furnish service to the project groups. We do about $3,000,000 a year engineering business alone, and seem to have no difficulty in acquiring more. We're growing fast!

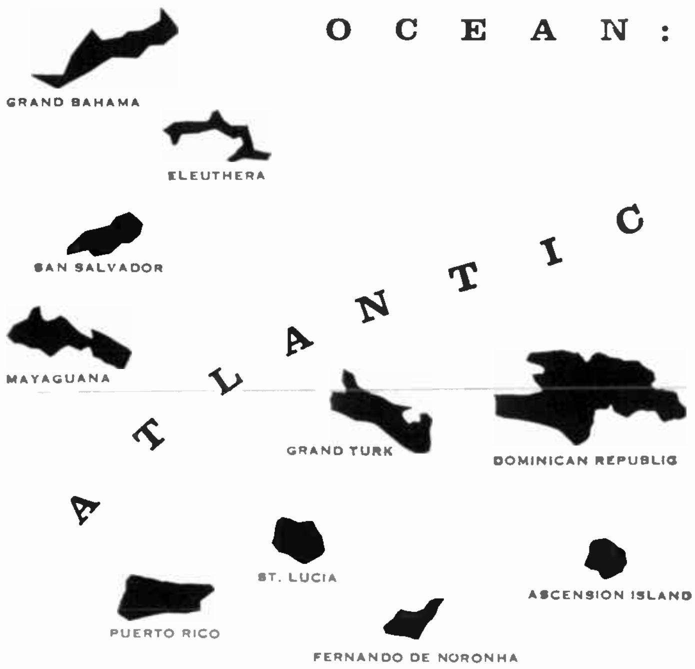
We don't offer you the moon, but we do offer you a fair shake!

Sincerely yours,

W H Sims Jr

W. H. Sims, Jr.
Chief Engineer

P.S. If you're interested, get in touch with me.
WHS.



Section Meetings

(Continued from page 142A)

LAS CRUCES-WHITE SANDS

Films, and Nomination of Officers; 5/28/59.

LEHIGH VALLEY

"The Atlas Guidance Computer," E. Lohse, Burroughs Research Center; 4/29/59.

"TASI—A Time Assignment System," F. Saal, Bell Tel. Labs.; 5/27/59.

MEMPHIS

Report on the IRE National Convention, F. Ray, Baptist Memorial Hosp.; 4/22/59.

"Applications of Ceramic Resistors, Capacitors," B. Vizzier, Fryling Electronic Products, Inc.; 5/28/59.

NORTHERN VERMONT

"Bat Radar," D. R. Griffin, Harvard Univ.

PANAMA CITY

"A Simple Technique for Radio Tracking of Space Vehicles," M. Stupar, Underwood Corp.; 6/9/59.

PASADENA

"National Space Program," A. R. Hibbs, Caltech Jet Propulsion Lab.; "Goldstone Tracking Facility," W. Larkin, Goldstone Tracking Facility; 4/2/59.

READING

"The History of Telephone Switching Systems," G. W. Espenshade, Bell Tel. Co.; 5/20/59.

RICHLAND

"Modern Engineering Curricula," K. B. Woods, Purdue Univ.; 3/17/59.

"Radiation Damage to Transistors," D. A. Hicks, Boeing Airplane Co.; 4/30/59.

SANTA BARBARA

"Pattern Recognition," L. Brotman, Litton Industries; "Electrical Physiological Measurements," M. Sosnow, Litton Industries; Newly elected Officers '59-60 introduced; 5/12/59.

WESTCHESTER

Field Trip, Sonotone Manufacturing and Engineering Facilities; 3/21/59.

"Computer and Brains—A Survey of Learning and Pattern Recognition," B. G. Farley, Lincoln Labs.; 4/15/59.

"Microwave Carrier Techniques for High Speed Digital Computing," F. Sterzer, RCA; 5/20/59. Election of New Officers '59-60; 5/20/59.

Professional Group Meetings

AERONAUTICAL AND NAVIGATIONAL ELECTRONICS

Florida West Coast—June 3

"Universal Multiplexer AN/FCC-17," D. B. Nowakoski, U. S. Air Force.

(Continued on page 146A)

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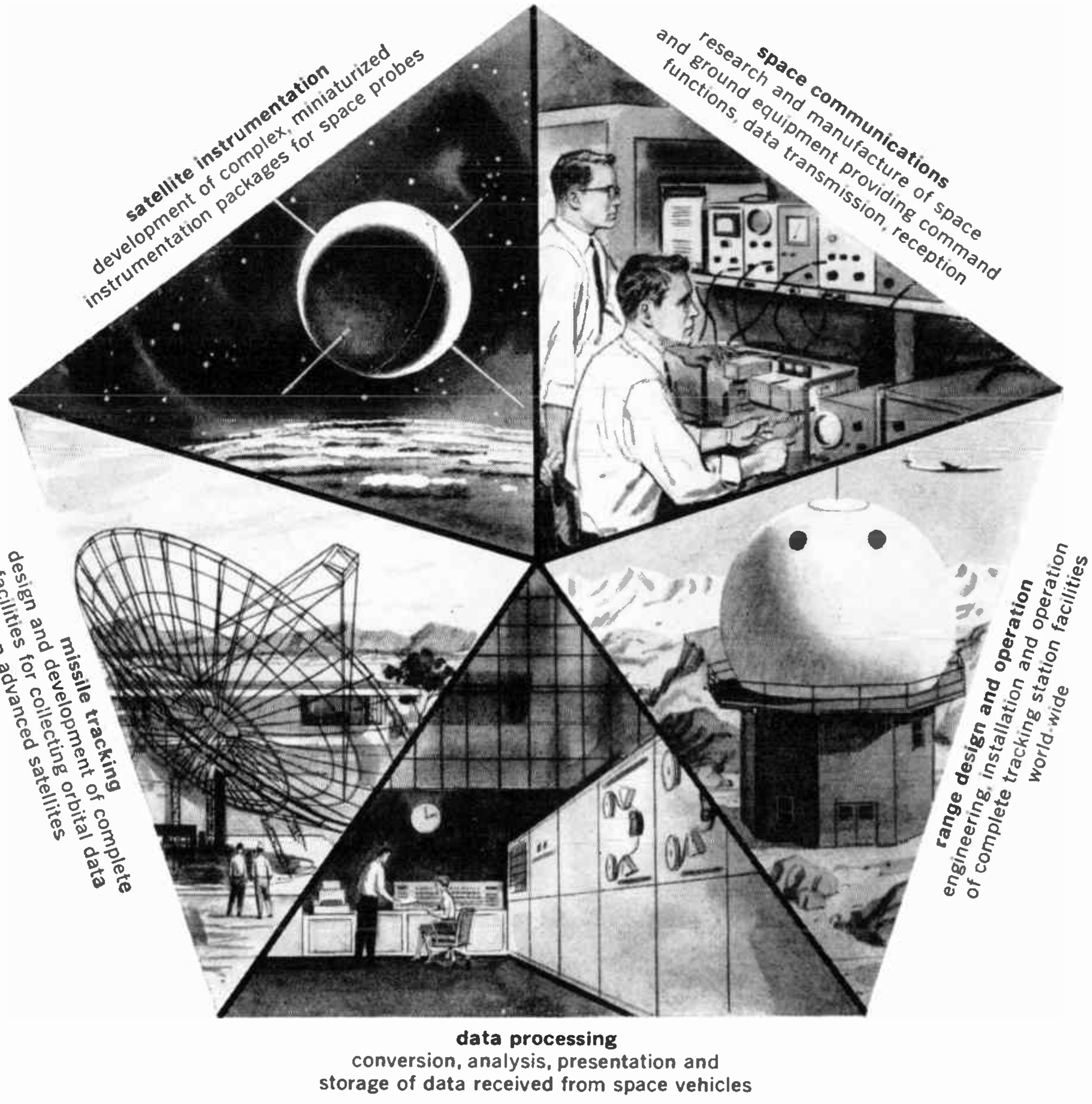

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Professional Group Meetings

(*Continued from page 144A*)

Antennas and Propagation

Chicago—May 8

"Radio Telescopes and Satellite-Tracking Antennas," R. F. H. Yang, Andrew Corp.

Los Angeles—January 22

"Use of Radar Transmission Techniques in Determining Radio Transmission Loss," Sam Bradshaw, Motorola.

Los Angeles—February 19

"Large Antennas: Theory and Practice," R. W. Bickmore, Hughes Systems Dev. Labs.

"Recent Developments in Tropospheric Propagation Phenomena," L. G. Trolese, Smyth Res. Assoc.

San Francisco—April 14

"Mutual Coupling Effects in Large Scanning Arrays," R. S. Elliot Rantec Corp.

San Francisco—May 12

"JPL's Goldstone Tracking Facility," K. W. Linnes, Jet Propulsion Lab.

Audio

Albuquerque-Los Alamos—February 27

"Journey into Hi-Fi," D. David and P. Klipsch, Klipsch & Assoc.

Chicago—April 10

"Some Aspects of the Future of High Fidelity and Stereophonic Sound," R. O. Jordan.

Dayton—April 2

"New Techniques and Devices for Telephony," R. P. Palomo, Ohio Bell Telephone Co.

Dayton—April 16

Tour of The Baldwin Piano Co. Plant, J. P. Quitter, The Baldwin Piano Co.

Philadelphia—April 15

"The Four Track Magnetic Tape Cartridge System," D. R. Andrews, RCA.

Philadelphia—May 13

"Sounds from Satellites," Prof. T. A. Benham, Haverford College.

Automatic Control

Boston—February 9

"Problems of Safe Reentry of a Manned Satellite," H. Wexler, AVCO Research RAD.

Boston—March 3

"Wide Band Carrier Type Amplification for Electrohydraulic Systems," R. E. Clafin, Jr., Servocontrol Div. of the Oilgear Co.

(*Continued on page 148A*)

Professional Group Meetings

(Continued from page 146A)

Dallas—May 5, 1959

"Helicopter Simulator," H. Upton, Bell Helicopter.

Long Island—May 19

"The Sperry Gyrofin Stabilizer," J. Chadwick, R. Cronemeyer, D. Price, Sperry Gyroscope Co.

Los Angeles—May 12

"Some Control Problems in Astronautics," R. E. Roberson, Ed. *Jour. of Astronautical Sciences*, and Assoc. Ed. *Astronautical Sciences Rev.*

Broadcast and Television Receivers

Chicago—April 10

"A Compatible Multiplex System for Stereo Sound on TV," N. W. Parker, Motorola, Inc.

Los Angeles—May 21

"The Philosophy & Technique of Pay Television," P. Court, International Telemeter Corp.

Broadcasting

Philadelphia—May 14

"An Automatic Programming System for Radio," G. A. Singer and P. W. Wildow, RCA.

Twin Cities—April 21

"Engineering and Organizational Aspects of the B.B.C.," F. C. McLean, British Broadcasting Co.

Circuit Theory

Philadelphia—June 10

"Spectrum Analyzer for Transient Phenomena," E. M. Gore, American Electronic Labs.

"Real Time Panora Spectrum Analyzers," B. D. Steinberg, and W. G. Ehrich, General Atronics Corp.

Communications Systems

Los Angeles—December 10

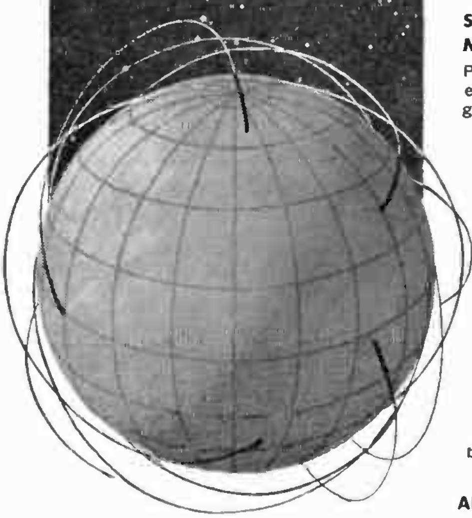
"Two-Way Doppler and Command Link for Space Flight," R. E. Graves and H. A. Samulon.

"High Frequency Crystal Filters for Use in Communications Equipment," R. G. Kinsman.

Florida West Coast—June 3

"Universal Multiplexer AN/FCC-17," D. B. Nowakoski, U. S. Air Force.

(Continued on page 150A)



Professional Group Meetings

(Continued from page 148A)

Los Angeles—February 11

"RF Translator for AN/ARC 68 HF Transcoiver," C. S. Root, Hughes Aircraft Co.

"Direct Stabilization of Microwave Oscillators for Communications Applications," M. B Rudin, Aeronutronic Systems.

Component Parts

Baltimore—May 26

"Component Reliability in Crash Programs," G. W. Milligan, Bendix Aviation Corp.

Dayton—April 9

Tour of Armco Plant.

Philadelphia—May 19

"Micro-Miniature Connectors for Micro-Electronics," H. E. Ruchlemann, Elco Corp.

"Micro-Miniature Connectors for Micro-Electronics," A. N. Lane, USASRDL.

Washington—May 20

"Some Aspects of Solid State Research on Dielectric Materials at Philco," M. Francombe, Philco Corp.

"Recent Advances in Ceramic Capacitors," A. R. Rodriguez, Aerovox Corp.

Electron Devices

Boston—May 13

"Sorting in M-type Traveling Wave Tubes," J. M. Osepchuck, Raytheon Co.

Los Angeles—April 20

"Solid State Aspects of Microminiaturization," I. Weiman & W. V. Wright, Jr., Electro-Optical Systems, Inc.

San Francisco—April 21

"Eitel-McCullough, its Past and Its Future," W. W. Eitel and J. A. McCullough.

San Francisco—May 26

"Vacuum Tube Design Using a Manned Space Tank," J. E. Orr, Litton Industries.

Washington—May 21

"Thermoelectric Power Generating and Cooling Devices," S. J. Angello, Westinghouse Elec. Corp.

Washington, D. C.—June 8

"Status of the Electron Device and Instrumentation Arts in Russia," C. P. Marsden, Nat. Bur. of Stand.

(Continued on page 152A)

Professional Group Meetings

(Continued from page 150A)

Electronic Computers

Akron—April 28

"Biological Feedback Systems," A. J. Gold, Goodyear Aircraft Corp.

Akron—May 19

"Computers in Decision Making," K. F. Powell, IBM Corp.

Detroit—April 1

"The Design and Use of Special Purpose Digital Equipment for Automatic Missile Testing," W. B. Gross, Chrysler Corp.

San Francisco—May 19

"High-frequency Carrier Techniques for Computer Logic," B. L. Havens, IBM Advanced Dev. Div.

Washington—May 4

"Use of Electronic Computers in the Design of Nuclear Reactors," H. Polachek, Applied Mathematics Lab.

Washington—May 13

"Automatic Machine and Program Testing Routines," W. C. Carter, Minneapolis-Honeywell Regulator Co.

Engineering Management

Boston—February 12

"RCA's Approach to Engineering Management Selection and Development," David Cook, RCA.

Boston—April 23

"Problems of Financing and Managing New Research-Based Enterprises," A. Rubenstein, M.I.T.

Washington—May 11

"Operations Analysis—What it is Not," A. L. Rayhawk, American Univ.

Industrial Electronics

Schenectady—February 10

"Non-Destructive Testing of Large Castings and Forgings," H. A. Rocha, Gen. Elec. Co., Schenectady, N. Y.

Information Theory

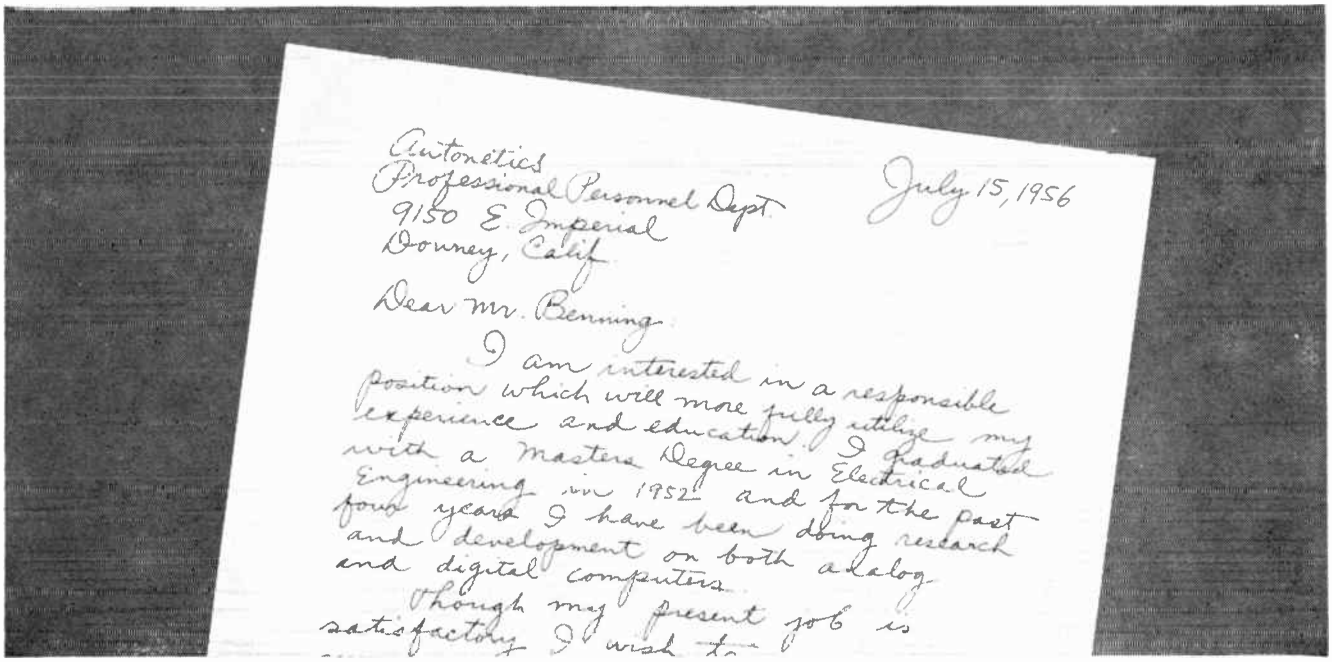
Boston—December 10

"Mechanization of Inductive Inference and An Approach to Artificial Intelligence," R. Salmonoff, Zator Co.

Boston—April 9

"Orthogonal Error-Correcting Codes," J. Dutka, RCA.

(Continued on page 154A)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Engineering in 1952 and for the past
four years I have been doing research
and development on both analog
and digital computers.
Though my present job is
satisfactory I wish to

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N E R V E C E N T E R O F T H E N E W I N D U S T R I A L E R A

Professional Group Meetings

(Continued from page 152A)

Boston—April 23

"New Techniques in the Study of Nonlinear Systems," A. G. Bose, M.I.T.

Instrumentation

Los Angeles—April 29

"Standardization Chaos—Whose Responsibility," (Panel) C. J. McNeil, Hughes Acft.; R. T. Merriam, NAOTS; C. H. Hoeppner, Radiation Inc.; A. W. Newbury, J. P. L.

Washington—May 18

"A Look Toward the Future in Electronic Standardization," H. W. Lance, Nat. Bur. of Stand.

Medical Electronics

Chicago—May 8

"Adventures in Medical Electronics," V. K. Zworykin, RCA.

Organization of Medical Electronics Groups, V. K. Zworykin.

Los Angeles—April 23

A five-speaker panel on "Medical Data Processing," M. L. Pearce; J. E. Walsh; S. J. Roach, Systems Dev. Corp., F. J. Moore, University of S. Calif., & E. C. Smith, IBM Corp.

Microwave Theory and Techniques

Albuquerque-Los Alamos—February 16

"Parametric Amplifier," Dr. C. F. Quate, Sandia Corp.

Albuquerque-Los Alamos—April 21

"Noise in RF Systems," R. P. McCann, Sandia Corp.

Chicago—April 10

"Some Unusual Aspects of Traveling Wave Tubes," R. Hankin, Hallicrafters Co.

Northern New Jersey—October 15

"Advanced Microwave Measurement Techniques," S. Levine, Stavid Eng. Co.

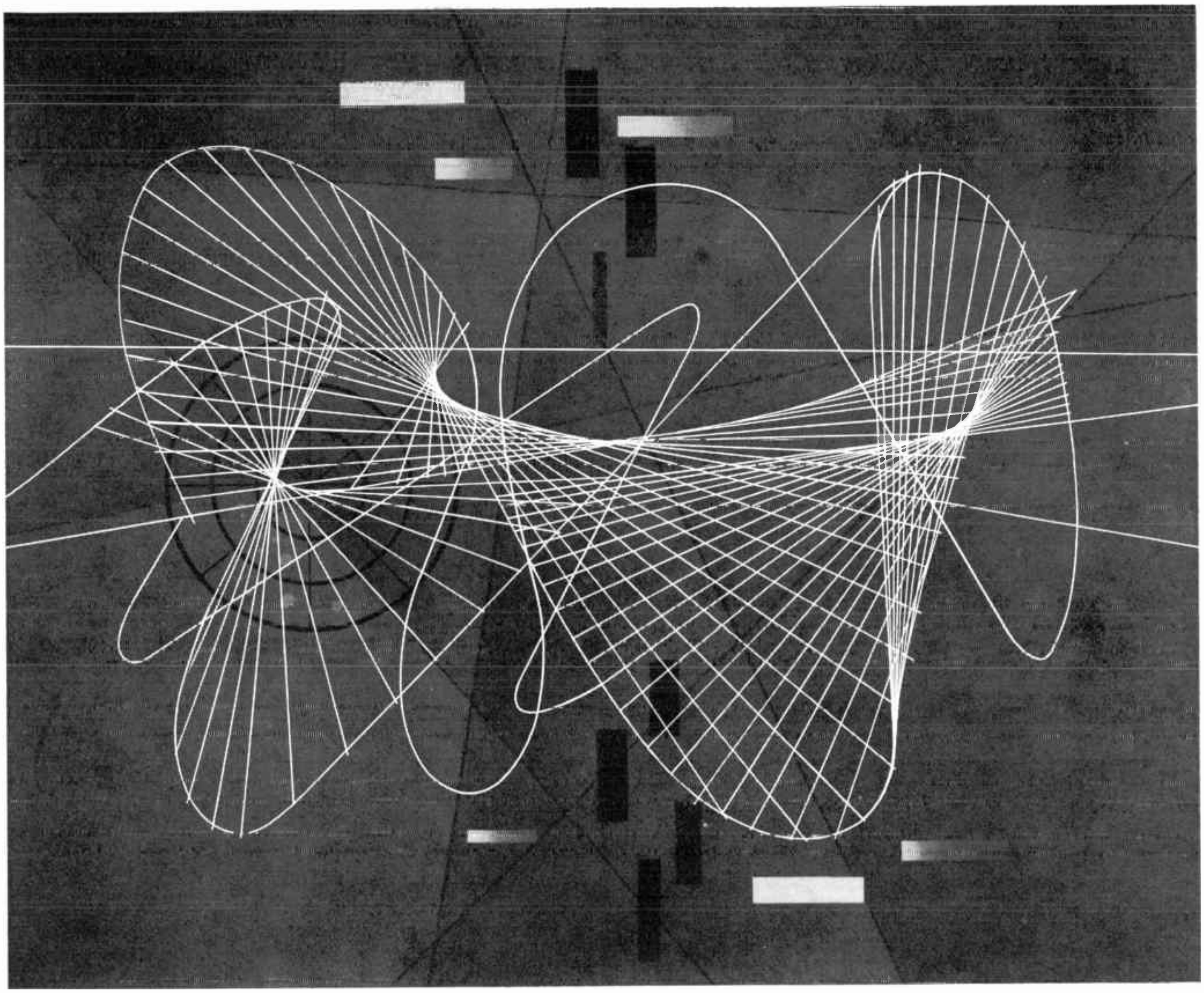
Northern New Jersey—November 19

"General Guided Wave Concepts," N. Marcuvitz, Polytechnic Inst. of Brooklyn.

Northern New Jersey—January 21

"Review of Solid State Microwave Amplifiers," J. H. Rowan, Bell Telephone Labs.

(Continued on page 156A)



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As the domestic research organization of the world-wide International Telephone and Telegraph Corporation, we are carrying on our tradition of pioneering in electronics. As our engineering responsibilities have increased so our organization has grown. Today, in addition to our main laboratories in New Jersey, laboratories in Ft. Wayne, Chicago and in California are pursuing projects of great magnitude and importance.

You will find in our staff the same fine creative thinking and engineering imagination which brought distinction to our old names. Formerly Federal Telecommunication Laboratories and Farnsworth Electronics research laboratories, our names have been changed to identify us clearly with our parent company, and to reflect our expanded responsibilities and growth.

Electronic engineers will find here opportunity to express initiative and competence in such areas as long range radar systems, digital computer applications to data processing and communications, space technology, microwave tube research and missile systems instrumentation. We are continuing our work in air navigation and control, and in electronic systems . . . and making new contributions to electronic theory and techniques. In fact, it would be hard to find another research organization that offers the engineer such a wide scope of activities.

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Professional Group Meetings

(Continued from page 154A)

Northern New Jersey—February 18

"Microwave Path Testing," J. P. Robertson, Amer. Telephone & Telegraph Co.

Northern New Jersey—April 15

"Interaction Circuits for High Power Traveling Wave Tubes," W. H. Yocum, Varian Assoc.

Northern New Jersey—May 20

"Circular Electric Waveguides," A. C. Beck, Bell Telephone Labs.

Schenectady—January 20

"Microwave Application of Ferrites," T. N. Anderson, Airtron, Inc.

Schenectady—June 9

"Recent Developments in Sealed-Off Ammonia Masers," S. Hopfer, Polytechnic Res. & Dev. Co., Brooklyn, N. Y.

Washington—May 12

Election of officers for 1959–60.

Microwave Theory and Techniques/Antennas and Propagation

Syracuse—April 21

"Physical Limitations of Directive Antennas," R. F. Harrington, Syracuse Univ.

Military Electronics

Boston—September 25

"Effect of High Intensity Sound on Structures," J. Barauch.

Boston—November 6

"Acoustic Noise Test Equipment," M. T. Anderson, Avco Mfg. Corp.

Boston—April 20

"A Passive Electromagnetic Space Navigation System," P. Zilczer, Fairchild Astrionics Div.

Buffalo-Niagara—May 13

"Problems Associated with Communicating with Hypersonic Vehicles," S. G. Homic, Bendix Systems Div.

Long Island—April 21

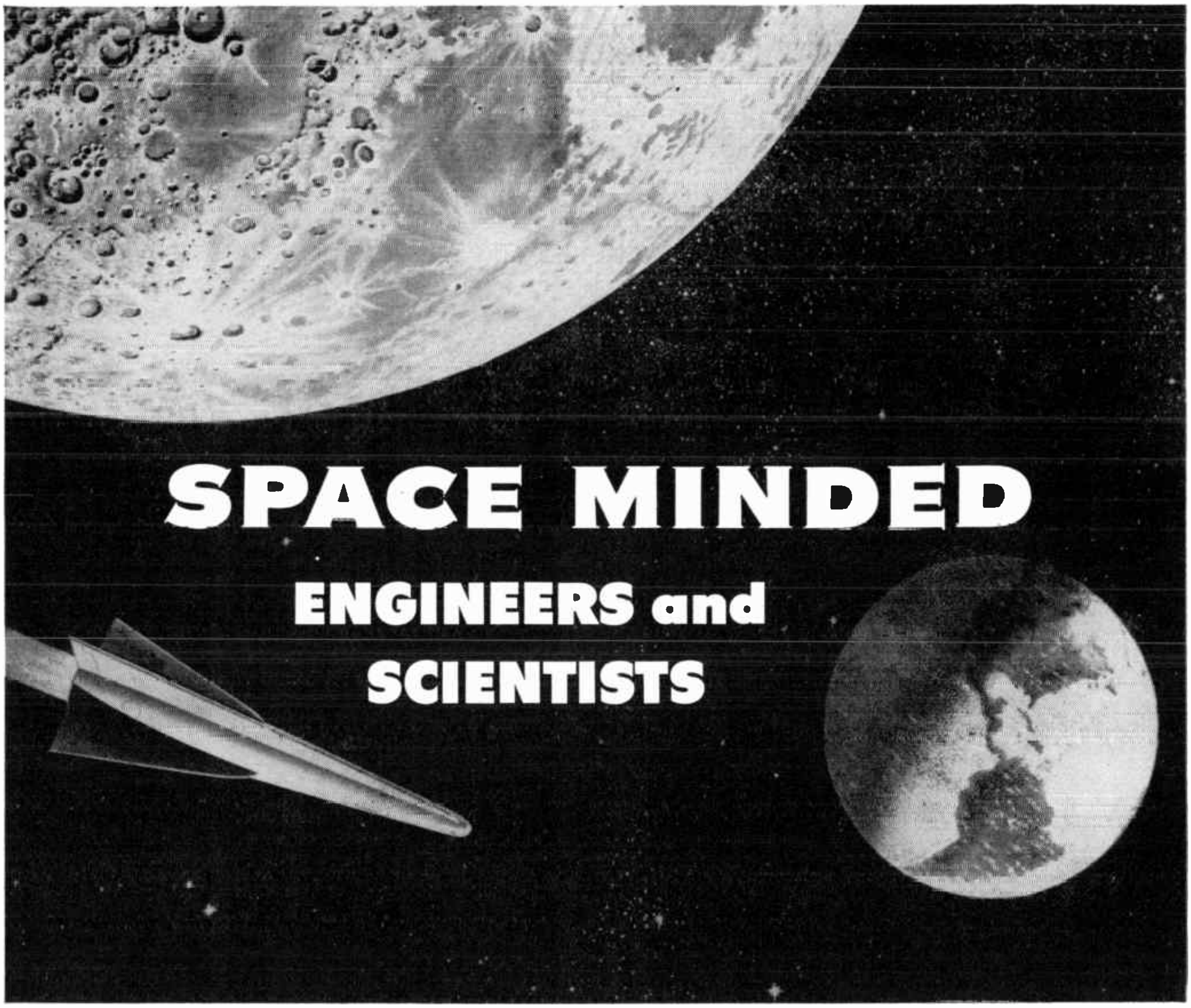
"Inertial Platform Progress," D. Mascucci, Arma Co.

"Computers for Space Travel," H. H. Schiller, Arma Co.

"Future of Space Travel and Inertial Guidance in the Space Age," P. Savet, Arma Co.

"Arma Inertial Components," M. Taylor, Arma Co.

(Continued on page 158A)



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FIELDSTONE 7-3665

Professional Group Meetings

(Continued from page 156A)

Long Island—February 24

"Introduction to Reliability," B. Mandell, Sperry Gyroscope.

"Present Methods of Approach to Reliability Analysis and Control," R. Cazanjian, Sperry Gyroscope.

"Reliability Program for the Sparrow I Missile," E. Derr, Sperry Gyroscope.

"Transition Period in Reliability Engineering," J. Keller, Sperry Gyroscope.

"Today's Challenge for Developing Future Effective Military Equipment," D. Ehrenpreis, Sperry Gyroscope.

Los Angeles—March 25

"Automation of Information Handling for the Tactical Field Army," L. W. Murphy, U. S. Army Electronic Proving Grounds.

"Systems Engineering for Automatic Data Handling," E. C. Nelson, Ramo-Wooldridge Corp.

Philadelphia—April 28

"A Survey and Comparison of Airborne Digital Computers," J. L. Lindinger, Aero. Instr. Lab., N.A.D.C.

Philadelphia—June 11

"Department of the Army Long Range Electronic Warfare Program," S. Stiber, USARDL.

San Diego—May 20

"Communication Techniques for Space Exploration," E. Rectin, Jet Propulsion Lab.

San Francisco—May 12

"Analytical Methods of Estimating Mean Life and Reliability," B. Epstein, Stanford Univ.

"Demonstration of Lockheed 'Hot Shot' Tunnel," R. L. Kramer, Lockheed M. & S. Div.

Syracuse—April 30

"The Impact of the Weapon System Concept on Industry," P. J. Schenk, Raytheon Mfg. Co.

Nuclear Science

Albuquerque-Los Alamos—April 10

"Scintillation Detectors: Their Physics and Application," M. Van Dilla, Los Alamos Scientific Lab.

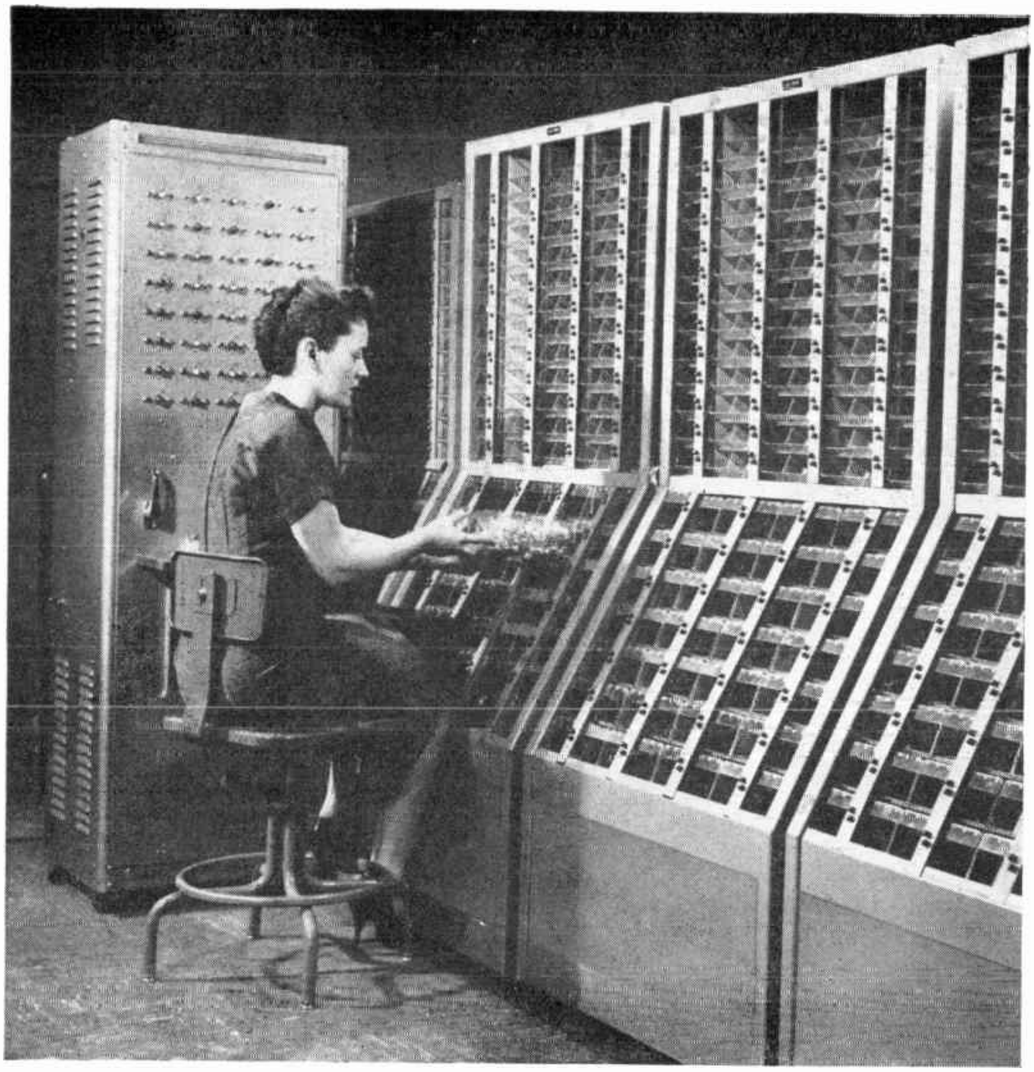
Albuquerque-Los Alamos—May 19

"Detection of Nuclear Particles," R. S. Claassen, Sandia Corp.

Washington—May 4

"Use of Electronic Computers in the Design of Nuclear Reactors," H. Polachek, Applied Mathematics Lab.

(Continued on page 160A)



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Newton 58, Massachusetts

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PHONE NUMBER__________

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Professional Group Meetings

(Continued from page 158A)

PRODUCTION TECHNIQUES

San Francisco—April 28

"The Manufacturing Organization of Litton Industries," R. Woenne, Litton Industries, Tube Div.

RELIABILITY AND QUALITY CONTROL

Chicago—March 20

Field trip through Quality Control Facilities of Zenith Radio Corp. Host: Mr. John Trzyna, Mgr. Outgoing Quality.

Los Angeles—April 20

"Reliability Vibration Testing at Low Cost," L. Woods, L. C. Miller Co.

SPACE ELECTRONICS AND TELEMETRY

Albuquerque-Los Alamos—April 14

"Reduction of Bandwidth Through the Use of Statistical Techniques in Information Transmissions," A. S. Westneat, Jr., Appl. Sci. Corp. of Princeton.

San Francisco—March 17

"Transmission of Intelligence in the Induction Field," D. G. Curphey, Dalmo-Victor Co.

San Francisco—April 28

"Digital Control Systems—High Predictability with Low Cost," O. E. Thompson, Secode Corp.

San Francisco—May 19

"Instrumentation of Pioneer IV, Lunar Probe," J. Casani, Jet Propulsion Lab.

Washington—May 19

"Communications Satellites," L. Jaffe, NASA.

VEHICULAR COMMUNICATIONS

Detroit—May 27

"Trans-Horizon 160 mc Measurements and Interference Considerations," Lloyd Morris, Motorola, Inc.

BROADCAST TRANSMISSION/COMMUNICATION SYSTEMS/VEHICULAR COMMUNICATIONS

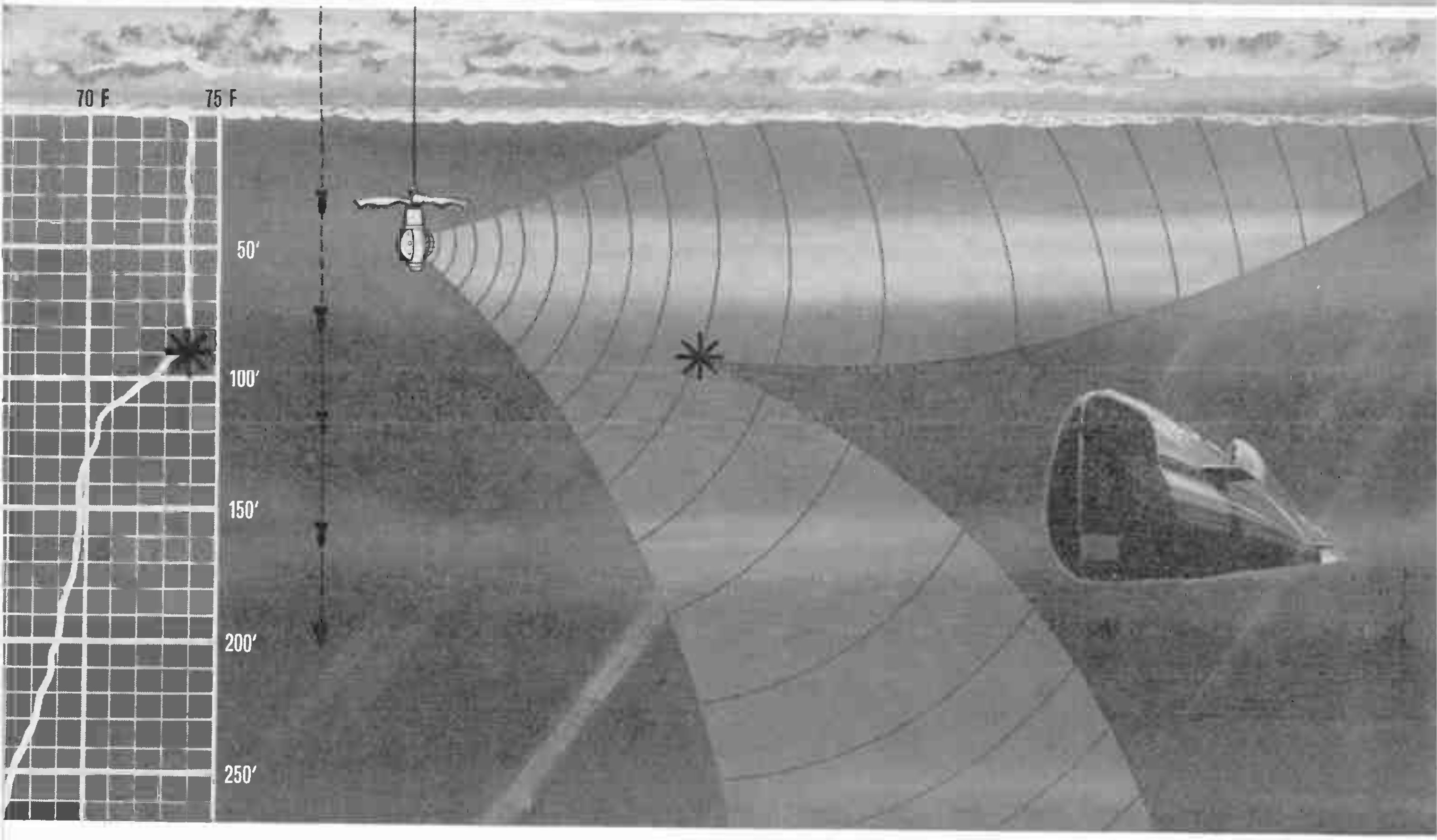
Omaha-Lincoln—May 22

"Compatible Single Sideband," L. R. Kahn, Kahn Res. Labs.

idea:

Submarines can hide within range of helicopter-borne sonar by "riding the thermocline"—a water temperature change that casts shadows in sonar search patterns. Precise temperature-vs.-depth records allow the operator to spot thermoclines and change his search pattern to look into the shadows. Existing gear "worked", but it took too long and could not define the shadow zones very accurately. TI engineers created an automatic recorder, the **bathythermograph,** more accurate than a laboratory thermometer, that gives results instantly where they were needed — in the helicopter. Small as a portable typewriter, it easily fits with the sonar into the space available.

RESULT: Same sonar—fewer missed submarines.



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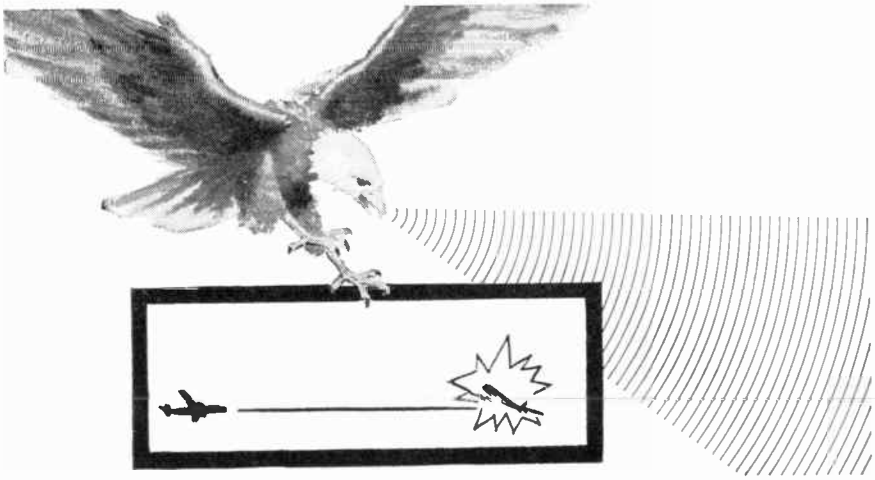


Industrial Engineering Notes*

Association Activities

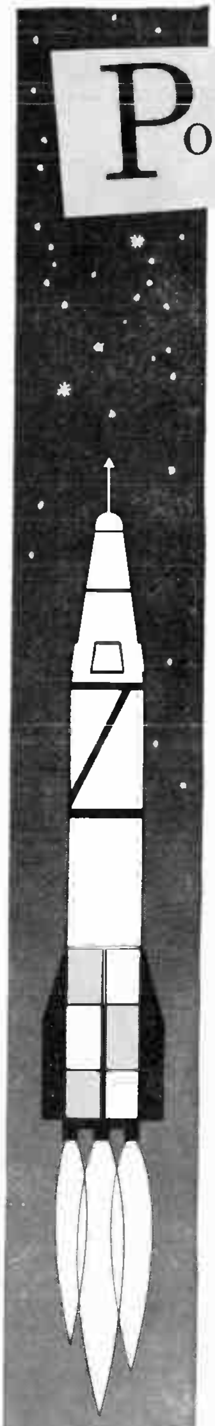
At the 35th Annual Convention of the Electronic Industries Association, in May, 1959 the EIA Board of Directors elected D. R. Hull as President of EIA for a second year. Award of the 1959 EIA Medal of Honor to Frederick R. Lack, former vice president and director representing the Military Products Division, was another highlight of the conference. All five Vice Presidents, Treasurer Leslie F. Muter, and Executive Vice President James D. Secrest were reelected. Six new Directors, two new division chairmen, and one department head were elected. All other Directors and division chairmen were reelected. Dr. W. R. G. Baker was elected to a new position of Director Emeritus of the Engineering Department. . . . **An optimistic report on the state of the electronics industry and the progress of the Electronic Industries Association during the past year was made to EIA members by President D. R. Hull at the annual membership luncheon.** Noting that the present mood of EIA members was in sharp contrast with that of last year during the recession, Mr. Hull predicted that the recent upgrade in electronics business would continue through 1959 and probably for several years thereafter. He estimated that total electronics sales at the factory level will rise to $9 billion this year for a new record and that military procurement of electronic equipment and components will continue to rise. The military market for electronics, which now absorbs 52 per cent of the industry's sales and 30 per cent of the Department of Defense's major procurement dollars, will approach $5 billion this year, Mr. Hull said. Part of this increase, he explained, is due to the fact that the electronic portion of missiles is increasing and this year will total about $2 billion. President Hull also called attention to a study of the EIA Marketing Data Department which forecasts expenditures of about $4.8 billion for electronics by civilian space agencies through 1970. This represents 33 per cent of the total anticipated requirements for civilian space equipment, he said. . . . **All Division and Department heads and major committee chairmen reported on their respective activities and the state of the industry during the 35th annual convention in Chicago.** Executive Vice President James D. Secrest announced that for the first time all EIA annual reports will be published this summer in an illustrated brochure. Some of the more newsworthy highlights of the annual reports were:

Consumer Products—While TV set sales declined in 1958, along with most other consumer goods, radio and phonograph

(Continued on page 164A)

* The data on which these Notes are based were selected by permission from *Weekly Reports*, issues of May 25, June 8 and 15, published by the Electronic Industries Association whose helpfulness is gratefully acknowledged.

Power Through Solid State Physics



Delco Radio is a world leader in automotive radio engineering and production. And, since our beginning in 1936, we have grown steadily, keeping pace with the rapidly expanding electronics industry.

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COMPUTER ENGINEERS for development of control type, special, or general purpose units. Experience in digital to analog and analog to digital converter design. Or magnetic core or drum type memory. Mechanical engineers for package design. Electronic engineers for test design, servo-analysis, and circuit design.

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SEMI-CONDUCTOR SALES ENGINEERS—Also customer assistance engineers. Prefer semi-conductor applications or similar experiences.

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DELCO RADIO

DELCO RADIO DIVISION OF GENERAL MOTORS

KOKOMO, INDIANA

Industrial Engineering Notes

(Continued from page 162A)

sales increased over the previous year, Chairman Robert S. Bell reported. The radio-phonograph increase, he said, is due largely to "improvements in sound reproduction for phonographs (stereophonic) and new compactness and reliability in radio portables (transistor)." Consumers have purchased 8.6 million table, clock, and portable radios since EIA's 1958 convention—400,000 more than during the previous fiscal year. Transistorized portable radios increased from 2 to 3.3 million. Auto radios rose 17 per cent—4.8 million units during fiscal year 1958–59 vs 4.1 million during fiscal year 1957–58. "The dynamic phonograph industry," Mr. Bell said, "has provided the public with a new product which it is receiving enthusiastically. During 1957–58, only 50,000 stereophonic phonos were sold by factories. EIA estimates 2.2 million stereo units have been sold this year. While the impact of stereo has brought an expected decline in monaural sales from 4.4 million to 2.5 million units, total sales of monaural and stereo are up from slightly under 4.5 million to more than 4.7 million units. Consumer purchases of television declined from 5.9 million units last year to 5.2 million during this past year. However, consumer purchases during March and April were ahead of the same months last year. Factory production holds near the 100,000 per week mark and is now 15 per cent ahead on a 'year-to-date' basis." *Tube and Semiconductor*—The past fiscal year was one of the most dynamic and progressive for the EIA Tube and Semiconductor Division, Chairman D. W. Gunn reported. Citing the increased strength of the Semiconductor Section, he said: "This is a youthful industry and the usual growing pains are apparent. Semiconductor sales reached $226 million in 1958. This compares with semiconductor sales of $172 million during 1957, or 19 per cent of total valving device sales of $925 million. During the five year period beginning with 1954 and ending with 1958, the dollar value of transistor sales by factories has increased more than 20 times from $5.1 million to $112.7 million. The germanium silicon semiconductor diode-rectifier industry has increased during the same period nearly 4 times, from $20 million to $96 million. Industry sources envision a continued growth in the semiconductor market. It is possible that the $300 million mark for all semiconductors will be reached during 1959. By 1965, semiconductor manufacturers may well be sharing a $1 billion annual market." *Marketing Data Department*—The electronics industry generally has enjoyed a continuance of its growth during the fiscal year 1958–59 according to Chairman Frank W. Mansfield of the Marketing Data Department. The military market in 1959 "is expected to reach the $5 billion level, in terms of factory sales, and to exceed the $21 billion level by 1970," he said. "Sales of transis-

(Continued on page 166A)

National Gallery of Art, Washington, D.C.

(Continued from page 164A)

tors, which have increased more than twentyfold in terms of dollars since 1954, may well rise to the $200 million level—nearly 100 per cent greater than the $113 million sales recorded during 1958. With these strong growth factors, total factory sales of the electronic industries should easily reach the $9 billion mark during the calendar year 1959 as compared to $7.5 billion last year. Already the fifth largest U. S. industry employing 700,000 persons in manufacturing, these new sales levels promise a rapid ascendancy to an even higher rank." *International Department*—U. S. exports of electronic equipments and parts increased by nearly 10 per cent between 1957 and 1958, according to Chairman Ray C. Ellis, of the International Department. Electronic exports totaled $427 million in 1958, or nearly 6 per cent of the industry's total production, he said. Radio shipments increased from 298,000 units worth $7,967,000 in 1957 to 316,000 units with a value of $10,258,000 in 1958, Mr. Ellis said. From the 156,000 television receivers priced at $19,583,000 exported in 1957, the total rose to 219,000 sets valued at over $25 million in 1958. Chairman Ellis reported that all segments of the tube industry recorded export gains between 1957 and 1958, with the most spectacular increase being registered in the semiconductor field where exports jumped from 2.7 million units worth $4.2 million in 1957 to 5.8 million units worth $7.8 million in 1958. In addition to the number of components used in the end equipments exported, Mr. Ellis said, direct 1958 exports increased to 40.6 million capacitors, 43.6 million resistors, 5.7 million inductors and 508,000 speakers. The value of unclassified parts and accessories increased from $27.6 million in 1957 to $31.8 million in 1958. *Credit*—The 1958 depression was reflected in the electronics industry, according to a report of the Credit Committee. The Committee's annual report covered the 12 month period ending April 30 and was prepared by Chairman D. B. Shaw. While there was an over-all gain of 15 per cent in the number of companies experiencing financial difficulties in 1958–59 as compared with the previous year, the level still is below 1955 or 1956, Mr. Shaw said. The report noted that 31 electronic manufacturing concerns and 16 distributors had financial trouble during the 12 month period as compared with 27 manufacturers and 14 distributors in the 1957–58 period. These totaled 47 and 41, respectively, as against combined totals of 52 concerns in 1956–57 and 51 in 1955–56. Component manufacturers failures increased 50 per cent, the report said, while radio and TV producers having financial

(Continued on page 168A)

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. . . where there's time and opportunity to enjoy yourself while climbing to the top in the field you like best.

It's summer in Minnesota. Fish are biting—right here in Minneapolis. Boys and girls are curling their toes in the warm sand along the beaches of our 23 lakes. They're taking in water carnivals, playing baseball, relaxing in cool breezes. Some families go camping nearly every weekend—up along the pine and balsam fringed shore of Lake Superior. Great country, this Minnesota. You should be here with your family—and you can be . . .

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- Advanced Digital Computer Circuit Development
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Industrial Engineering Notes

(Continued from page 166A)

difficulties declined to one. "Our study," Mr. Shaw said, "also indicates that during 1957 the average recovery was about 35 per cent but that during 1958 the average recovery is around 20 per cent. Of the manufacturing companies in financial difficulties only 16 are continuing in business," he added. "Total liabilities among manufacturers were up to $19,082,000 as compared with $12,678,000 in 1957 and $18,720,000 in 1956."

Military Electronics

A revision of the 1957 Environmental Requirements Guide for Electronic Component Parts, published by the Department of Defense for use by the Armed Forces, has been released to the public by the Department of Commerce. In addition to the R&D environmental design requirements for current and future electronics planning, the guide also reviews appropriate test procedures. Information presented in the original guide, published in 1957, is brought up to date. Electronic components dealt with include basic circuit elements such as capacitors, resistors, switches, relays, transformers, crystals, waveguides, electron tubes, and semiconductor devices. The parts are divided into eight groups depending on the requirements of their application. These groups cover use in shipboard and ground components; high-performance and nuclear-powered aircraft; nuclear-powered weapons and missiles; and other applications having special requirements. The volume, PB 131423R *Environmental Requirements Guide for Electronic Component Parts*, Advisory Groups on Electronic Parts and Electronic Tubes of the Department of Defense, March 1959, may be ordered from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. It contains 13 pages, price 50 cents.

Governmental and Legislative

Efforts have been made by the government to update and further refine the data to be published by the Bureau of the Census in connection with the 1958 Census of Manufacturers. The new move was agreed upon at a meeting of various government officials, including representatives of Census and the Bureau of the Budget. The electronics industry is understood to be one of several which would obtain more refined figures than would be possible under the designations or codes of the current Standard Industry Classification manual. EIA learned that the interdepartmental group recommended that Census publish the results of the 1958 manufacturers survey under both the old SIC classifications and a new and more definitive breakdown of the electronics and some other industries sections. As an example the new proposal, it is understood, includes separate codes or classifications

(Continued on page 170A)

Industrial Engineering Notes

(Continued from page 168A)

for such electronic items as navigational aids and missile control guidance systems and related equipment. . . . **The Department of Commerce has announced that bids are being invited for a tropospheric scatter link to be established between the Egyptian and Syrian regions of the United Arab Republic.** Preferred sites of the scatter terminals are Saroukhia in Syria and Port Said in Egypt, approximately 280 miles apart. The project covers supply and installation of tropospheric scatter equipment, including aerials, transmitters and diversity receivers, 24 voice channels, carrier broadcast terminals, telegraph terminal equipment, standby power plant, auxiliary equipment and apparatus, as well as an optional offer of VHF link of about 19 miles between Saroukhia and Damascus in Syria, and 31 miles between Port Said and a site in Egypt. Bids, accompanied by a provisional deposit of two per cent of the value of the proposed contract, should be submitted to the Director General, Radiocommunication Administration, 9 Cherifein Street, Cairo, as soon as possible. Copies of the specifications may be obtained from Bureau of Foreign Commerce Trade Development Division, U. S. Department of Commerce, Washington 25, D. C. . . . **Commissioner T. A. M. Craven has announced the appointment of George K. Ashenden, Jr., as his engineering assistant.** Since joining the Commission in 1941, Mr. Ashenden has served in engineering capacities with the Field Engineering and Monitoring Bureau at the Kingsville, Texas, monitoring station and the 9th District Office at Houston, transferring to Washington, D. C., in 1952 as an engineer with the Broadcast Bureau in its Aural and Television Facilities Divisions. In 1955 he moved to the Office of Opinions and Review where he was serving as a reviewing engineer at the time of his new appointment.

Engineering

The Engineering Department has recently announced the availability of Components Bulletin No. 2 entitled *Contamination of Printed Wiring Boards*. This twenty-five page document defines the types of contamination and gives tests for determining both the sources of such contamination and their effects. This report was prepared by representatives of Committee 40C on Printed Wiring and may be purchased at $1.25 from the Engineering Office, 11 West 42 Street, New York 36, N. Y.

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 32A)

Microwave Power Supply

Production of a 4000-volt electronic power supply designed to power and modulate any klystron used in laboratory and production testing of radars and other microwave equipment was announced by **Sperry Microwave Electronics Co., Div., Sperry Rand Corp.,** Clearwater, Fla.

The new universal design, half the size of earlier klystron power supplies, can also operate low-power magnetrons and traveling wave tubes.

Automatic switching and other control features greatly simplify operation of the unit.

Electrode voltages supplied by the unit range from +150 to −4000 volts to provide the greatest operating range and power capacity yet available in small bench-top supplies. New electronic circuits automatically regulate output voltages to less than one part in 10,000 for precise control and stable operation of sensitive microwave amplifiers and oscillators. Switching of the beam voltmeter is also automatic.

The unit supplies square wave, sawtooth, and sine wave voltages for generating pulse, frequency or phase modulation information in the outputs of microwave tubes. It also contains an amplifier which can boost other modulation voltages derived from external source.

The unit operates on 800 watts of ordinary 60 cps, 110-volt current.

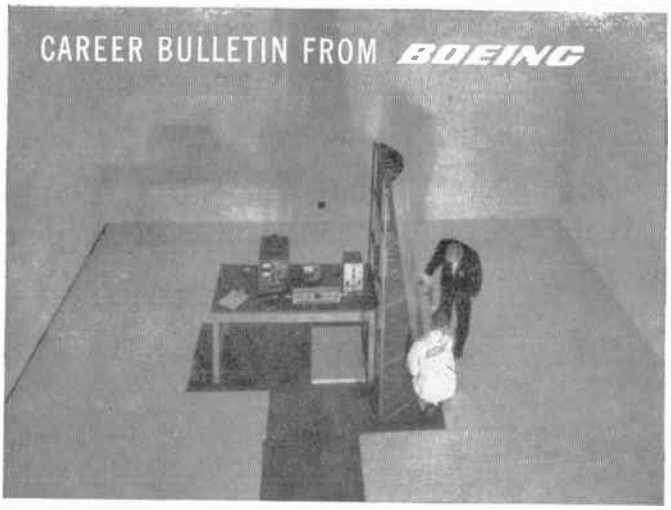
Digital Instrumentation Catalog

A new 12 page two-color digital instrumentation catalog has been released by **Computer Measurements Co.,** 5528 Vineland Ave., North Hollywood, Calif.

Thirty-two instruments and accesories are described including a new transistorized 150 kc frequency-period meter, a new digital voltmeter, and a fast versatile digital printer. Other instruments included in the catalog are universal countertimers, frequency-period meters, time interval meters, inline-inplane readouts, electronic go-no-go gauges, preset counter controllers, and decade counting units.

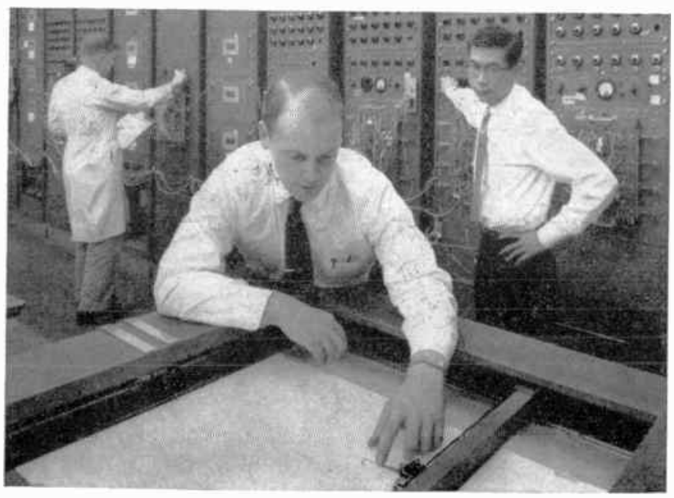
For your free copy, please write to the firm.

(Continued on page 174A)

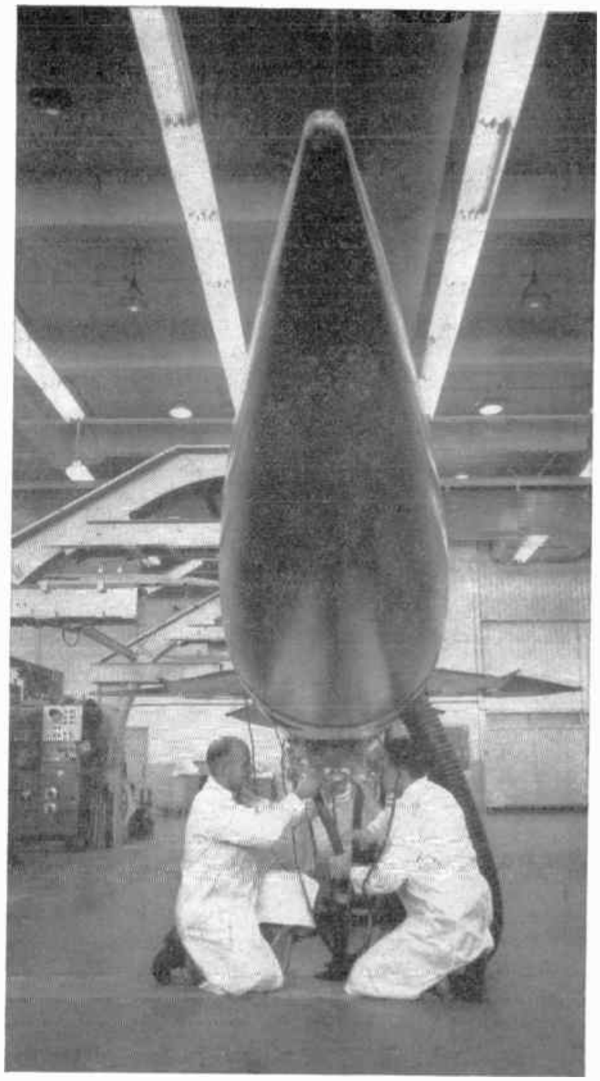


FREE-SPACE ROOM in Boeing antenna and radar laboratory, built for advanced antenna and radome development and testing. Expanding missile and advanced jet aircraft projects at Boeing provide outstanding career opportunities for engineers in virtually every area of electronics.

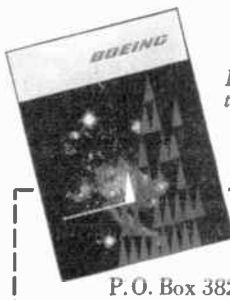
BOEING-DEVELOPED and built electronic counter-measures simulator, typical of many advanced areas of assignments open at Boeing in electronics. Openings also available in fields of infrared techniques, radar and beacon interrogator systems, electronic circuitry, and guidance and control systems, among others. Boeing research and development facilities are the most extensive in the industry. They could help *you* get ahead faster.



ANALOG COMPUTER installation used to simulate missile trajectory, ground control and terminal guidance. Boeing missile assignments are available on BOMARC, the nation's longest-range supersonic defense missile, and on Minuteman, an extremely advanced solid-propellant intercontinental ballistic missile system.



BOEING ENGINEERS attaching missile monitor plug for dynamic compatibility test of BOMARC interceptor. In addition to wide variety of simulated tests, BOMARC test firings are conducted at Cape Canaveral, Florida. Expanding Boeing projects offer engineers and scientists outstanding career openings, all with plenty of opportunities for advancement.



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Mr. Stanley M. Little,
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P.O. Box 3822 - PIC, Seattle 24, Washington.

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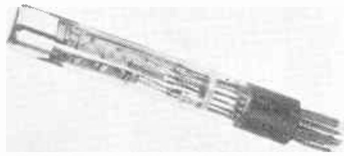
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 172A)

Multiplier Phototubes

Two new $\frac{3}{4}$ inch diameter multiplier phototubes for use where size and weight are important considerations are announced by the **Electronic Tube Div., Allen B. Du Mont Laboratories, Inc.,** 750 Bloomfield Ave., Clifton, N. J. Both tubes have 10 dynode stages and feature potted bases for moisture and shock resistance, socket elimination, and noise-free connections.

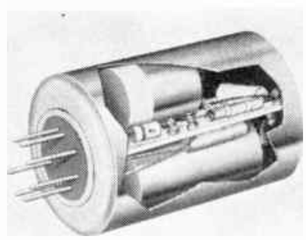


Applications include deep-down geological exploration, aircraft and space vehicle installations, medical probing, scintillation probes, spectroscopy, and various low level light source analysis. The two tubes that are announced are identical in design and performance except in secondary emission characteristics. Type 6362 with silver magnesium dynodes features maximum stability at high voltages, while Type 6934 with cesium antimony dynodes features high gain at low operating voltages.

For technical specifications and additional information write to the firm.

Voltage Reference

A voltage reference which is extremely stable over wide variations in input and environment is announced by **Networks Electronic Corp.,** 14806 Oxnard St., Van Nuys, Calif.



Unit has a 1-volt output operating into 1000 ohms. It holds this output to within ±1.2 millivolts over input conditions from 100 to 130 volts, at frequencies from 25 cps to 10,000 cps. The 1-volt output is maintained over an operating temperature range of −55°C to +100°C, and any combination of specified variations in tem-

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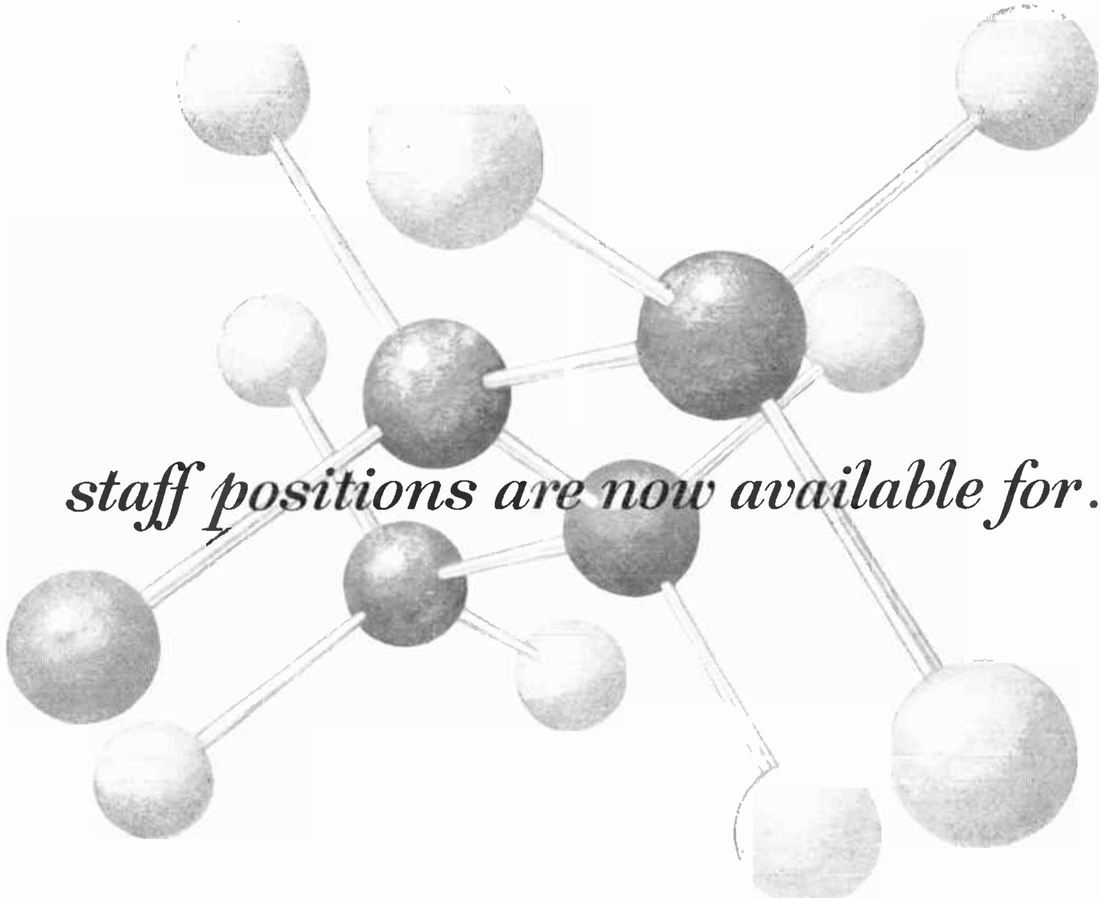

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Argonne provides a unique combination of basic and applied research . . . effective inter-disciplinary approach to major problems . . . dedication to knowledge of interest and significance to the individual . . . atmosphere and facilities conducive to creativity . . . opportunity for professional growth and individual expression. The positions described represent some of the Laboratory's specific opportunities. However, staff positions are available in virtually all of the major scientific and engineering disciplines.

- **B.S. Electrical Engineer** with 3-5 years of experience for work in the adaptation of commercial type television to problems of remote viewing—advanced techniques for stereo viewing—radiation damage effects and closed circuit television.

- **B.S.-M.S. Electronics Engineer** for work in reactor instrumentation and research.

- **B.S.-M.S. Computer Engineer** to work in the areas of logical design, circuit design, and data processing systems design.

- **B.S.-M.S. Electrical Engineer** to assist in engineering and design primarily concerned with large pulsed power supplies, power utilization as related to the Argonne 12.5 Bev proton synchrotron. Includes unusual engineering applications of large rotating equipment, rectifiers, and associated equipment for experimental work.

- **B.S.-M.S. Electronics Engineer** to assist in the design and development of switching circuits, timing circuits, and computer and data processing circuitry related to the Argonne 12.5 Bev proton synchrotron.

- **B.S.-M.S. Electrical Engineer** for design of primary power distribution systems, industrial plant distribution systems, selection of switch gear, transformers, regulating transformers, generators, motors, motor starters, controls, design of control, lighting and interior power systems, and preparation of specifications relating to pertinent equipment.

Argonne

NATIONAL LABORATORY

Operated by the University of Chicago under contract with the United States Atomic Energy Commission.

Direct Inquiries To: DR. LOUIS A. TURNER, DEPUTY DIRECTOR
P.O. BOX 299-Q2 · LEMONT, ILLINOIS

NEWS New Products

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(Continued from page 174A)

perature and power input. Unit is designed to meet MIL-E-5272A.

Power required is 3 VA nominal. Dimensions: 1.75 long × 1.35 inches diameter. Unit weighs 3 ounces, and mounts in any position. The glass-seal header has 7 pins for a miniature tube socket.

This regulator is used as a reference voltage source in power supplies, metering circuits, and strip chart recorders. Units are in production.

X-Y Recorder

Milgo Electronic Corp., 7601 N.W. 37th Ave., Miami 47, Fla., announces the *X-Y* Recorder MEC Model 3010 designed to operate in conjunction with digital computers, coordinate converters, and other analog devices. It provides two simultaneous ink recordings, each recording consisting of an *X-Y* or *X-H* plot in a Cartesian Coordinate System. These plots are accomplished by means of two individual recording pens each mounted on a separate moveable arm capable of transversing the entire recording surface. Automatic, all

(Continued on page 178A)

NEWS New Products

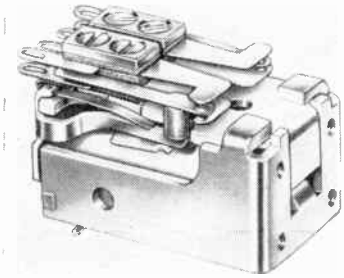
These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 176A)

electronic function interchange circuits are provided to assure that these two arms do not collide. A timing pen that moves in conjunction with the recording pen is provided on each arm.

The accuracy of the recorded plot is within 0.05 per cent of the input signal. Higher accuracies are available upon request. Slew speed in each axis is up to 50 inches per second. Acceleration in the vertical axis is up to 1,500 in/sec², in the horizontal, up to 500 in/sec². Pen actuating speed is up to 100 marks per second.

Miniature Relay



Comar Electric Co., 3349 W. Addison St., Chicago 18, Ill., announces the type TQA is a sturdy, yet sensitive, miniature relay intended for dc operation at sensitivities from 20 to 100 milliwatts. Where shock and vibration are negligible, sensisitivity of 15 milliwatts per pole is available. Contact assemblies, forms A, B or C, have up to a total of 18 springs. Contact rating with resistive load at 28 vdc, or 115 vac: silver contacts, 3 amperes; palladium or gold alloy, 0.5 amperes. Contact life is 100,000 operations, minimum. Operating temperature is −55 to +100°C. Also available, −65 to +125° C on special order. Shock: Up to 50G. Vibration: Up to 10G, from 10 to 500 cps. Available in hermetically sealed enclosures as Type TQAH.

DuBois Purchases Tech Art Plastics

Tech Art Plastics Co., Morristown, N. J., the world's first molder of organic plastics, has been purchased by J. Harry DuBois of Montclair, N. J. DuBois is proprietor of his own plastics consulting firm and is a director of National Beryllia Corp. He will become chairman of the board of Tech Art.

Harold J. Cook of Plainfield, N. J., will continue as president of the company.

Tech Art Plastics was established in 1891. In 1907 Richard W. Seabury, then general manager of Boonton Rubber Co., learned from Dr. Leo Hendrik Baekeland of his invention of the new synthetic phe-

(Continued on page 180A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 178A)

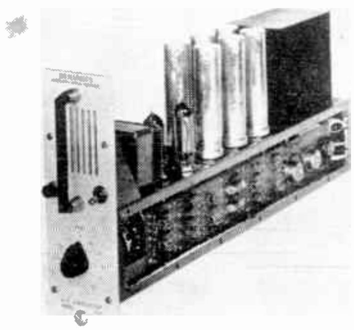
nolic resins, which appeared to offer many possibilities as replacements for Seabury's rubber and sulphur combination. Seabury obtained some of Baekeland's phenolic resin, mixed it with asbestos and produced the first commercial phenolic molded products for Weston Electrical Co. These parts were so useful and successful that Seabury immediately developed a molded product market for Baekeland's invention. Thus, Richard W. Seabury was among the first to foresee the future of organic plastics in the molded products field and Boonton Rubber (now Tech Art Plastics Co.) became the world's first molder of organic plastics. The firm name was changed to Tech Art Plastics Co. later, when plastics became dominant over molded rubber products. It is interesting to note that in this 68-year cycle, synthetic rubber plastics have again become important, and the company is again in the "rubber" products field where the new elastomers provide superior properties for critical application.

A 1000-ton press with 9-foot daylight opening, particularly suitable for nose cone and radome molding, is available for missile programs.

Tech Art sales are handled by Insulating Fabricators Company, East Rutherford, N. J., and by Insulating Fabricators Company of New England, Watertown, Mass.

Wideband Instrumentation Amplifier

Dynamics Instrumentation Co., Div. of Alberhill Corp., 1118 Mission St., South Pasadena, Calif., has developed a linear instrument amplifier with integral power supply, the Model 1634 which offers voltage gains from 1 to 100 with 100,000 ohm input impedance in a low-noise all-transistor design.



A 2 cps to 100,000 cps ($\pm$0.5 db) frequency response makes the model 1634 fully compatible with other elements of modern instrumentation systems such as wideband magnetic tape recorders.

Cables (up to at least 2,000 $\mu\mu$f) can be driven without signal distortion up to 50,000 cps. The transistor output circuits provide low voltage high current cable drive efficiently and reliably.

AC Potentiometer

A 40-ohm output impedance with a linearity of ±0.01 per cent is obtained in a new ac potentiometer developed by the **Vernistat Div., Perkin-Elmer Corp.,** Norwalk, Conn.

The new precision potentiometer designated as the "Vernistat" Model 3-B, substantially eliminates loading error problems with its low output impedance, and its high order of accuracy makes it well suited for use as a component in inertial guidance, navigation, fire control, and other analog systems.

The "Vernistat" was developed by Perkin-Elmer to meet the need for a servo component with low output impedance, high linearity, high resolution, and minimal phase shift combined in a small lightweight package. These characteristics are obtained by the combination of a precision wire-wound potentiometer and a precisely tapped autotransformer. The performance of this combination has often resulted in the elimination of isolation amplifiers and other system components, and the appreciable reduction of noise problems encountered in many analog applications.

Voltage Regulated Power Supply

A completely new line of all semiconductor voltage regulated power supplies is now offered with "off the shelf" delivery from **Transistor Devices, Inc.,** 11 Hamburg Turnpike, Riverdale, N. J.

(Continued on page 182A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 181A)

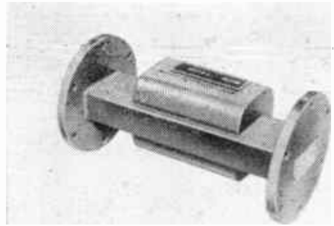
Taking advantage of the economies of unitized design, the entire series is built up from the same mechanical parts and the savings are reflected in the low cost. All models in the series are completely interchangeable, replacement is accomplished by merely plugging in the desired unit.

Among the features are included variable output voltage, good regulation, variable supply frequency operation and complete protection against short circuits. Nonsealed construction enables maintenance of these supplies, they need not be discarded if a capacitor fails!

All units are unconditionally guaranteed to meet specifications and to be free from defects due to materials or workmanship. Regulation is 0.1 per cent line or load. Ripple is 2.5 mv maximum. Multiple frequencies are usable from 60 to 400 cps.

Ferrite Isolators

A new line of Ferrite Isolators designed to optimize the output from microwave generators by completely isolating them from reflected load signals, is announced by **Polytechnic Research & Development Co., Inc.**, 202 Tillary St., Brooklyn 1, N. Y.



Covering the frequency range from 3.95 to 12.4 kmc in three broadband models, these isolators have an insertion loss of 1.0 db and a vswr of 1.2. Each covers an entire waveguide band.

Conservatively rated at 5 watts, these isolators can actually handle up to 25 watts with only a temporary electrical degradation. Model 1205 covers the entire 2×1 inch waveguide range with a minimum isolation of 16 db. Model 1204 covers the entire $1\frac{1}{2}\times\frac{3}{4}$ inch waveguide range with a minimum isolation of 20 db. Model 1203 covers the entire $1\times\frac{1}{2}$ inch waveguide range with a minimum isolation of 30 db.

For further information write to the firm.

Hercon Electronics Formerly Hermetic Connector

Hermetic Connector Corp., announces the formal changing of the company name to: **Hercon Electronics Corp.** The address will remain the same—481 Washington St., Newark, N. J., the telephone number is new—MArket 2-2402.

(Continued on page 184A)

ENGINEERS

These **2** *Halves* → **QUALITY ENGINEERING** / **STATE-OF-THE-ART ADVANCES** → *Make a Whole Job*

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"*There's nothing finer than a Stromberg-Carlson*" is as true of its diversified research and development projects as it is of the famous radio-phonographs.

Examples of the diverse areas in which qualified engineers may enjoy full utilization of their professional know-how and creative talents are: *research in non-acoustic detection... new development in sonar... electronic passive reconnaissance system of global scope for which S-C is both Systems Manager & Prime Contractor... revolutionary developments in telecommunications . . . nuclear instrumentation for Enrico Fermi Atomic Power Plant... a new approach to Single-Sideband radio*

One evidence of the frequency with which outstanding individual contributions occur at S-C lies in the fact that 174 patents were issued to inventors here in 1958 with 385 more still pending at year's end. (A substantial number of these represent applications of solid state devices.)

Currently opportunities exist in these areas:

NUCLEONIC SYSTEMS ENGINEERS

Degree in EE or Physics and experience in the development of system philosophy in nuclear reactor instrumentation. Work includes application of solid state devices to nuclear instrumentation and control with emphasis on monitoring, safety and neutron measurement.

SALES ENGINEERS

Specific sales experience in one of the following areas required: Navigational Systems... Automatic Test Equipment... Sonar Systems.

PRODUCTION ENGINEERS

IE, EE, or ME degree with experience in production of electronic equipment.

COMMUNICATIONS SYSTEMS

SECTION HEAD—*Human factors. Recognized authority in the application of human factors within the military electronics field. PhD desirable.*

ENGINEERING MANAGER — *Antenna Systems Design and analysis, HF to SHF. Requires supervision of design engineers and antenna fabrication.*

SENIOR RECEIVER ENGINEERS—*Broadband, low-noise receiver design—HF, VHF, UHF, microwave—panaramic, signal seeking and manual.*

SENIOR ENGINEERS—*System Integration Standardization of "black boxes," hardware and components requiring broad knowledge of electronic systems design problems.*

TECHNICAL WRITERS

EE degree or equivalent with technical writing experience. To work on military publications. Must be capable of working with schematics, electronic equipment and specifications to derive theory and maintenance information.

MICROWAVE ENGINEERS

For work in fields of navigational equipment, countermeasures, automatic test equipment and missile instrumentation. Specific experience desired in microwave system analysis, design of microwave components, amplifier converters, tunable and fixed filters or coaxial and waveguide components.

▶ *All inquiries in confidence. Please address your resumes to* Fred E. Lee, Manager of Technical Personnel.

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STROMBERG-CARLSON DIVISION

1476 N. Goodman St., Rochester 3, New York

NEWS New Products

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(Continued from page 182A)

These changes are the result of the growth in the past three years at Hercon in both personnel and production facilities. The product roster now includes: Crystal Mounts, Transistor Mounts, AN-Type Connectors, Single Terminals, Multi-Headers, Diode Closures and custom designed Glass-To-Metal Seals.

New Instrument Company

The formation of **Analab Instrument Corp.**, 30 Canfield Rd., Cedar Grove, N. J., to design and manufacture ANAlytical LABoratory Instruments for Science and Industry was announced today by Morton G. Scheraga, President of the new corporation. Scheraga stated that the corporation is now ready to begin operations in the field of scientific instrumentation since the initial stock issue has been fully subscribed in a private offering.

"The specific plans for Analab Instrument Corporation call for us to assemble a team of engineers to develop a line of unique new products in the broad area of instrumentation," said Scheraga.

Officers of the new Corporation are: Morton G. Scheraga, President; Glee O. Marsh, Vice-President and Treasurer; and Robert B. Shepard, Jr., Secretary.

Klystron Power Supply

Latest addition to the "Pacemaker" line of **Polytechnic Research & Development Co., Inc.**, 202 Tillary St., Brooklyn 1, N. Y., is the Type 812 Universal Klystron Power Supply.

The new wide-range klystron power sup'y features digital read-out for beam and reflector voltages; dual outputs for simultaneous operation of two klystrons; and front panel provision for checking calibration of reflector and grid voltage readings. The 812 also provides multi-range beam current overload protection;

(Continued on page 186A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 184A)

safety lock on transferring from negative to positive grid voltage; and external triggering of internal pulse generator.

Consisting of four separately regulated supplies, including beam, reflector, grid and heater, it is designed with internal modulation for pulse, square wave, sawtooth, and sine wave operation. Rise and decay time is only 2 microseconds maximum.

Voltage range of the beam supply is 200–3600 volts dc; current is 0–125 ma (limited to a load power of 360 watts maximum). Reflector supply has voltage range of 0 to 1000 volts dc negative; current of 50 microamperes maximum for stated output voltage accuracy. The grid supply voltage range is 0–150 volts positive and 0 to 300 volts negative; current is 5 ma maximum (positive grid).

The unit is $22\frac{5}{32}$ H$\times 20\frac{3}{16}$ W$\times 15\frac{3}{4}$ inches D), weighs about 180 lbs., and is suitable for rack mounting.

For further information, contact the firm.

Synchronous Timing Motors

The **A. W. Haydon Co.,** 232 N. Elm St., Waterbury, Conn., announced the introduction of a new line of synchronous timing motors for 25, 50 or 60 cps operation in five standard voltage ratings.

Main features of these motors are: Extremely thin design with available torque equivalent to much thicker motors, and completely electrical operation.

About $\frac{7}{8}$ inch thick, these motors were designed to occupy considerably less space than others available. Mounting dimensions conform to those of the industry in general.

The progressive design of these motors has completely eliminated the need for mechanical devices to control the direction of rotation of the motor. Although mechanical devices have been used in the industry for years, they have many troublesome disadvantages such as being noisy and offering only limited life.

The 22100 series motors described in Bulletin AWH MO-806 (available on request) meet all significant requirements of specification MIL-E-5272A. Also available is a non-military version (42100 series) for

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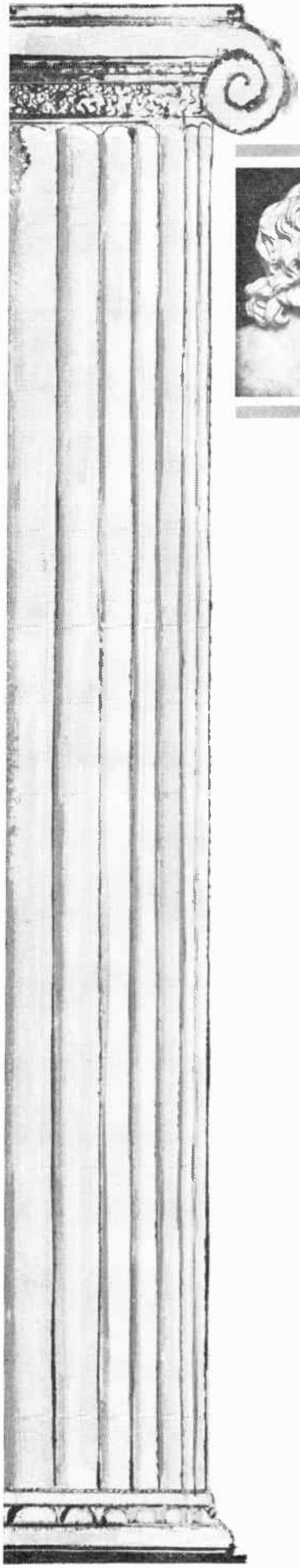

NEWS New Products

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(Continued from page 186A)

high volume industrial and commercial applications.

Over 125 standard output speeds from 300 rpm down to one revolution in six hours can be supplied with either standard or heavy duty gear trains. With a nominal 30 ounce/inch running torque at 1 rpm, these motors can be used in a wide variety of applications.

Balog Named Plant Manager by CBS

Michael Balog has been named plant manager of the **CBS-Hytron** receiving-tube plant in Newburyport, Mass., it has been announced by Michael F. Callahan, vice-president of CBS-Hytron and general manager of the firm's receiving tube operations. He replaces Joe Harmony, who has been named director of general engineering for receiving tube operations. Balog was manager of the semiconductor division for Sylvania Electric Products Inc.

He began his career in the electronics industry in 1941 as an engineer in Sylvania's receiving-tube operations at Emporium, Pennsylvania. In 1949, he was named manager of production engineering at that location, and in 1954, was made manager of the firm's receiving-tube operations at Mill Hall, Pa. He was appointed semiconductor division manager in 1958.

Balog was graduated from Penn State University with a degree in electrical engineering.

Semiconductor Power Supply

Model ME36-5EM Power Supply available from **Mid-Eastern Electronics, Inc.**, 32 Commerce St., Springfield, N. J., features a magnetic line voltage regulator and a transistorized regulator circuit. The line voltage regulator causes the voltage across the transistors to drop to zero when the output is shorted, thus reducing the amount of power the transistors must dissipate to a negligible value. The tran-

(Continued on page 190A)

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

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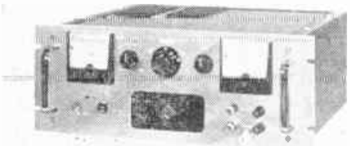

sistorized regulator permits a recovery time of considerably less than 50 μsec (in some cases as low as 7 μsec) with overshoot less than 1.0 per cent of the voltage setting. Output voltage is 0 to 36 volts continuously variable, with vernier control, at 0 to 5 amperes dc. Unit has external circuit protection with the output current cutoff adjustable over the entire range. Ripple is less than 1 mv rms. Line regulation is 0.05 per cent for changes between 105–125 volts ac, and load regulation 0.1 per cent from 0 to full load.

Power supply fits standard 19 inch relay rack and front panel measures 7 inches in height. Price F.O.B. Springfield, N. J. $610.00.

Inverter

Power Sources, Inc., South Ave., Burlington, Mass., reveals the development of an exclusive new technique for the design of transistorized inverters that is said to provide 100 per cent reliability with any dc input voltage. Inverters are now developed with inputs up to 130 volts dc. Theoretically there is no upper limit on the dc input.

In the past, 30–35 volts dc was the maximum input that could be reliably handled by transistors. This, of course, limited the applications of transistorized inverters because higher voltages, or transients, would blow out the transistors.

Power Sources new technique also permits the design of inverters which can convert directly from dc to ac without the use of an input transformer. This results in substantial reduction in size, weight and

(Continued on page 192A)

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These and other vital missile and space projects at DOUGLAS have created prime opportunities for

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Specialists critically needed in the following categories:

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Excellent opportunities also exist for

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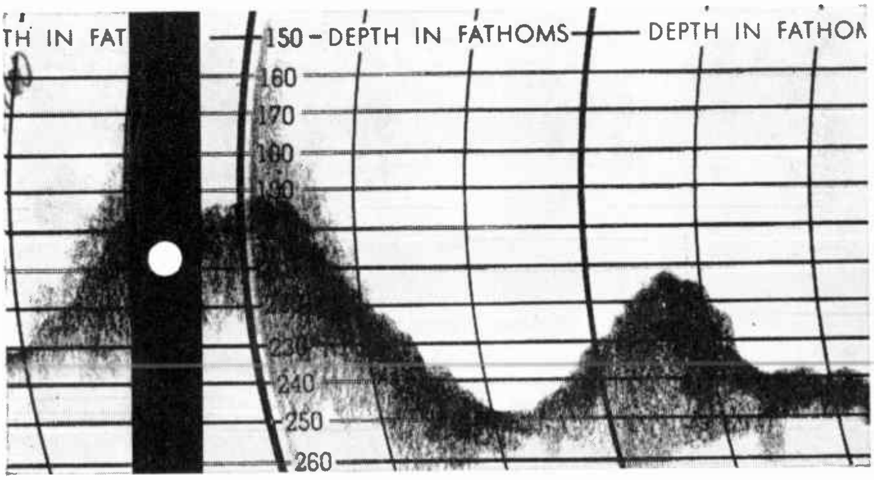

DATA SYSTEMS IN UNDERWATER RESEARCH

Work is expanding at IBM on the design of new information-handling techniques required to explore the depths of the ocean. These investigations in oceanography are expected to have far-reaching scientific and military implications. They will require major contributions from many fields. Original and basic work will be needed in acoustics, information theory, advanced network theory, delay lines and cross-correlation techniques. Work will include systems design, real-time data processing, analysis of experimental equipment, and hybrid analog-digital techniques in unique data processing configurations. All phases of these varied projects will provide excellent career opportunities for qualified engineers and scientists.

IBM is now interviewing personnel for the following specialties:

COMPUTER ANALYSTS: M.S. or Ph.D. in Physics or Engineering Science with strong math background. Navy experience in digital techniques for solution of real-time control problems is required. Must be capable of making mathematical analyses of fire and navigational control systems plus math analyses of beam formation, ray tracing and signal cross correlation.

SONAR SYSTEMS ENGINEERS: M.S. or Ph.D. in Physics or E.E. Should have extensive experience in Navy sonar systems analysis and design. Experience desired in signal data processing instrumentation, correlation analysis, propagation studies, beam formation and signal analysis.

SYSTEMS ENGINEERS: M.S. or Ph.D. in E.E. Navy experience in one or more of these specialties is desired: sonar, fire control, ASW, navigational systems or in applying information theory concepts to signal processing. Experience desirable in signal cross-correlation techniques, statistical data processing, sampled-data control theory, analog-digital data processing techniques, signal propagation and beam formation.

You will enjoy unusual professional freedom and the support of a wealth of systems knowledge. Comprehensive education programs are available—plus the assistance of specialists of many disciplines.

Working independently or with a small team, your individual contributions are quickly recognized and rewarded. This is a unique opportunity for a career with a company that has an outstanding growth record.

Write, outlining your qualifications and experience, to:

Mr. R. L. Lang, Dept. 645H2
IBM Corporation
Owego, New York

IBM® INTERNATIONAL BUSINESS MACHINES CORPORATION

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(Continued from page 190A)

cost. This technique also eliminates the need for a filter input or transient eliminator. It is applicable to square or sine-wave outputs. Inverters using this circuit will meet input requirements of MIL-E-7894A.

Electrical Connectors Brochure

America's spacecraft and missiles are pictured in full color in a 12-page brochure by **Burndy Corp.**, Norwalk, Conn., manufacturer of electrical connectors. Photographs and engineering drawings illustrate the company's principal connector types used in missiles and their ground-control equipment.

Environmental and performance standards of connectors for missile electrical and electronic circuits are reviewed. The publication outlines how connectors are engineered for the electrical characteristics, flexibility and reliability required of guidance, propulsion-control and telemetering systems.

A final section briefly discusses the installation of connectors for missile electrical systems. Types of hand operated, semi-automatic, and automatic tooling are shown, each designed for dependable, economical connector installation under specified conditions. Automatic machines install connectors at rates up to 4,000 an hour.

Copies of the brochure are available on request.

Furst Appointed by Vitramon

Mr. Lawrence Furst has been named Plant Manager of **Vitramon, Inc.**, Box 544, Bridgeport 1, Conn., manufacturers of specialized miniature electronic components in Trumbull, Conn.

Furst was associated since 1956 with the Arma Division in Garden City, L. I. of American Bosch-Arma Corp. He was engaged there in the formulation of new weapons systems concepts. He also contributed to the development of the Titan ICBM inertial guidance system and the fire-control system of the B-52 long-range bomber.

He had previously worked in the Special Devices Division of the Austin Company, where he did fundamental research in automated techniques.

Recognized as an authority in his field, Furst has been a frequent lecturer and contributor of scientific papers to technical societies on such subjects as scientific management, electronic reliability, cybernetics, automation, information theory, digital computers, missiles and space systems.

(Continued on page 194A)

Engineering careers grow better at Link-Palo Alto

The climate is right for achievement at Link-Palo Alto . . .
for your career, and for your enjoyment of life

Among the burgeoning projects at Link's attractive new laboratory are those requiring cultivation by engineers who have a green thumb with *analog and digital computers.* If you have such talents, you will want to investigate a career at Link - Palo Alto.

The professional atmosphere at Link is based on a recognition of technical competence and accomplishment. For those interested in advanced university study, Link will arrange tuition.

Salaries are excellent. The Link health, medical, and retirement plans are outstanding.

Palo Alto, a charming suburban community, offers an ideal location for career advancement and for raising a family.

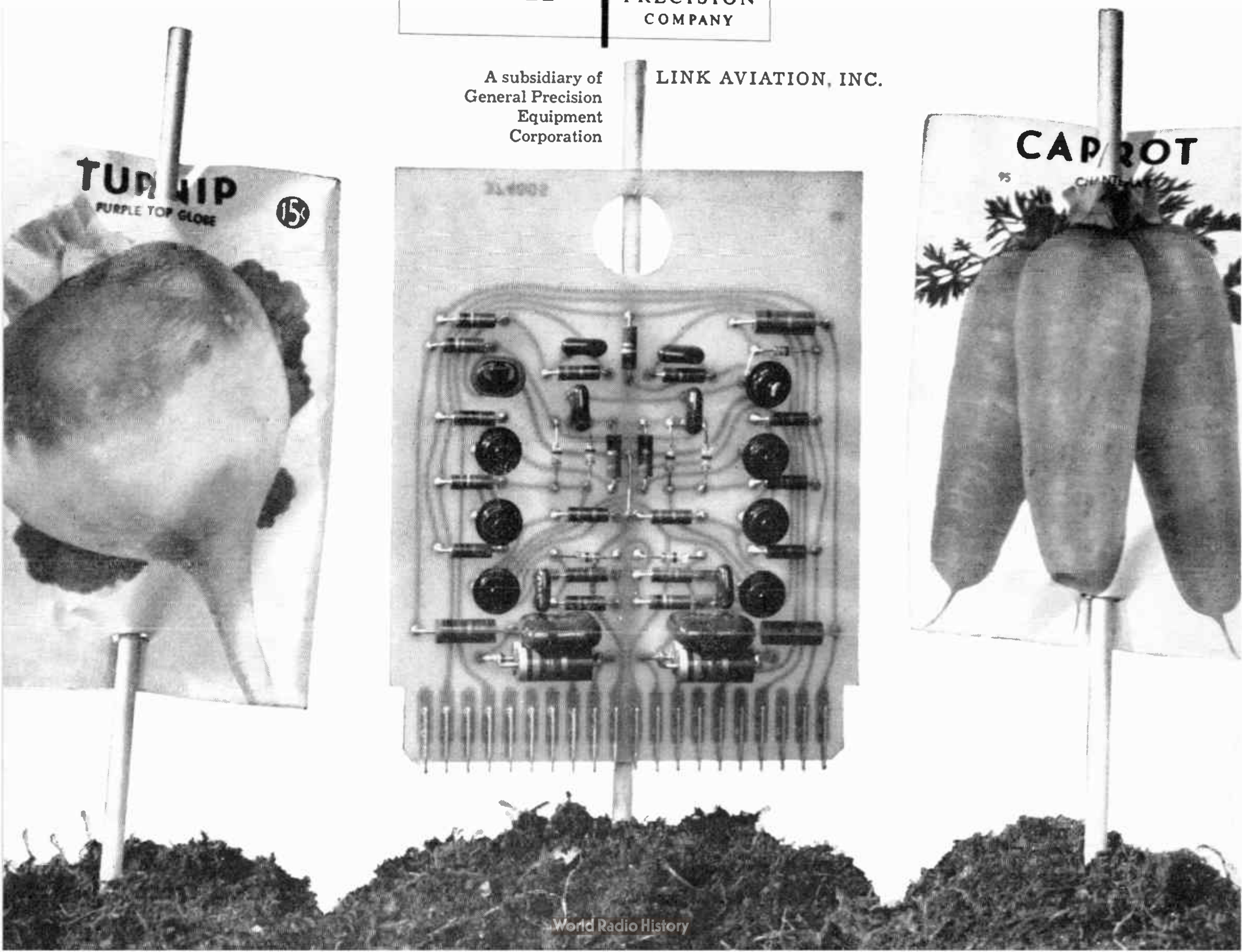
There are immediate openings at all levels for engineers with experience in analog computer components and systems, radar simulation and fire control computer design.

Your engineering career can grow better at Link - Palo Alto.
Contact us at once. Write to Mr. A.M. Rutman, Link Aviation, Inc., P. O. Box 1318, Palo Alto, California.

LINK | A GENERAL PRECISION COMPANY

A subsidiary of General Precision Equipment Corporation

LINK AVIATION, INC.



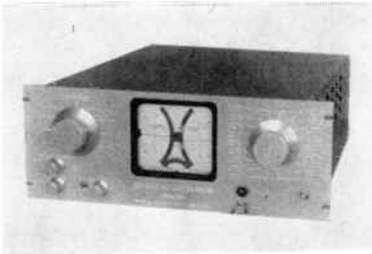
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 192A)

Subcarrier Oscillator Calibrator

Wayne D. Patterson, Inc., 807 Yale St., Los Angeles, Calif., announces the release of the subcarrier oscillator calibrator.



Rugged construction of the digital circuitry of the instrument maintains the accuracy of ¼ per cent bandwidth under all conditions of use. The panel meter reads reads directly in per cent bandwidth, and may be read under high ambient light conditions. A remote indicating meter is available for situations where the subcarrier oscillators to be calibrated are installed at a distance from instrument facilities. The subcarrier oscillator calibrator is also adaptable to high speed automatic checkout systems.

Patterson is a manufacturing firm specializing in the development and production of high quality instruments, equipment, and components in the aircraft and missile fields; and in the field of high production equipment for photographic processing and finishing.

Power-Supply Accessories

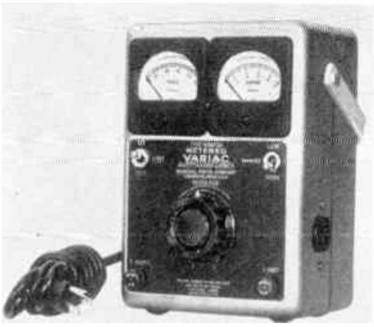
An assortment of highly ruggedized power-supply accessories, featuring improved Duratrak control-surface 10-ampere Variac® adjustable autotransformers and direct-reading metered models, plus militarized 3-phase voltage regulators, are now being manufactured by **General Radio Co.,** West Concord, Mass.

The 10-ampere (0–135 volt) line (Type W10), available in three styles of mountings—uncased, cased with conduit knockouts and portable for 2 or 3-wire service—can be used with motor drive or manual control, with driving torques of 15–30 ounce/inches.

The open models (Types W10 and W10H) have a 5¾ inch square base for mounting ease and are 4$\frac{11}{16}$ inches deep behind a ½ inch (max.) panel. The cased (Types W10M and W10HM) and portable (Types W10MT3 and W10HMT3) styles

Use your IRE DIRECTORY! It's valuable!

are $6\frac{3}{4}$ inches wide, $9\frac{1}{2}$ inches high and $5\frac{1}{4}$ inches deep; the portable model is supplied with an overload protector, carrying handle, cord, plug and outlet.

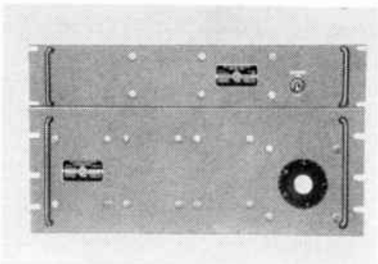


Metered Variacs®

There are two types of metered Variacs (using 5-ampere-rated Variacs) being produced, both with meters in the output or load circuit so that voltage, current or power measurements can be made directly. One provides direct volt and ampere readings (W5MT3A) and the other affords direct voltage and wattage information (W5MT3W).

Constructional features include meter shielding which reduces the Variac stray field so that an overall accuracy of 3 per cent (full scale) can be obtained with 2 per cent meters.

A make-before-break range switch permits switching (under load) of the ammeter or wattmeter (which have dual scales) from 1 to 5 amperes or 150 to 750 watts (full scale), respectively.



Militarized Line-Voltage Regulators

The militarized line-voltage regulator (Type 1570-AS25)—designed to meet (and exceed) military environmental requirements (MIL-E4158B and MIL-E-16400B) of shock, vibration, temperature and humidity—is servocontrolled and for 3-phase service.

The regulator can be used on 50- or 60-cycle line. Switches are provided for this purpose; the switch in the 50-cycle position permits operation in the 45- to 55-cps range, while in the standard 60-cycle setting the range is 55 to 65 cps.

Solid State Relay

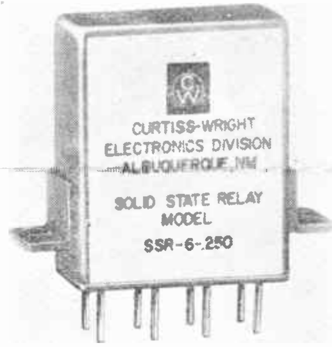
Development of a 6 volt, $\frac{1}{4}$ ampere, SPST solid state relay for aircraft, missile and other high environment dc power switching applications, without utilizing moving parts, has been announced by the **Inter Mountain Instruments Branch, Curtiss-Wright Corp., Electronics Div.,** P.O. Box 8324, Albuquerque, N. M.

(Continued on page 196A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 195A)



Known as Model SSR-6-.250, this unit has a pickup time of 2 microseconds and a dropout of 5 microseconds. First of a complete line of 6, 12, and 28 volts relays, the device can withstand shocks of 1000 g. The relay may be used as a current limiting device to protect power sources from over loads.

Price on this device is $55 f.o.b. Albuquerque, N. M. Further information concerning the solid state relays may be obtained by contacting firm.

(Continued on page 198A)

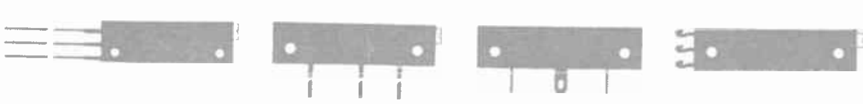
SEE US AT WESCON
BOOTHS 2810 – 2812

NEW PANEL MOUNT TRIMPOT®

Now, Bourns combines the convenience of a panel mount potentiometer with all the advantages of a rectangular unit—**Small Size**: requires 1/12 sq. in. or less of panel area—**Setting Stability**: self-locking shaft with no cumbersome locknuts—**Adjustment Accuracy**: multi-turn shaft provides up to 9000° rotation.

All of the many Trimpot models are now available with the panel mount feature as a result of a unique design that permits quick attachment of a panel mounting assembly to standard "on-the-shelf" potentiometers. Rugged stainless steel construction assures compliance to Mil-Specs for vibration, shock, salt spray, etc. Screwdriver adjustment is easily made from the front of the panel... recessed head prevents accidental changes of setting... silicon rubber O-ring and Teflon washer provide moisture barrier from outside elements.

Specify the panel mount Trimpot. Get reliability backed by years of engineering, manufacturing and field experience. **Write for complete data and list of stocking distributors.**



CHASSIS MOUNTING, PRINTED CIRCUIT OR PANEL MOUNTING—[illegible]atever your need, Bourns has a [illegible]ilitar, or commercial poten[illegible] to me[illegible]t your exac[illegible] requirements. Choice of t[illegible]rminal typ[illegible]s... resistances from 10 ohms to 1 Meg.

BOURNS, Inc.

P.O. Box 2112K, Riverside, California

Plants: Riverside, California
and Ames, Iowa

In Canada: Douglas Randall (Canada), Ltd., licensee

Exclusive manufacturers of Trimpot®, Trimit®. Pioneers in potentiometer transducers for position, pressure and acceleration.

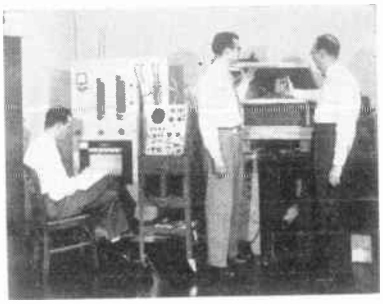
NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 196A)

Test Equipment For Electronic Modules

Designed by **Melpar, Inc.**, a subsidiary of Westinghouse Air Brake Co., Falls Church, Va., for testing the effects of heat, air flow and air temperature on the operating reliability of electronic modules, this new test equipment includes an environmental test fixture which works into standard recording instruments.



The impetus for this module cooling test fixture development came during the revision of MIL-E-19600A (Aer) specification for the Bureau of Aeronautics, under a U. S. Naval Air Development Center contract. The need for a new type of test equipment for simulating flight operational conditions was foreseen for the development of modules in order to predict the penalty on the airframe in terms of amount and inlet temperature of the cooling air supplied by the airframe.

The module cooling test fixture, possibly the first of its kind ever built, describes the amount of cooling air necessary to keep a module operating reliably, as well as establishing the true hot spot temperatures of critical component parts within the modules for varying amounts of cooling air through the modules. It is equipped with heated walls for maintaining effective insulating temperatures and is adjustable for simulating higher or lower temperature environments.

As a result of the development of the module tester, several types of modules designed under the NADC contract were tested according to the exacting specifications of the contract.

Other developments which resulted from this work on modules include: A unique modular plug-in chassis, a new means for power transistor mounting, and a more efficient method for cooling electron tubes and transistors.

Solid-State Relay

Trepac Corp. of America, 30 West Hamilton Ave., Englewood, N. J., announces the availability of the new Model 530-B Solid State Teleprinter Relay, de-

(Continued on page 200A)

A Technical Inventory of the Professional Groups

On June 2, 1948, one of the most startling developments in engineering society history came to fruition: the formation of the first Professional Group of the IRE. Just how important this development was, and is, can be convincingly demonstrated by a brief inventory of the Professional Group activities.

As of June 30, 76,855 IRE members had joined 28 Professional Groups. They joined because these groups were able to provide them with specialized technical services and information they could not afford to miss.

One of the services they could not afford to miss was the Professional Group *Transactions*. In 1958 alone, 81 issues of *Transactions* totaling 5,388 pages of valuable technical material. This was 2½ time as many editorial pages as were published in THE PROCEEDINGS. And this wealth of technical information could be had by paying only the small assessment fees levied by the various Groups.

Another service which 76,000 Group members found extremly important was the many meetings, sessions, and symposia held all over the country by the Groups. In fact, during 1958 the Groups participated in over 40 major conferences and conventions, thus making available to their members, in still another way, the latest information on important new developments in their field.

The extensive national activities of the Groups were greatly supplemented by the activities of local Group Chapters in all parts of the country. A total of 234 Chapters have been organized in 51 local IRE Sections and have been holding meetings regularly.

The members of each Group have been introduced to one other important commodity—each other. Through local and national meetings and committees, thousands of engineers have had an invaluable opportunity to meet and exchange ideas with other engineers who are interested in exactly the same technical problems.

The inventory shows that if you have not yet joined a Professional Group, you are not getting the most out of your IRE membership.

W. R. G. Baker

Chairman, Professional Groups Committee

At least one of your interests is now served by one of IRE's 28 Professional Groups

Each group publishes its own specialized papers in its *Transactions*, some annually, and some bi-monthly. The larger groups have organized local Chapters, and they also sponsor technical sessions at IRE Conventions.

Aeronautical and Navigational Electronics (G 11)	Fee $2
Antennas and Propagation (G 3)	Fee $4
Audio (G 1)	Fee $2
Automatic Control (G 23)	Fee $2
Broadcast & Television Receivers (G 8)	Fee $2
Broadcasting (G 2)	Fee $2
Circuit Theory (G 4)	Fee $3
Communication Systems (G 19)	Fee $2
Component Parts (G 21)	Fee $3
Education (G 25)	Fee $3
Electron Devices (G 15)	Fee $3
Electronic Computers (G 16)	Fee $2
Engineering Management (G 14)	Fee $3
Engineering Writing and Speech (G 26)	Fee $2
Human Factors in Electronics (G 28)	Fee $2
Industrial Electronics (G 13)	Fee $3
Information Theory (G 12)	Fee $3
Instrumentation (G 9)	Fee $2
Medical Electronics (G 18)	Fee $3
Microwave Theory and Techniques (G 17)	Fee $3
Military Electronics (G 24)	Fee $2
Nuclear Science (G 5)	Fee $3
Production Techniques (G 22)	Fee $2
Radio Frequency Interference (G 27)	Fee $2
Reliability and Quality Control (G 7)	Fee $3
Space Electronics and Telemetry (G 10)	Fee $2
Ultrasonics Engineering (G 20)	Fee $2
Vehicular Communications (G 6)	Fee $2

IRE Professional Groups are only open to those who are already members of the IRE. Copies of Professional Group Transactions are available to non-members at three times the cost-price to group members.

The Institute of Radio Engineers
1 East 79th Street, New York 21, N.Y.

USE THIS COUPON

Miss Emily Sirjane — PG-8-59
IRE—1 East 79th St., New York 21, N.Y.

Please enroll me for these IRE Professional Groups

.... $....................
.... $....................

Name ....
Address ....
Place ....

Please enclose remittance with this order.

NEWS New Products

(Continued from page 198A)

signed specifically to eliminate the conventional polar relays in teletypewriters. The circuit design utilizes silicon diodes and transistors to perform the switching functions formerly accomplished by polar relays. Incoming signals are accurately reproduced under wide variations in line-circuit current and conditions. The Model 530-B introduces no distortion and, having a purely resistive input, generates no inductive "kicks" to disturb the signal loop and cause interaction with other printers on the line. It uses no moving parts, no vacuum tubes, and requires no periodic adjustment or recalibration.

(Continued on page 202A)

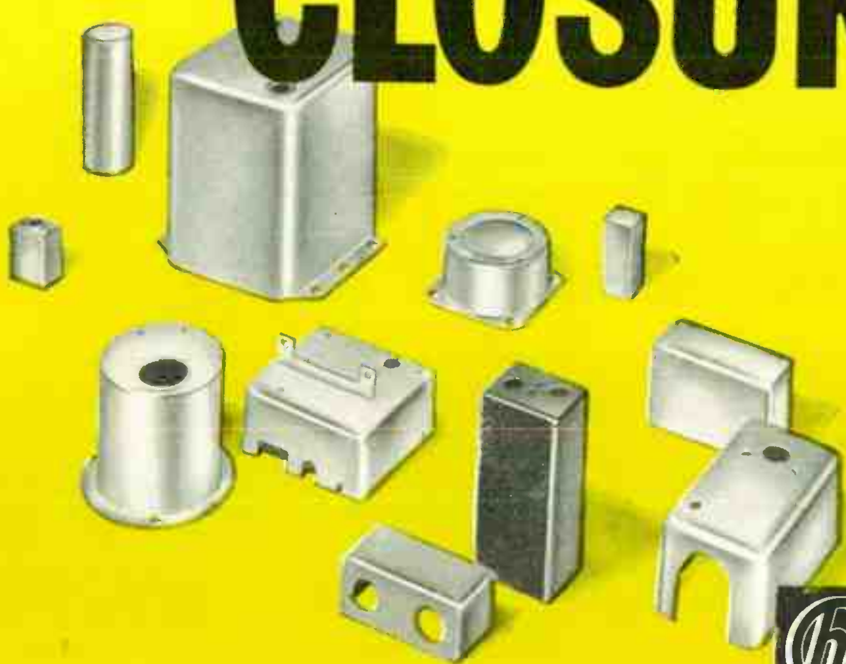
Offering the Most Complete Line in the Industry!

HUDSON STANDARD CLOSURES

Hudson has the answer!

Hudson offers the widest selection of standard tooling, cover assemblies with innumerable modifications and special cases and covers for unusual applications. All finishes are available for components of mu metal, nickel-silver, aluminum, brass, copper, steel and stainless steel.

Hudson facilities range from batteries of standard and special presses to a fully equipped sheet metal department capable of handling your most rigid requirements.



If you need commercial or military closures, or help on a special design problem, call or write Hudson outlining your requirements.

HUDSON
TOOL & DIE CO · INC
18-38 Malvern St., Newark 5, N. J.
TELEPHONE: MARKET 4-1802
TELETYPE: NK 1066

Precision Metal Components for Electronics, Nucleonics, Avionics and General Industrial Applications

VISIT BOOTH 1217 WESCON SHOW

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(*Continued from page 200A*)

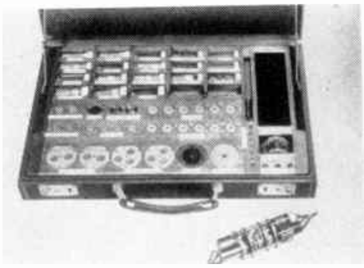
All components are rigidly mounted on a heavy epoxy resin fibre glass printed circuit board in a steel case 3⅛ wide, 2⅝ deep and 4¼ inches high (seated), equipped with an octal plug and four threaded mounting studs. The complete unit weighs 26 ounces.

Moisture Gage

The Model 101 Moisture Gage, developed by **Henry Francis Parks Laboratory**, P. O. Box 1665, Lake City Station, Seattle 55, Wash., is an inexpensive, accurate direct reading moisture percentage meter for soils and other granular materials. Sensitivity is high with use of a 0 to 100 μa microammeter. Accuracy is ±2 per cent at 70°F ambient, for materials whose dc resistance ranges between zero and 85,000 ohms and for which it has been calibrated. The gauge comes with one prong-type electrode and carrying strap. Those who prefer a soil-type must so state. The unit is battery operated and is 6¼ long by 3¾ wide and 2¾ inches deep. Weight is less than 1½ pounds.

Servomechanism Kit

Servo Development Corp., 567 Main St., Westbury, N. Y., announces the complete Servo Development Kit No. 1 which contains all mechanical parts and tools necessary to construct 1⅞ inch diameter mechanisms up to the complexity of the computer component shown. The completed mechanisms can be sealed into standard two-inch diameter enclosures for airborne applications and prototype evaluation.



Rotating units such as motors, potentiometers, and synchros are not included but may consist of as many as six size 8 or four size 8 plus one size 10, forming up to three complete servo loops in a single instrument. The outputs can be in the form of electrical signals, torque shafts, dial and pointer, or counter if desired.

This pre-engineered system assures rapid, economical and interference-free construction for developmental, laboratory, prototype or production applications requiring small precision servos. An illus-

(*Continued on page 204A*)

PUTTING MAGNETICS TO WORK

Hold your frequency under fire (and ice)!

New linear permalloy core keeps filters frequency-stable over a wide range of temperature conditions—at half the cost

Designers of audio filter networks, faced with the high price of components and the need for frequency stability over a wide swing in ambient temperatures, can now benefit from a most significant development—the linear molybdenum permalloy powder core.

The linear cores we've developed are used with polystyrene capacitors. This combination costs as little as half the price of temperature-stabilized moly-permalloy cores and the silvered mica capacitors with which they must be used.

What's more, frequency stability is increased! For temperatures ranging from −55°C to +85°C we have observed frequency stability variations as low as 0.05%. This is considerably less frequency shift than normally expected with temperature-stabilized combinations.

We guarantee the temperature coefficient of these linear cores within a very narrow range! Information regarding sizes, prices and performance behavior awaits your request. Popular sizes, in 125 permeability only, available immediately from stock. *Magnetics, Inc., Dept. P-74, Butler, Pa.*

MAGNETICS inc.

SEE US AT WESCON!

(Continued from page 202A)

trated catalog showing the kit, giving descriptions and outlines of the individually stocked servomechanical parts, and listing gear data and prices is available.

Moisture Filter Protects Aircraft Instruments

A ceramic filter which looks like an aspirin tablet will soon stop condensation from interfering with the performance of instruments in high-flying aircraft.

The unusual porosity of the filter permits air to pass in and out of the instrument case, equalizing pressure, but excludes moisture. It is made of an industrial ceramic called SP-WD, developed by **General Ceramics Corp.**, Keasbey, N. J.

Various companies, at the request of the U. S. Air Force, have been seeking a means of eliminating vapor condensation in aircraft instruments. The condensation is caused by sudden shifts in pressure and temperature resulting from rapid changes in altitude. In some instances moisture which collected inside the instrument case had interfered with performance. The SP-WD filter proved to offer a solution.

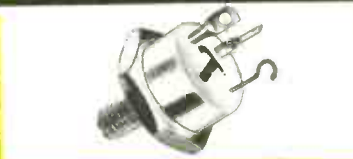
The filter keeps sea water from entering emergency communications equipment in planes forced down at sea.

(Continued on page 208A)

5 EXCITING NEW SILICON TRANSISTOR

1. HI-POWER STUD-MOUNTED SILICON TRANSISTOR

A rugged package — easier to mount, with greater strength and lower thermal resistance. Has good beta linearity and switching characteristics good high frequency betas, low saturation voltage. Ratings up to 100 volts available.



Type	V_{cb} Max. Volts	I_c max. Amps	B Typical	R_{cs} Typical (Ohms)
2N1208	60	5	35	1.5
2N1209	45	5	40	1.5
2N1212	60	5	25	2.5

APPLICATIONS Regulated Power Supplies . . . High Current Switching . . . High Frequency Power Amplifiers

Send for Bulletin No 1355M

2. CORE SWITCH

Improved switching speed and input characteristics. High-current capabilities with good power handling ability (5w @ 100°c). Rated and tested at 60v.

Type	V_{cb} Max. Volts	(β) Min.	Typ. Input Voltage (Volts)	Typ. Saturation Resistance (Ohms)	Switching Characteristics (μsec)
ST4100	60	15	2.5	10	t_r .2
					t_s .2
					t_f .2

APPLICATIONS . . . magnetic core memory . . . high level multivibrators . . . buffer amplifiers . . . clock source

Send for bulletin 1355X

3. 150mc VERY HIGH FREQUENCY TRANSISTOR

New silicon logic transistor with speed surpassing the fastest silicon types, plus unusual power handling ability. Technical breakthrough now provides minimum and typical DC current gains of 20 and 40 respectively.

TYPE 2N1139

		Min.	Typical	Max.	Test Conditions
D.C. Current Gain	h_{FE}	20	40	—	I_C = 10ma, V_{CE} = 10V
D.C. Collector Saturation Voltage	V_{CE}	—	5	0.7V	I_C = 10ma, I_B = 1ma
Collector Cutoff Current	I_{CO}	—	2	5 μa	V_{CB} = Rating
Output Capacitance	C_{ob}	—	8	12 μμf	V_{CB} = 10V, I_E = 0 mA
High Frequency Current Gain	h_{fe}	5	7.5	—	F = 20mc, V_{CE} = 10V, I_E = 10 mA
Delay Time	t_d	—	6		mμsec.
Rise Time	t_r	—	12		mμsec.
Fall Time	t_f	—	10		mμsec.

Send for bulletin TE1355 B2

4. UNIVERSAL 50mc LOGIC TRANSISTOR

This transistor features universal application (replaces 2N337, 2N338, 2N1005, 2N1006) and high frequency response, with low saturation resistance, low input impedance, low capacitance.

Type	Typ. Alpha Cutoff (Mc)	Beta Typical	Co (Typical) (μμf)	Max. (Volts)	Typ. Saturation Resistance (ohms)
ST3031	70	50	2	20	40

APPLICATIONS . . . flip-flops . . . IF and video amplifiers . . . transistor logic . . . pulse amplifiers

Send for bulletin 1353X

5. STABISTOR COUPLED LOGIC TRANSISTOR

Designed to provide minimum storage times under severe base overdrive conditions in transistor logic circuitry. Tightly controlled input characteristics provide interchangeability; low R_{cs} assures reliable operation at high temperature.

Type	Beta Typical	V_c max. (Volts)	Typical Saturation Resistance (ohms)	Typ. Alpha Cutoff (Mc)	Switching Characteristics (μsec)
ST3030	12	15	40	50	t_r .05
					t_s .20
					t_f .10

APPLICATIONS . . . designed specifically for SCTL and DCTL circuits (write for descriptive paper on SCTL)

Send for Bulletin 1353Y

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 204A)

Digital Interval Timer

Specially developed for military applications, a new fully-portable transistorized digital interval timer is now available from the **Erie-Pacific Div., Erie Resistor Corp.,** 12932 S. Weber Way, Hawthorne, Calif.

The Model 2202TL Timer is the first in a line of JANized miniature transistorized counters. It provides an accuracy of ±1 count ±0.05 per cent and a service life of over 5000 hours. It weighs less than two pounds and occupies 160 cubic inches. Performance exceeds the shock, vibration, high and low temperature, pressure salt spray, sand and dust requirements of MIL-T 945A.

Model 2202TL measures time intervals for a total indicated time of 9.9 ms (2 decades) or 99.9 ms (3 decades). Longer intervals can be provided. Start and stop signals in the form of contact closures or 10 volt pulses are applied to separate inputs.

Silicon solid-state devices are used throughout, except in the regulated power supply. Here, germanium transistors are used because of their low saturation resistance.

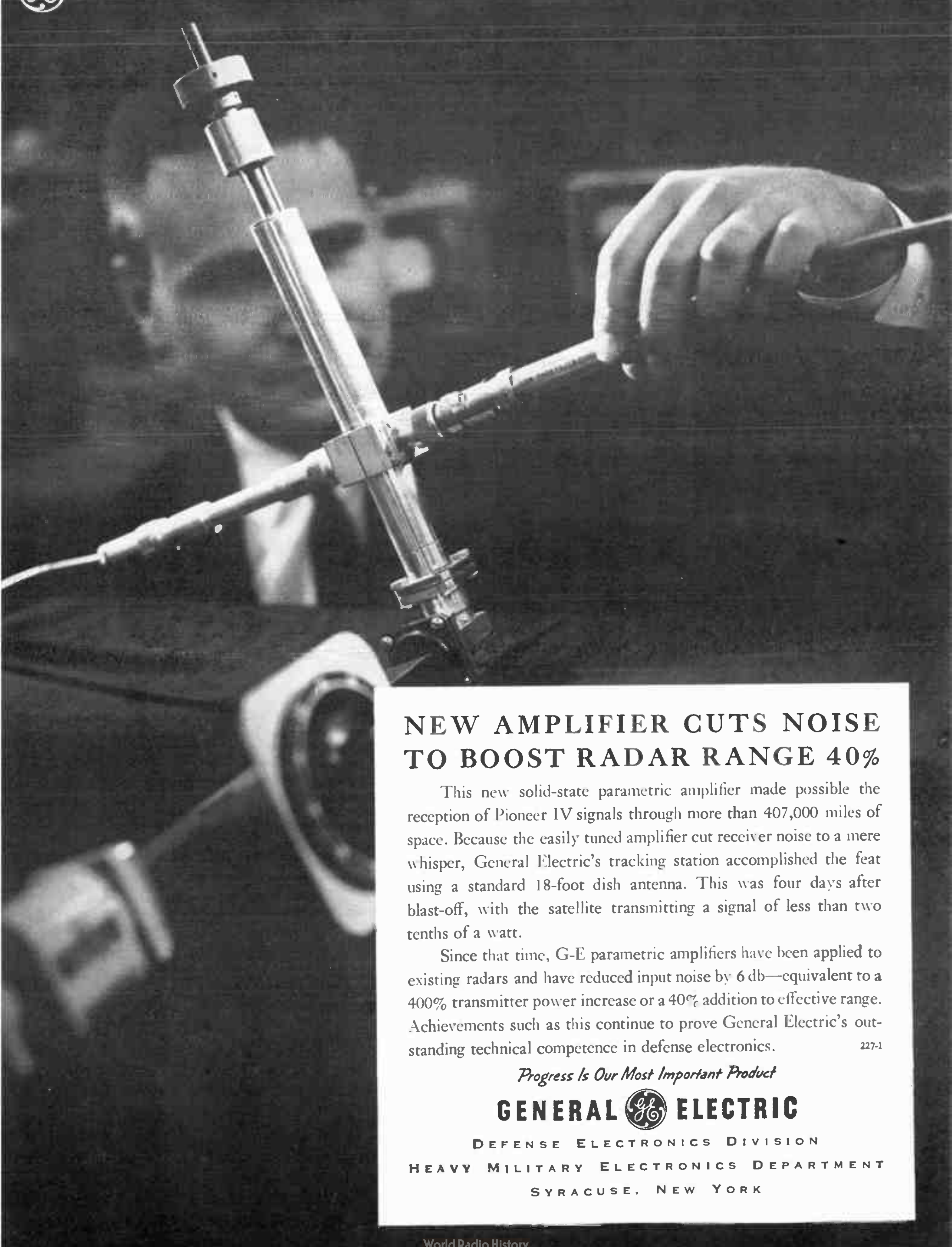
Additional information and specifications can be obtained by writing to the manufacturer.

S-Band Power Amplifier

Rated at 3 mw peak, 15 kw average power output the QK 622, a new S-band power amplifier stage with wide RF bandwidth, is available from the **Raytheon Co., Microwave & Power Tube Div.,** Waltham 54, Mass. This tube supplies full power over an operating band of 2900 to 3100 mc at efficiencies greater than 70 per cent. Operating life of more than 1000 hours at rated power output has been demonstrated. Phase stability and pulse stability are excellent. No heater power is required for starting or during operation. Other general characteristics are as follows: Pulse Duration, 10 μsec; Bandwidth, 200 mc; Duty Cycle, 0.005; Pulse Voltage, 50 to 55 kv; Peak Anode Current, 65 amperes; Efficiency, 70 per cent; RF Input, 475 kw; Weight (with permanent magnet) 125 pounds.

(Continued on page 210A)

AN ACHIEVEMENT IN DEFENSE ELECTRONICS



NEW AMPLIFIER CUTS NOISE TO BOOST RADAR RANGE 40%

This new solid-state parametric amplifier made possible the reception of Pioneer IV signals through more than 407,000 miles of space. Because the easily tuned amplifier cut receiver noise to a mere whisper, General Electric's tracking station accomplished the feat using a standard 18-foot dish antenna. This was four days after blast-off, with the satellite transmitting a signal of less than two tenths of a watt.

Since that time, G-E parametric amplifiers have been applied to existing radars and have reduced input noise by 6 db—equivalent to a 400% transmitter power increase or a 40% addition to effective range. Achievements such as this continue to prove General Electric's outstanding technical competence in defense electronics. 227-1

Progress Is Our Most Important Product

GENERAL ELECTRIC

DEFENSE ELECTRONICS DIVISION

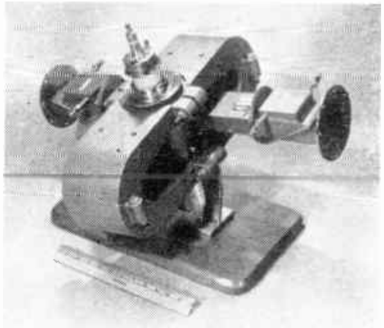
HEAVY MILITARY ELECTRONICS DEPARTMENT

SYRACUSE, NEW YORK

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 208A)



The QK622 can be operated at reduced peak power level to serve as a driver stage. High efficiency is retained at a peak power output of 600 kw and gain of 10 db.

Digital Logic Circuitry

The Walkirt Company, 141 W. Hazel St., Inglewood 3, Calif., announces a complete new line of digital logic circuitry, supplementing their other pulse circuit packages, the type PM8393 dual NPN "AND" Gate is pictured.

The new series is comprised of "AND" Gates, "OR" Gates, Inverters and Emitter Followers, and all units are available with either single or dual circuits in each plug-in package. Wide applicational versatility is claimed since the units are available in three basic types, which are NPN, PNP, or Complementary Symmetry units employing both NPN and PNP transistors, all of which have emitter follower outputs, enabling the direct drive of other logic circuits without intervening buffer stages. The complementary symmetry units utilize the low impedance diode logic and have modified emitter follower outputs.

All of the new units are stocked in 9 pin plug-in form, ¾ inch diameter. Single units are 1 9/16 inch high and the dual units are 2⅛ inches high and all are encapsulated in epoxy resin. The circuits can also be provided in diminutive cartridge form for airborne applications.

Multiple Band Equalizer and Noise Source

The Model 3-MAN-8 Octave Band Equalizer and Noise Source designed by **Allison Laboratories, Inc.,** 14185 Skyline

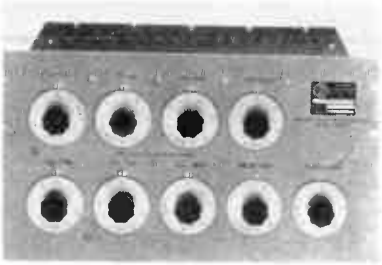
(Continued on page 212A)

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 210A)

Dr., La Puente, Calif., can be used as a tailored random noise source. Each band can be adjusted for level to simulate a given environmental noise spectrum.



The 3-MAX-8 is more than a filter set. It has a "white" noise generator and amplifiers as an integral part of the unit. The unit will supply signals for low frequency and high frequency power amplifiers. These amplifiers, through transducers, can produce high acoustical noise levels in test chambers.

The unit as normally supplied consists of a white noise generator feeding a driver amplifier. This in turn feeds eight attenuators each of which is connected to an octave band filter. The output is divided into two sections of four bands each. The four bands of each section are mixed and fed into a line amplifier.

The noise generator is a Zener diode and the amplifiers are transistorized. This combination reduces pickup and microphonics to a minimum.

The octave band filters are passive networks with hum-bucking construction. They have an attenuation rate of 40 db per octave. The spectrum coverage is from 20 to 9600 cps with provision for a ninth band 9600 to 19,200 cps. The flat pass band with accurate setting of cutoff points assures equal representation of energy throughout the band.

Time Code Generator

An accurate instrument for the generation of time signals has just been introduced by the **Systems Division of Beckman Instruments,** 325 N. Muller Ave., Anaheim, Calif.

(Continued on page 216A)

POWER

handling capacity of the new Westinghouse Silicon

POWER

transistor!

Greater than 99% efficiency when used to handle 1.5 kw of power in a low-frequency DC switch! Power loss is only 10-15 watts when handling 1.5 kw. That's just one of the impressive specifications established by a remarkable new semiconductor device—the Westinghouse Silicon Power Transistor.

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- It can operate at higher temperatures than germanium (150°C., compared to 85°C).
- It has astonishingly low saturation resistance—less than .5 ohms at 5 amperes and .75 ohms at 2 amperes, an achievement made possible through extensive research and development of hyper-pure Siemens-Westinghouse Silicon.
- It is 100% power-tested under actual maximum rated specifications before leaving the plant.
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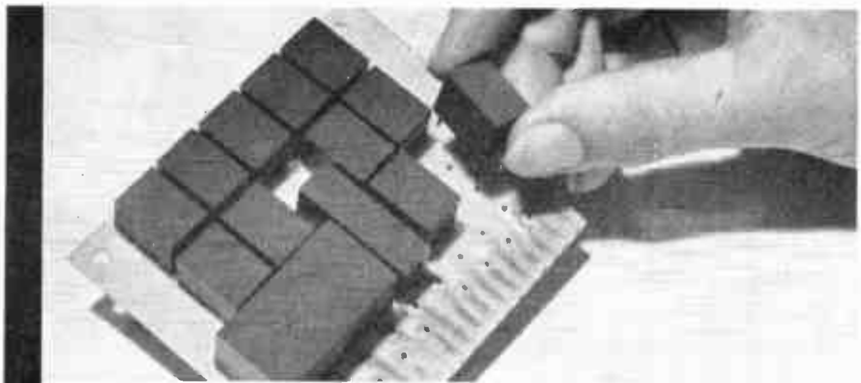
HERE ARE A FEW OF THE APPLICATIONS . . .

• Inverters and converters • Data processing circuits • Servo output circuits • Series regulated power supplies • As a low frequency switch • In class A amplifiers.

Available in 2 and 5 ampere collector ratings in production quantities now. For complete specifications and details, contact your local Westinghouse representative.

YOU CAN BE SURE...IF IT'S Westinghouse

Westinghouse Electric Corporation, Semiconductor Department Youngwood, Pa.



New *SHIFT REGISTERS* by General Electric *CUSTOM DESIGNED* from 0 to 700 kc/s

Catalog components or devices oftentimes do not truly fit design needs. General Electric, working directly from your specifications, custom designs the new *Voltage Controlled* Shift Register for any frequency between 70 and 700 kc. Within a matter of days, first prototypes will be shipped. VCSR's deliver far higher shift rates than core-diode registers, with considerably less power dissipation. For shift speeds below 100 kc/s, custom designed core-diode registers are also a part of this General Electric service.

G-E Shift Registers can be designed within these parameters:

Shift Pulse Power:	as low as .001 watts per kc
Shift Pulse Voltage:	5 to 50
Signal Voltage:	3 to 25
Signal-to-Noise Ratio:	up to 15:1
Temperature:	−65°C to +125°C

For complete information write to Defense Industries Sales, Section 227-20D

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- RW-I to III: Toroidal Winders
- RWO: Toroidal (see listing above)
- RWP: Precision Potentiometer Winder
- ST-I: Stator Winder
- AWO: Small Armature Winder
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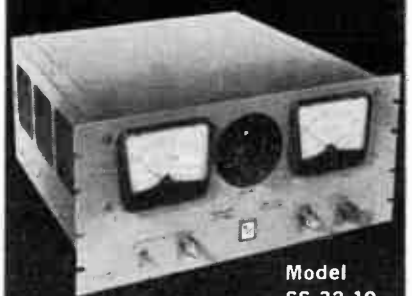

Model SS-32-10

Output, volts: 0-36.
Output, amps: 0-10.
RMS ripple: 1 millivolt.
Regulation, load: ±0.015% or ±1 MV.
Regulation, line: ±0.03% or ±2 MV.
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PRICE: $750
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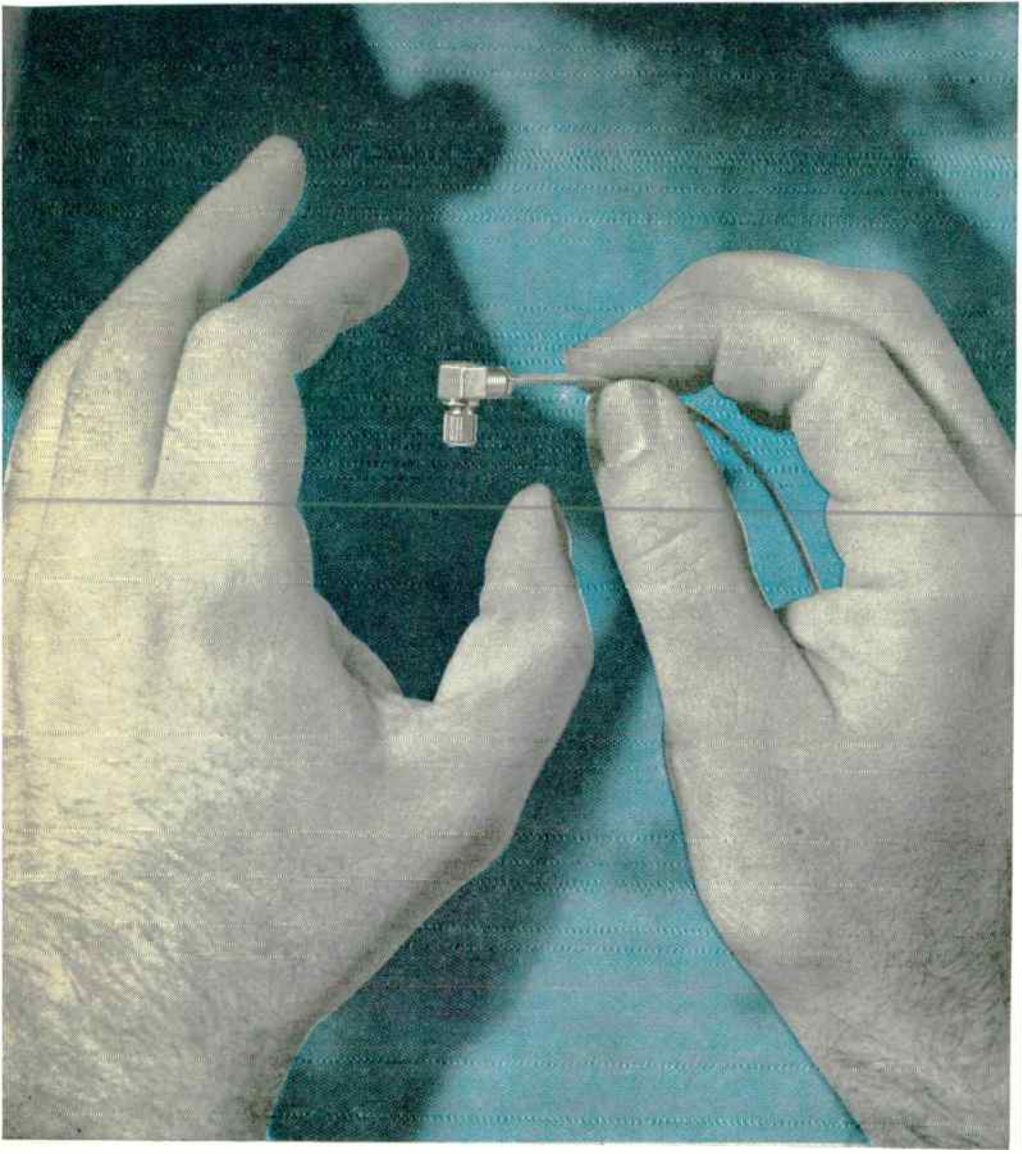


These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 212A)

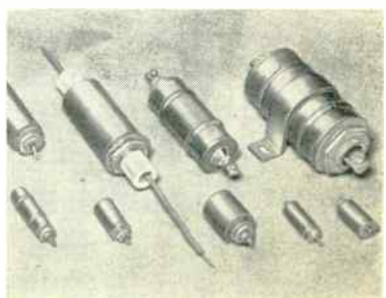
Called the Model 5631-82 Time Code Generator, it is basically an electronic clock, accurate within several microseconds, supplying an output signal that may be recorded together with other data or events. The output is coded so that the time between two events or the absolute time of an event can be quickly determined visually in the case of strip chart recorders, or electronically by tape search units in the case of magnetic tape recordings. The base carrier signal is a 100 cps sine-wave from which the 0.01 second marks can be read, and even interpolated to 0.0025 second.

Time announcements are made in decimal form every minute. An intermediate signal of 10 cycles and an amplitude of 2A is superimposed on the 100 cps carrier to show the area of the announcement. Four such marks are generated representing two digits for hours, two for minutes. The position of a superimposed single cycle pulse with full amplitude determines the value of the time reading. Seconds and fractions are read by straight cycle count.

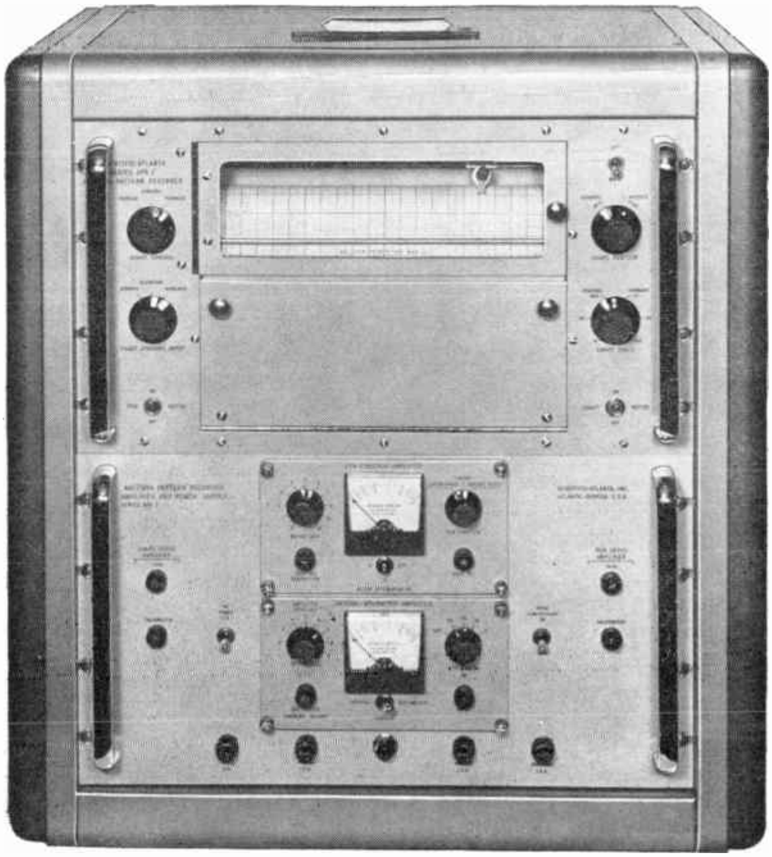
Start time may be preset to Greenwich Mean or other bases by a series of switches and activated either manually or automatically by a WWV signal.

Bulkhead-Mounting Filters

A series of 68 bulkhead-mounting low-pass filters for suppression of electronic interference generated by electrical and electronic equipment has been announced by **Sprague Electric Co.,** 235 Marshall St., North Adams, Mass.



The new series of standard filters range in current rating from 5 ma to 50 amperes to cover the great majority of application needs. All filters are of the "high performance" type utilizing toroidal inductors and Thru-Pass® duct-type capacitor sections to achieve maximum attenuation. These filters have been designed to meet military environmental conditions, as well as operation at high temperatures. Complete technical information is listed in Sprague Engineering Bulletin 8100, available on letterhead request only to the Technical Literature Section.



THE NEW S·A

ANTENNA PATTERN RECORDER

∗ Noise suppressor for better S/N ratio ∗ Bolometer burnout protector ∗ DB meter for signal monitoring ∗ Automatic single chart cycle advance

Scientific-Atlanta's new series of rectangular antenna pattern recorders bring you new standards of performance, reliability and flexibility.

Compare these key features

Writing speed of better than 40 inches per second • Log, linear, or square root pen response obtained with plug-in balance pots • One electronics system drives both polar and rectangular recorder heads • Overload indicator to prevent amplifier saturation • 60 db dynamic range system available • Chart scale expansion of 1:1, 6:1, and 36:1 • Page size recordings optional at extra cost • 100 db gain in bolometer amplifier • Lighted chart • Improved pen mechanism • DC input pre-amplifier available • Plug-in selective filter • Simplified controls.

PRICES, Series APR-20 Rectangular Antenna Pattern Recorders

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New high gain, low noise bolometer—crystal amplifier

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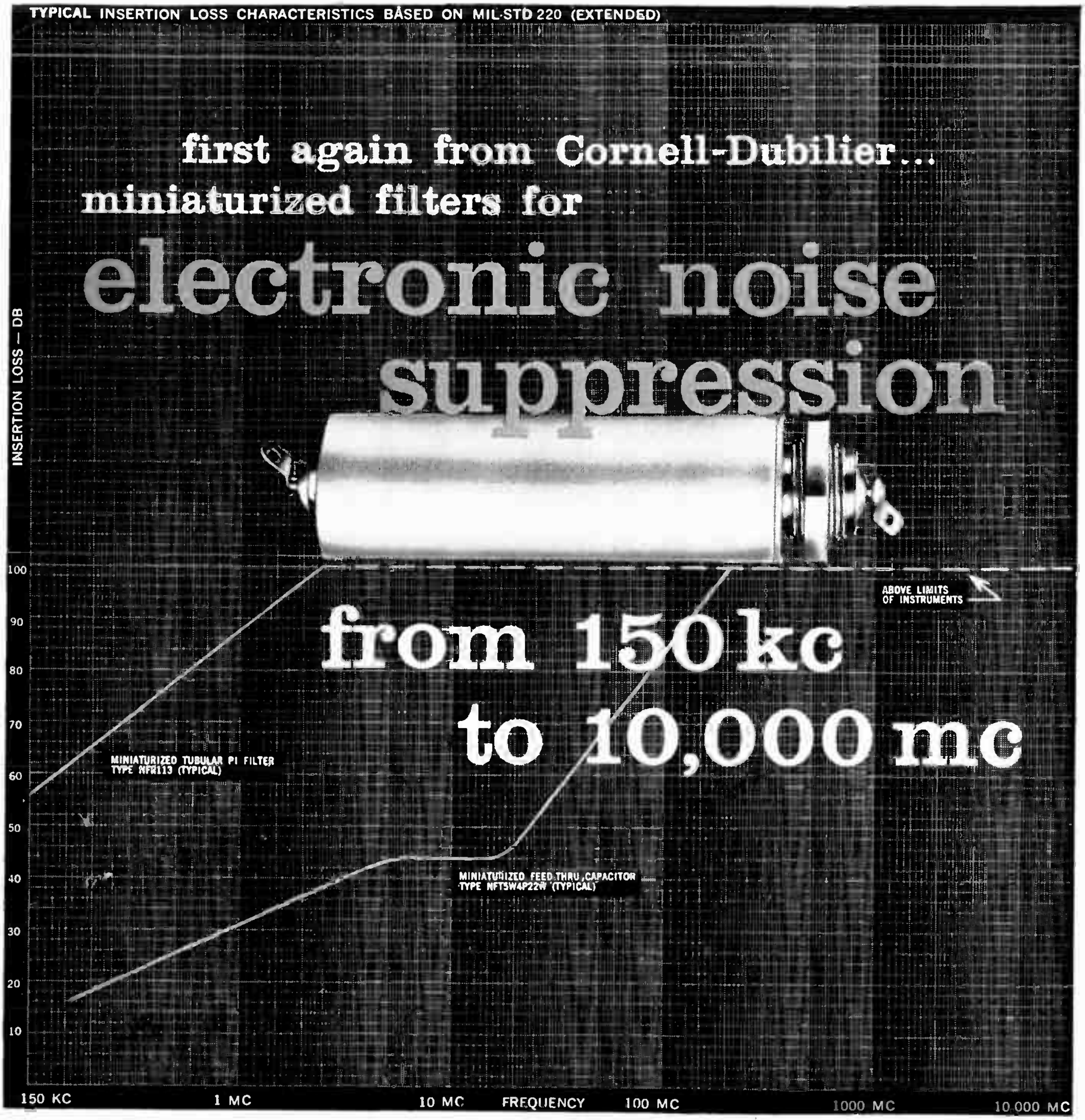
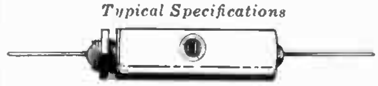


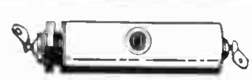
Another First From The Cornell-Dubilier Filter Laboratories. Now... MINIATURIZED pi filters and 3-terminal feed-thru capacitors for interference suppression at any frequency from 150 kc to 10,000 mc. No matter how unusual your design requirements, the C-D Filter Laboratories can deliver the precise suppression component you need. Tubular shapes, neck-mounting designs and smallest possible case sizes save space and weight, and provide easy installation. C-D's *miniaturized* tubular pi filters and feed-thru's also provide better insertion loss per unit volume, lighter unit weight and lower unit cost as compared to other types of suppression devices at identical ratings. To obtain complete specifications, write for Engineering Bulletins 171, 172 and 166 to Cornell-Dubilier Electric Corp., South Plainfield, N. J.

MINIATURIZED SUPPRESSION COMPONENTS

Typical Specifications



Tubular Pi Filter TYPE NFR113
Voltage: 120 VAC (60 cycles), 300 VDC
Current: 0.5 Amperes, Weight: 4.0 oz.
Dimensions: 1" x 2-11/16"



Feed-Through Capacitor TYPE NFT5W4P22W
Voltage: 125 VAC (60 cycles) 400 VDC
Current: 25.0 Amperes Capacitance: 0.22 mfd.
Dimensions: .562" x 1-29/32" Weight: 0.83 oz

Consistently Dependable

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CAPACITORS