april 1962
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Proceedings of the IRE

in this issue

LOW FREQUENCY PROPAGATION
DELTA MODULATION FOR TV
ELF DISPLAY SYSTEM
MULTIPACTOR DISCHARGE DEVICES
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MICROWAVE MODULATION OF LIGHT
RADAR SEA RETURN
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ABSTRACTS AND REFERENCES

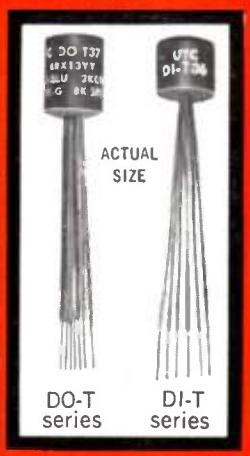


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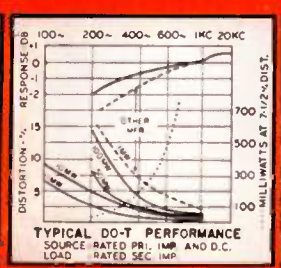
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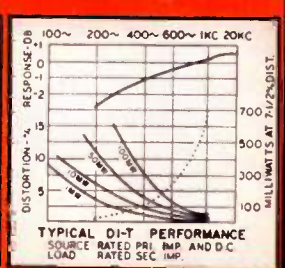
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DO-T38	10,000 CT 12,000 CT	1 1	2000 Split 2400 Split	560	600	100	DI-T38
DO-T39	20,000 CT 30,000 CT	.5 .5	1000 Split 1500 Split	800		100	
DO-T40	40,000 CT 50,000 CT	.25 .25	400 Split 500 Split	1700		50	
DO-T41	400 CT 500 CT	8 6	400 Split 500 Split	46	48	500	DI-T41
DO-T42	400 CT 500 CT	8 6	120 Split 150 Split	46		500	
DO-T43	400 CT 500 CT	8 6	40 Split 50 Split	46		500	
DO-T44	80 CT 100 CT	12 10	32 Split 40 Split	9.8		500	
DO-T45	1000 CT 1250 CT	3.5 3.5	16,000 split 20,000 split	120		100	
DO-T46	100,000 CT	0	500 CT	7900		25	
DO-T1	20,000 30,000	.5 .5	800 1200	830	815	50	DI-T1
DO-T2	500 600	3 3	50 60	60	65	100	DI-T2
DO-T3	1000 1200	3 3	50 60	115	110	100	DI-T3
DO-T4	600	3	3.2	60		100	
DO-T5	1200	2	3.2	105	110	100	DI-T5
DO-T6	10,000	1	3.2	790		100	
DO-T7	200,000 500	0 0	1000 100,000	8500 —		25	
	Reactor 2.5 Hys./2 Ma., .9 Hy./4 Ma				630		DI-T8
DO-T8	" 3.5 Hys./2 Ma., 1 Hy./5 Ma.			560			
DO-T9	10,000 12,000	1 1	500 CT 600 CT	780	870	100	DI-T9
DO-T10	10,000 12,500	1 1	1200 CT 1500 CT	780	870	100	DI-T10
DO-T11	10,000 12,500	1 1	2000 CT 2500 CT	780	870	100	DI-T11
DO-T12	150 CT 200 CT	10 10	12 16	11		500	
DO-T13	300 CT 400 CT	7 7	12 16	20		500	
DO-T14	600 CT 800 CT	5 5	12 16	43		500	
DO-T15	800 CT 1070 CT	4 4	12 16	51		500	
DO-T16	1000 CT 1330 CT	3.5 3.5	12 16	71		500	
DO-T17	1500 CT 2000 CT	3 3	12 16	108		500	
DO-T18	7500 CT 10,000 CT	1 1	12 16	505		500	
DO-T19	300 CT	7	600	19	20	500	DI-T19
DO-T20	500 CT	5.5	600	31	32	500	DI-T20
DO-T21	900 CT	4	600	53	53	500	DI-T21
DO-T22	1500 CT 600	3 5	600 1500 CT	86 —	87	500	DI-T22
DO-T23	20,000 CT 30,000 CT	.5 .5	800 CT 1200 CT	830	815	100	DI-T23
DO-T24	200,000 CT 500 CT	0 0	1000 CT 100,000 CT	8500 —		25	
DO-T25	10,000 CT 12,000 CT	1 1	1500 CT 1800 CT	780	870	100	DI-T25
	Reactor 4.5 Hys./2 Ma., 1.2 Hys./4 Ma.				2300		DI-T26
DO-T26	" 6 Hys./2 Ma., 1.5 Hys./5 Ma.			2100			
	Reactor .9 Hy./2 Ma., .5 Hy./6 Ma.				105		DI-T27
DO-T27	" 1.25 Hys./2 Ma., .5 Hy./11 Ma.			100			
	Reactor .1 Hy./4 Ma., .08 Hy./10 Ma.				25		DI-T28
DO-T28	" .3 Hy./4 Ma., .15 Hys./20 Ma.			25			
DO-T29	120 CT 150 CT	10 10	3.2 4	10		500	
DO-T30	320 CT 400 CT	7 7	3.2 4	20		500	
DO-T31	640 CT 800 CT	5 5	3.2 4	43		500	
DO-T32	800 CT 1000 CT	4 4	3.2 4	51		500	
DO-T33	1060 CT 1330 CT	3.5 3.5	3.2 4	71		500	
DO-T34	1600 CT 2000 CT	3 3	3.2 4	109		500	
DO-T35	8000 CT 10,000 CT	1 1	3.2 4	505		100	
DO-T36	10,000 CT 12,000 CT	1 1	10,000 CT 12,000 CT	975	970	100	DI-T36
DO-TSH	Drawn Hipermalloy shield and cover 20/30 db						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 & DI-T units designed for transistor application only. Pats. Pend.

*Units in tinted area newly added to series

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The large photograph showing light reflected from a wind-swept water surface and the smaller photograph showing the profile of a wave were taken in a transparent water-wind tunnel in order to obtain experimental data on radar sea return phenomena, as described on page 456.

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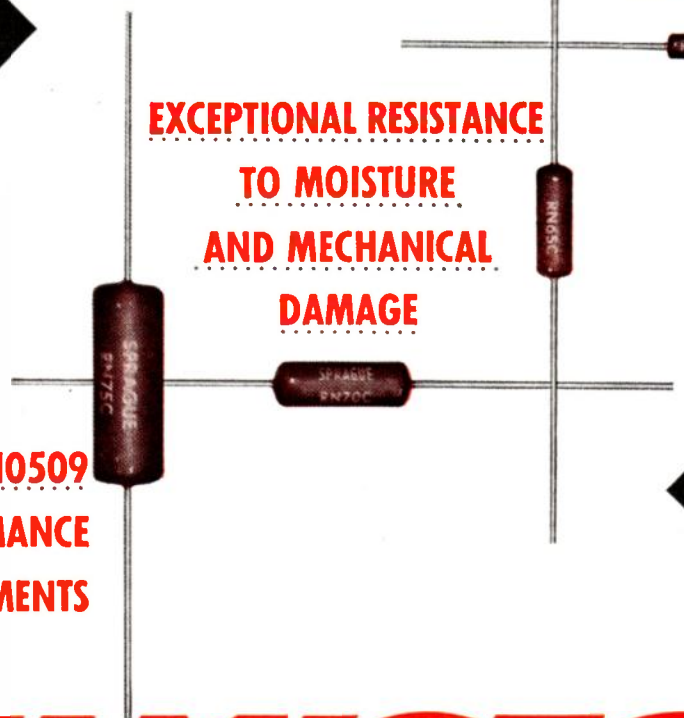
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That the Cassegrain antenna has important advantages for certain applications is by now rather well known. Not so well known is the fact that the reflectors of a Cassegrain antenna can be modified in shape to obtain even greater advantages. This month Warren White and Lorne DeSize report some of the results of a recent investigation of the off-axis performance of various two-reflector systems.

Coma Aberrations in Two-Reflector Antenna Systems

Two-reflector antenna systems have two important advantages that recommend their use in certain situations. First, they permit the mounting of bulky transmitters and receiver equipment close to the feed without interfering with the beam formation and second, they permit the antenna to have a long effective focal length in a compact structure. This last advantage is especially important when the antenna is called upon to deliver multiple beams including beams substantially off boresight.

As is rather well known, the coma aberration of the off-boresight beams depends rather critically on the effective f/D ratio, and increasing the effective focal length will reduce the coma. What is not so generally known is that the coma can be reduced even further by distorting the reflector cross sections from simple conic sections to transcendental curves. This principle was first discovered by K. Schwarzschild in 1905. Schwarzschild was concerned with optical systems and his technique has been applied to telescopes. The Schwarzschild telescope has, however, since been replaced by the Schmidt telescope for wide angle observations.

The accompanying illustrations show the type of performance available with two-reflector antennas. What is plotted is the coefficient of the coma aberration. The actual path error is $Kh^3/3$, where K is the coefficient plotted* and h is the distance of a point on the surface of the primary reflector from the central axis of the system. In Figure 1, we show a number of systems scaled to have the same effective focal length, and in Figure 2 these same systems are rescaled so that the focal lengths of the primary mirrors are the same. Consider now the case of a simple parabolic reflector, a Cassegrain system having a magnification of two, and a Cassegrain system having a magnification of 4. As shown in Figure 1, all three curves are tangent at the origin. This indicates that, for small angles off axis, the performance of a Cassegrain is a function only of the effective focal length and is independent of the magnification. As we go further, however, we find that the Cassegrain curves deviate from that of the parabola and that, for high magnifications, the deviation becomes apparent earlier.

* In scaling to other focal lengths, the coma coefficient varies inversely as the square of the focal length.

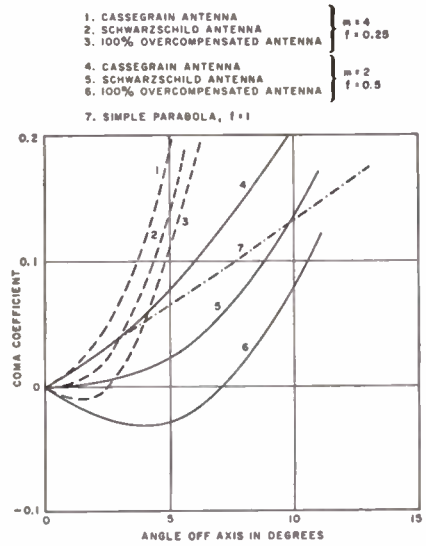


FIGURE 1. COMA COEFFICIENT VERSUS ANGLE OFF AXIS (NORMALIZED FOR EFFECTIVE FOCAL LENGTH OF ONE)

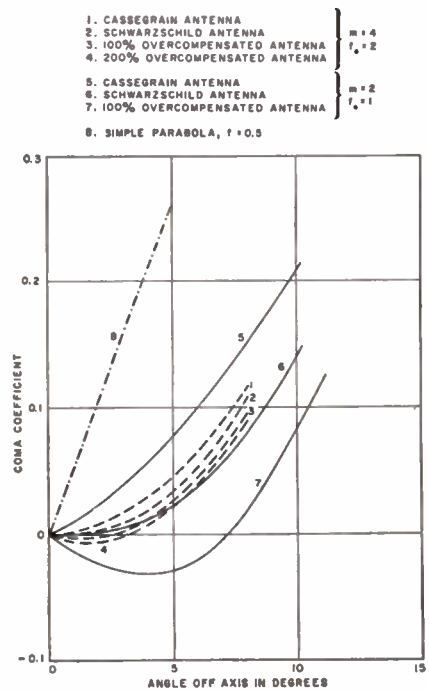


FIGURE 2. COMA COEFFICIENT VERSUS ANGLE OFF AXIS (NORMALIZED FOR PRIMARY FOCAL LENGTH OF 0.5)

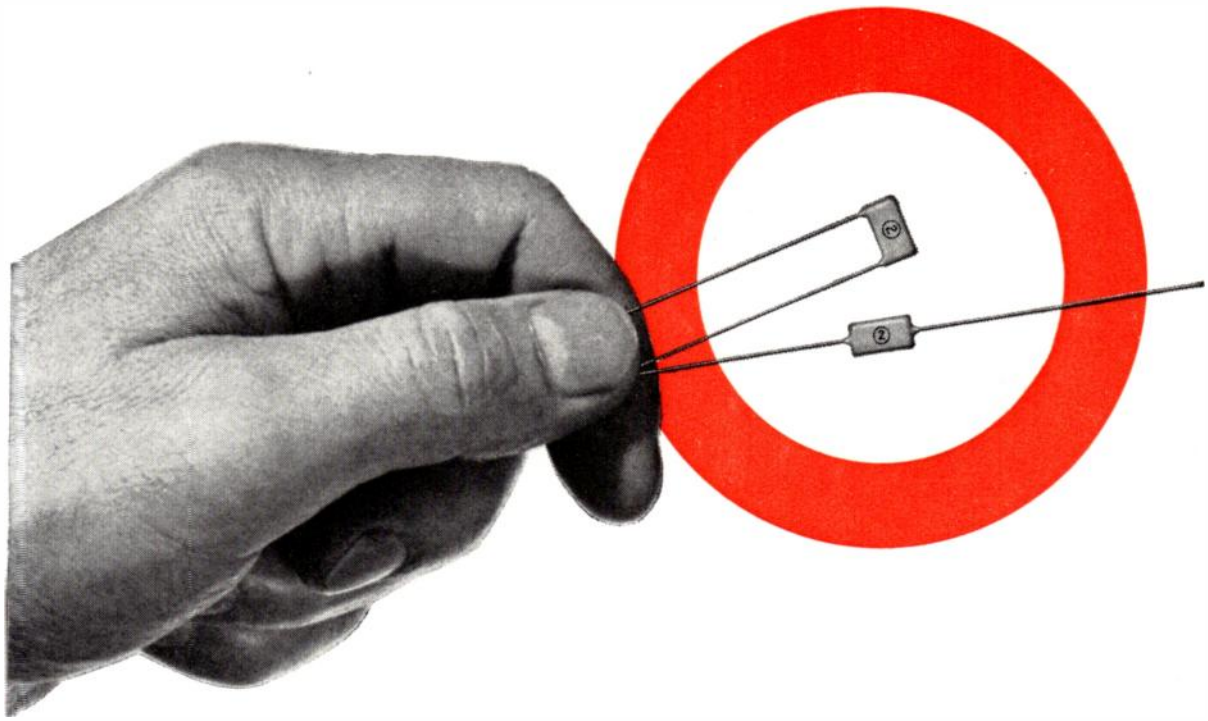
In the case of the Schwarzschild antenna, the curves approach the origin with zero slope. For small angles then, the coma of a Schwarzschild system is much less than that of the equivalent Cassegrain. For larger deviations off axis the improvement is less pronounced but in all the cases we have investigated, the Schwarzschild always outperforms the equivalent Cassegrain. In some cases, it appears that an overall improvement can be obtained by going beyond the Schwarzschild design somewhat. These overcompensated antennas have a negative coma for small deviations and null the aberration at some finite angle.

Figure 2 shows the beneficial effects of using high magnification with a given primary reflector. For small angles, the higher the magnification the better. For larger angles, there appears to be an optimum magnification and for still larger angles, it would probably be wise to use a different type of antenna.

Since the Schwarzschild antenna always has better performance than the equivalent Cassegrain, it is somewhat surprising that it has not seen more widespread use. When it comes to hardware, the only difference is the shape of the reflectors. It would appear that this is due, at least in part, to the lack of design information in the published literature. To alleviate this problem we have prepared some reprints of a paper presented at the 1962 IRE International Convention. The paper, "Scanning Characteristics of Two-Reflector Antenna Systems," summarizes some of the results that have been obtained. If you are interested in a copy, write to Harold Hechtman at AIL. Copies of this paper are yours for the asking.

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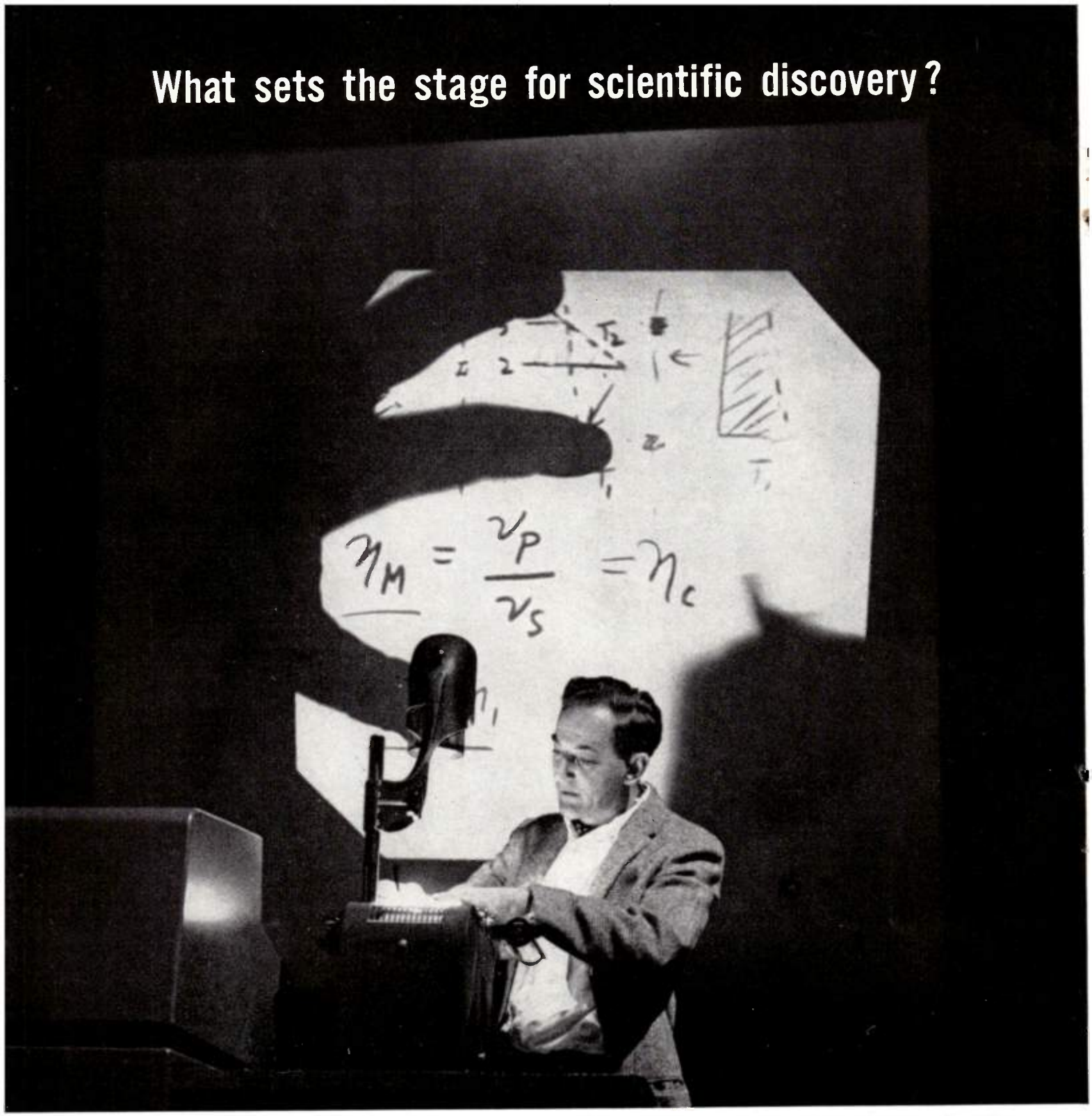
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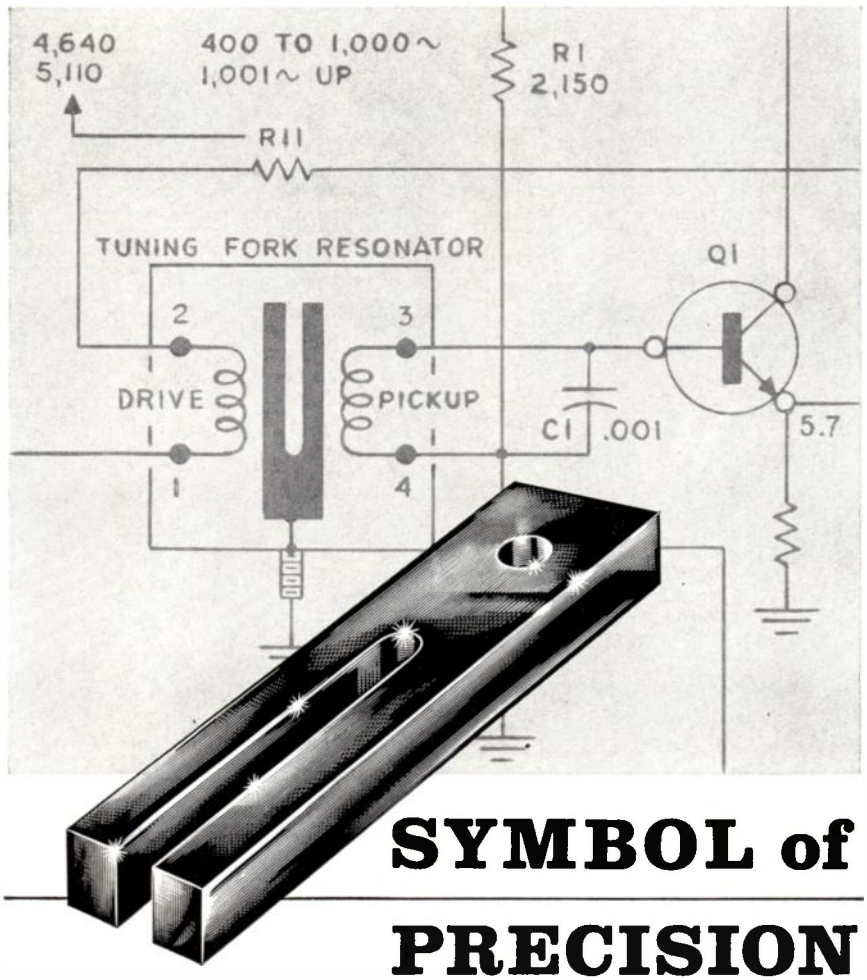
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Meetings with Exhibits

● 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.

Δ

April 11-13, 1962

SWIRECO (South West IRE Conference & Electronics Show), Rice Hotel, Houston, Texas

Exhibits: Mr. J. C. Robinson, P.O. Box 1505, Houston, Texas.

May 1-3, 1692

Spring Joint Computer Conference, Fairmont Hotel, San Francisco, Calif.

Exhibits: Mr. John W. Ball, Pacific Telephone Co., 3240 Arden Way, Sacramento, Calif.

May 14-16, 1962

NAECON (National Aerospace Electronics Conference), Biltmore Hotel, Dayton, Ohio

Exhibits: Mr. Robert J. Stein, 19 Beverly Place, Dayton 19, Ohio

May 23-25, 1962

National Telemetering Conference, Sheraton Park Hotel, Washington, D.C.

Exhibits: Mr. L. H. King, Jansky & Bailey Co., Shirley Highway & Edsall Rd., Alexandria, Va.

May 24-26, 1962

IRE Seventh Region Conference on "Space Communications," Olympic Hotel, Seattle, Wash.

Exhibits: Mr. J. K. Schloss, 1520 N.E. 106th, Seattle 55, Wash.

June 12-14, 1962

Armed Forces Communications & Electronics Show, Sheraton Park Hotel, Washington, D.C.

Exhibits: Mr. William C. Copp, 72 W. 45th St., New York 36, N.Y.

June 18-19, 1962

Chicago Spring Conference on Broadcast and Television Receivers, O'Hare Inn, Chicago, Ill.

Exhibits: Mr. John H. Landeck, Admiral Corp., 3800 W. Cortland St., Chicago 47, Ill.

June 25-27, 1962

Sixth National Convention on Military Electronics, Shoreham Hotel, Washington, D.C.

Exhibits: Mr. L. D. Whitelock, 5614 Greentree Rd., Bethesda 14, Md.

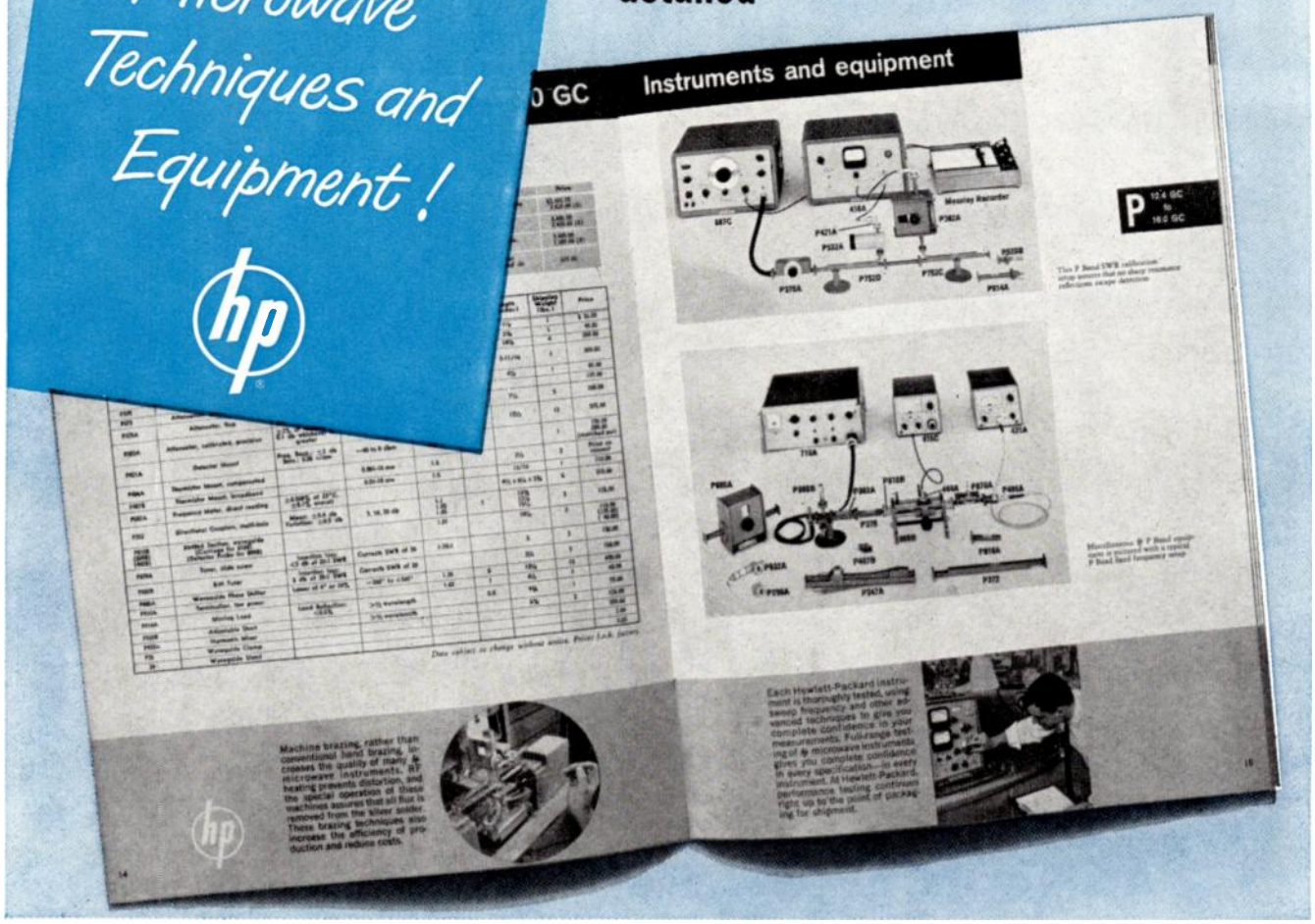
(Continued on page 10A)

Send for this New Guide to Microwave Techniques and Equipment!

Instruments, specs listed by frequency band!

Typical bench setups pictured

Microwave techniques authoritatively detailed



This new ⓗ Microwave Catalog gives you a complete listing of Hewlett-Packard's full-range tested microwave instrumentation, together with helpful descriptions of various microwave measurement techniques. The information and the instrumentation are fully indexed, with instruments and equipment listed by frequency bands. Just find the frequency ranges in which you are interested . . . and you have basic specs on all available equipment and instrumentation, together with a photograph of a setup incorporating the instruments.

Typical of the information in the catalog are discussions of swept frequency measuring techniques, methods for measuring SWR, and measurement of frequency, impedance, attenuation, power and noise figure.

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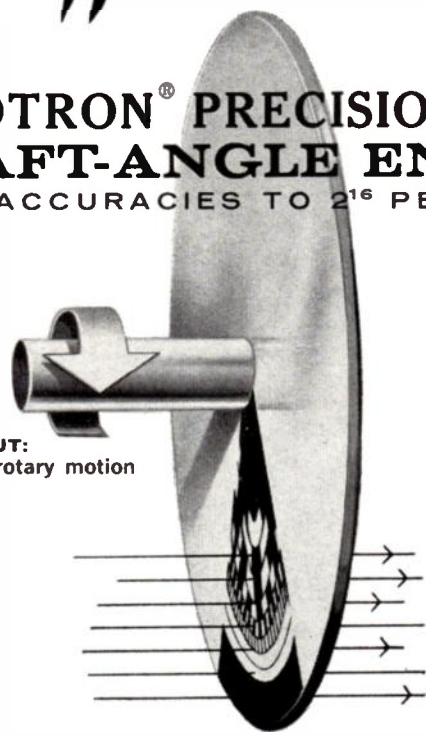
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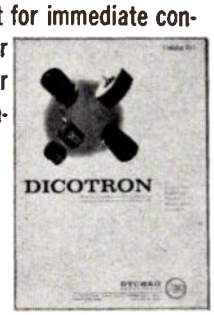
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Meetings with Exhibits

(Continued from page 8A)

June 25-27, 1962

Sixth National Conference on Product Engineering & Production, Los Angeles, Calif.

Exhibits: Mr. Lionel Crown, International Computer, 4301 Redwood Ave., Los Angeles 66, Calif.

August 21-24, 1962

Western Electronics Show and Conference (WESCON), Ambassador Hotel & Memorial Sports Arena, Los Angeles, Calif.

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

August 29-September 1, 1962

Second International Conference on Information Processing, Munich Germany

Exhibits: Dr. Heinz Billing, Max Planck Institute, Munich, Germany

September 3-7, 1962

National Advanced Technology Management Conference, Opera House, Seattle World's Fair Grounds, Seattle, Wash.

Exhibits: Mr. Hugh Fairclough, 1624 22nd Avenue East, Seattle 2, Wash.

October 1-3, 1962

Eighth National Communications Symposium, Hotel Utica & Utica Municipal Auditorium, Utica, N.Y.

Exhibits: Mr. R. E. Gaffney, General Electric Co., Light Military Electronics Dept., Utica, N.Y.

October 2-4, 1962

Seventh National Symposium on Space Electronics & Telemetry, Fontainebleau Hotel, Miami, Fla.

Exhibits: Dr. Martin J. Gould, 2400 East El Segundo Blvd., Trailer 23, El Segundo, Calif.

October 8-10, 1962

National Electronics Conference, McCormick Place, Chicago, Ill.

Exhibits: Mr. Rudy Napolitan, National Electronics Conference, 228 N. LaSalle St., Chicago, Ill.

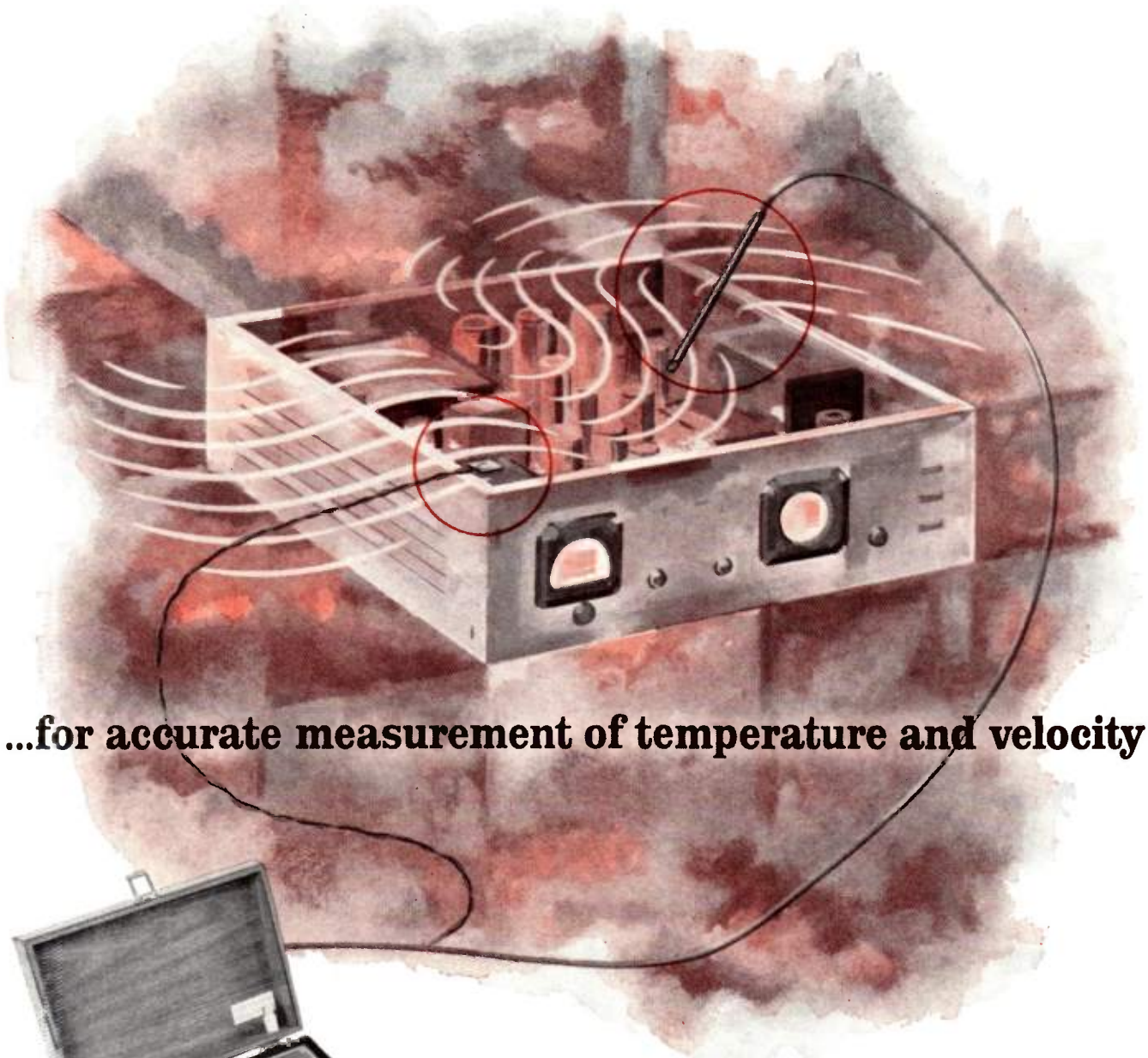
October 15-18, 1962

Symposium on Space Phenomena & Measurement, Statler Hilton Hotel, Detroit, Mich.

Exhibits: Mr. D. J. Niehaus, Bendix Research Laboratories, Southfield, Mich.

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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.



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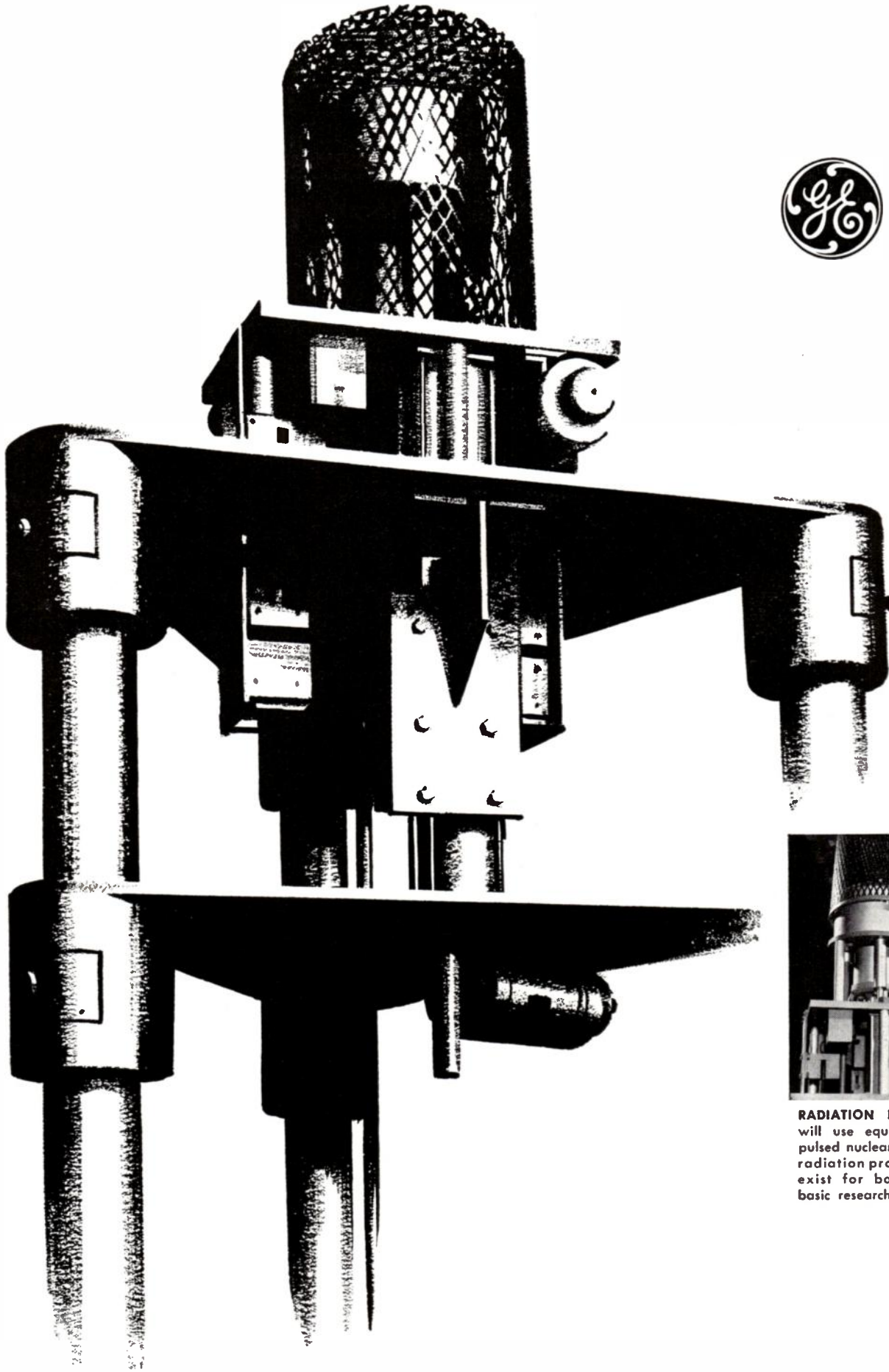
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GE NEWS.



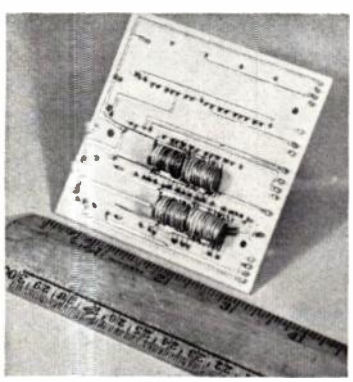
RADIATION EFFECTS OPERATION will use equipment such as this pulsed nuclear test reactor to solve radiation problems. Capabilities exist for both simulation and basic research in radiation effects.

...OF DEFENSE TECHNOLOGIES

NUCLEONICS

The damaging effects of radiation from nuclear weapons and space have introduced a whole new class of problems in the design of electronic systems and support equipment. For example, gamma radiation ionizes air to provide leakage paths for stray currents. Conventional insulating materials become partial conductors. The performance of transistors and ferrites is altered and voltages are induced in coils, wires, and cables. Van Allen radiation darkens the windows of space vehicles and causes deterioration of semi-conductor materials, such as solar cells.

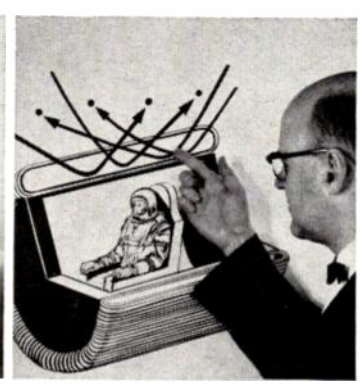
The creation of systems and equipment to function reliably in these environments requires special test facilities, skills tools, and knowledge that have been developing at General Electric for more than twenty years. A newly organized Radiation Effects Operation is now integrating nuclear and electronic disciplines (nucleonics) and further developing the capabilities of the Company in this new field.



HARDENED ELECTRONICS, such as this Thermionic Integrated Micro Module Board, are being developed. TIMM circuits operate above 500°C. and can tolerate 1000 times more radiation than conventional circuits.



NUCLEAR DETECTION SYSTEM (NUDETS-477L) is the first defense system combining nuclear and electronic technologies. It is being developed for U. S. Air Force to locate and measure any nuclear explosion in U. S.



SHIELDING OF SPACE VEHICLES from radiation may be possible by surrounding them with magnetic energy. This new concept, under study for NASA, may alleviate the need for heavier solid shielding.



ELECTRO-HYDRAULIC HANDYMAN is an example of remotely operated servo systems being produced to manipulate radioactive materials for routine tasks as well as highly specialized nuclear research projects.

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IRE News and Radio Notes

Current IRE Statistics

(As of February 28, 1962)

Membership—97,133
Sections—111
Subsections—33
Professional Groups—29
Professional Group Chapters—296
Student Branches†—220

† See June, 1961, issue for a list.

Calendar of Coming Events and Author's Deadlines*

1962

Mar. 1–3: 8th Scintillation and Semiconductor Counter Symp., Shoreham Hotel, Washington, D. C.
Mar. 26–29: IRE Internat'l. Conv., Coliseum and Waldorf-Astoria Hotel, New York, N. Y.
Mar. 28–30: 3rd Symp. on Engrg. Aspects of Magnetohydrodynamics, Univ. of Rochester, Rochester, N. Y.
Apr. 10–12: 2nd Symp. on the Plasma Sheath, New England Mutual Hall, Boston, Mass.
Apr. 11–13: SWIRECO (S. W. IRE Conf. and Electronics Show), Rice Hotel, Houston, Tex.
Apr. 24–26: Symp. on the Mathematical Theory of Automata, United Engrg. Ctr., New York, N. Y.
May 1–3: Spring Joint Computer Conference, Fairmont Hotel, San Francisco, Calif.
May 3–4: 1st International Congress on Human Factors in Electronics, Lafayette Hotel, Long Beach, Calif.
May 4–5: Bay Area Symp. on Reliability and Quality Control, U. S. Naval Postgraduate School, Monterey, Calif.
May 8–10: Electronic Components Conf., Marriott Twin Bridges Hotel, Washington, D. C.
May 14–16: NAECON, Dayton, Ohio.
May 14–16: Symp. on Thermionic Power Conversion, Antlers Hotel, Colorado Springs, Colo.
May 22–24: Nat'l. Microwave Theory and Techniques Symp., Boulder, Colo.
May 22–24: Conf. on Self-Organizing Principles, Museum of Science and Industry, Chicago, Ill.
May 23–25: Nat'l. Telemetering Conf., Sheraton Park Hotel, Washington, D. C.
May 24–26: IRE 7th Region Conf. on "Space Communications," Olympic Hotel, Seattle, Wash.
June 18–19: Chicago Spring Conf. on Broadcast and Television Receivers, O'Hare Inn, Chicago, Ill.
June 25–27: 6th Nat'l. Conf. on Product Engrg. and Production, Los Angeles, Calif.

* DL = Deadline for submitting abstracts.

(*Continued on page 15A*)

Call For Papers

GEOSCIENCE ELECTRONICS ISSUE

PROCEEDINGS OF THE IRE

A special issue of the PROCEEDINGS OF THE IRE will be devoted to Geoscience Electronics during the Fall of 1962. The emphasis will be on electronic instrumentation and systems which has important application in the study of the earth and other planetary bodies, the ocean, the lower ionosphere, and the upper ionosphere.

The issue is being organized under the co-editorship of Arthur H. Waynick, Electrical Engineering Dept., Pennsylvania State University, and Richard A. Arnett, Geosciences Div., Texas Instruments Inc.

Manuscripts should be submitted in triplicate to: E. K. Gannett, Managing Editor, Geoscience Electronics Issue, Institute of Radio Engineers, 1 E. 79 St., New York 21, N. Y. The deadline for submission is June 1, 1962.

GOLDEN ANNIVERSARY OF AMATEUR RADIO LICENSING

Amateur radio operators who were first licensed in 1912 and who are still active today will be honored at a Golden Anniversary Banquet to be held at the Statler-Hilton Hotel, New York City, on October 13, 1962 to celebrate 50 years of amateur radio licensing by the U. S. Government.

Fifty years ago Congress adopted the Radio Act of 1912. As one of its features, the Act required for the first time that amateur radio operators obtain a license from the Department of Commerce and Labor after passing an examination. The Secretary of Commerce and Labor at that time who signed these first licenses was Charles Nagel.

The celebration of the Golden Anniversary of Amateur Radio Licensing is being handled by a special Committee comprising representatives of a number of sponsoring societies including the American Radio Relay league, Armed Forces Communications and Electronics Association, IRE, Quarter Century Wireless Association, Radio Club of America, Hudson Amateur Radio Council and the Single Sideband Amateur Radio Association. The officers of this Committee are John DiBlasi, Chairman, who is also President of the Quarter Century Wireless Association; John Huntoon, Vice-Chairman and General Manager of the American Radio Relay League, and David Talley, Secretary-Treasurer, who is a member of all of the aforementioned sponsoring societies.

A search is now in progress to locate those who obtained their ham "tickets" during the initial months of licensing in 1912 and are currently licensed by the Federal Communications Commission as amateur radio operators. An appropriate award will be made to all such amateurs by the sponsoring societies. It will be presented to those able to attend the Golden Anniversary Banquet which will be held in conjunction with the Hudson Division Convention of the American Radio Relay League.

Old-time hams who meet the requirements of the award should send documentary proof of eligibility which can be in the form of the original or an attested photocopy of the initial amateur radio license issued in 1912, to the American Radio Relay League, Inc., West Hartford, Conn., Attention Mr. John Huntoon, before August 15, 1962. In cases where the original 1912 license has been lost or destroyed, the listing of the ham's name and amateur station call letters in the July 1, 1913 edition of the government callbook, "Radio Stations of the United States," may be considered as satisfactory proof.

CALL FOR PAPERS 1962 MAECON

The 1962 Mid-America Electronics Conference will be held November 13–14 at the Hotel Muehlebach, Kansas City, Mo. The theme of the Conference will be "Electronics and Automation." Papers are solicited which deal with some aspect of this general theme.

The following materials should be submitted by June 15, 1962:

1) 100 to 200 word abstract, including title of paper, name and address of author.

2) 500 to 1000 word summary of the paper.

There is no proceedings for this conference, but authors are encouraged to distribute copies of their papers at the time of delivery.

Address all materials to Dr. John N. Warfield, MAECON Papers Chairman, Electrical Engineering Department, University of Kansas, Lawrence, Kansas.

RQC SYMPOSIUM CALL FOR PAPERS

The Ninth National Symposium on Reliability and Quality Control will be held at the Sheraton-Palace Hotel, San Francisco, Calif. on January 22–24, 1963. Authors who are interested in presenting a paper should observe the time table of the Program Committee which is as follows:

May 15, 1962 is the deadline for submission of title of paper and abstract of not more than 800 words. The letters and

spaces in the title for the program must not exceed 50. Submit brief biographical sketches of the author or authors, suitable for publication in the Proceedings. For papers with more than one author, please indicate a single author for the oral presentation.

The Program Committee must perform the difficult task of selecting only a fraction of the papers that are submitted. It would be most helpful if, in a covering letter, authors would provide supplementary information such as:

1) *New Work.* A reference to the author's most recent paper in the same subject area, together with a summary of what will be new in the symposium presentation.
2) *Speaking Ability.* Reference to presentations that have been made to technical society chapters, together with identification of any chapter program chairmen who may be used as reference.

Ten copies of the abstract and biographies should be sent to: Leslie W. Ball, The Boeing Company, P.O. Box 3707, Seattle 24, Washington.

Authors will be notified of paper acceptance or rejection June 30, 1962, and the complete paper should be submitted to the Program Committee for publication in the Symposium Proceedings by October 6, 1962. All papers must be new and not presented prior to the Symposium at a national society meeting. Papers presented at local meetings are acceptable.

Symposium on Automatic Control

A Symposium on Automatic Control will be held on April 10, 1962 at the Cohen Arts Center, Tufts University, Boston, Mass. The meeting is jointly sponsored by the Boston Section of the AIEE and the Boston Chapter of the IRE-PGAC.

The objective of the Symposium is to bring together representatives of industry and universities working in the Automatic Control field for an interchange of ideas on recent theoretical developments and applications. Seven papers will be presented covering topics on adaptive control, computer control systems, process applications, industrial dynamics, high performance servo systems and nonlinear systems.

Symposium programs and abstracts of the papers may be obtained by contacting J. P. Lienesch, The Foxboro Company, Foxboro, Mass.

ACM Conference Call for Papers

The 1962 ACM National Conference, the 17th annual meeting, which will include an International Data Processing Exhibit, will be held on September 4–7 at the Hotel Syracuse and the War Memorial Auditorium, Syracuse, New York.

The conference, sponsored by the Association for Computing Machinery, will include contributed papers on the areas and suggested topics detailed below:

1) Scientific Information Processing: a) Numerical Analysis and Mathematical Applications, b) Applications in the Physical Sciences, c) Engineering Analysis, Simulation and Synthesis.

2) Automatic Programming and Computer Languages: a) Compilers and Assemblers, b) Monitor Systems, c) ALGOL, COBOL, etc.

3) Business Information Processing: a) Business and Management Control Systems, b) Automated Clerical Systems, c) Operations Research and Management Simulation.

4) Information Retrieval: a) Memory Devices, b) Automatic Abstracting, c) Indexing Methods.

5) Language Translation: a) Natural Languages (English, French, Russian, etc.), b) Artificial Languages.

6) Education: a) Use of Computers in Education, b) Education of Computer Personnel.

7) Real Time Information Processing: a) Programming Real Time Computers, b) Simulation of Real Time Processes.

8) Social Aspects and Philosophies: a) Responsibilities of Computer Personnel, b) Social Problems of Today, c) Predictions for the Future.

Papers representing original contributions in these and related fields are invited.

On or before May 1, 1962, such contributions in the following form (in quadruplicate) should be mailed for screening to the Technical Program Co-Chairman, R. W. Beckwith, 7614 Hunt Lane, Fayetteville, N. Y.:

800–1000 word illustrated summary (about 4 pages) and a 35-word abstract.

Both the summary and abstract should highlight the nature of the contribution, its significance in the art and theoretical and experimental results. Accompanied by key drawings or photos, or both, the manuscripts should be submitted on single-side, black on white, double-spaced typewritten form, with the author's name, affiliation, address and telephone on the first page, and author's name and abbreviated paper title on subsequent pages. On papers with multiple authorship, the name of the speaker who will deliver the paper should be so noted. The 35-word abstract will be published in an advance program.

An innovation at ACM 62 will be a *Digest of Technical Papers* which will be distributed at the meeting and will include illustrated condensations of all papers.

The program will include a number of invited papers, round-table discussions and "Halls of Discussions" periods. Suggestions for topics here will be welcomed.

General Chairman of the ACM 62 conference is R. S. Jones, Sylvania Electric Products, Inc., Camillus, N. Y.; J. C. Batz, General Electric Co., Syracuse, is Vice-Chairman. J. P. Menard, Syracuse University, is serving as Technical Program Co-Chairman.

Calendar of Coming Events and Author's Deadlines*

(Continued from page 14A)

June 25–27: 6th Nat'l. Convention on Military Electronics, Shoreham Hotel, Washington, D. C.

June 25–30: Symp. on Electromagnetic Theory and Antennas, Tech. Univ. of Denmark, Copenhagen.

June 27–29: Joint Automatic Control Conf., New York Univ., New York, N. Y.

June 27–28: 9th Annual Symp. on Computers and Data Processings, Elkhorn Lodges, Estes Park, Colo.

June 28–29: 4th Nat'l. Symp. on Radio Frequency Interference, Town House Hotel, San Francisco, Calif.

July 18–19: Data Acquisition and Processing in Medicine and Biology, Whipple Aud., Strong Mem. Hosp., Rochester, N. Y.

Aug. 14–16: Internat'l. Conf. on Precision Electromagnetic Measurements (former title: Conf. on Standards and Electronic Measurements), Nat'l. Bur. Standards, Boulder, Colo. (DL*: Mar. 15, 1962, Dr. G. Birnbaum, Hughes Res. Lab., Malibu, Calif.)

Aug. 21–24: WESCON (Western Electronics Show and Conf.) Los Angeles, Calif.

Aug. 27–Sept. 1: 2nd Internat'l. Federation of Information Processing Societies Congress, Munich, Germany.

Sept. 3–7: Internat'l. Symp. on Information Theory, Brussels, Belgium.

Sept. 3–7: Nat'l. Advanced Technology, Management Conf., Seattle, Wash.

Sept. 3–7: 4th Internat'l. Congress on Microwave Tubes, Kurhaus Hotel, Scheveningen, Netherlands. (DL*: Mar. 15, 1962, Congress Office, Postbox 62, Eindhoven, Netherlands.)

Sept. 13–14: 10th Annual Engineering Management Conf., Hotel Roosevelt, New Orleans, La.

Sept. 13–14: Nat'l. Symp. on Engineering Writing and Speech, Mayflower Hotel, Washington, D. C. (DL*: Mar. 15, 1962, J. E. Durkovic, c/o ARINC, 1700 K St., N.W., Washington 6, D. C.)

Sept. 19–20: 11th Annual Industrial Electronics Symp., Chicago, Ill.

Sept. 28–29: 12th Annual Broadcast Symp., Willard Hotel, Washington, D. C.

Oct. 7–12: AIEE 1962 Fall General Meeting—3rd Ann. Symp. on Switching, Circuit Theory and Logical Design, Chicago, Ill. (DL*: Apr. 1, 1962, W. Semon, Sperry Rand Res. Ctr., North Rd., Sudbury, Mass.)

Oct. 30–31: Conf. on Engrg. Techniques in Missile and Spaceborne Computers, Disneyland Hotel, Anaheim, Calif.

Nov. 12–14: Radio Fall Meeting, King Edward Hotel, Toronto, Ont., Canada.

Nov. 13–14: MAECON (Mid-America Electronics Conf.), Hotel Muehlebach, Kansas City, Mo.

* DL = Deadline for submitting abstracts.

Call for Papers

NORTHEAST ELECTRONICS RESEARCH AND ENGINEERING MEETING

Technical papers describing significant original advancements—focused on research and development—are invited for presentation at the 1962 Northeast Electronics Research and Engineering Meeting (NEREM), which will be held November 5–7, 1962, in the Commonwealth Armory and the Somerset Hotel, Boston, Mass. This year's program will include many invited state-of-the-art tutorial sessions, discussion panels, as well as contributed topical papers on new developments. All IRE-Member registrants will receive at the conference, free of additional charge, a copy of the *Nerem Record* with digests of every paper presented at the meeting.

A suggestive, but not inclusive, list of subject areas for NEREM-62 is:

Radar Astronomy: Systems, Antennas, Superpower tubes, and Low-Noise front ends.

Quantum Electronics: Coherent-Light Generation, Modulation, Detection, and Application.

Information Technology: Pattern Recognition, Learning, and Teaching Machines.

Plasmas: Interaction with Microwave, Theory and Applications as Energy Converters, and Millimeter-Wave Generators.

Solid-State Devices: Semiconducting, Paramagnetic, Ferrimagnetic, Ferromagnetic, and Ferroelectric.

Engineering Management: Marketing, Production Techniques, and Reliability.

Communication and Control: Theory and Applications.

Also: Antennas and Wave Propagation, Biophysics and Medical Electronics, Microelectronics, and Electron Devices.

To permit the development of well-integrated technical sessions, speakers are requested to furnish either complete papers or 400–500 word abstracts, in triplicate, plus 50-word summaries for advance program mailings.

All material should be mailed on or before June 11, 1962, to the NEREM-62 Program Chairman: I. Goldstein, Raytheon Company, Box 555, Hartwell Rd., Bedford, Mass. Authors will be notified of acceptance or rejection by August 1, 1962.

1962 SPRING URSI MEETING

The 1962 Spring URSI Meeting will be held April 30 to May 3, 1962 at Georgetown University in Washington, D. C. The URSI Commissions involved are: 1) Radio Measurement Methods and Standards, 2) Tropospheric Radio, 3) Ionospheric Radio, 4) Magnetospheric Radio, 5) Radio Astronomy, 6) Radio Waves and Circuits, and 7) Radio Electronics. IRE Professional Groups jointly sponsoring the meeting with URSI are: Antennas and Propagation, Circuit Theory, Information Theory, Instrumentation, and Microwave Theory and Techniques, in coordination with COSPAR, which is the Committee on Space Research of the International Council of Scientific Unions (ICSU). COSPAR is holding a Plenary Meeting and the Third International Space Science Symposium in Washington on April 30 to May 9. Inasmuch as these dates include the dates of the URSI Meeting, certain mutual coordination has been arranged.

Official delegates to the COSPAR Plenary Meetings and Space Science Symposium are invited to attend the technical sessions of URSI without paying the registration fee. An effort will be made to schedule all URSI sessions of interest to COSPAR delegates on April 30 and May 1.

Persons registered at the URSI Meeting are invited to attend the sessions of the COSPAR Space Science Symposium on May 2 and 3. The sessions on May 2 will be devoted to "Upper Atmosphere and Exosphere of the Earth and Relationship to Solar Disturbances;" and on May 3 to a continuation of this topic, to "Technologies of Space Research," and to "Life Sciences."

The membership of U.S.A. Commission 2 has considered a revised definition of its fields of interest within URSI and was authorized by the National Commmittee at its 1961 Fall Meeting to solicit papers from a broader scope of interest for the 1962 Spring Meeting. These fields transcend the troposphere. Broadly, they include all natural non-ionized media as related to the propagation of electromagnetic waves. Thus in addition to the refraction, absorption, and scintillation of radio waves within line of sight, and the diffraction and scattering of waves beyond line of sight, they cover propagation along and below the earth's surface as well as backscattering from that surface. They overlap the fields of radiometeorology, satellite communications and signal statistics insofar as these subjects pertain to propagation and its mechanisms. In the case of non-terrestrial environments, as for example in the consideration of backscatter from lunar and planetary surfaces, and refraction and absorption in non-ionized planetary atmospheres, Commission 2 can assist Commission 5.

Certain other meetings of interest to those attending the URSI Meeting will be held in Washington during the preceding week:

1) American Geophysical Union (AGU) —Annual Meeting: April 25–28.

For information, write: Waldo Smith, American Geophysical Union, 1515 Massachusetts Ave., N.W., Washington 5, D. C.

2) International Symposium on the Meteorological Uses of Satellites: April 23–25.

This meeting is sponsored by World Meteorological Organization (WMO), International Union of Geodesy and Geophysics (UGGI), and Committee on Space Research (COSPAR). For information, write: Dr. Harry Wexler, U. S. Weather Bureau, 2400 M Street, N.W., Washington 25, D. C.

3) International Symposium on the Use of Artificial Satellites for Geodesy: April 26–28.

This meeting is sponsored by International Association of Geodesy (of UGGI), and Committee on Space Research. For information, write: William M. Kaula, National Aeronautics and Space Admn., Washington 25, D. C.

Note: The international symposia are not open to the public but special arrangements have been made to accommodate persons attending the AGU Meeting.

ELECTROMAGNETIC SCATTERING CONFERENCE SET FOR AUGUST

An Interdisciplinary Conference on Electromagnetic Scattering will be held August 13–15, 1962 at Clarkson College of Technology, Potsdam, N. Y.

The purpose of this conference is to bring together scientists of widely different backgrounds interested in Electromagnetic Scattering in order to discuss problems of mutual interest which transcend disciplinary lines. In addition to the lectures, the program will be scheduled to allow maximum time for general discussion by all participants.

This program is being sponsored by the Division of Colloid and Surface Chemistry of the American Chemical Society, and the Air Force Cambridge Research Labs., Office of Aerospace Research, U. S. Air Force.

Preregistration will be necessary by May 15. In the event of an exceptionally large response, it may be necessary to limit the number of participants. Final invitations will be mailed about June 1. For preregistration write directly to Dr. Milton Kerker, Clarkson College of Technology, Potsdam, N. Y.

NEC TO BE HELD IN CHICAGO

The 1962 National Electronics Conference will be held at Chicago's new exposition hall, McCormick Place, on October 8–10. Attendance at the forum for electronic research, design and application is expected to reach 18,000. Over 600 electronic firms are expected to participate in the exhibit portion of the Conference, and 100 technical papers will be presented at the McCormick Place meeting rooms and theater.

An additional 2000 American Institute of Electrical Engineers will also be visiting the Conference. The AIEE will be conducting its Fall General Meeting in Chicago during the NEC period, and a convenient joint registration procedure has been arranged.

10 NEW INSTRUMENTS



MODEL LE

New

Lindeck Microvolt Source for use as:

- A comparator in the calibration of volt ratio boxes, saturated standard cells and similar instrumentation.
- A direct measuring instrument in the microvolt range.

Ranges: 0-1/2/5/10/20/50/100/200/500 μv; 1/2/5/200 mv; 2 v.

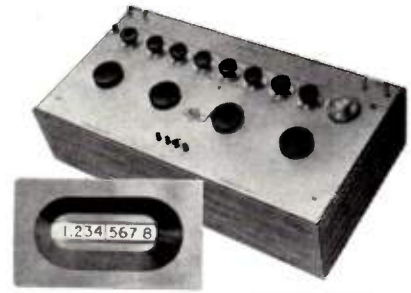
Accuracy: ±.5% of full scale

Readout: SRIC Model C. 100 division, 6.3" hand-drawn scale. Accuracy .25%. Diamond pivoted!

Application is described in NBS Paper RP1419, "Testing and Performance of Volt Ratio Boxes". Copies available upon request.

Model PCM "Pocket-Pot." A new multirange, high sensitivity, miniature potentiometer, with self-contained galvanometer and battery operated standardization circuit. In-line readout. Continuous resolution on slidewire with 1 mv. divisions. Infinite resistance at null. Total measuring range 0-5.100 v. Plug in unit available to increase measuring range to 500 v. and 1 amp. (Model PC-S). Accuracy ±.05% of reading; ±.5 mv. on x1 range; ±.1 mv. on x.1 and x.01 ranges.





SINGLE WINDOW READOUT

COMMANDER TYPE 9120

New

A 4 dial, 7 figure precision potentiometer with single window readout and a resolution of 1 part in 20 million. Total measuring range of 2.099,999,9 volts in steps of .1 μv. is achieved without the necessity of switching ranges. **Accuracy ±(.0015% of reading +.1 μv.)**

Facilities are incorporated to enable the user to completely "Self Check" the potentiometer within its guaranteed accuracy. All positions on the measuring dials are calibrated steps (no slidewire). Thermal emf's are less than .1 μv.

SENSITIVE RESEARCH

ELECTRICAL MEASURING INSTRUMENTS SINCE 1927



COMMANDER TYPE 9152P

New

A portable constant temperature air bath designed to eliminate the hazards involved in transporting saturated standard cells. It is an ideal transfer standard when direct intercomparison of saturated standard cells is desired between a calibration laboratory and NBS or between variously located calibration facilities of the same organization. Enclosure accommodates three saturated cadmium cells constructed with a porous partition to greatly improve portability. Cells can be certified to ±.0001%.

Weight (30 lbs.) and box size (18" L x 10" W x 10" H) are convenient for hand carrying. Provision is made for operation from a portable battery pack, a 110 volt AC line or a car cigarette lighter outlet. Enclosure is maintained at a nominal 32°C and is guaranteed not to vary more than ±.01C° even after continuous exposure to ambient temperatures down to 0°F (−17.4°C) in still air.



MODEL PC-R

"Plug-in" Wheatstone Bridge for use with PocketPot to make DC resistance measurements from .1 Ω to 9.999 megohms. Accuracy is ±1% from .1 Ω to 10 Ω; ±.2% above 10 Ω to 1 megohm; ±2% above 1 megohm to 9.999 megohms.

New

COMMANDER Type 9770: Constant current source for standardizing a DC potentiometer or supplying a stable current to any circuit in the range of 10 ma. to 100 ma. Current stability is ±(1 ppm + stability of reference cell).

New

COMMANDER Type 9180: A 3 dial, 5 figure version of the Dauphinee Potentiometer. Accuracy ±.002% of reading. Range: −10μv. to +2.10100 v. in steps of 10 μv. on X1. Additional ranges of X.1, X.01 and X.001 with resolution to .01 μv. Thermal emf's less than .1 μv. "Self Checking".

New

COMMANDER Type 9174: A dual range, 2 dial, 4 figure microvolt potentiometer. Thermal emf's less than .02 μv. Accuracy ±.01% of reading. Range: −10 μv. to + 1010 μv.

New

Model ESX: AC/DC, 0-150 v., electrostatic voltmeter with DC scale expansion enabling practical readings down to 2 v. Input resistances from 1×10^{14} Ω.



COMMANDER TYPE 9790

New

A DC amplifier for the measurement of low level voltages in the fractional microvolt range. Features are:

1. .03 μv. lowest range.
2. Immediate recovery from overloads of 1,000,000%.
3. .003 μv. stability over a 24 hour period.
4. Facility for compensation of stray thermal emf's.
5. Easy accessibility for maintenance purposes.

Output is 1 ma. into 1500 Ω, or 1 mv., 10 mv. or 100 mv. F.S. Input resistance of 50 Ω to 1000 Ω depending on input transformer selected. Continuously variable gain control. Calibration signals to the input (accuracy ±5%) are .03/.1/.3/1/3/10/30/100/300 μv. Response time is 2 to 5 seconds to 90% F.S.

SENSITIVE RESEARCH
INSTRUMENT CORPORATION
New Rochelle, N. Y.

COMMANDER instruments are manufactured for Sensitive Research by Guildline Instruments, Ltd., Smiths Falls, Canada.

Fifth Annual UCLA Leadership Laboratory

University of California Extension's fifth annual "Leadership Laboratory" in human relations and supervisory skills for managers and leaders, will be held at the Ojai Valley Inn in Ojai, Calif., from May 27 through June 2, 1962. Charles K. Ferguson, Head of the Department of Conferences and Program Consultation for University of California Extension, will be instructor. Others in the staff will include Richard Beckhard, Management Consultant of New York; Robert Blake, Professor of Psychology and Industrial Administration, Carnegie Institute of Technology in Pittsburgh; Frank Tallman, Professor of Psychiatry at UCLA Medical Center and John Weir, Professor of Psychology, California Institute of Technology.

Other short courses scheduled for June will be as follows: "Atomic Physics and Space Science," June 11 through 25; "Information Display Systems," June 18 through 22; "Ceramics for Space Vehicles," June 18 through 29; "Astrodynamics and Rocket Navigation," June 18 through 29; "Magnetofluid and Plasma Dynamics," June 18 through 29; "Advances in Space Propulsion," June 18 through 29; and "Automatic Checkout for Aerospace Vehicles," June 18 through 29. Most of them will be held on the UCLA campus.

Further information concerning these and other Engineering courses may be obtained from University of California Engineering and Physical Sciences Extension, UCLA, Los Angeles 24, Calif.

Air Force MARS Announces Schedule

The Air Force MARS Eastern Technical Net broadcasting on 3295, 7540, and 15,715 kc announces the following schedule of broadcasts on Sundays, 2–4 P.M., EST:

April 1—"Advantages of Compactron Multi-Function Tubes in Electronic Equipment," L. T. Bowles and C. W. McCool, General Electric Co., Receiving Tube Dept.

April 8—"What Computers Can Do," E. Wolff, General Electric Co., General Engineering Laboratory.

April 15—"Latest Trends in Military-Type Transistors," D. T. Geiser, General Electric Co., Light Military Electronics Department.

April 22—"Transistorized Citizens Band Transceivers," W. D. Williams, RCA Semiconductor Products Laboratory.

April 29—"Use of Transistors as High Power Oscillators and Amplifiers," K. E. Loofbourrow, RCA Semiconductor Division.

May 6—"Novel Equipment for MARS and Amateur Stations," R. Gunderson, Braille Technical Press.

Tech Sessions Set For 1962 SJCC

A technical program offering 37 papers in 11 sessions has been set for the 1962 Spring Joint Computer Conference at the Fairmont Hotel, San Francisco, Calif., May 1–3. Sponsor of the conference is the American Federation of Information Processing Societies. Dr. Richard I. Tanaka, manager of Computer Systems-Logical Design for Lockheed Missiles and Space Co., Palo Alto, is Technical Program Chairman. He is being assisted in developing the conference program by Dr. Robert S. Minnick, senior research engineer at Stanford Research Institute, Vice-Chairman; John E. Sherman, manager of Analog Computing for Lockheed at Sunnyvale, Associate Chairman; and R. J. Andrews, Industry Analysis manager for IBM at San Jose, Chairman of a Special Education Program.

The professional presentations will place focus on new developments, suggest trends and, in general, try to "nail down" the contributions computer technology are expected to make in the near and distant future. Accordingly, one session entitled "Peace and the Role of Computers" will describe the part computers may be expected to take in man's search for world peace. Dr. Louis Fein, Palo Alto, Calif., consultant, will serve as chairman for this symposium.

In addition to the symposium to be headed by Dr. Fein, the sessions and chairmen will be as follows:

"Computer Systems," James H. Pomerene of IBM Research Center, Yorktown Heights, N. Y.; "Circuits and Memory Devices," Jack I. Raffel of MIT's Lincoln Laboratory, Cambridge, Mass.; "Information Retrieval," Jacob Goldberg of Stanford Research Institute, Menlo Park; "Man-Machine Cooperation," Dr. Douglas C. Engelbart of Stanford Research Institute.

"Theoretical Problems in Artificial Intelligence," Russell A. Kirsch, National Bureau of Standards, Washington, D. C.; "Data Analysis and Model Construction in the Study of the Nervous System," Dr. Belmont G. Farley of MIT's Lincoln Laboratory; "Programming and Coding," Dr. Bernard A. Galler of the University of Michigan Computing Center, Ann Arbor.

"Study of Business Systems," Dr. Frederick M. Tonge of the Graduate School of Business, Stanford University; "DDA and Hybrid Computation," Dr. Harold K. Skramstad of Naval Ordnance Laboratory, Corona, Calif.; and "Analog Applications and Techniques," Vernon L. Larrowe of the Analog Computing Laboratory, University of Michigan.

Professional Group News

At its meeting on February 13, 1962, the IRE Executive Committee approved the following new Chapters: PG on **Automatic Control**—San Francisco Chapter; PG on **Electron Devices**—Albuquerque-Los Alamos Chapter; PG on **Engineering Management**—Buenaventura Chapter; PG on **Engineering, Writing and Speech**—Syracuse Chapter; PG on **Information Theory**—Buffalo-Niagara Chapter; PG on **Radio Frequency Interference**—Canaveral Chapter; PG on **Radio Frequency Interference**—Seattle Chapter.

Electronic Components Conference

Marriott Twin Bridges Hotel, Washington, D. C., May 8–10, 1962

Tuesday Morning, May 8

Opening address: "New Directions at the Crossroads," *R. C. Sprague, Chairman of the Board, Sprague Electric Co., and Director of EIA.*

Session I

Chairman: *T. R. Finch, Bell Telephone Labs., Murray Hill, N. J.*

"The Approaching Integration of Devices, Systems, and Circuits—A Challenge to the Components Engineer," *R. Rice and R. B. Seeds, Thomas J. Watson Res. Ctr., Yorktown Heights, N. Y.*

"Reliability Through Controlled Environments and Microminiaturization," *G. W. A. Dummer, Royal Radar Establishment, Malvern, Eng.*

"Component Needs and Requirements—Present and Future," *H. W. Welch, Jr., Motorola, Inc., Phoenix, Ariz.*

Tuesday Afternoon

Session II

Chairman: *R. Cypser, IBM, Kingston, N. Y.*

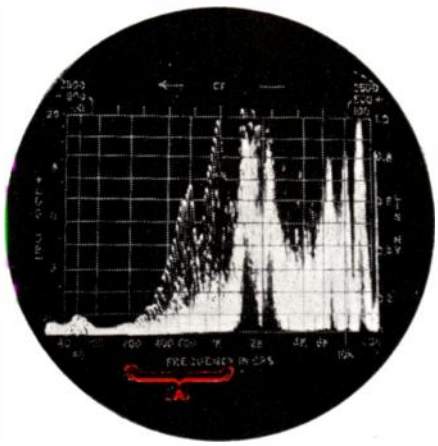
"High-Density Tantalum-Film Microcircuits," *T. V. Sikina, Philco Scientific Lab., Blue Bell, Pa.*

"Film Circuit Panel for Space Guidance Computer," *A. E. Lessor, J. W. Skerritt, R. E. Thun, D. S. Weed, IBM Command Control Ctr., Federal Systems Div., Kingston, N. Y.*

"Preparation and Evaluation of Thin Film Circuit Functions," *J. J. Bohrer, B. J. Patton, G. N. Queen, Jr., International Resistance Co., Philadelphia, Pa.*

"Design of a System for Deposition of Compound Thin Films by Evaporation from

fast, direct-reading, easy-to-use



"Coast-down" analysis of Gyro Motor by Model LP-1a Spectrum Analyzer. Area A shows decreasing fundamental frequency, resonant rise and decay, and vibration components over 60 successive scans in one minute.

PANORAMIC LP-1a
SONIC SPECTRUM ANALYZER
20 cps-22.5 kc.

HIGHLIGHT FEATURES:

- 1-sec. "quick-look" at entire spectrum (40 cps—20 kc)
- Magnified analysis on reduced sweep widths
- Direct reading frequency—selective voltmeter
- Exceptionally stable circuitry; better than 5 cps/hr.
- Economical
- Simple Operation

The Model LP-1a "quick-look" helps locate and evaluate discrete or random signals *faster* and *easier* by scanning the entire spectrum logarithmically from 40 cps to 20 kc. Once every second it automatically separates, measures and plots the frequency and voltage of waveform components on the calibrated X and Y axes, respectively, of a long persistence 5" CRT.

For very detailed analysis, linear segments 40 to 5000 cps wide, centerable between 0 and 20 kc, may be magnified on the screen. Amplitude ratios of up to 40 db can be simultaneously measured.

High sampling rate and panoramic displays assure

1. **Minimum risk of missing weak signals or spectrum holes.**
2. **Fast measurements by eliminating slow point by point plots.**
3. **Simultaneous measurement of signals with widely divergent amplitudes and/or frequencies.**
4. **Continuous analysis of rapid changes in spectral content or design parameters.**

Proved in hundreds of research, design and production installations, the LP-1a is a valuable tool for Noise and Vibration analysis. Harmonic and IM measurements. • General waveform studies. • Power Spectral Density analysis. • Response Curve Tracing.

SUMMARY OF SPECIFICATIONS:

Frequency Range: 20 cps—22.5 kc.
(1) Preset linear frequency scans: any segment width of 200, 1000, 5000 cps centerable from 0-20 kc : Variable from 40 cps to 5000 cps with Auxiliary Function Unit C.
(2) Preset Log Scan—40 cps to 20 kc

Frequency Scales: Linear and Log

Center Frequency Control: Calibrated 0-20 kc (used on lin scan)

Dynamic Range: 60 db

Amplitude Scales: Linear and 2 decade log (Expandable to 60 db)

Sensitivity: 500 μv to 500 v for full scale linear deflection

Voltage Accuracy: Lin Sweep (40 cps—22.5 kc) : ± 5% or ± 0.5 db. Log Sweep (40 cps—20 kc) : ± 10% on lin ampl. scale, ±1.5 db on log ampl. scale.

Scan Rate: 1/sec., internally generated; adjustable with accessory equipments

Resolution: For log scan, automatically optimized. For lin scan, preset 30, 75 and 170 cps at 200, 1000 and 5000 cps sweepwidth, respectively. Variable from 10 cps to 1 kc with Auxiliary Function Unit C.



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Separate Sources," *D. R. Frankl, A. Hagenlocher, E. D. Haffner, A. Sandor, General Telephone and Electronics Labs., Inc., Bayside N. Y.; P. H. Keck, Texas Instruments, Inc., Dallas, Tex.; E. Both, H. J. Degenhart, USASRDL, Fort Monmouth, N. J.*

"The Conjugate Function Approach for Describing Current Density and Resistance in Odd-Shaped Conductors," *R. J. Dow, Bell Telephone Labs., Whippany, N. J.*

"Integrally Fabricated Resistors and Their Performance," *M. Beckerman and R. L. Bullard, IBM, Command Control Ctr., Federal Systems Div., Kingston, N. Y.*

"Properties of Tantalum Sputtered Films," *D. Gerstenberg and E. H. Mayer, Bell Telephone Labs., Murray Hill, N. J.*

Alternate: "Substrate Considerations in the Deposition of Film Passive Components," *R. J. Settzo, Corning Glass Works, Bradford, Pa.*

Wednesday Morning, May 9

Session III

Chairman: *H. Hazzard, Sprague Electric Co., North Adams, Mass.*

"Mylar Capacitors," *E. Bushnell, Sprague Electric Co., North Adams, Mass.*

"Miniature Lacquer Film Capacitor Pilot Production," *W. S. Banzhof, Western Electric Co., Inc., Winston-Salem, N. C.*

"Some New Developments in Solid-Aluminum Electrolytic Capacitors with Etched Aluminum Foil," *W. Post, Aluminium-Walzwerke Singen G.m.b.H., Singen, Ger.*

"The Use of Conducting Ceramics in the Preparation of a New Type of Ceramic Capacitor Having a Large Space Factor," *A. W. Stirling, R. A. Hill, Standard Telecommunication Labs. Limited, Harlow, Essex, Eng.; N. J. Hellicar, Standard Telephones and Cables Limited, Paignton, Devon, Eng.*

"Sputtered Dielectric Capacitors," *E. E. Smith and S. G. Ayling, Standard Telecommunications Labs., Limited, Harlow, Essex, Eng.*

"Microminiature Titanium Oxide and Silicon Oxide Capacitors," *J. R. Johnson, L. C. White and H. G. Rudenberg, Transitron Electronic Corp., East Boston, Mass.*

Wednesday Afternoon

Session IV

Chairman: *W. M. Redler, NASA, Washington, D. C.*

"The Design of Piezoelectric Ceramic Resonator Filters with Prescribed Insertion Loss," *J. D. Schoeffler, Case Institute of Technology, Cleveland, Ohio; D. R. Curran and W. M. Szczecinski, Clevite Corp., Cleveland, Ohio.*

"Miniature Crystal Controlled Oscillators for Satellite Environments," *W. L. Smith and W. J. Spencer, Bell Telephone Labs., North Andover, Mass.*

"Some New Developments in the Design of Band-Pass Filters Composed of Coupled Resonant Elements," *E. C. Johnson, U. S. Naval Air Development Ctr., Johnsville, Pa.*

"Guided Wave Ultrasonic Delay Lines," *J. E. May, Jr., Bell Telephone Labs., Whippany, N. J.*

"High Dimensional Acoustic Coders," *J. E. Taylor, General Dynamics, Electronics, Rochester, N. Y.*

"A Distributed Network Oscillator and Bandpass Amplifier," *M. Kahn, Sprague Electric Co., North Adams, Mass.*

Thursday Morning, May 10

Session V

Chairman: *J. H. Schumacher, Electronic Industries Association, New York, N. Y.*

"Development and Application of Fiber Optics Techniques to Precision Measuring Devices, Transducers and Automatic Control Systems," *E. D. Grim, Radio Corp. of America, Camden, N. J.*

"Design of Broadband Ferrite Load Isolators," *R. A. Henschke and D. A. Parkes, Melabs, Palo Alto, Calif.; E. Friebergs, USASRDL, Fort Monmouth, N. J.*

"Ferrielectric Components," *D. J. Boaz, Aeronautical Systems Div., ASRNEB-2, Wright-Patterson A F Base, Ohio.*

"The Influence of Deposition Temperatures on Magnetic Parameters of Permalloy Thin Films," *J. S. Lemke and R. D. Morrison, Remington Rand Univac, St. Paul, Minn.*

"Measuring Thickness and Composition of Thin Surface Films by Means of an Electron Probe," *B. W. Schumacher and S. S. Mitra, Ontario Research Foundation, Toronto, Can.*

"Cooling Micromodules Internally by Peltier Junctions," *D. K. Allison, Albuquerque, N. Mex.*

Alternate: "New Broadband RF Connectors," *M. Pomerantz and W. E. Mayo, USASRDL, Fort Monmouth, N. J.; R. M. Janowiak, Armour Research Foundation, Chicago, Ill.*

Thursday Afternoon

Session VI

Chairman: *A. Sternberg, General Electric Co., Philadelphia, Pa.*

"Surface Failure of Electrical Insulating Materials in a Space Environment," *L. J. Frisco and A. M. Muhlbaum, The Johns Hopkins University, Baltimore, Md.*

"Component Reliability in Orbiting Satellites," *C. F. Willard, ARINC Research Corp., Washington, D. C.*

"Fuse Usage in Reliable Equipment," *M. A. Dean, Sperry Gyroscope Co., Great Neck, N. Y.*

"The Unimite Relay—Its Characteristics and Statistically Planned Test Program," *R. A. Holcomb and W. H. Lesser, General Electric Co., Waynesboro, Va.*

"Aging Studies on Transformer Insulating Materials (Class A) by Means of Infrared Spectroscopy," *G. Lengyel, Ontario Research Foundation, Toronto, Can.*

"Micromodule Reliability," *D. T. Levy, Radio Corp. of America, Somerville, N. J.*

Alternate: "Human Factors Control and Display Design Standards for the Fleet Ballistic Missile Weapon System (Polaris)," *A. N. Chambers and P. B. Preusser, Dunlap and Associates, Inc., Stamford, Conn.*

Symposium on Thermionic Power Conversion

ANTLERS HOTEL, COLORADO SPRINGS, COLO., MAY 14–17, 1962

The Symposium is co-sponsored by the Technical Society and the Department of Defense. Participating societies are the IRE, AIEE, American Nuclear Society, Division of Electron Physics of the American Physical Society, and the American Rocket Society.

It is intended that the proceedings of the Conference will be published as special issues of the *Journal of Advanced Energy Conversion;* papers will be included in the published proceedings by agreement of the author and the editors.

No preregistration is required, but in order to facilitate planning, it is requested that hotel reservations be made at the earliest possible date. Requests for rooms should be sent directly to The Antlers Hotel where special rates have been established for the Symposium.

The technical program is as follows:

Monday Morning, May 14

Welcome: *G. B. Wareham, DOD, R&E, General Chairman.*

Introductory Remarks, *V. C. Wilson, Program Chairman.*

Session I—Data on Converter Performance and Characteristics

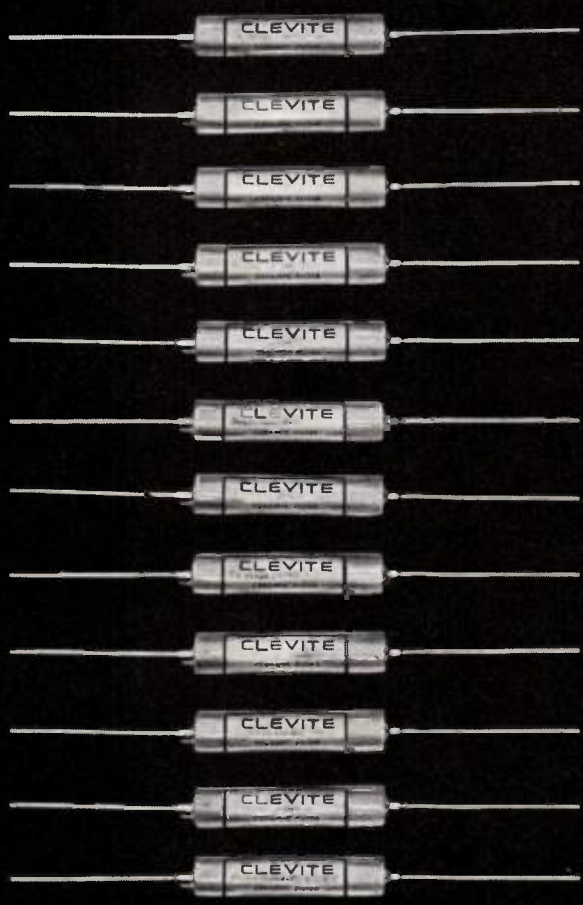
Session Chairmen: *W. B. Nottingham and John Blair.*

"Experimental Measurement and Interpretation of Volt-Ampere Curves," *J. E. Gingrich, C. Warner, and C. C. Weeks.*

"Experimental Optimization of Cesium Vapor Thermionic Converters with Metal Emitters," *C. C. Weeks, R. C. Dahleen, and J. E. Gingrich.*

"Design and Operation of Laboratory Type Parallel Plane Cesium Thermionic Converters." *V. C. Wilson and J. Lawrence.*

"Characteristics and Life Tests of Cylindrical Thermionic Converters," *J. Lawrence and V. C. Wilson.*



MODEL	6db BANDWIDTH
TL-2D5A	2 kc
TL-4D9A	4 kc
TL-6D12A	6 kc
TL-8D16A	8 kc
TL-10D18A	10 kc
TL-16D25A	16 kc
TL-20D32A	20 kc
TL-30D45A	30 kc
TL-40D55A	40 kc
TL-45D60A	45 kc
TL-32E48C	32 kc
TL-50D85C	50 kc

(suffix "A" denotes 455 kc center frequency;
suffix "C" denotes 500 kc center frequency)

Clevite Ceramic Ladder Filters

Now in stock in 12 bandwidths... 80 db rejection in 0.1 cu. in.

Clevite ceramic ladder filters provide more selectivity for their size than any conventional i-f filter. They are fixed tuned and need no alignment—are non-magnetic and non-microphonic. Leading manufacturers now have Clevite ladder filters in their communications equipment. Improve your newest design with these unique filters. Write now for complete specifications—Bulletin 94012, or for selectivity curves available on each stock model. ■ Dimensions: 5/16" diameter x 1½" long. ■ Selectivity: 60 db/6db shape factor from 1.3:1 to 2.6:1. ■ Center Frequency Stability: within 0.2% for 5 years, and within 0.2% from −40° to +85° C. ■ Impedance: 1200-1500 ohms. ■ Designed for military environment.

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WRH

"Conduction Diodes," *C. A. vonDamm and H. M. Ogle.*

"Nuclear Thermionic Fuel Element Experiments," *R. J. Duncan, H. M. Ogle, and G. I. Samstad.*

"Thermionic Converter Experiments," *J. H. Ingold, E. Blue, and W. J. Ozeroff.*

"Research on Cesium-Vapor Cells Employing Carbide Cathodes," *H. L. Garvin.*

"A High Temperature Carbide Converter," *A. Campbell.*

Monday Evening

Session II—Theoretical Models of Converters

Session Chairmen: *George N. Hatsopoulos and John M. Houston.*

"Diffusion of Electrons and Ions in a Neutral Gas," *E. Blue and J. H. Ingold.*

"Analysis and Numerical Solutions to the Space-Charge Potential Problem in Low-Pressure Thermionic Converters," *R. G. McIntyre.*

"A Plasma Sheath Theory for Noble Gas Thermionic Converters," *C. B. Leffert.*

"General Analytical Study of Cesium-Filled Thermionic Converters," *J. Psarouthakis.*

"Preliminary Analysis of Arc Mode Cesium Converter," *T. Jarvis.*

"The Surface Ionization and Volume Ionization Modes of Operation in the Thermionic Plasma Energy Converter," *M. E. Talaat.*

"Space Charge Analysis of the Cesium-Filled Thermionic Diode," *C. Warner.*

Tuesday Morning, May 15

Session III—Correlation of Experiment and Theory

Session Chairmen: *Volney C. Wilson and George A. Haas.*

"Performance Limitations on Thermionic Energy Conversion," *N. S. Rasor.*

"The Space Charge Controlled Transition from Surface to Volume Ionization," *H. Steele and R. Gillette.*

"Probe Measurements in a High-Pressure Cesium Thermionic Converter," *J. M. Houston.*

"Experimental Studies of the Emission and Discharge Characteristics in the Ta-Cs System," *M. D. Gibbons.*

"Analysis of Experimental Voltage-Current Characteristics of Cesium Thermionic Converters," *G. N. Hatsopoulos and S. S. Kitrilakis.*

Oscillations

"Space Charge Analysis of a Plasma Diode," *K. G. Hernqvist and F. M. Johnson.*

"R.F. Oscillations and Power Output in Alkaline Thermionic Converters," *H. K. Richards.*

"Cesium Plasma Triode," *B. Devin, J. D. McElroy, and S. Klein.*

"Electron Reflection from Cesium Coated Surfaces," *R. J. Zollweg.*

"Noise in Thermionic Converters," *E. Kuhn.*

Tuesday Evening

Session IV—Plasma Physics

Session Chairmen: *Frank E. Jamerson and George M. Grover.*

Fundamental

"Collision Probability of Low Energy Electrons with Cesium Atoms," *R. K. Flavin and R. G. Meyerand, Jr.*

"Thermodynamic and Transport Properties of a Cesium Plasma," *L. B. Robinson.*

"Thermal Conductivity of Cesium Vapor," *M. Gottlieb.*

"Theoretical Calculation of the Thermal Conductivity of Cesium Vapor at Thermionic Temperatures," *W. R. Martini.*

"Experimental Determination of the Heat Conduction of Cesium Gas," *S. Kitrilakis and M. Meeker.*

"The Electrical Resistivity of a Partially Ionized Cesium Plasma," *D. Roehling.*

Optical Spectra

"Experimental Cesium Line Shapes," *L. Agnew and C. Summers.*

"Plasma Broadened Line Shapes and Oscillator Strengths of Cesium," *P. M. Stone.*

"Optical Studies of the Cesium Arc," *F. M. Johnson.*

Wednesday Morning, May 16

Session V—Materials

Session Chairmen: *LCDR John J. Connelly and Robert W. Pidd.*

"Some Critical Material Problems for Thermionic Emitters Used in Fission Heat Conversion," *L. Yang, R. G. Hudson, F. D. Carpenter, A. F. Weinberg, and S. Langer.*

"Interdiffusion Between Uranium-Bearing Reactor Fuels and Refractory Metal Thermionic Emitters," *A. Weinberg and L. Yang.*

"The Development of Emitter Materials for Use in the Noble Gas Plasma Diode," *R. F. Hill and D. L. Keller.*

"Progress in the Development of Flame-Heated Thermionic Power Sources," *W. R. Martini and R. L. McKisson.*

"Emitter Corrosion in Thermionic Converters," *R. L. McKisson.*

"A Study of Cesium Vapor Attack on Thermionic Converter Construction Materials," *M. J. Slivka.*

"Physiochemical Properties of Boride Thermionic Cathode Materials," *A. I. Kaznoff, L. N. Grossman, and E. Hoyt.*

"Evaporation of Molybdenum in the Presence of Cesium Vapor," *M. Gottlieb, R. J. Zollweg, and L. S. Richardson.*

"Analyses of the Chemical Regeneration of Sublimating Thermionic Components," *L. K. Tower.*

Wednesday Evening

Session VI—Surface Phenomena

Session Chairmen: *Ned S. Rasor and H. F. Webster.*

"On the Thermodynamics of Surface Films," *E. N. Carabateas.*

"Cesium Adsorption on Refractory Metals," *A. J. Kennedy.*

"Experimental Evidence for Cyclic and Spontaneous Migration of Cesium on Rhenium and Tungsten," *G. J. Daley and J. L. Gumnick.*

"Experimental Studies of Low Work Function Anodes," *R. A. Missman.*

"Experimental Studies of Cs-CsF-Mo and Cs-CsF-W Plasma Diode Emitters," *W. A. Ranken and R. L. Aamodt, L. J. Brown and B. D. Nichols.*

"Ionization of Cesium at Surfaces," *W. B. Nottingham.*

"A Pulsed-Molecular-Beam Mass Spectrometer," *M. Kaminsky.*

"Work Function Measurements in Experimental Tubes Containing Cathodes of Uranium and Zirconium Carbides," *B. J. Hopkins, K. J. Ross, and B. H. Blott.*

"Study of Thermoemissive Properties of Uranium Carbides by an Emission Electron Microscope," *B. Devin, B. Gayte, L. Koch, and L. Sondaar.*

"Spectral Emissivities of Electrode Materials," *J. R. Branstetter.*

"Total Optical Emissivity of $(U_{.3}\ Zr_{.7})C$ in the Temperature Range 1400°K to 2800°K," *L. Miller.*

Thursday Morning, May 17

Session VII—Auxiliary Ion Sources

Session Chairmen: *Karl G. Hernqvist and Nathan W. Snyder.*

Auxiliary Discharge

"The Theory of Gas Discharges with Extraneous Ion Supply," *D. Gabor.*

"Investigations on Noble Gas Filled Thermionic Converters," *W. Bloss.*

"A Thermionic Generator with Ion Injection," *K. G. Cook, D. A. Fraser, and G. G. Isaacs.*

"Theory and Performance of Auxiliary Discharge Thermionic Energy Converters," *M. Fox and R. C. Knechtli.*

"Sources of Positive Ions for Space Charge Neutralization at Low Temperatures," *R. A. Laubenstein, C. Kaplan, and K. R. Pinckney.*

Nuclear Generated Ions

"Nuclear Generated Plasmas in Noble Gas Thermionic Converters," *F. E. Jamerson R. H. Abrams, Jr., C. B. Leffert, and R. Silver.*

"Space Charge Neutralization is Thermionic Diodes Containing Fission Product Krypton," *R. Forman and J. A. Ghormley.*

Liquid Metal Collectors

"Thermionic Energy Converter with a Liquid Collector," *P. Brosens and G. N. Hatsopoulos.*

"Thermionic Energy Conversion Diode Using a Film Boiling Liquid Metal Anode," *A. J. Ulrich.*



TUNG-SOL PRESS-FIT DIODES RATED TO 30 AMPS

NEW RELIABILITY/ECONOMY IN SILICON RECTIFIERS

Now it is possible to have the advantages of the most reliable stud-mounted diodes with the convenience and economy of press-fit assembly.

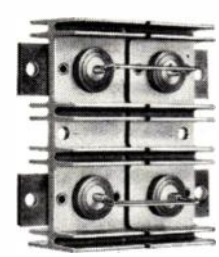
COMPACT, SMALL SIZE, INTERCHANGEABLE. Available in both polarities; one heat sink can carry more than one diode. Easily installed with hand tools or automatic machinery. Eliminate the need for mounting hardware.

RELIABILITY. Tung-Sol 30 amp press-fit silicon rectifiers are available as types 1N3659-1N3665, with ratings and characteristics as indicated below. The only press-fit diodes with welded cases and ceramic-to-metal seals to minimize leakage and resist thermal shock. Environmental testing through thousands of operational thermal cycles verifies stability of characteristics. Also available are lower current rectifiers in the same construction, types 1N3491-1N3495.

Electrically these units are the equivalent of the best available stud mounted diodes with comparable ratings. Write for complete technical information. Tung-Sol Electric Inc., Newark 4, N. J. TWK: NK193

	1N3659	1N3660	1N3661	1N3662	1N3663	1N3664	1N3665	Unit
Transient Peak Reverse Voltage.....	100	200	350	450	600	700	800	V
Repetitive Peak Reverse Voltage.....	50	100	200	300	400	500	600	V
Max. Rectified Output Current @ 100°C. case.....	30	30	30	30	30	30	30	A
@ 150°C. case.....	25	25	25	25	25	25	25	A
Max. Peak one-cycle Surge Current 60 cps..	400	400	400	400	400	400	400	A
Max. Full Load Reverse Current, Full Cycle average, 150°C. case.	5.0	4.5	4.0	3.5	3.0	2.5	2.0	mA
Max. Operating Temperature Range.....	—65°C.to + 175°C.							

INTEGRATED CIRCUITS. Tung-Sol supplies modular rectifier assemblies which embody the many practical features of the press-fit diodes. Typical is the single phase bridge assembly shown; from a package measuring only 1 1/16" x 3 1/4" x 3 1/2", outputs to 55 amperes are possible.



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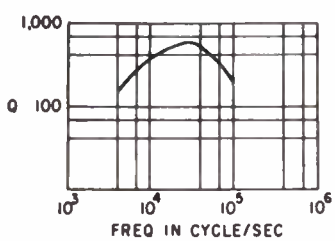
Ferrite improvements extend core use, save assembly costs

Significant advances in ferrite materials by Ferroxcube Corporation of America make possible cost and size reductions in inductive components. Such components include transformers, filters, delay lines, loading coils, modulation reactors, chokes, accelerators, pulse networks and transformers, amplifiers, oscillators, r-f tuners and many others operating at frequencies from a few hundred cycles to several hundred Mc/sec.

In the past few years, temperature stability of Ferroxcube ferrites have been radically improved while permeabilities have been increased from 500 to as high as 5000. Ferrites offer material resistivity from 10^6 to 10^{11} higher than other metal cores, reducing eddy current losses even at frequencies approaching microwave regions.

The lower losses of ferrite also give rise to higher Q components. In recording heads, and especially in erase heads, less driving power is required. Ferrites are also extremely well suited to low-power transistor applications.

Special consideration should be given to the wide frequency range over which permeability of the ferrite remains constant. Reasonably high Q values at relatively low frequencies are possible when ferrite cores are employed, (see Figure).



Typical Q curve for a particular pot curve configuration.

When selecting material for inductance or magnetic applications requiring magnetic cores, check ferrite advantages in: core costs, efficiency, ease of installation, required accuracy in the duplication of parts, size of core, possible core configurations, power requirements, frequency of operation, power losses, environmental effects, mechanical requirements, cost of assembly, overall initial and long range cost of the component.

Complete details on the various core shapes and materials are available from Ferroxcube upon request.

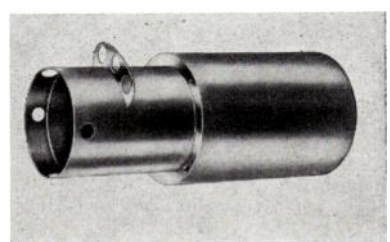
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These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

C-R Tube Shields

A new Netic Co-Netic magnetic shield, precision manufactured for close fit and retrofit display tube applications has been developed by **Magnetic Shield Div., Perfection Mica Co.,** 1322 N. Elston Ave., Chicago 22, Ill. All exposed edges of the dual lamina shield are completely sealed



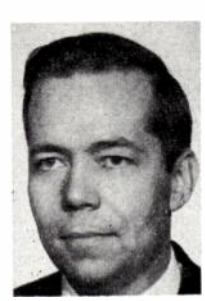
by a new fusion process. The sealed edges prevent electroplating solution from collecting between the laminates, eliminating the possibility of corrosive activity starting at a future date. This permits a highly protective electro-plated deposit of any metal to be applied. The Netic Co-Netic alloys are non-shock sensitive and non-retentive so the outer surface of the shield may be precision ground to dimensional tolerance after heat treatment. A cable guide bracket and access holes are provided for high voltage cable and associated circuitry. Special close fitting tapered edge aluminum disks are pressed in both ends of the shield to maintain concentricity in case of rough handling during shipment.

Bein and Yard Appointed by Kenyon

Kenyon Transformer Co., Inc., 1957 Summit Ave., Jersey City 7, N. J., manufacturers of industrial and military transformers, magnetic amplifiers and reactors, announces the appointment of Mr. Walter Bein and Mr. Rod Yard to their staff.



Bein



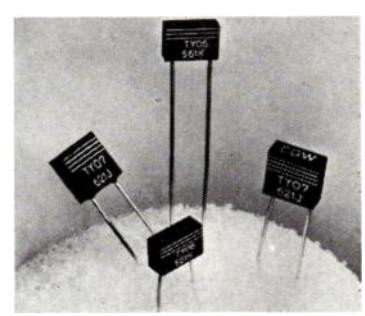
Yard

Bein has had more than twelve years of experience in the electronic wave band filters field, including ten years at Burnell and Co. where he held the position of Director of Engineering. Mr. Bein has been appointed Project Manager—Filters. He will be responsible for the design and manufacture of electronic wave band filters, operating in the frequency range from low audio to low 30 mc.

Prior to coming to Kenyon, Yard was Project Engineer at ESC Corp. where in addition to his design duties, he was responsible for the model shop, quality control and inspection departments. Mr. Yard was also connected with the Federal Telecommunications Laboratory, where he was engaged in the design and development of Pulse Communications and Missile Guidance Systems. At Kenyon, Yard will supervise manufacture of lumped constant, distributed rod and continuously variable electro-magnetic Delay Lines.

PC Glass Capacitors

Corning Electronic Components, Corning, N. Y., had developed printed circuit glass dielectric capacitors that eliminate electrical shorts between components.



The capacitive elements are made by stacking alternate layers of glass dielectric and conductor foil, then fusing the assembly into a monolithic unit. Dumet leads are welded to the conductor foil before the potting process takes place. The gold-flashed leads are 1¼-inches long, convenient for multi-board connections and also for long spans between connector holes on top of the board. The leads are 0.200-inch apart, convenient for the standard 0.1-inch grid systems for printed circuitry.

Nominal dimensions of the TY-06 are 0.300-inch length, 0.115-inch width, and 0.200-inch height. For the TY-07 they are the same except that height is 0.300-inch.

Operating temperatures are from −55 to +125°C, with no derating, and DCVW is 300 volts.

Applications are circuits requiring high component density and the reliability and stability of glass dielectric capacitors.

MINUTEMAN RELIABILITY AVAILABLE FROM FAIRCHILD

Under the auspices of Autonetics, a division of North American Aviation, Inc., Fairchild has completed the most comprehensive reliability program in the semiconductor industry. The results of this program demonstrate that Fairchild reliability is not a claim – it's a fact. MINUTEMAN parts – with proven reliability – are now available in quantity through your nearest Fairchild Sales Office.

MINUTEMAN FAIRCHILD RELIABILITY EVALUATION RESULTS

FAIRCHILD 2N1613 MINUTEMAN PART NO. 853M

Environmental Conditions	No. of Units	Millions of Transistor Hours	Observed Failure Rate	Upper 60% Confidence Limit
25°C, 10V, 150mW	13,815	45.6	.002	.004
All Units Within Ratings	14,607	46.4	.002	.004

FAIRCHILD 2N1132 MINUTEMAN PART NO. 501M

Environmental Conditions	No. of Units	Millions of Transistor Hours	Observed Failure Rate	Upper 60% Confidence Limit
25°C, 10V, 150mW	21,163	84.6	.004	.005
All Units Within Ratings	21,924	85.5	.004	.005

Note – Failure Rates expressed in %/1000 hours based on assumption of exponential distribution without any acceleration factors.

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mercury-wetted
relays!

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Industrial Engineering Notes*

Association Activities

A study of proposals for stereophonic radio broadcasting in the AM frequencies will be undertaken by EIA's Engineering Department, James D. Secrest, EIA Executive Vice President, disclosed last week. The purpose of the study, Mr. Secrest emphasized, is to lay the basis for determining whether preparation of a formal proposal to the Federal Communications Commission on AM stereo would be warranted. More than 50 FM stations have gone on the air with stereophonic broadcasts since the FCC authorized the service last spring, Mr. Secrest recalled. The authorization, he pointed out, was based on technical studies, made at the FCC's request, by the EIA-financed National Stereophonic Radio Committee. C. J. Votava (Delco Radio Division, General Motors Corp.) has been named Chairman of the AM Stereo Study Group of the Engineering Department. "The immediate goal of the group will be to determine the necessity of a more complete, thorough survey of the AM stereo situation," Mr. Votava said in accepting the chairmanship. "If the initial study indicates need and interest in the possibilities of AM stereo, a program similar to that undertaken for analysis of the FM stereo would be recommended to EIA." Manufacturers, broadcasters, and other companies having an interest in AM stereo were invited by Mr. Votava to submit names of their representatives to him in care of the EIA Engineering Department, 11 West 42nd Street, New York 36, N. Y. Mr. Votava also asked companies having technical proposals covering AM stereo systems to submit to him brief statements describing such systems. These would be used as background information in the initial phases of the study, he said.

Governmental and Legislative

Allocation of $189 million for Federal aid to airports and for air navigation facilities was announced last week by N. E. Halaby, Administrator of the Federal Aviation Agency. Mr. Halaby said the bulk of the investment is in the $114 million Federal program for purchase and installation of air navigation equipment, from long-range radar units to flashing lights to mark the ends of runways. The remaining $75 million investment is in the Federal Aid to Airports Program.

* The data on which these NOTES are based were selected by permission from *Weekly Report*, issues of January 2, 8, 15, and 22, 1962, published by the Electronic Industries Association, whose helpfulness is gratefully acknowledged.

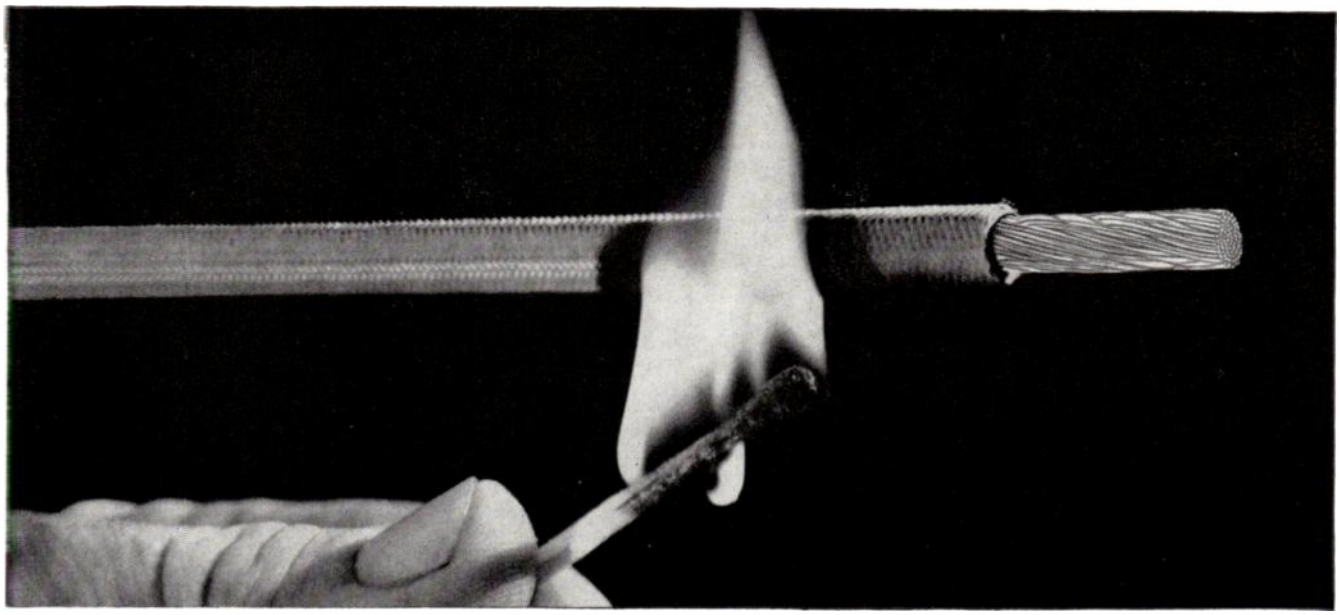
Military and Space

Centralization of electronics and communications functions in a single new arm of the proposed Army Materiel Development and Logistic Command (MDLC) is envisioned in the Army's plan for sweeping reorganization (see January 22 *Weekly Report*). The Army Communications and Electronics Command, one of seven new commands, would handle development and procurement of communications systems, electronic warfare systems, combat surveillance systems, automatic data processing equipment, and radar. The Command would also take over the current materiel functions of the Signal Corps and fire control radar functions of the Ordnance Corps.

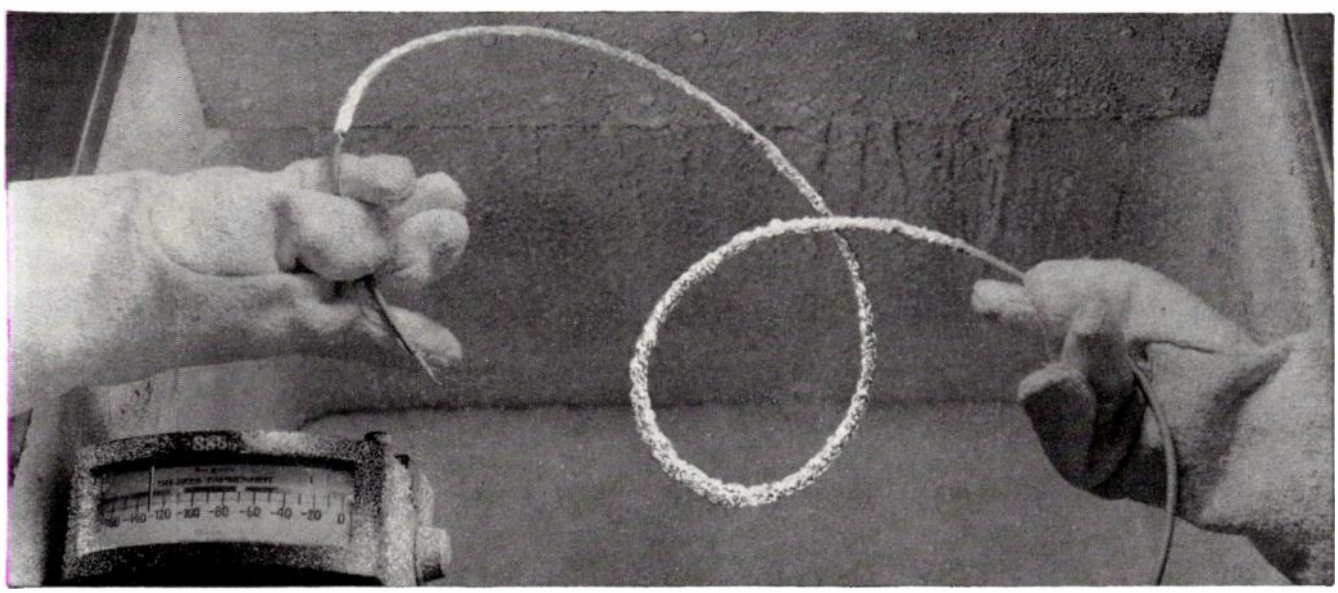
Industry Marketing Data

A spurt in radio production in December moved the 12-month total for last year 247,328 sets ahead of output during 1960, and a relatively good final month for television boosted 1961's production total 469,451 units above the previous year's. The December output of 1,845,206 radios was the second highest monthly total for 1961, the Marketing Data Department reported, and brought year-end production to 17,373,846. In 1960, 17,126,518 sets were produced. Production of 580,262 TV receivers in December raised total output last year to 6,177,797, against 5,708,346 produced in 1960. . . . **A delegation of chairmen of EIA Marketing Data Committees headed by Frank W. Mansfield (Sylvania Electric Products Inc.), Director of the Marketing Data Department, met recently with Commerce Department officials to discuss a proposed annual census of the electronics industries.** The proposal, advanced by the Business and Defense Services Administration, envisions a yearly collection by the Census Bureau of information from some 4000 companies on approximately 300 to 400 line items. The broad categories which would be covered under the BDSA plan are the following: Entertainment electronics equipment; electronic test, measuring, and recording equipment; scientific and medical electronics systems and equipment; industrial control and processing equipment; data processing equipment; broadcast, studio, and related electronic equipment; communications systems and equipment; navigation and guidance systems and equipment; search, detection, identification, and tracking systems and equipment; electronic warfare systems and equipment; electronic systems, equipment, and sub assemblies, n.e.c.; electron tubes; semiconductor devices; electronic parts; and electronic research, development, test, and evaluation.

(Continued on page 28A)



PACKARD ELECTRIC / *Heat at 500° F. inside or outside doesn't harm it!*



PE-400 AIRCRAFT CABLE / *Cold at −90° F. doesn't harden it!*

Teflon*-insulated aircraft cable is an original Packard Electric development specially designed to meet the higher service requirements of modern high-speed, high-altitude aircraft, missiles and space craft.

Packard PE-400 will withstand prolonged operating temperatures up to 500° F. Flame will not destroy its effectiveness. And it is not affected by any of the fuels or chemicals used in aircraft operation.

When temperatures drop to sub-zero, Packard PE-400 doesn't stiffen, either. For example, at −90° F. it still flexes easily and there's no cracking or crazing of insulation.

Packard PE-400 is made to exceed the requirements of the latest revised military specification MIL W-7139. This outstanding cable gives high abrasion resistance and its construction provides a hermetic seal against moisture and chemicals.

Packard cable is available in multiple colors or color coded tracers. Packard PE-400 is only one of the wide range of aircraft, missile and rocket cables produced by Packard Electric. Ask about them. Packard Electric maintains branch offices in Detroit and Los Angeles for your convenience.

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"Live Wire" division of General Motors

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NEW!

This Ballantine VTVM measures voltages

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PARTIAL SPECIFICATIONS:

Voltage range..... 30 μV to 300 V
Frequency range..... 10 cps to 1 Mc
Accuracy above 300 μV
2%, 10 cps to 700 kc
3%, 700 kc to 1 Mc

Accuracy below 300 μV
3%, 100 cps to 100 kc
Input impedance. 2 megohms shunted by 15 pF or 25 pF
Scales...Logarithmic, 3-33 volts, 0-20 db

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Industrial Engineering Notes

(Continued from page 26A)

ENGINEERING

The EIA Engineering Department's new AM Stereo Study Group needs participants and ideas for its investigation into the need for and interest in AM stereo, Group Chairman C. J. Votava (Delco Radio Division, General Motors Corp.) reminded EIA member-companies last week. The study is aimed at determining whether to prepare a formal proposal on AM stereo to the Federal Communications Commission. . . . **An 1100-page catalog of digital computers, one of the most comprehensive yet compiled, has just been released through the Office of Technical Services, U. S. Department of Commerce.** Both engineering and programming characteristics of the 222 electronics, digital computing systems either in operation or commercially available in the United States, are described in the third of a series of surveys conducted by the Ballistic Research Laboratories, Department of Defense. Large, intermediate, and small "complete" scale systems are described, regardless of whether scale is based on size, weight, cost, storage capacity or other criteria. By a "complete system," the survey refers to any electronic digital computing system with input, output, control, arithmetic and/or logical and storage units. Purpose of this survey

(Continued on page 30A)



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DIGITAL READOUT of pulse amplitudes as small as 2 millivolts peak-to-peak.

With a Tektronix Readout Oscilloscope you can check production-run units faster and easier—for simultaneously with the analog display on the 5-inch crt, you have a digital presentation on the automatic computing programmer.

You set the program *once* for all successive similar measurements.

For each quality-control check, you merely read the up-to-4-digit decimal units of actual measurement.

Indicators light to designate the readout status—whether *in* the preset-limit range, *below* it, or *above* it.

In a typical application such as transistor-switching-time measurements, you can read directly such characteristics as the delay, rise, storage, anc fall times; the total turn-on and turn-off times; the width of pulse A and pulse B; and time and amplitude between two selected points on either or both waveforms. You know immediately by the digital presentation and indicator lights whether or not the item tested has met specifications.

On a production line, in a laboratory, or for sustained testing programs, the digital readout convenience of a Type 567 can speed-up and simplify measurement of pulse amplitudes and time increments between percentages of selected amplitude levels *on an absolute or relative basis*. In addition, you can also measure pulse amplitudes and time increments on differential signals between A and B inputs.

To achieve this faster and simpler approach to precision measurement, the Type 567 incorporates many features *new* to an oscilloscope. In the automatic computing programmer, for example, some of these new features include: positionable measurement-reference zones, automatic normalization, zone-intensity markers, automatic and manual start-timing and stop-timing systems, preset-limit selector and indicators, provision for external programming. These features—and others in the two sampling plug-in units and the oscilloscope itself—enable the new Type 567 to greatly increase your measurement proficiency.

Type 567 Readout Oscilloscope (without plug-ins) . . . . . $ 700

Plug-In Units include:

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Type 3S76 Sampling Dual-Trace Unit $1100
Type 3T77 Sampling Sweep Unit . . . . . $ 650

U.S. Sales Prices, f.o.b. Beaverton, Oregon

For complete information about the characteristics and capabilities of this new Digital Readout Oscilloscope, please call your Tektronix Field Engineer.

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European and African countries, the countries of Lebanon and Turkey, please contact TEKTRONIX INTERNATIONAL A.G., Terrassenweg 1A, Zug, Switzerland, for the name of your local engineering representative. Other Overseas areas, please write or cable directly to Tektronix, Inc., International Marketing Department, P. O. Box 500, Beaverton, Oregon, U.S.A. Cable: TEKTRONIX.

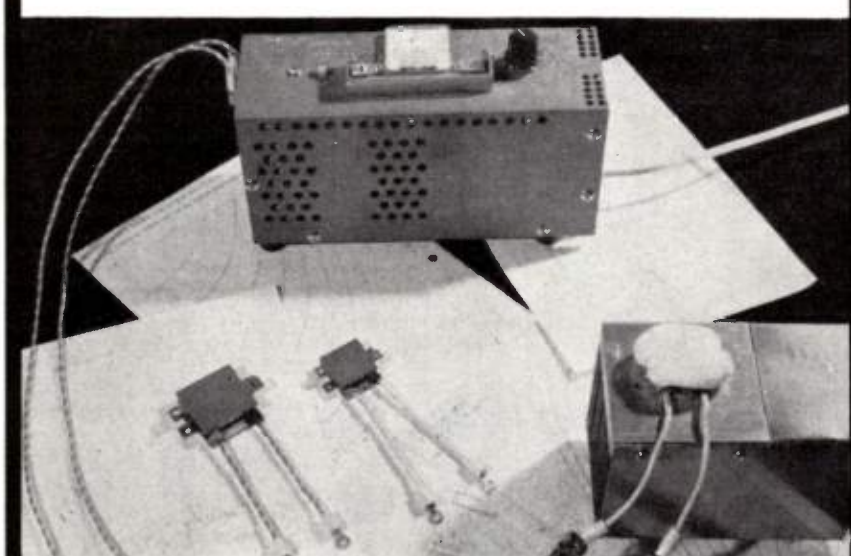
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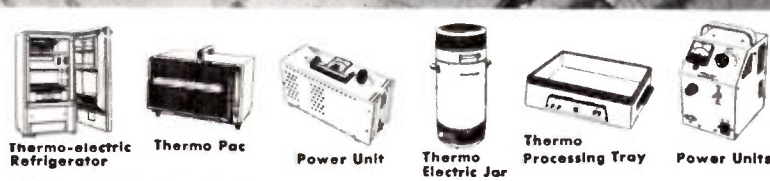
is the thermo module newly developed by Sanyo Electric Co. The technique evolved by Sanyo eliminates high cost and brittle nature of the bismuth telluride alloys used in production of thermoelements. Our exhaustive study reveals possibilities of still reducing its thinness, resulting in wider and more economical applications to scientific and electronic equipments.

SPECIFICATIONS

Type	Thermo couple	Optimum Current (amp.)	Optimum Voltage (Volt)	(1) ΔT (°C)	Insulation Voltage(2) (Volt)	Dimensions mm (inch)
STM-1025	10	25	0.9	55	50	57 × 43 × 10.5 (2.24 × 1.69 × 0.413)
STM-1021	10	21	0.9	55	50	57 × 43 × 10.5 (2.24 × 1.69 × 0.413)
STM-1016	10	16	0.9	55	50	57 × 43 × 10.0 (2.24 × 1.69 × 0.393)
STM-1012	10	12	0.9	55	50	41 × 32.5 × 9.5 (1.62 × 1.28 × 0.374)
STM-1006	10	6	0.9	55	50	41 × 29 × 9.5 (1.62 × 1.28 × 0.374)

Subject to change without notice
Note: (1) No heat load; T_h is 27°C.
(2) Voltage applied between circuit and hot or cold plate.





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Industrial Engineering Notes

(Continued from page 28A)

report "is to allow Government agencies and their contractors to benefit from the results of the computing system surveillance and evaluating program conducted by the Ballistic Research Laboratories," according to the report. Information concerning each computing system is divided into the following sub-headings: Applications; programming and numerical system; arithmetic unit; storage; input; output; circuit elements of entire system; checking features; power, space, weight and site preparation; production record; cost, price, and rental rates; personnel requirements; reliability, operating experience and time availability; additional features and remarks; future plans; and installations. Prior computing-system surveys were conducted by the Ballistic Research Laboratories in 1955 and in the period October 1956–January 1957. This third survey report, in addition to providing programming systems and other technical data for each computer, also contains photographs of each system wherever possible. The report is "A Third Survey of Domestic Electronic Digital Computing Systems," M. Weik, Ballistic Research Laboratories, for Department of the Army, March 1961; 1116 pages. Order from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Use order number PB 171 265. Price $10.

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Q-max

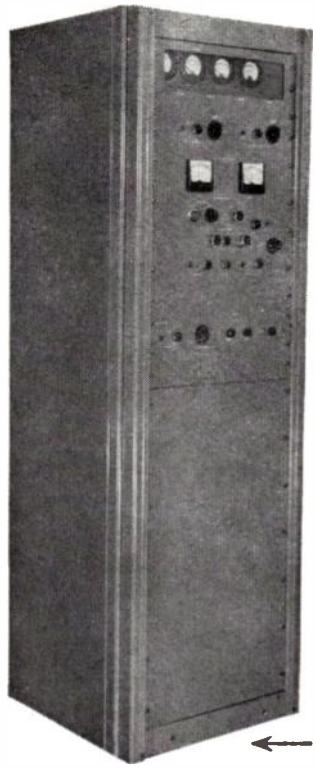
A-27
SUPERFINE
LOW-LOSS RF LACQUER

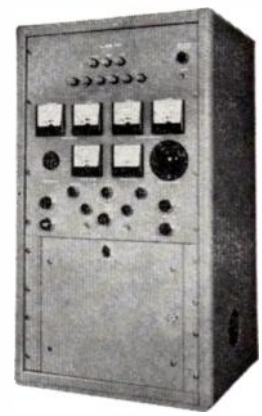
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• Q-max applies easily by dipping or brushing, dries quickly, adheres well; meets most temperature requirements. Q-max is industry's standard RF lacquer. Engineers who know specify Q-max! Write for new catalog.

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MODULATORS

Model Number	Peak Power Output	Pulse Width (μsec)	Maximum Duty Cycle	Pulse Freq. (pps)	Droop %/μsec	Rise Time (μsec)	Price
10003	−4.5KV at 2A	0.25 to 2.2	0.002	200–4000	1%	0.1	$2,450
10004	−4.5KV at 4A	0.25 to 5.0	0.001	100–2500	2%	0.1	$2,925
10005	−9KV at 4A	0.25 to 5.0	0.001	100–2500	1%	0.1	$3,850
10010	−16KV at 16A	0.25 to 5.0	0.001	100–2500	2%	0.1	$5,875
11020	−18KV at 20A	0.5, 1.0 & 2.0	0.001	200–2000	5%	0.1	$5,560
11040	−33KV at 33A	0.5, 1.0 & 2.0	0.001	200–2000	5%	0.1	$9,650

TWT SUPPLY

DC Output: −2 to −12 KV DC at 75 ma.
Regulation: 0.5% max. for 95 to 135 V line variation, 0.5% max. from no load to full load.
Grid Pulse: 0 to 600 V peak, 0.25 to 2.5 microseconds pulse width, 0.1 microsecond max. rise time. Internal repetition rate generator variable from 400 to 4000 pps, or by external trigger input. Maximum duty cycle 0.005.
D.C. Bias: 0 to 250 V at 15 ma.
D.C. Filament: 0 to 10 V at 5 A.

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FOR STANDARDS LABORATORIES



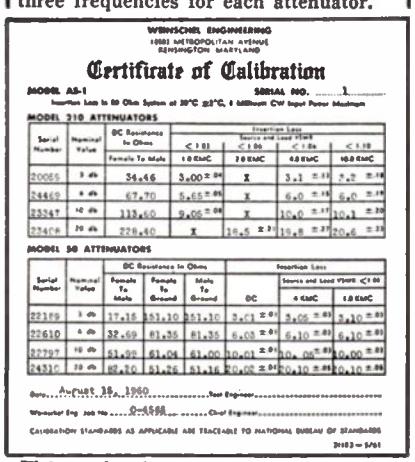
MODEL AS-1

PRECISION ATTENUATOR SET

This set contains eight Weinschel precision coaxial attenuators in a solid walnut, velvet-lined case. Included in the set are Weinschel Model 210 attenuators and Weinschel Model 50 attenuators, in attenuation values of 3, 6, 10, and 20 db. The set covers the frequency range of DC to 12.4 kmc. All eight attenuators are made with Weinschel's own stable film resistors, and have stainless steel bodies and stainless steel connectors which give maximum life with minimum wear.

CERTIFICATE OF CALIBRATION

A Certificate of Calibration showing calibration data for each attenuator is supplied with the set. The certificate gives DC resistance and insertion loss at three frequencies for each attenuator.



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KENSINGTON MARYLAND

Certificate of Calibration

MODEL AS-1 SERIAL NO. 1

MODEL 210 ATTENUATORS

Serial Number	Nominal Value	DC Resistance in Ohms	Insertion Loss			
			< 1.01	< 1.06	< 1.06	< 1.10
		Female To Male	1.0 KMC	2.0 KMC	4.0 KMC	10.0 KMC
20065	3 db	34.46	3.00 ± .04	X	3.1 ± .11	3.2 ± .16
24469	6 db	67.70	6.05 ± .05	X	6.0 ± .15	6.0 ± .19
23267	10 db	133.60	9.96 ± .08	X	10.0 ± .17	10.1 ± .20
23406	20 db	226.40	X	19.5 ± .21	19.8 ± .27	20.6 ± .35

MODEL 50 ATTENUATORS

Serial Number	Nominal Value	DC Resistance in Ohms			Insertion Loss		
		Female To Male	Female To Ground	Male To Ground	DC	Source and Load VSWR < 1.05	
						4 KMC	8.0 KMC
22189	3 db	17.15	151.10	151.10	3.01 ± .01	3.05 ± .03	3.10 ± .03
22610	6 db	32.69	61.35	61.35	6.03 ± .01	6.10 ± .03	6.10 ± .03
22797	10 db	51.92	61.04	61.00	10.01 ± .01	10.06 ± .03	10.00 ± .03
24510	20 db	82.20	51.26	51.16	20.02 ± .01	20.10 ± .05	20.10 ± .06

August 16, 1960

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IRE People

Microwave Services International of Denville, New Jersey announces the appointment of **Dr. Wallace L. Anderson** (M'58) as Chief Consultant in radio wave propagation.



W. L. ANDERSON

Dr. Anderson is a graduate of the University of New Mexico, and received the Sc.D. in electrical engineering in 1961. He was formerly lecturer and research associate on the staff of the University of New Mexico. He is currently an associate professor of electrical engineering at New York University.

Dr. Anderson has written a number of papers on tropospheric refraction and propagation. He is a member of the IRE Professional Group on Antennas and Propagation and the Society of Exploration Geophysicists.

❖

Professor Raymond G. Anthes (S'37–A'38–SM'46) has been appointed Acting Chairman of the Department of Electrical Engineering, University of Waterloo, Waterloo, Ontario, Canada.



R. G. ANTHES

Professor Anthes graduated from the University of Toronto with the degree of B.A.Sc. in Electrical Engineering in 1937, and in 1950 with the degree of M.A.Sc. From 1937 to 1947 he served as demonstrator and lecturer in the Department of Electrical Engineering at the University of Toronto. He was Senior Radio Engineer at Stromberg-Carlson Co., Ltd., Toronto, Ontario, from 1947 to 1948. He served from 1948 to 1953 as Assistant Professor and Professor on the staff of the Department of Electrical Engineering, University of Manitoba, Winnipeg, Canada. In 1953 he joined Canadian Westinghouse Co., Ltd., at Hamilton, Ontario, Canada, as Advanced Development Engineer in the Radio and Television Section of the Electronics Division of Canadian General Communications Section of the Electronics Division of Canadian Westinghouse. In 1960, he joined the faculty of the University of Waterloo as Professor of Electrical Engineering.

During his professional career, Professor Anthes has been active in IRE. He is a past chairman of the Toronto section, has been Institute representative at the University of Toronto and the University of Manitoba, and has served on the executive committees of the Toronto, Winnipeg, Hamilton and Kitchener-Waterloo sections. He has presented several papers before various Canadian IRE sections in the fields of high frequencies, audio amplifiers, and color television.

Professor Anthes is a Registered Professional Engineer in the Province of Ontario, and a member of the Canadian Association of University Teachers.

❖

Arthur B. Bronwell (A'39–SM'43–F'56) has resigned as president of Worcester Polytechnic Institute. He will become dean of engineering at the University of Connecticut.

Mr. Bronwell was graduated from Illinois Institute of Technology in 1933 and took his Master's degree there in 1936. He joined the Northwestern faculty the next year and became professor of electrical engineering in 1947, the year he received his Master's degree in business administration at Northwestern.

In that year, he also became secretary of the American Society for Engineering Education, a post he held until 1955.

In the latter year, he received an honorary doctorate of literature from Northeastern and in 1958, an honorary doctorate of engineering from Wayne State University.

While serving the American Society for Engineering Education, he was editor of its Journal for eight years. He has written for popular magazines as well as technical journals and is the author of two text books.

❖

Spectran Electronics Corp., Maynard, Mass., announced the appointment of **Joseph M. Chirnitch** (S'56–M'59) to Product Line Manager, Spectrum Analyzers. In this new post Mr. Chirnitch will be responsible for design, development and manufacture of the company's line of spectrum analyzers and related systems.



J. M. CHIRNITCH

He was formerly with MB Electronics Co., New Haven, and with Lessells and Associates Boston, Mass. While at MB Electronics, he was a co-author of "An Automatic Equalizer in a Random Vibration Analysis System."

Mr. Chirnitch was graduated from the University of Connecticut in electrical engineering.

❖

(Continued on page 34A)

New from Sprague!



TO-9 CASE

The Most Widely-Used Logic Transistor, Type 2N1499A, Now Has a Smaller Brother...

TYPE 2N979



TO-18 CASE

LOW-COST LOGIC TRANSISTOR

Here is a new Sprague Transistor that is smaller in size, yet identical in performance with the well-known 2N1499A Logic Transistor.

Designed for use in saturated switching circuits, this low-cost, hermetically-sealed MADT® Transistor is capable of switching at frequencies in excess of 10 megacycles.

In addition to computer applications, this rugged transistor is ideally suited for data processing and instrumentation equipment.

There are two major reasons why The Sprague 2N979, as with the 2N1499A, is earning a high level of acceptance:

1. DEPENDABLE PERFORMANCE — Specifically designed with parameters intended for logic circuits, these transistors consistently show low storage time, low saturation voltage, high beta, high switching speed. Their cases are cold welded to insure reliability.

2. ATTRACTIVE PRICE — Available in production quantities, these transistors are first-run devices, *not* "fall-outs". They are produced on FAST (Fast Automatic Semiconductor Transfer) lines with direct in-line process feedback, especially programmed to insure high production yields.

Here are some key parameters:

I_{CBO}	1 μa typ.
BV_{CBO}	20V min.
BV_{CES}	20V min.
f_T	100 mc min.

For application engineering assistance without obligation, write Transistor Division, Product Marketing Section, Sprague Electric Co., Concord, New Hampshire.

For complete technical data, write Technical Literature Section, Sprague Electric Company, 235 Marshall Street, North Adams, Mass.

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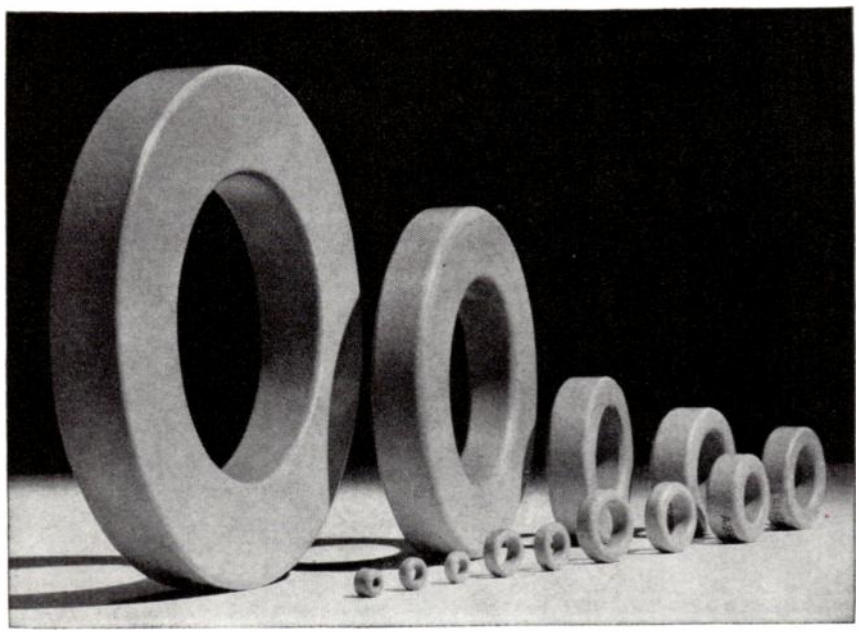
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For greater design flexibility, Arnold leads the way in offering you a full range of Molybdenum Permalloy powder cores . . . 25 different sizes, from the smallest to the largest on the market, from 0.260″ to 5.218″ OD.

In addition to pioneering the development of the cherrio-size cores, Arnold is the exclusive producer of the largest 125 Mu core commercially available. A huge 2000-ton press is required for its manufacture, and insures its uniform physical and magnetic properties. This big core is also available in three other standard permeabilities: 60, 26 and 14 Mu.

High-permeability cores of 173 Mu are now available in most sizes. These cores are specifically designed for low-frequency applications where the use of 125 Mu cores does not result in sufficient Q or inductance per turn. They are primarily intended for applications at frequencies below 2000 cps.

Most sizes of Arnold M-PP cores can be furnished with a controlled temperature coefficient of inductance in the range of 30 to 130° F. Many can be supplied temperature stabilized over the MIL-T-27 wide-range specification of −55 to +85°C . . . another special Arnold feature.

Graded cores are available upon special request. All popular sizes of Arnold M-PP cores are produced to a standard inductance tolerance of + or −8%, and many of these sizes are available for immediate delivery from strategically located warehouses.

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IRE People

(Continued from page 32A)

Dr. George I. Cohn (S'42–A'43–M'49–SM'51) has joined Electro-Optical Systems, Inc., as Chief Scientist of the Fluid Physics Division. He is involved in broad areas of research in plasma physics, electromagnetic phenomena, and magnetogas dynamics.



G. I. Cohn

Prior to joining EOS, Dr. Cohn was with Illinois Institute of Technology for 14 years, with the rank of professor the last eight. He was in charge of electronics research and graduate courses in field theory, network theory, and communication theory, and government sponsored projects on radar, information processing, electronically phased arrays, and filters.

Dr. Cohn has written numerous publications on electrical engineering, mathematics, and physics and has prepared a number of senior-college-level programmed learning books (worktexts) on applied mathematics. A graduate of California Institute of Technology, he obtained his Masters Degree and Doctorate in Electrical Engineering at Illinois Institute of Technology.

He is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, American Association of Physics Teachers, American Institute of Electrical Engineers, American Mathematical Society, American Physical Society, American Society of Engineering Education, Physical Society of Japan, and a Registered Professional Engineer in the State of Illinois. He has served in various offices of the Chicago IRE Chapter from 1952 to 1959 and the National Electronics Conference between 1948 and 1955.

❖

The appointment of **Ralph I. Cole** (A'29–SM'46–F'58) as director of Westinghouse Air Brake Company's Government Project Service was announced recently. He will direct a new activity created for the purpose of making available the total corporate engineering and production resources for large military and government sponsored programs. Especially concerned with planning utilization of combined resources, he will serve as an executive channel of communications to the subsidiaries and divisions of WABCO.



R. I. Cole

Before receiving this assignment he served as manager of Military Projects

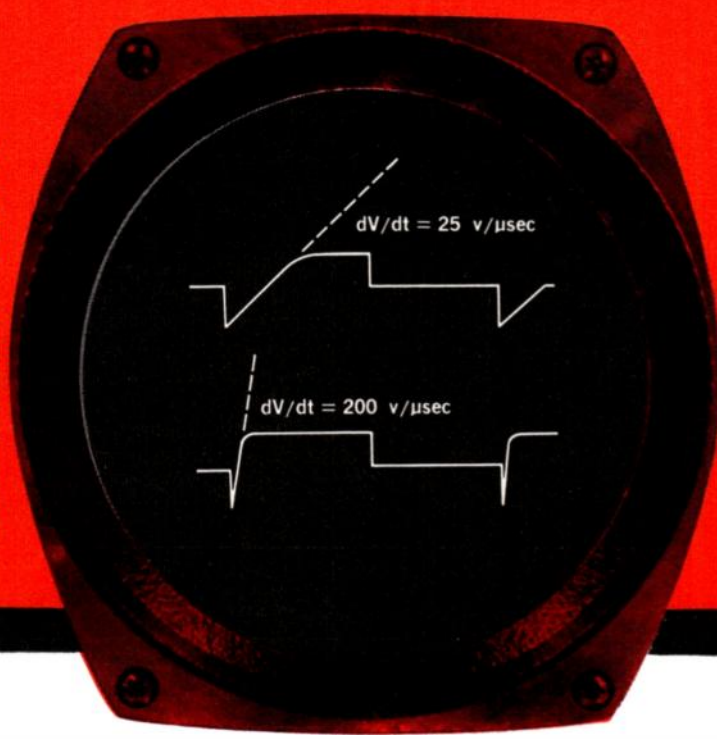
(Continued on page 36A)

TI SILICON CONTROLLED RECTIFIER REPORT

What 200 V/μsec dV/dt can do for you

In any switching application or where high line transients exist, false firing of low dV/dt SCR's is possible. This makes high dV/dt capability extremely important for circuit reliability.

For example, in inverter circuits, high dV/dt capability permits smaller commutating capacitors which improves the overall circuit reliability. The possibility of both devices being turned on by high line transients when the line switch is closed is no longer a problem with Texas Instruments guaranteed 200 V/μsec dV/dt SCR's.



HIGH RELIABILITY SILICON CONTROLLED RECTIFIERS

dV/dt ratings represent the capability of an SCR to resist "false" firing due to transients or pulses in the anode-to-cathode voltage. The possibility of turning an SCR "on" *without an applied gate signal and without exceeding the Forward Breakdown Voltage* exists in any circuit where transients are experienced, where supply voltage may be applied rapidly, or where fast fuses are used in the circuit.

Texas Instruments SCR's eliminate "false" firing by giving you guaranteed 200 V/μsec dV/dt @ 100°C for high reliability, long life and low cost control circuits. Other TI SCR's are rated above 50 V/μsec, exceeding industry's average rating . . . giving you added safety.

For information on TI Silicon Controlled Rectifiers, write for the new application tip, "dV/dt Considerations in SCR Circuit Design." Address your correspondence to Texas Instruments Incorporated, Components division, Department 573, P. O. Box 5012, Dallas 22, Texas or circle reader service number.

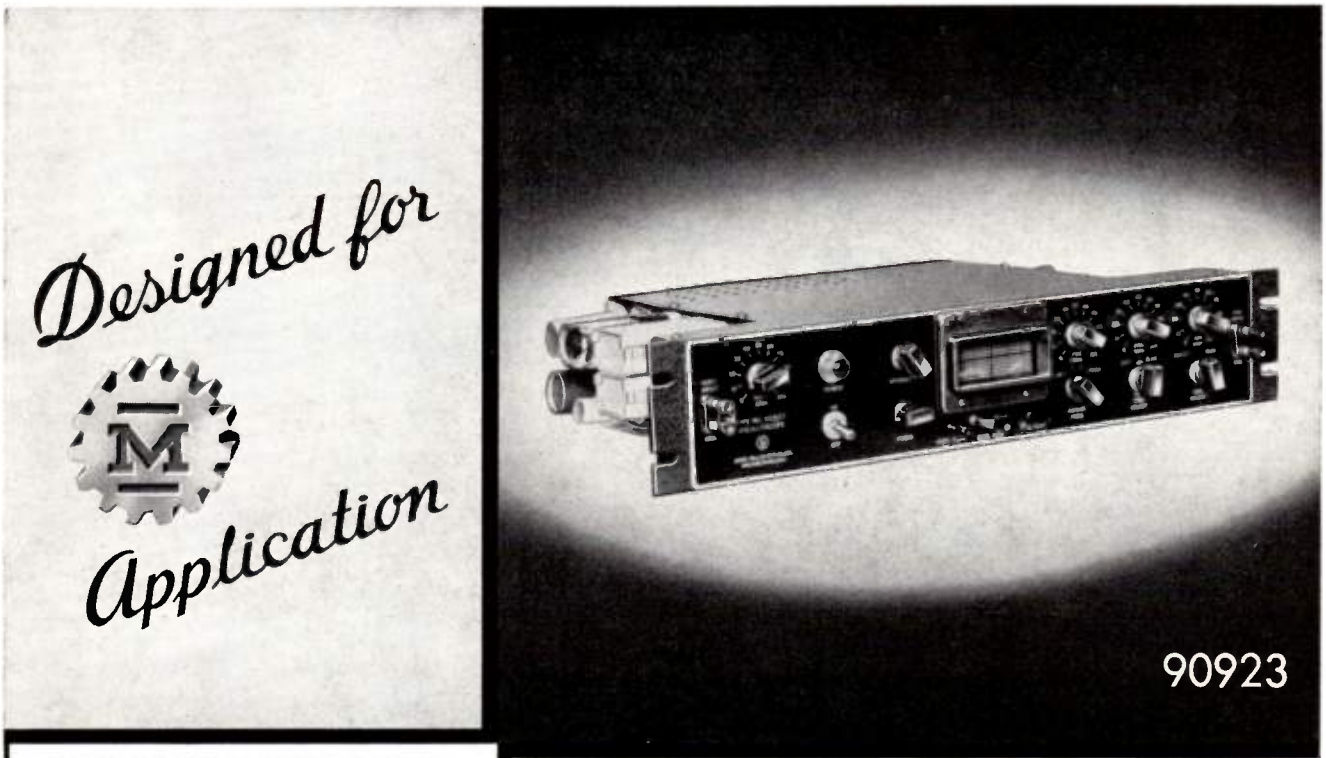
Rating	TI-116 Series	TI-136 Series	2N1595 Series	2N1929 Series	2N1600 Series	TI-40A Series	2N681A Series	TI-150 Series	2N1770 Series
Voltage	200-400	200-400	50-400	25-300	50-400	50-400	25-400	50-400	25-400
dc Current	1.3 amp	4 amp	1.3 amp	1.1 amp	4 amp	4 amp	25 amp	35 amp	7 amp
V/μsec dV/dt	>200†	>200†	>50*	>50*	>50*	>50*	>200†	>50*	>50*
	†Guaranteed @ 100°C @ rated voltage *Typically greater than 50V/μsec.								



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Illustrated is No. 90923, one of the Millen line of rack mounted oscilloscopes. No. 90923 is complete with amplifiers and sweep. Good low frequency response and linearity. For monitoring, production test, or laboratory use. Compact. Uses type 3XP1 3" x 1 ½" rectangular cathode ray tube.

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IRE People

(Continued from page 34A)

Planning for Melpar, Inc. from 1952 to 1961.

Mr. Cole's prior experience has been with Signal Corps and Air Force Laboratories, holding the position of Technical Director, Rome Air Development Center. For his wartime direction of Research and Development he received the Legion of Merit. He has retained his military affiliation and is currently a Colonel in the Active Air Force Reserve.

Mr. Cole received the B.S. degree in electrical engineering from Washington University, St. Louis, Mo., in 1927. He received the M.S. degree in Physics from Rutgers University, New Brunswick, N. J., in 1936.

He is a licensed professional engineer in the Commonwealth of Virginia. He is also Secretary of the Joint Board on Science Education, Greater Washington. Mr. Cole is a member of the Advisory Committee on the Administration of Research, American University, a member and past Director of the Washington Society of Engineers, and a member of the Institute of Navigation. He is a past chairman of the D. C. Council of Engineering and Architectural Societies.

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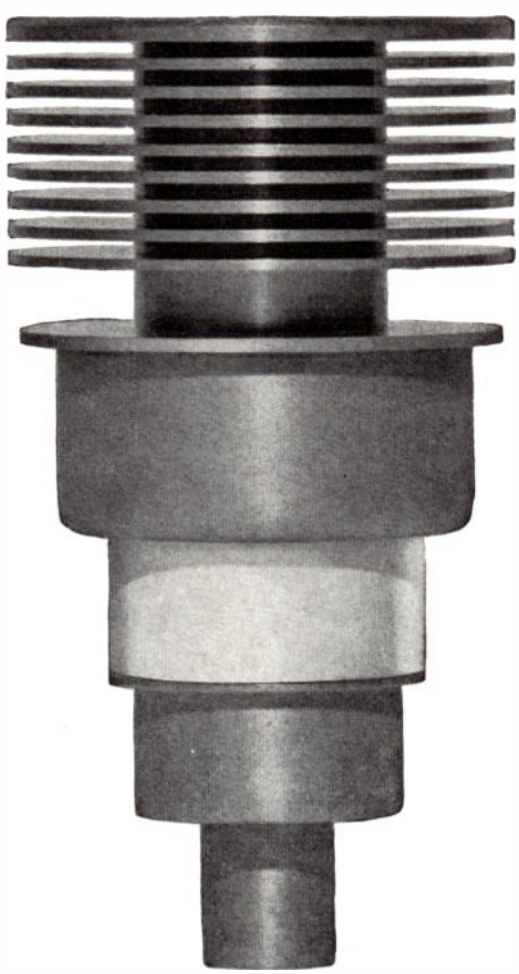
(Continued on page 38A)

UHF

Frequency Stable

CW or Plate-Pulsed

ML-7855



Special anode design of ML-7855 permits frequency stable operation within 10-15 seconds after application of high voltage. (Frequency change during this initial period is within 1 mc).

ML-7855 provides frequency stable operation with unregulated supply, as change of plate dissipation has no effect on change of frequency.

CW operation to 2500 Mc, with 1000 V Ebb, 100 ma Ia.

Plate-pulsed to 3000 Mc, with 3500 v eb, 3.0 a ib, with a tp of 3 usec at 0.0025 Du.

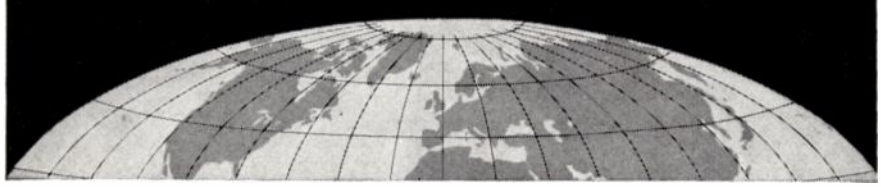
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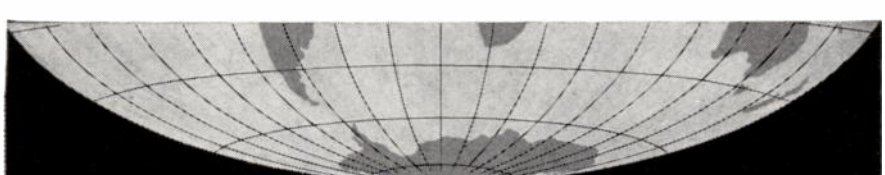
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H28

IRE People

(Continued from page 36A)

Philip D. Doersam (S'40–M'46–SM'50) has been appointed manager, Advanced Systems Engineering, for Raytheon Company's Missile and Space Division Santa Barbara Operation. He has had more than 20 years' experience in the electronics field and most recently directed a major subdivision in Lockheed Company's satellite systems activity. He was a member of its original technical group in the satellite field. He has also served in military electronics positions with RAND Corporation, Hughes Aircraft and Martin.



P. D. DOERSAM

A graduate of Columbia University, Mr. Doersam was with the Radiation Laboratory of Massachusetts Institute of Technology during World War II.

He has written many classified reports on radar, electronics reconnaissance and related fields. He formerly served on an Air Force consulting group.

❖

Dr. David O. Ellis (M'57) has been appointed head of the Advanced Development Section of the Data Systems Division of Litton Systems, Canoga Park, Calif.

Dr. Ellis was graduated from the University of Missouri with the A.B. degree in 1947, the M.A. degree in 1948 and the Ph.D. degree in 1950, all in mathematics. He is a member of the Association for Computing Machinery, American Mathematical Society, Society for Industrial and Applied Mathematics and Sigma Xi.

❖

Dr. Lester M. Field (M'48–F'52) was appointed a vice president of Hughes Aircraft Company, Culver City, Calif. He is vice president and assistant group executive, components group, and director of the Hughes microwave tube division.



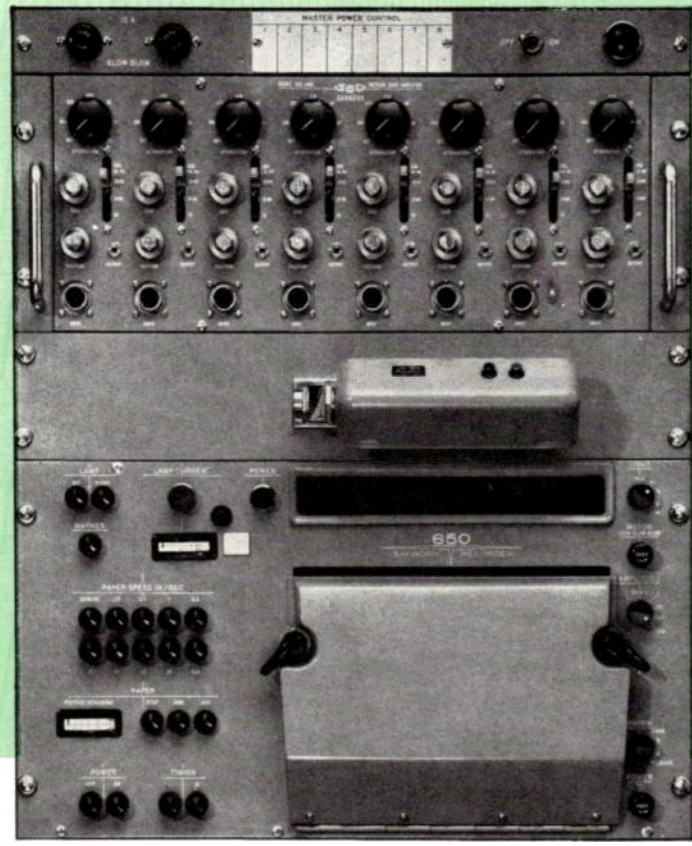
L. M. FIELD

Dr. Field joined the Hughes Aircraft Company in 1958. He has been associate director of the Hughes Research Laboratories, head of its physics laboratory, and in 1959 he became director of the microwave tube division.

He received his B.S. degree from Purdue University in electrical engineering and his Ph.D. from Stanford University

(Continued on page 40A)

DC to 5000 cycles over an amplitude of 4" peak to peak



NEW SANBORN "650" SYSTEM OFFERS DIRECT READOUT, 8 TO 24 CHANNELS, ALL SOLID STATE CIRCUITS, FOR RACK MOUNTING OR INDIVIDUAL CASES.

Here's the *one* system that lets you record inputs from DC to 5 KC within 3 db at 4" peak-to-peak amplitudes, without changing galvanometers. The "650" system consists of an 8-channel medium gain, general purpose amplifier unit driving a high speed, high resolution optical oscillographic recorder. It can be easily built into your system, packaged in a mobile cabinet or housed in individual cases. The single-chassis, 7" high amplifier module has 8 separate channels, *complete from floating and guarded inputs to galvanometer outputs;* each channel comprises a front end modulator and input transformer, carrier amplifier, demodulator, filter and driver amplifier. Power Supply and Master Oscillator Power Amplifier are built-in. All amplifier elements are plug-in transistorized units for easy servicing.

Immediately readable recordings are made on 8" wide daylight-loading ultra-violet-sensitive charts which require no chemical development. Features of the 12¼" high recorder unit include 9 electrically controlled chart speeds from ¼" to 100"/sec; calibrated monitoring screen; automatic trace identification and timing lines at 0.01 or 0.1 sec. intervals; amplitude lines spaced 0.1" apart which can be blanked from ¼, ½, ¾ or all of chart. Recorder is available with an 8-, 16- or 24-channel galvanometer block which is then equipped with the number of galvanometer elements desired by the customer. Either the Recorder or Amplifier are also available as individual units for use with other equipment.

SENSITIVITY 20 mv input gives 8" deflection; 12 attenuator steps to X5000, smooth gain control.

INPUT RESISTANCE 100,000 ohms all ranges, floating and guarded; DC source resistance must be kept below 1000 ohms on mv ranges only.

COMMON MODE PERFORMANCE Rejection at least 140 db at DC, tolerance to ±500 volts, max.

GAIN STABILITY Better than 1% to 50° C. and for line voltage variation from 103 to 127 volts.

LINEARITY 1½% of full scale (8 in.)

NOISE 0.02" peak-to-peak, max.

MONITOR OUTPUT On front panel; provides ±1v full scale across 100,000 ohm load

POWER REQUIREMENTS 103-127 volts, 60 cycle AC, 625 watts



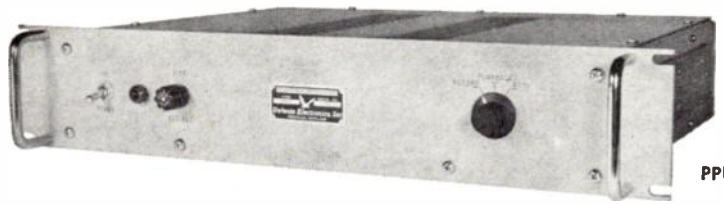
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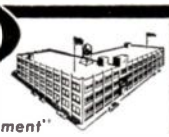
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IRE People

(Continued from page 38A)

in 1943. He subsequently joined the Electron Dynamics Group at Bell Telephone Laboratories. In 1946 he returned to Stanford, where he was one of the originators of their electron and tube laboratory. He became a full professor at age 32. While there he invented many modern forms of travelling-wave tube propagating structures.

In 1953 he became a full professor at the California Institute of Technology, and established a tube research activity there which also conducted studies in plasma physics and microwave interaction matter.

Dr. Field is a member of Sigma Xi, and is a Wilbur Scholar of Tau Beta Pi. He won the Eta Kappa Nu outstanding young American engineer award in 1949. He is also a member of the American Physical Society.

❖

William F. Gates (A'44–M'55) has been named President of Dalmo Victor Company, a division of Textron, Inc., it was recently announced. Mr. Gates, who has been a Vice President of Dalmo Victor, succeeds T. I. Moseley as President. Mr. Gates has been associated with Mr. Moseley and Dalmo Victor since 1944, when he joined the company as a research engineer. He was named Vice President and Chief Engineer in 1948, and in 1961 became Vice President of the Products Division. He was one of the three principals of Dalmo Victor prior to acquisition by Textron in 1954.

Mr. Gates received his degree in physics from the University of California in 1944. After performing postgraduate work in electrical engineering, he served as a visiting staff member of the Massachusetts Institute of Technology Radiation Laboratory.

He has served with the U. S. Office of Scientific Research and Development, and as a member of the Board of Directors of the Western Electronic Manufacturers Association.

❖

The Grow Corporation, electronics and chemical firm, of Plainview, N. Y., and Detroit, has appointed **William H. Greenbaum** (S'45–M'49) as engineering manager, it was announced recently.

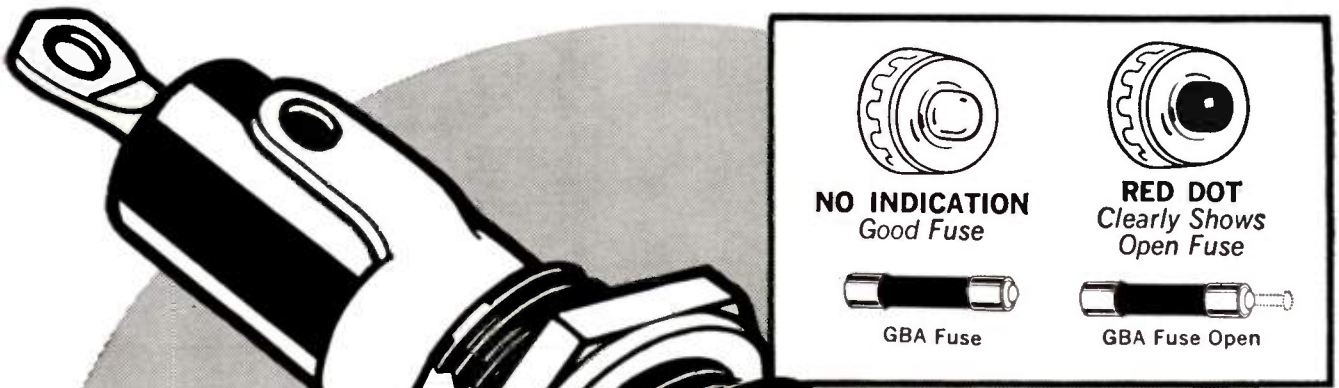


W. H. GREENBAUM

Mr. Greenbaum is a former vice president and director of engineering of Otarion Electronics, Inc., and senior supervising engineer of the Sonotone Corporation.

He has bachelor and master's degrees in electrical engineering from New York University, holds patents on hearing aid

(Continued on page 42A)



Another outstanding development by the makers of BUSS fuses

New! BUSS VISUAL INDICATING

HLD Fuseholders and GBA Fuses...

for all types of electrical and electronic equipment

New BUSS fuse and holder combination provides quick, positive, visual identification of faulted circuit.

When the fuse opens, an indicating pin pops out of fuse into transparent knob of holder. Head of pin is red. It is clearly visible and makes it easy to spot open circuit, even after power is off.

BUSS HLD fuseholders are for panel mounting in circuits of 125 volts or less. They take ¼ x 1¼ inch BUSS GBA fuses. Knob of holder grips fuse tightly and pulls fuse from holder when knob is removed.

Side terminal is held mechanically as well as by solder. Heat of soldering cannot cause it to loosen or come off.

Vibration will not cause failure of terminals as they are designed to withstand severe service.

Get the full story, write for **BUSS Bulletin SFH-9.**

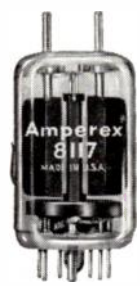
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TYPICAL OPERATION AB, LINEAR RF AMPLIFIER BOTH UNITS IN PARALLEL

Frequency	30	30 Mc.
D.C. Plate Voltage	1000	800 volts
D.C. Grid #2 Voltage	250	250 volts
D.C. Grid #1 Voltage	−34	−34 volts
Zero Signal D.C. Plate Current	50	50 ma
Effective RF Load Resistance	3100	2300 ohms
Average D.C. Plate Current	131	130 ma
Peak RF Grid Voltage	34	34 volts
Average Plate Power Output	70.5	56 watts
Peak Envelope Plate Power Output	141	112 watts
3rd Order IM Distortion	30	30 db

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IRE People

(Continued from page 40A)

inventions and is the author of several papers on hearing aids and transistors.

Mr. Greenbaum is a senior member of the Audio Engineering Society and a member of the American Radio Relay League, the Acoustical Society of America, and the American Institute of Physics.

❖

Appointment of **Donald L. Gunter** (M'47) as marketing manager of Sperry Gyroscope Company's Air Armament Division was recently announced. He replaces G. B. Wright, present marketing manager of the Polaris Management Group. In his new position, Mr. Gunter will be responsible for the planning and execution of a complete marketing program for the division. He joined Sperry after serving 14 years with Lockheed Aircraft Corporation and Radio Corporation of America where he was in charge of military marketing operations. Before that, Mr. Gunter was a radar project engineer in the Navy's Bureau of Ships and then spent two years at the Johns Hopkins University Applied Physics Laboratory working on the Bumblebee guided missile project.



D. L. GUNTER

A native of West Virginia, Mr. Gunter received his degree in electrical engineering from the Virginia Polytechnic Institute in 1937. He holds memberships in the American Ordnance Association, Air Force Association, American Rocket Society and the American Society of Naval Engineers.

❖

Earl L. Guyton (A'61) has been appointed a technical information specialist at The Sprague Electric Company, it was announced recently. Prior to joining Sprague, he was a technical writer for the Army Rocket and Guided Missile Agency in Huntsville, Alabama. He holds a B.S. degree from Mississippi State University and did graduate work in creative writing at the University of Alabama.



E. L. GUYTON

Mr. Guyton is a member of the Society of Technical Writers and Publishers. He was formerly active in amateur radio as W50D1.

❖

(Continued on page 44A)

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Partial contents: Axial dipole within a corner reflector and slots on wedges; The fields of axial dipoles in the presence of a circular conducting cylinder; Residue series representation for the fields of an axial slot; Fields of current distribution in wedge regions.

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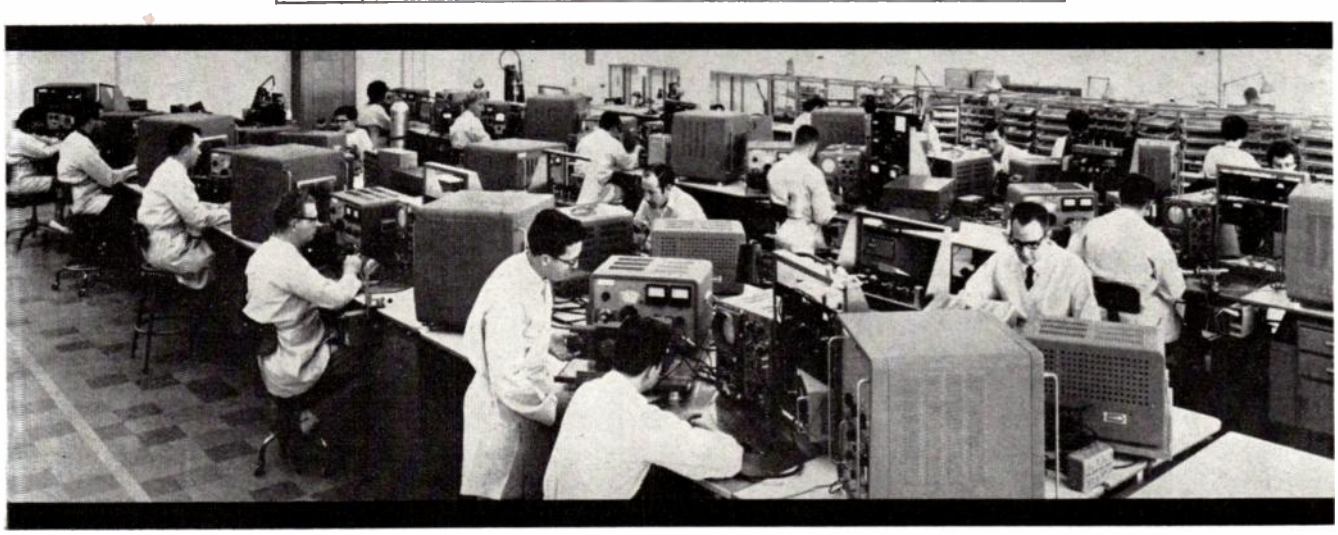
Backed by tremendous resources, constantly expanding facilities, and a vast technical staff, Hughes offers an exclusive advantage of long-term business stability. Thousands of precision crystal filters and discriminators have been delivered by Hughes over the past three years for applications in radar, missile guidance, and communications systems. For your long-run production requirements, this stability assures uninterrupted continuity in systems manufacturing.

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Model Number	Center Frequency	Bandpass 3 db Bandwidth	Shape Factor 60/3db	Insertion Loss (Max.)	Passband Ripple (Max.)	Nominal Impedance (Ohms)	Approximate Case Size L x W x H (Inches)
B203CA	200 KC	800 cps	4:1	6 db	±.75 db	20K/20K	3.2 x 1 x 1.4
B144CA	1.4 MC	500 cps	10:1 (30/3)	2 db	±0.25 db	8.25K/5.1K	1.4 x .9 x 1.2
B174CE	1.75 MC	6 KC	1.8:1	4 db	±.5 db	50/50	4.2 x 1 x 2.2
B664CA	6.6 MC	2.1 KC	32:1	3 db	±.5 db	2K/2K	2 x .6 x 1
B105CH	10.7 MC	180 KC	2:1	16 db	±1 db	250/250	2.6 x 1.2 x .7
B145CA	14-15 MC	165 KC	2:1	8 db	±.75 db	75/75	4.2 x .65 x 1.4
B305CF	30 MC	100 KC	1.6:1	6 db	±1 db	50/50	2.4 x 1 x 1.5
B355CI	35 MC	3.5 KC	14:1(70/3)	3 db	—	700/700	2.4 x 1 x 1.5
U503CD	500 KC	17 KC	1.15:1(40/3)	12 db	±.5 db	10K/10K	4.4 x 2.4 x 2
U174CE	1.75 MC	2.7 KC	1.3:1	3 db	±.5 db	50/50	4.2 x 1 x 2.2
L174CE	1.75 MC	2.7 KC	1.3:1	3 db	±.5 db	50/50	4.2 x 1 x 2.2
U214CA	2.1 MC	3.2 KC	1.4:1	6 db	±.5 db	4.7K/4.7K	4.7 x 1 x 1.2



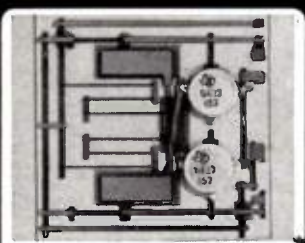
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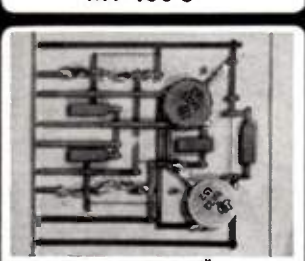
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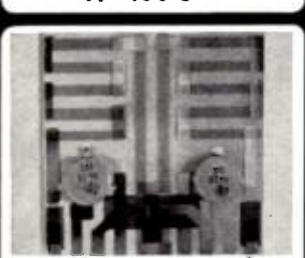
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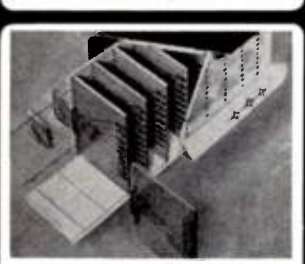
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To Be Continued .....

IRE People

(Continued from page 42A)

The appointment of **Robert J. Hannon** (SM'60) as assistant program manager and technical manager of the ZMAR (Zeus multi-function array radar) program at the eastern operation of Sylvania Electronic Systems has been recently announced.



R. J. HANNON

Since July, 1960, Mr. Hannon has served as acting manager of the equipment engineering laboratory at the division's Waltham Laboratories, which combined last month with the Data Systems Operations at Needham, Mass., to form the eastern operation. He joined Sylvania in 1957 as a section head in the missile systems laboratory at the Waltham facility, and subsequently was a department manager in both that laboratory and the equipment engineering laboratory.

Before coming to Sylvania, he was a senior engineer with Empire Devices, Inc., Flushing, N. Y., and a project engineer for Telephonics Corp., New York City. He also served as a senior projects engineer

(Continued on page 46A)

R F TRANSISTOR
parameters . . .

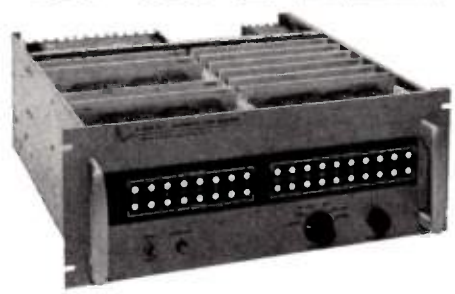


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256	8-256R	8-256S	8-256SI
512	8-512R	8-512S	8-512SI
1024	8-1024R	8-1024S	8-1024SI
2048	8-2048R	8-2048S	8-2048SI

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LOW NOISE TWT EXTENDS RADAR RANGE

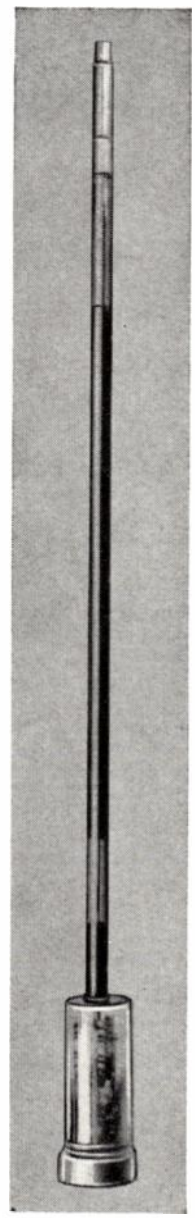
A limitation on the effective range of a radar equipment is the noise level in the receiver: the limiting range is reached when signal to noise ratio approaches unity. The signal to noise ratio in the equipment cannot be better than that in the first stage, therefore the use of a low noise amplifying tube in that stage is of paramount importance.

STC offers two tubes of eminently suitable design for use in S-band:

Type W9/2E for broadband coverage with a gain of 40 dB and noise factor of about 8·5 dB. It is intended for operation over the whole frequency range 2·5 to 4·1 Gc/s with fixed voltages. An aluminium foil mount is available with coaxial r.f. connectors.

Type W10/3E for narrow band operation with about 23 dB gain and 6·8 dB noise factor with the grid voltages set for optimum noise factor at the appropriate centre frequency.

W10/3E has a frequency range 2·7 to 3·3 Gc/s in solenoid curcuit 495—LVA—003 with waveguide r.f. connectors or frequency range 2·8 to 3·8 Gc/s in solenoid circuit 495—LVA—006 with coaxial r.f. connectors.



W9/2E



W10/3E with mount 495-LVA-006S

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Type Y333/1E

ABRIDGED DATA

Band	Valve Code	Freq. Range (Gc/s)	Line Voltage (V)	Output Power (mW)
K	Y322/1E	18–26·5	650–3000	30 to 200
Q	Y333/1E	26·5–40	700–3200	10 to 80

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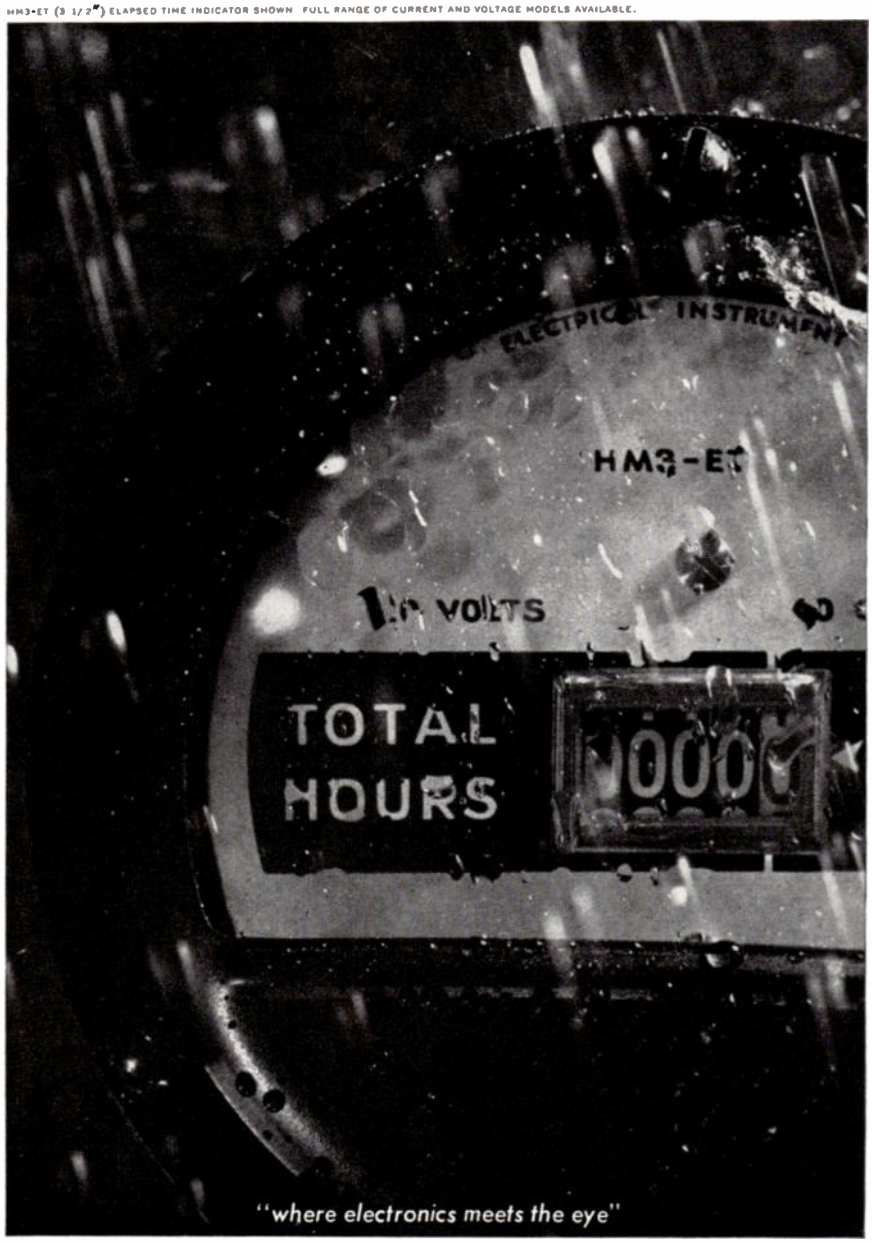
USA enquiries for price and delivery to ITT Components Division, P.O. Box 412, Clifton, N.J.

62/18MS

ENVIRONMENT-PROOF

Honeywell HM and HS series meters are immune to hazardous climatic or atmospheric conditions. True glass-to-metal hermetic sealing makes them completely dust-proof and moistureproof, and plated steel cases provide magnetic and electrostatic shielding. ■ HS series meters, in addition, are ruggedized to withstand exceptional levels of shock, vibration, stress and strain. HS2Z and HS3Z types have external gasket-sealed zero adjusters and conform to the requirements of MIL-M-10304B. ■ For a catalog describing the full line of Honeywell meters, write Honeywell Precision Meters, Manchester, New Hampshire. ■ There's no charge or obligation.

HM3-ET (3 1/2") ELAPSED TIME INDICATOR SHOWN FULL RANGE OF CURRENT AND VOLTAGE MODELS AVAILABLE.



"where electronics meets the eye"

Honeywell

Precision Meters

IRE People

(Continued from page 44A)

and program manager for the Fairchild Camera and Instrument Corp., and a project director in military electronics research and development for Kollsman Instrument Corp., Elmhurst, N. Y.

A graduate of Tufts University with a Bachelor's degree in electrical engineering, Mr. Hannon is a member of the American Management Association.

❖

Jack G. Hofeld (M'53), formerly with RCA, was recently appointed to the position of Mobile Communications Product Manager of the Industrial Products Division of International Telephone and Telegraph Corp.



J. G. HOFELD

Hofeld comes to ITT following broad experience as Merchandising Manager of Mobile Communications at RCA in Washington, Pa. Prior to that he was Sales Engineer for Allied Radio Corporation in Chicago and Manufacturing Engineer with Western Electric Co. As a member of ITT-Industrial Products Division's new Mobile Communications management team, Hofeld will concentrate on merchandising and market planning. A veteran of naval service as an Electronic Specialist, he is presently a member of IRE's Professional Group on Vehicular Communications.

❖

The appointment of **Charles N. Hood II** (SM'56) as Manager of the new Electronics Division of Research-Cottrell, Inc., Bound Brook, N. J., has been recently announced. He comes to Research-Cottrell from Airborne Accessories Corporation, Hillside, N. J., where he was Engineering Director. Before this he was associated with the General Electric Company for 12 years.



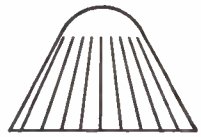
C. N. HOOD II

Mr. Hood was graduated from Princeton University in 1947 with the degree of Bachelor of Science in electrical engineering, and studied aeronautical engineering at the University of Michigan. He is a member of the American Helicopter Society.

❖

Dr. Harvard L. Hull (SM'54) President of Hull Associates, Electronics-Nucleonics Consultants, Chicago, has been elected to

(Continued on page 48A)



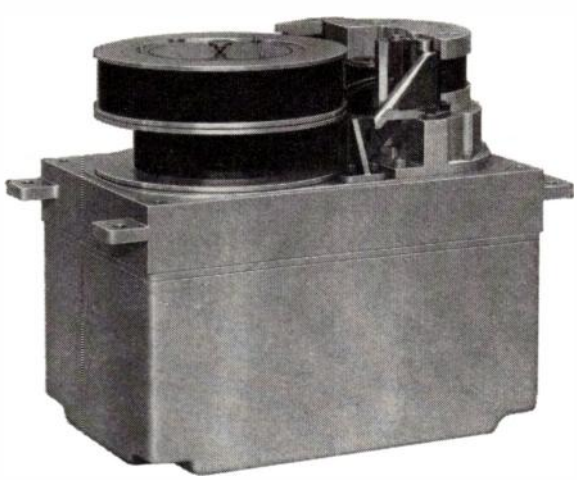
a shocking development

The new Westrex 2101 Data Recording System withstands extreme shock, vibration, acceleration, pressure, and temperature, offers consistent recording integrity and survivability for re-use. Its predecessor, the RA-1653 Recorder, recorded data under impact shocks of 1500 g without damage.

Primary subsystems of the 2101 are: the RA-1660-A Data Recorder, a precision tape transport which records 14 channels on 650 feet of 1-inch magnetic tape driven at 30 ips; and the RA-1670-A Electronic Module Assembly which contains the signal processing components. Seven of the RA-1670-A's 14 wideband Subcarrier Oscillator Modules for converting analog signal inputs to frequency-modulated carriers are interchangeable with Analog Direct Record Amplifier Modules.

Overall System Specifications

Frequency response—FM, within 0.1 db for wideband (dc to 10 kc). Center frequency of voltage control oscillator 54 kc; other standard IRIG frequencies available. Direct analog, within ± 1 db (50 cps to 100 kc). Flutter and wow—less than 1% over frequency range from dc to 10 kc. Shock—records through 300 g's square wave. Vibration—20 g's, 20 to 2000 cps. Acceleration—150 g. Recording time—4⅓ minutes. Reels fit 3-inch standard NAB spindle. Write for data bulletin.

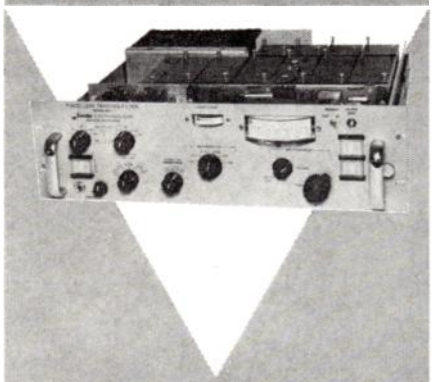


WESTREX 2101 DATA RECORDING SYSTEM OPERATES WITH PRECISION IN EXTREME MISSILE ENVIRONMENTS

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A DIVISION OF LITTON SYSTEMS, INC.
Recording Equipment Division
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SERIES 450 SOLID-STATE
PHASE-LOCK TRACKING FILTER

The Series 450... distinguished addition to Interstate's complete line of tracking filters. Only 5-1/4 inches high, the compact, all-solid-state series offers the following features:

- *Acquires and tracks varying-frequency signals as weak as −38 db in a 120-kc noise bandwidth*
- *Bandwidth of phase-lock tracking loop adjustable to 2.5, 5, 10, 25, 50, or 100 cps*
- *Input frequency range of 100 cps to 120 kc*
- *Front-panel selection of phase-lock-loop bandwidth, manual or automatic signal acquisition, memory, AGC time constants, course and fine tuning*
- *Output frequency of 1, 10, and 100 times frequency input*
- *Self-contained power supply. Power requirement less than 40 watts, 115 or 200 vac, 50 to 400 cps*
- *Wide range of options including: correlated AM and PM demodulators; pilot frequency to facilitate signal acquisition; continuously tunable phase-lock discriminator*

Write or phone Marketing Department, Area Code 714 Prospect 2-2222 TWX AH 5217

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IRE People

(Continued from page 46A)



H. L. HULL

the Board of Directors of Frederick Research Corporation, Wheaton, Md.

Dr. Hull brings to Frederick Research broad experience in research and development, and general management in electronics and atomic energy. He was active in the Manhattan Project and in the postwar organization and development of Argonne National Laboratory. Subsequently, he was President of the Farnsworth Electronics Company, a division of International Telephone & Telegraph Corporation. He is also a member of the Board of Directors of Central Research Laboratories of Red Wing, Minnesota.

❖

Dr. Lester Clark Lewis (SM'57) has been appointed Curator of Physical Sciences at the Museum of Science and Technology, the Smithsonian Institution, Washington, D. C.

Dr. Lewis has had a broad experience in industrial physics, 1922–1940, the ministry, 1940–1956, and in teaching, since 1956 as Professor of Mathematics and Physics at Wagner College.

Dr. Lewis' scientific experience includes that in gaseous conduction with the General Electric Company, Schenectady laboratory. Also he has done doctoral work in molecular beams at Hamburg, Germany. He has done research at the National Bureau of Standards on the optical properties of fibers, and at the Mead Corporation on the optical properties of paper and the mechanics of printing. Dr. Lewis has also done research at the Radiation Lab, MIT on magnetrons.

His recent interests have been in the fruitful relations of science with society, especially religion, and in the improvement of teaching.

He is a graduate of MIT and of Harvard Divinity School.

❖

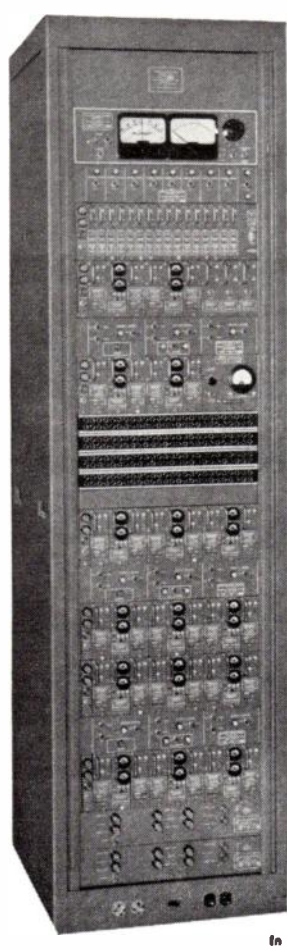
The appointment of **Dr. D. L. Jaffe** (A'37–SM'46) President of Polarad Electronics Corporation, to the Board of Directors of the Armstrong Memorial Research Foundation has recently been announced.



D. L. JAFFE

The Armstrong Memorial Research Foundation was established at Columbia University in 1955 to honor the memory of the late professor Edwin Howard Armstrong,

(Continued on page 50A)



NEW BETTER-THAN-EVER
RELIABILITY
for long-distance point-to-point communications

NORTHERN RADIO

NEW 16-CHANNEL TRANSISTORIZED
VOICE FREQUENCY DIVERSITY CARRIER
TELEGRAPH TERMINAL TYPE 235 MODEL 3
MIL DESIGNATION AN/FGC-61A

NEW

. . . **All units militarized:** components and design approved by U.S. Military.

. . . **Converters** have equalized gain and adjustable time delay in each channel for better diversity performance and interchangeability.

. . . **Switching Panels** provide "local" or "remote" selection of 2-channel or 4-channel diversity modes.

. . . **Combiners** have adjustable gains in each channel, for complete switching flexibility, and the combining follows an ideally modified square law function for both 2-channel space or frequency and 4-channel space plus frequency diversity.

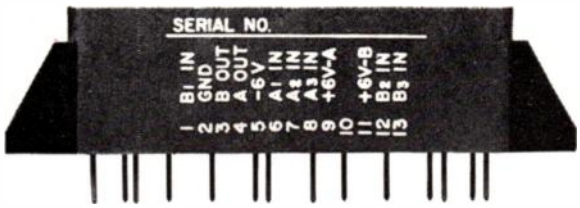
. . . **Keyers** have adjustable "threshold" sensitivity control and simplified input circuit selection.

. . . **Dotter and Delay Indicator** provides test keying signal source for keyers and delay equalizers in all channels.

Write for complete literature.

Pace-Setters in Quality Communication Equipment

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In Canada: Northern Radio Mfg. Co., Ltd., 1950 Bank St., Billings Bridge, Ottawa, Ontario.



In less time than it takes light to cross this room, a new product, **DELCO'S NEW** high speed **10 MC** silicon modules, could: (1) correct the course of a missile in flight; (2) make it possible for sonar pickups to track and compute the position of targets with microsecond accuracy; and (3) handle any number of other airborne guidance and control functions that previous modules—due to low speed or environmental or performance limitations—could not handle. Delco Radio's 10mc modules, with a maximum gate-switch speed of 40 nanoseconds, convert data 100 times faster—even under the most extreme environmental conditions.

These **SILICON** modules come epoxy encapsulated, and operate over a temperature range of −55°C to +100°C. And these same reliable **DIGITAL** circuits are available packaged on plug-in circuit cards. These Delco **MODULES** are environmentally proved to: **SHOCK,** 1,000G's in all planes. **VIBRATION,** 15G's at 10 to 2,000 cps. **HUMIDITY,** 95% at max. temp. **STORAGE AND STERILIZATION TEMP.** −65°C to +125°C. **ACCELERATION,** 20G's. Designed for systems using from one module to 100,000, and the module's rated performance considers the problems of interconnection. Data sheets are available. Just write or call our Military Sales Department.

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Division of General Motors • Kokomo, Indiana

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DEFLECTRONS
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DISPLAYS
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REPEATABILITY to 0.1%!
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IRE People

(Continued from page 48A)

the developer of FM radio, by helping to perpetuate the principles that guided him to a life devoted to research in electronics; to aid in the continuation of the basic research and to contribute to the education and training of engineers and scientists. Dr. Jaffe, an alumnus of Columbia University, was a close associate of the late Major Armstrong and worked with him on the original FM radio project.

A founding member of the Armstrong Memorial Research Foundation, Dr. Jaffe is the chief executive officer of Polarad Electronics Corporation, a pioneer firm in the development and production of microwave test equipment.

❖

David E. Klingler (S'51–A'52–M'56–SM'62) was promoted recently to the post of general manager of the Electronic Assistance Corporation's Systems Engineering Division at Dexter, Mich. Formerly assistant general manager, Mr. Klingler joined EAC in September. The Systems Engineering Division designs and develops ultrasonic equipment for cleaning, food processing applications and for the beverage industry.



D. E. KLINGLER

Prior to joining EAC, Mr. Klingler was employed at the Bendix Systems Division in Ann Arbor, Michigan, supervising the Radar Techniques Group. During his employment at Bendix, he was actively engaged in the field of signal processing for radar in space, air and ground applications. From 1955 to 1958 he was employed as the technical assistant to the production manager at the Burroughs Division in Plymouth, Michigan, where he had prime technical responsibility for developing and directing manufacturing methods in connection with production of electronic banking machines. Prior to this, he was employed by The University of Michigan Research Center and was involved in the development of display systems.

Mr. Klingler received his B.S. and M.S. degrees in electrical engineering from The University of Michigan.

❖

George A. Krutilek (A'58) has recently been appointed Chief Engineer of Thunderbird Electronics, Sunland Park, N. Mex. He will be in charge of engineering and research for that company. He will also continue his work as an independent engineer and manufacturer's representative for various firms.

Mr. Krutilek has assisted Thunderbird Electronics over the past twenty-five years in the construction of many small radio stations and power plants in Mexico.

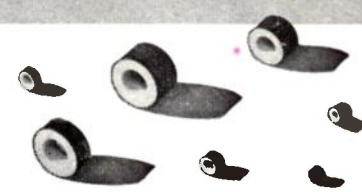
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(Continued on page 52A)

TOUGH



...AS A TURTLE'S BACK



ARMAG*-PROTECTED DYNACOR® BOBBIN CORES AT NO EXTRA COST!

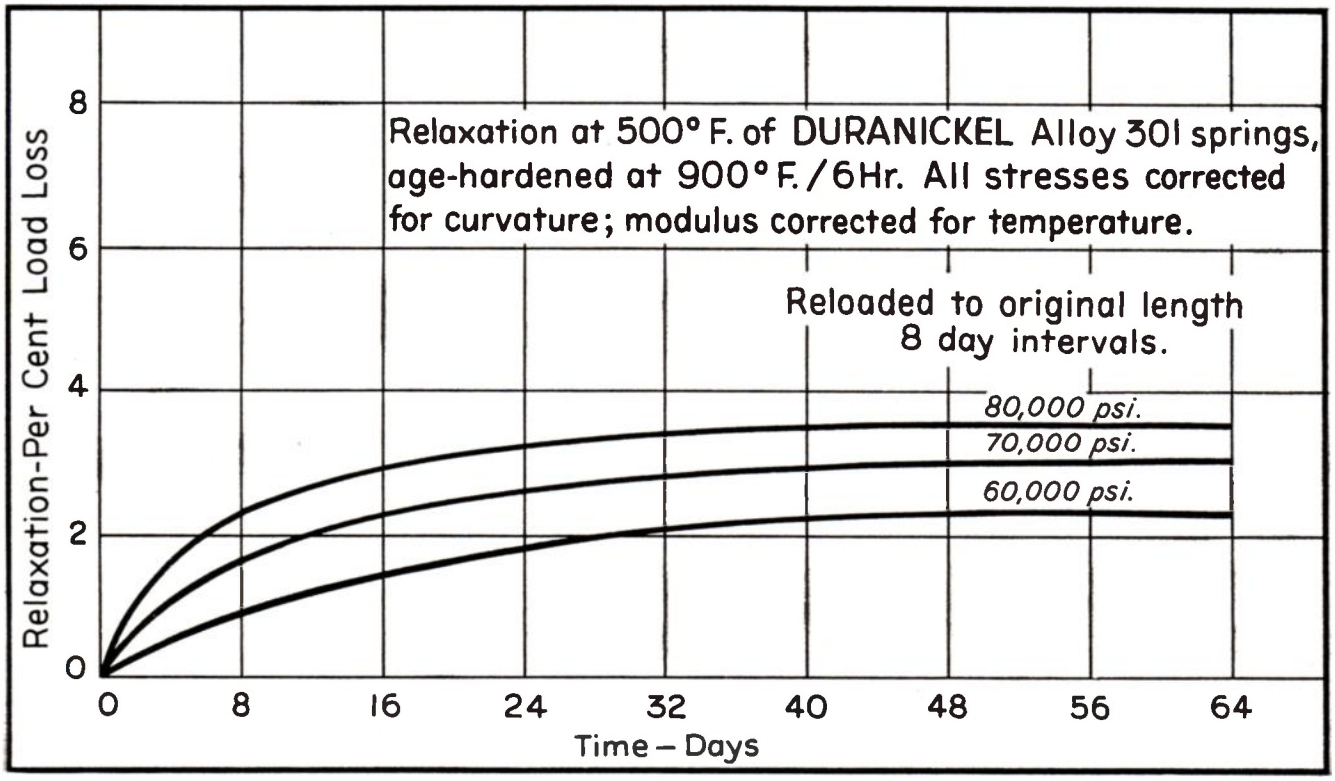
Tough-as-tortoise-shell Armag armor is an exclusive Dynacor development. It is a thin, non-metallic laminated jacket for bobbin cores that replaces the defects of nylon materials and polyester tape *with very definite advantages* —and, you pay no premium for Armag extra protection.

Tough Armag is suitable for use with normal encapsulation techniques on both ceramic and stainless steel bobbins. It withstands 180°C without deterioration—is completely compatible with poured potted compounds—has no abrasive effect on copper wire during winding—fabricates easily to close-tolerance dimensions—inner layer is compressible to assure tight fit on bobbin—does not shrink, age or discolor.

Write for Engineering Bulletins DN 1500, DN 1000A, DN 1003 for complete performance and specification data covering the wide range of Dynacor low cost Standard, Special and Custom Bobbin Cores—all available with Armag non-metallic armor.

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Nickel Alloy Springs last longer in Corrosive Environments and at High Temperatures

Kick out switches, relays, circuit breakers, solenoid valves, diaphragms and other spring type assemblies play a vital part in the efficiency of electrical equipment. If corrosion or high temperatures are important factors in the reliability and service life of your spring assembly, make sure they are made from a high nickel alloy for: (1) high strength stability; (2) resistance to relaxation at elevated temperatures; (3) oxidation resistance; (4) resistance to corrosive environments with good electrical properties.

INCONEL* Alloy X-750 is the outstanding choice for springs operating up to 1200° F because of its high strength stability, good oxidation and corrosion resistance, and resistance to relaxation.

DURANICKEL* Alloy 301 gives excellent service at temperatures up to 600° F. It is used for infrared bulb spring contacts, springs in sun lamps and spark plugs, electric toaster coils and numerous other applications requiring relaxation resistance at elevated temperatures.

Design Stress for age-hardened DURANICKEL Alloy 301 and PERMANICKEL Alloy 300 springs at elevated temperatures.

Coiling Method	Maximum Shearing Stress for temperatures (°F.) indicated	
	Up to 400°F.	550 to 600°F.
Cold	70,000 psi	60,000 psi
Hot	70,000 psi	60,000 psi

The physical constants of DURANICKEL Alloy 301 and PERMANICKEL Alloy 300

PHYSICAL CONSTANT	DURANICKEL Alloy 301	PERMANICKEL Alloy 300
SPECIFIC GRAVITY, GM/CM	8.26	8.75
DENSITY, LB./CU. IN.	0.298	0.316
THERMAL CONDUCTIVITY AT (32°-212°F.) BTU./SQ. FT./HR. °F./IN.	128/137**	400
ELECTRICAL RESISTIVITY OHMS/CIR. MIL. FT. (68°F.)	260**	94.5**
MICROHMS/CM. (20°C.)	43**	15.7**
TEMP. COEF. OF RESISTIVITY PER°F. (68°-212°F.)	0.0006	0.002
PER°C. (20°-100°C.)	0.001	0.0036
MEAN COEF. OF THERMAL EXPAN. AT (77°-212°F.), IN./IN./°F.	0.0000072	0.0000072
AT (25-100°C.) CM./CM./°C.	0.000013	0.000013
MAGNETIC TRANSFORMATION TEMP. F. (APPROX.)	200**	563**

**Age-Hardened

Other nickel alloys recommended for electrical spring assemblies include – PERMANICKEL* Alloy 300 high electrical and thermal conductivity requirements, MONEL* Alloy 400 for general applications requiring corrosion resistance in addition to toughness and strength up to temperatures of 450° F and INCONEL Alloy 600 for good strength, ductility, resistance to oxidation and good spring properties up to 750° F.

You can get the complete story on nickel alloy springs. Write for our technical bulletin T-35. "High Nickel Alloy Helical Springs." Our corrosion and high temperature engineers will be glad to help you with any specific problem you may have. *Registered trademark

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HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
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HUNTINGTON ALLOYS

Component Power Supplies from PEERLESS





Designed to Your Requirements.....

Peerless power supplies are available with DC or AC inputs. AC inputs are normally 60 or 400 cps; DC outputs extend to 10 ma or higher. Regulation values normally range from 5% to 10% from no load to full load; peak-to-peak ripple voltages are less than 1% of output voltage within this range. When required, closer tolerances can be supplied.

Peerless power supplies can be packaged to meet any operating requirements from commercial to Mil. Spec. And, their dimensions and configurations may also vary to meet specific volume requirements. For complex applications, Peerless has designed and manufactured power supplies that provide two or more outputs, operate in ambients up to 125°C and withstand shocks up to 50 G's. Whether your requirements are conventional or exotic, Peerless can solve the design problems and manufacture in quantity to your exact specifications.

NEW! *Send Coupon For Free Catalog*



Contains detailed specs on 48 widely varied types of Peerless power supplies and comprehensive Estimating Specifications Sheet!

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IRE People

(Continued from page 50A)

Otarion Electronics, Inc., of Ossining, N. Y., has expanded its research activities with the formation of a separate Research Division. **Dr. Fred W Kranz** (A'23–VA'39–SM'51) (L), physicist and pioneer in hearing and acoustics research, has been named a vice president of the company and director of the division. Dr. Kranz, formerly a vice president of the Sonotone Corporation, served as a consultant to Otarion before his new appointment. He holds a number of important patents in the field of acoustics and has published several papers on various aspects of hearing. His early studies contributed to the development of bone conduction hearing aids.

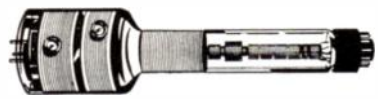


F. W Kranz

He is a graduate of Lawrence College and received his Master's from the University of Wisconsin and, in 1922, a doctorate from the University of Chicago. A former chief engineer of the Magnavox Company, he has also been on the staff of Western Electric Co.'s research laboratory, now known as Bell Labs.

(Continued on page 54A)

RECORDING STORAGE TUBE SYSTEMS



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■ ELECTROSTATIC PICTURE STORAGE AND RECALL SYSTEMS ■ LOW-LIGHT-LEVEL CAMERA AND DUAL STORAGE TUBE SYSTEMS ■ DOUBLE-ENDED STORAGE TUBE SYSTEMS ■ DATA SUMMATION UNITS ■ COMPUTER OUTPUT STORAGE FOR TELEVISION DISPLAY.

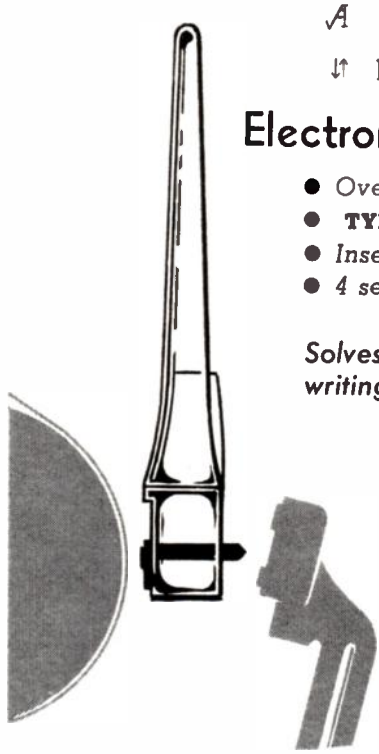
Standard storage tube systems are readily available. A custom-engineered system can be built to meet your special needs.

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MICROWAVE DIODES WITH CUTOFF FREQUENCY OF 36 kmc

Practical Operation to 9 kmc



These 250 milliwatt diffused silicon diodes come in vacuum-tight hexagonal cases which are threaded for screw mounting and are particularly suited for strip line application.

Applications for these microwave diodes include parametric amplifiers, second-stage protectors, and harmonic generators at ambient temperatures up to 200°C. The capacitance of these devices is closely controlled. The extremely low equivalent series resistance and inductance (approx. 0.4 nhy) makes them ideal for ultra high and super high frequency applications.

JEDEC NUMBER	BV Minimum @ I_R=10 mAdc	I_S Maximum @ V_R=2 Vdc	V_F Maximum @ I_F=100 mAdc	Q Typical @ f=9 kmc, V=0	R_S Maximum @ f=9 kmc, V=0	Total Capacitance f_o=500 mc, V=0 Minimum	Total Capacitance f_o=500 mc, V=0 Maximum
1N3152 & 1N3153*	5.5 Vdc	1.0 μAdc**	1.1 Vdc	4	2Ω	3.55 pf	4.45 pf

*1N3152 and 1N3153 have opposite polarities

**10 μAdc for 1N3152

These environmentally tested high reliability diodes may be purchased in quantity from Western Electric's Laureldale Plant. For technical information, price and delivery, please address your request to Sales Department, Room 106, Western Electric Company, Incorporated, Laureldale, Pa. Telephone: Area Code 215—WAlker 9-9411.

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Never before have our armed forces so badly needed the thinking and products of the electronics industry. Advertising in SIGNAL, the official journal of the *Armed Forces Communications and Electronics Association*, puts you in touch with almost 11,000 of the most successful men in the field—every one a prospect for your defense products!

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SIGNAL serves liaison duty between the armed forces and industry. It informs manufacturers about the latest government projects and military needs, while it lets armed forces buyers know what *you* have to offer to contribute to our armed might. SIGNAL coordinates needs with available products and makes developments possible.

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Besides *advertising* in SIGNAL which affords year-round exposure by focusing your firm and products directly on the proper market . . . besides *participation* in the huge AFCEA National Convention and Exhibit . . . the over-all plan of company membership in the AFCEA *gives your firm a highly influential organization's experience and prestige to draw upon.*

As a member, you join some 175 group members who feel the chances of winning million dollar contracts are worth the relatively low investment of time and money. On a local basis, you organize your team (9 of your top men with you as manager and team captain), attend monthly chapter meetings and dinners, meet defense buyers, procurement agents and sub-contractors. Like the other 59 local chapters of the AFCEA, your team gets to know the "right" people.

In effect, company membership in the AFCEA is a "three-barrelled" offensive aimed at putting your company in the "elite" group of government contractors —the group that, for example in 1957, for less than $8,000 (for the full AFCEA plan) made an amazing total of *459.7 million dollars!*

This "three-barrelled" offensive consists of

(1) Concentrated advertising coverage in SIGNAL, the official publication of the AFCEA;

(2) Group membership in the AFCEA, a select organization specializing in all aspects of production and sales in our growing communications and electronics industry; and

(3) Attending AFCEA chapter meetings, dinners and a big annual exposition for publicizing your firm and displaying your products.

If *you're* in the field of communications and electronics . . . and want prestige, contacts and exposure . . . let SIGNAL put your company on the *offense* for *defense!* Call or write for more details—now!

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APA

IRE People

(Continued from page 52A)

He is Chairman of the American Standards Association's Committee on Revision of Audiometer Standards, a Fellow of the Acoustical Society of America and a member of the American Association for the Advancement of Science.

❖

Robert B. Liepold (S'46–A'48–M'55) has been elected to the newly created position of Vice President and General Manager of Automatic Electric Sales Corp. He was formerly Vice President in charge of the Industrial Products Division of AESCORP, the domestic marketing and distribution affiliate of Automatic Electric Co., Northlake, Ill.



R. B. LIEPOLD

Mr. Liepold saw duty with the United States Navy in World War II, then joined Automatic Electric in 1947. He served with the installation and pricing departments, and as staff engineer in the Washington, D. C. offices of the company until 1952. He was then recalled by the Navy for duty aboard an aircraft carrier in the Korean action. In 1954 he returned to Automatic Electric and became manager of the East Central Sales District. He was appointed assistant to D. H. Deaver, president of AESCORP, in 1955 and was elected vice president in 1958.

Mr. Liepold was graduated from the University of Wisconsin in electrical engineering.

❖

Arthur V. Loughren (A'24–M'29–SM'43–F'44) has recently resigned from the Airborne Instruments Laboratory, a Division of Cutler-Hammer, Inc., in order to pursue studies in both the technical and business aspects of some electronic problems which have interested him for a considerable time.



A. V. LOUGHREN

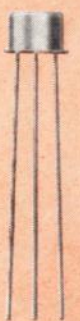
Mr. Loughren was born in Rensselaer, New York, on September 15, 1902. He received the B.A. and E.E. degrees from Columbia University in 1923 and 1925 respectively.

Upon graduation, Mr. Loughren spent two years at the Research Laboratories of General Electric, concerned with problems arising from the adaptation of vacuum tubes to circuits. Then followed two and a half years in the Radio Engineering Department. In 1930 he trans-

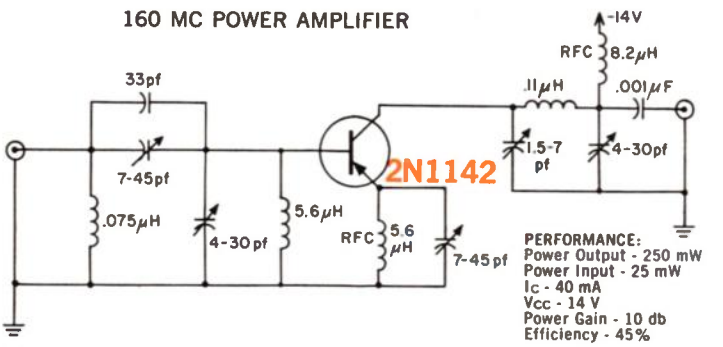
(Continued on page 56A)

LOOK WHAT ONE MOTOROLA EPITAXIAL 2N1142 MESA TRANSISTOR DOES IN THIS CIRCUIT!!!

PROVIDES 250 mW @ 160 mc WITH 10 db POWER GAIN AND 45% EFFICIENCY



160 MC POWER AMPLIFIER



The latest devices to join Motorola's epitaxial mesa family are four new PNP germanium transistors, the 2N1141-2-3 and the 2N1195. These new Motorola communication amplifiers provide very high power gain and low R-F noise in the VHF-UHF frequency ranges. They not only make ideal drivers for 160 mc power mesas (Motorola 2N1692) in transmitter output stages, but they also solve critical design problems in frequency multipliers, R-F and I-F amplifiers, mixers, and oscillators.

In addition to higher power gain and lower R-F noise, the new epitaxial units also offer typically:

$V_{CE(sat)} = .185$ V @ $I_c = 50$ mA;
100 mc $h_{fe} = 18$ db.

MOTOROLA
Semiconductor Products Inc.

A SUBSIDIARY OF MOTOROLA, INC.

1872

5005 EAST McDOWELL ROAD • PHOENIX 8, ARIZONA

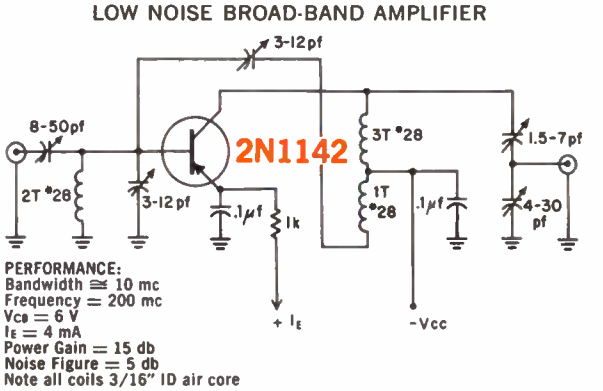
MOTOROLA DISTRICT OFFICES:
Belmont, Mass. / Burlingame, Calif. / Chicago / Cleveland / Clifton, N. J. / Dallas / Dayton / Detroit / Garden City, L. I. / Glenside, Pa. / Hollywood / Minneapolis / Orlando, Fla. / Phoenix / Silver Spring, Md. / Syracuse / Toronto, Canada.

LOW NOISE 200 MC AMPLIFIER

5 db noise figure at 15 db power gain

And, this new Motorola 2N1141 series offers performance breakthroughs in the communication field for low-noise R-F circuits and broad-band high-frequency amplifiers. In front-end applications the low noise of this series provides new extended receiver range. A typical low noise, broad-band amplifier circuit is shown below.

LOW NOISE BROAD-BAND AMPLIFIER



For more complete specifications, contact your Motorola district office, or write: Motorola Semiconductor Products, Inc., Technical Information Department, 5005 East McDowell Road, Phoenix 8, Arizona

SPRAGUE PIEZO-ELECTRIC CERAMIC ELEMENTS



ELEMENTS FOR ALL APPLICATIONS AS WELL AS COMPLETE TRANSDUCER ASSEMBLIES FOR MOST APPLICATIONS, SUCH AS UNDERWATER SOUND AND VARIOUS ORDNANCE AND MISSILE DEVICES.



Sprague-developed mass production and quality-control techniques assure lowest possible cost consistent with utmost quality and reliability. Here too, complete fabrication facilities permit prompt production in a full, wide range of sizes and shapes.

Look to Sprague for today's most advanced ceramic elements—where continuing intensive research promises new material with many properties extended beyond present limits.



YOUR INQUIRIES ARE INVITED

WRITE FOR LITERATURE

SPRAGUE ELECTRIC COMPANY
235 Marshall Street, North Adams, Mass.

SPRAGUE®
THE MARK OF RELIABILITY

IRE People

(Continued from page 54A)

ferred to the RCA Manufacturing Company where, successively, he became responsible for the design of tuned radio-frequency receivers, loudspeakers, and phonograph pickups, as well as all factory tests and inspections. In 1934 he rejoined General Electric at Bridgeport, Conn., to work on the design of radio receivers.

In 1936, Mr. Loughren joined the laboratories of Hazeltine Corporation. He then rose to become, successively, engineer in charge of television development, design supervisor for military equipment programs, Director of Research, Vice President in charge of Research for Hazeltine Corporation, and Executive Vice President of Hazeltine Research, Inc., a subsidiary of Hazeltine Corporation.

Mr. Loughren joined Airborne Instruments Laboratory in 1956 to become Vice President in charge of the Applied Research Division. In November, 1959 his duties at AIL were expanded to include those of the Applied Research Division and the Specialty Products Department. As Vice President heading up the new Apparatus Division he was responsible for the development and production of AIL's commercial and industrial products lines and special control systems. In November, 1960 he undertook the organizing of a

(Continued on page 58A)

GALLIUM

for technical and laboratory use in telecommunication

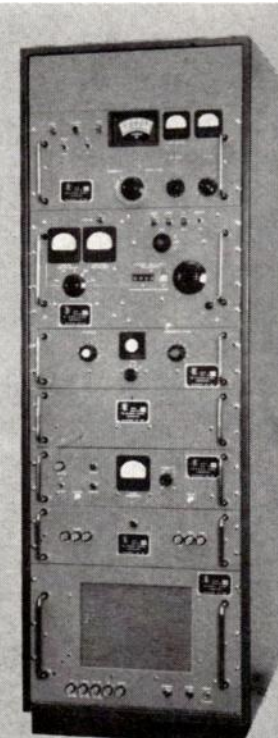
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99.999%
99.9999%

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CPO-1



CONTROLLED PRECISION OSCILLATOR

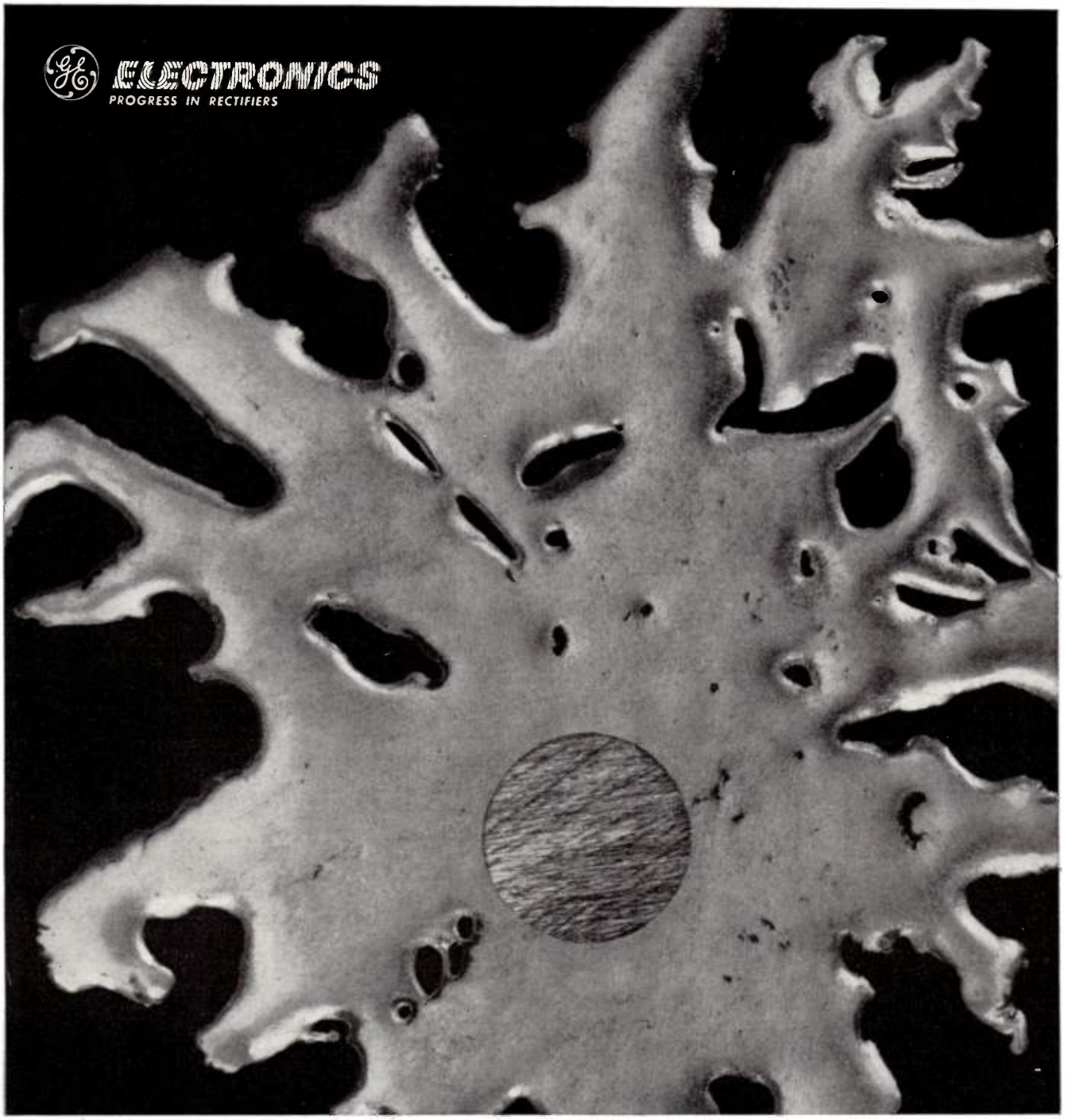
AN/URA-31

TMC Model CPO-1 (AN/URA-31) is a precision signal generator tunable from 1.75 to 33.75 megacycles in 100 cycle steps with an overall stability and accuracy of 1 part in 10^8 per day.

The CPO-1 is used in laboratories and production facilities to provide precise RF frequencies. It is also used operationally as the control oscillator in a transmitter or receiver to create a highly stable transmission system.

For additional information about the CPO-1 and other test equipment, please contact

The Test Equipment Division Of
THE TECHNICAL MATERIEL CORPORATION
World Wide Suppliers of Electronic Communications Equipment
and Subsidiaries MAMARONECK, NEW YORK
OTTAWA, CANADA • ALEXANDRIA, VIRGINIA • GARLAND, TEXAS • LA MESA, CALIFORNIA • POMPANO BEACH, FLORIDA



Soft solder melts at temperatures that leave hard solder disc unaffected.

HARD SOLDER



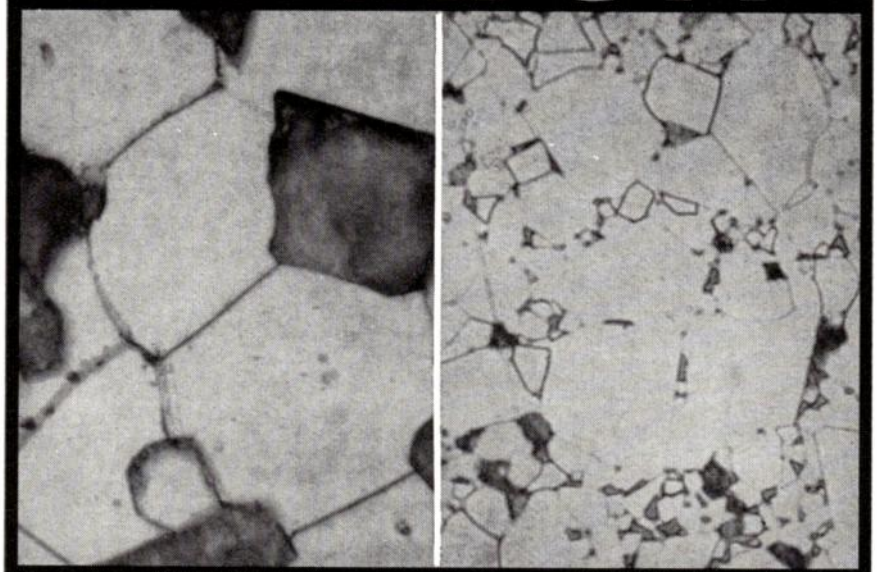
FREES GENERAL ELECTRIC RECTIFIERS FROM THERMAL FATIGUE

Hard solder resists heat and highly cyclical loads at levels that are just plain impossible for ordinary tin lead soft solder. A simple truth, but an important one if you design rectifier circuits. Soft solder joints deteriorate within approximately 1000 temperature swings from 35°C to 200°C. General Electric hard solder junction silicon rectifiers have been tested to 100,000 temperature cycles from 35°C to 200°C *with absolutely no trace of thermal resistance deterioration or fatigue* . . . and that's a cold, hard fact.

G-E type 4JA90 high current rectifiers are now available in ratings up to 800V at 250 Amps. Ask your G-E Semiconductor District Sales Manager. Or write Rectifier Components Department, Section 23D58, General Electric Company, Auburn, New York. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: International General Electric, 159 Madison Ave., N.Y. 16, N.Y. Also at your authorized G-E distributor.

GENERAL ELECTRIC

KEARFOTT



Kearfott MN-60 Brand X Ferrite

Both Micrographs Taken at 1067X Magnification

RECORDING-HEAD FERRITE APPROACHES SINGLE-CRYSTAL STRUCTURE

UNIFORMITY, DENSITY GIVE HIGH PERMEABILITY

Kearfott's MN-60 Recording-Head Ferrite is specially formulated for optimum performance. Uniform crystal structure, sharp crystal boundaries, and careful control of voids produces its excellent characteristics. Initial minimum permeability is 5000, with an average of 6000 in production quantities. It is easily machined into small difficult shapes with typical tolerances of 0.0001 inch. Surfaces are finished by machining to 16 microinches, and by lapping to 8 microinches.

OTHER FEATURES OF MN-60

Negligible Eddy Current Losses
High DC Resistivity
High Curie Temperature
Low Core-Loss Characteristics
Low Electrical Losses
Highest Uniform Quality



Typical Kearfott head configurations (actual size).

TYPICAL CHARACTERISTICS OF MN-60

Initial Permeability (at 21°C, 800 cps)	500 minimum
Maximum Permeability Range (at 3000 gauss)	9000-10,000 gauss
Flux Density (Bmax) (at 2 oersteds)	4800 gauss
Loss Factors (at 10 kc)	3×10^{-6}
(at 50 kc)	4.5×10^{-6}
(at 200 kc)	45×10^{-6}
Curie Temperature	190°C
DC Resistivity	300 ohm-cm

For complete data write Kearfott Division, General Precision, Inc., Little Falls, New Jersey.

GENERAL PRECISION

IRE People

(Continued from page 56A)

long-range planning activity for Airborne Instruments Laboratory.

During World War II, Mr. Loughren received the U. S. Navy Bureau of Ships Certificate of Commendation for outstanding service to the Navy for contributions to electronic development. He was awarded the David Sarnoff Gold Medal in 1953 by the Society of Motion Picture and Television Engineers for meritorious achievement in television engineering and the 1954 plaque of the RETMA-IRE Radio Fall Meeting for his contributions to color television circuitry. His outstanding contributions in the formulation of the signal specifications for compatible color television won him the coveted IRE Morris Liebman Memorial Prize in 1955. In 1959 he received a plaque in appreciation of his services as a member of the Signal Corps Research and Development Advisory Council. He has been a member of the Technical Advisory Panel for Electronics, Research and Engineering, of the Departments of Defense, for several years, and was Chairman of a subcommittee of the JTAC of IRE undertaking a frequency diversity study for the FCC.

His professional and industrial activities have included membership on various Panels of the first and second National Television System Committees, Panel 6 of the Radio Technical Planning Board, the Joint Technical Advisory Committee, various RETMA committees, and the National Stereophonic Radio Committee. He was President of the IRE in 1956, and a member of its Board of Directors from 1952 through 1958. He has served as a member of many IRE committees. He is a Fellow of AIEE, SMPTE, and the Radio Club of America.

During his career, Mr. Loughren has been awarded 33 electronic patents. He is a member of Phi Beta Kappa, Sigma Xi, and Tau Beta Pi.

❖

Dr. Samuel G. Lutz (A'35–M'40–SM'43) has been appointed chief scientist of Hughes Aircraft Company's research laboratories, where he will direct studies of satellite communications.

Dr. Lutz has been a senior scientist at the laboratories since 1958. Before that, he directed the company's communications engineering from 1951 to 1958. He was professor and chairman of the electrical engineering department of New York University, 1945–1951, and was associated with the Naval Research Laboratory from 1940–46.

Dr. Lutz holds a Ph.D. degree from Purdue University. He is a recipient of the U. S. Navy Distinguished Civilian Service Award.

❖

Microwave Associates, Inc. recently announced the appointment of **Daniel J. McCarthy** (S'54–M'57) as Sales Engineer in its newly organized Semiconduc-

(Continued on page 60A)

KAY Precision Random Noise Generators



Mega-Node **3000**



Microwave Mega-Nodes

1 kc to 1000 mc . . . *Therma-Node*

The **Therma-Node** is a basic noise source which provides extremely high accuracy by utilizing a basic noise generation technique—thermal noise from a heated resistive element.

- **Noise figure to 10 db • Output impedance, 50 ohms unbalanced**
- **Accuracy ±0.1 db • Operates from line or 24 V dc . . .**

2—1000 mc, Price **$550.00,** f.o.b. factory. (**$605.00** F.A.S., N. Y.)
1 kc—300 mc, add **$135.00** (**$149.00** F.A.S., N. Y.)

1 mc to 3000 mc . . . *Mega-Node* **3000**

The **Mega-Node 3000** is a calibrated random noise source providing output over a wide frequency and power range. It employs a coaxial-type noise diode with a tungsten filament as a temperature-limited noise generator.

- **Noise figure, 0-20 db • Output impedance, 50 ohms unbalanced**
- **Accuracy ±.25 db below 250 mc, ±1.0 db below 2000 mc, ±1.5 db at 3000 mc**

Price **$790.00,** f.o.b. factory. (**$869.00** F.A.S., N. Y.)

3 mc to 500 mc . . . *Mega-Node* **403-A**

The **Mega-Node 403-A** is a calibrated random noise source providing precise operation over a more limited frequency range at proportionately lower cost.

- **Noise figure, 0-19 db • Output impedance, 50 ohms unbalanced**
- **Accuracy ±0.5 db**

Price **$375.00,** f.o.b. factory. (**$413.00** F.A.S., N. Y.)

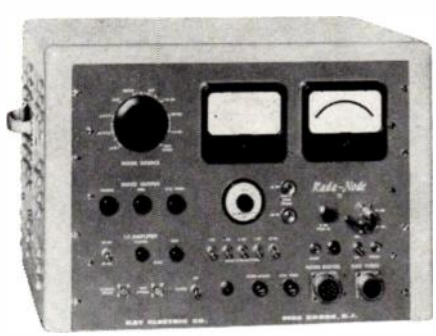
1120 mc to 26,500 mc . . . *Microwave Mega-Nodes*

The **Microwave Mega-Nodes** are precision machined and plated waveguide fixtures, utilizing argon, fluorescent, or neon gas discharge tubes. Single power supply operates all units. (Power Supply Price, $125.00.) ($138.00 F.A.S., N. Y.)

- **Noise output of 15.8 ±.025 db for fluorescent tubes, 15.45 ±0.2 db for argon, 18.0 ±0.2 db for neon. Supplied with power cables and fittings**

Price **$175.00** up. (**$193.00** F.A.S., N. Y.)

COMPLETE NOISE MEASUREMENT TEST SET



KAY

Rada-Node

Catalog No. 600-A

- EASY, STABLE MEASUREMENT
- BROAD BAND IF AMPLIFIERS
- COMPLETE FREQUENCY COVERAGE

The Rada-Node complements the Kay line of noise sources in providing a complete, precision radar noise figure measuring set, designed to cover the entire range from 5 mc to 400 mc. With optional higher-frequency noise sources available separately when required, this range may be extended to 26,500 mc. It can also be adapted for TV and other applications.

Features: The Rada-Node consists of two broad band IF amplifiers, an IF detector probe, a single noise diode, an electronically-regulated IF power supply, and noise diode and gas tube power supplies. With optional equipment, it may be used as an IF noise source operating in the 5-3000 mc range or as an RF noise source in the 1120-26,500 mc range. The IF detector probe may be adapted to fit various size tube sockets.

The IF input is fed through switched attenuators, totaling 21 db, and a single, fixed 3-db (2x power) step to the IF amplifiers. These amplifiers, centered at 30 mc and 60 mc, are 14 mc wide and have a gain of 70 db. Each contains a 2-db "interpolation" gain control, as well as "course" and "fine" gain controls common to both amplifiers. Each amplifier consists of six successive stages of IF amplification and a detector. The detector output is monitored by a calibrated db meter and is fed to the video output.

Price **$1595.00** f.o.b. factory (**$1755.00** F.A.S., N. Y.)

KAY

ELECTRIC COMPANY

MAPLE AVENUE • PINE BROOK, MORRIS COUNTY, N. J.
DEPT. I-4 CAPITAL 6-4000

0 TO 1500 V compliance



with

ELECTRONIC MEASUREMENTS constant-current POWER SUPPLIES

You'll find a whole new spectrum of application in Electronic Measurements Constant-Current Power Supplies. Take the husky Model C638A shown here. It'll deliver up to 1500 V DC at any output current from a few microamperes up to 100 MA. There are other features too... a modulation input, programmability, less than 0.01% +1 μa ripple... and the all-important voltage control that lets you set the maximum voltage compliance.

For complete information ask for Specification Sheet 3072C.

BRIEF SPECIFICATIONS

MODEL	CURRENT RANGE MIN.	CURRENT RANGE MAX.	†VOLTAGE COMPLIANCE MAX.	†VOLTAGE COMPLIANCE MIN.
C612A	1 μa	100 ma.	260 V	100 V
C631A	1 μa	100 ma.	420 V	300 V
*C638A	0.5 μa	100 ma.	2100 V	1500 V
C624A	2.2 μa	220 ma.	260 V	100 V
C632A	2.2 μa	220 ma.	420 V	300 V
*C636A	2.2 μa	220 ma.	735 V	600 V
C629A	2.2 μa	300 ma.	205 V	150 V
C633A	2.2 μa	300 ma.	420 V	300 V
C620A	5 μa	500 ma.	110 V	50 V
C621A	5 μa	500 ma.	160 V	100 V
C613A	10 μa	1 AMP	115 V	50 V
C614A	10 μa	1 AMP	170 V	100 V
*C628A	10 μa	1 AMP	215 V	150 V
*C630A	10 μa	1 AMP	280 V	200 V
*C625A	22 μa	2 AMP	150 V	75 V
*C626A	22 μa	2 AMP	190 V	100 V
*C615A	22 μa	3 AMP	125 V	50 V
*C618A	22 μa	3 AMP	170 V	100 V

** Voltage limiting control standard. Optional on all other models.*

† For current vs. voltage compliance curves, request Specification Sheet 3072C.

ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

IRE People

(Continued from page 58A)



D. J. McCarthy

tor Division. Mr. McCarthy will specialize in such solid state devices as frequency multipliers, solid state switches, limiters, duplexers and phase shifters.

Prior to joining Microwave Associates, Mr. McCarthy was a Design Engineer at the Wayland Laboratory of Raytheon Company where he specialized in the design and development of various microwave radar components including low-noise amplifiers, mixers, ferrite devices, and other microwave components.

He was also associated with the Power Tube Division of Raytheon where he participated in research and development of high power microwave tubes.

In 1956 Mr. McCarthy was graduated from Northeastern University with a B.S. degree in Electrical Engineering.

❖

Microwave Associates, Inc., Burlington, Mass., announced the appointment of **Henry W. McMurtray** (A'60) as Director of Quality Control and Reliability. In the newly created position, Mr. McMurtray will be responsible for the overall direction and coordination of the quality control and reliability programs at Microwave Associates.



H. W. McMurtray

Prior to joining Microwave Associates, Mr. McMurtray was Manager of Quality Control, Airborne Operations of the Aero Weapons Division, Raytheon Company, Waltham, Mass. From 1944 to 1959 he was employed by Melpar, Inc., Falls Church, Virginia as Manager of Quality Control in charge of a group working on radars, countermeasure equipment, flight simulators, tracking beacons, and components for Talos, Atlas and Jupiter missiles. From 1947 to 1951 he was an instructor in basic electronics at Kessler Air Base, Biloxi, Mississippi.

He is a graduate of the University of Mississippi.

Mr. McMurtray served on active duty with the U. S. Navy during World War II as a Communications Officer, and again during the Korean Conflict as an Electronics Officer with the rank of Lt. Commander.

He is a member of the American Society for Quality Control.

❖

(Continued on page 62A)

USE YOUR IRE DIRECTORY IT'S VALUABLE

LINDE — RARE GASES — and MIXTURES

Helium

PURER OBTAINABLE

ALL YOU NEED

—from the foremost producer of atmospheric gases!

- **Produced under continuous mass spectrometer control.**
- **Fast nationwide delivery.**
- **Guaranteed ultra-high purity.**
- **Scientifically blended and tested mixtures for any need.**
- **Quality based on more than 50 years of rare gas know-how.**
- **Complete technical service.**

SEND FOR NEW 20-PAGE ONE-SOURCE RARE GAS BOOKLET

First comprehensive price and specification list for all rare gases and mixtures...



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Rare Gases, Dept. IRE-4
Linde Company
Division of Union Carbide Corporation
270 Park Avenue, New York 17, N. Y.

☐ Please send a copy of your booklet listing prices, specifications, and information on LINDE Rare Gases.

☐ Have a representative contact me.

UNION CARBIDE

LINDE COMPANY

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Professional Group on Communications Systems

The field of communications systems is as old as radio itself. For three decades after Marconi first spanned the Atlantic by radio in 1901 radio researchers devoted practically all their efforts to developing and perfecting new systems for utilizing electromagnetic waves for communication purposes.

Gradually, however, this newfound knowledge opened the doors to other applications in industrial, military, scientific, and medical fields. Under the stimulus of wartime research these newer applications multiplied and expanded at a tremendous rate so that at the end of World War II the complexion of the radio engineering field had altered drastically.

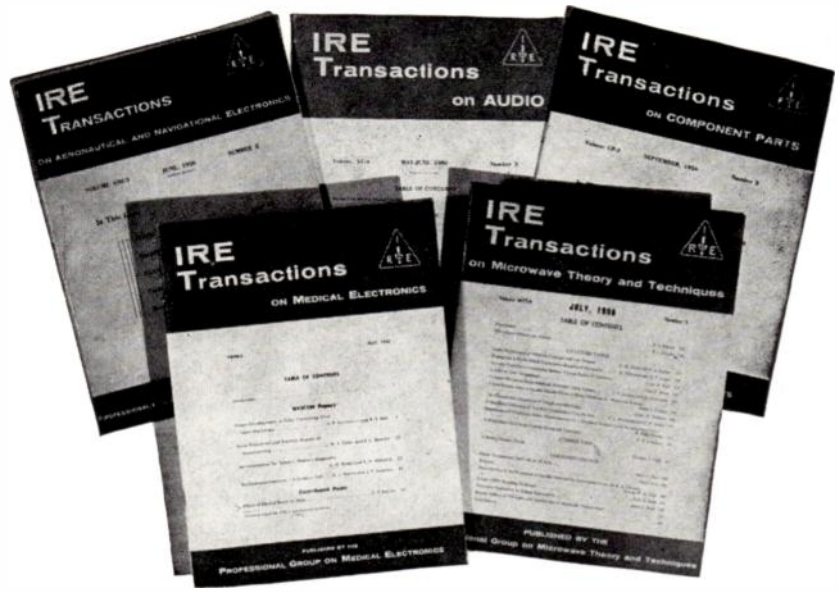
What had once been a fairly small, homogeneous group with common technical interests had now become a large body of engineers and scientists working in at least a score of separate and distinct specialized fields. Communications engineers found it increasingly difficult to find the specialized technical information they urgently needed since the sources for such information now had to serve many other fields as well.

On April 8, 1952, the IRE formed the Professional Group on Communications Systems. The response was almost instantaneous as communications engineers all over the U.S., and in other countries as well realized that for the first time an organization had been formed just to serve their particular technical needs.

As membership increased, the Group began publishing its own TRANSACTIONS, which is issued free to all members. Last year alone, Group members received more than 300 pages of valuable technical papers. The Group also has become very active in sponsoring meetings in various parts of the country throughout the year. The value of these activities is attested to by the fact that over 4000 engineers have joined the Group and have found this affiliation indispensable to their professional well being.

Ernst Weber

Chairman, Professional Groups Committee



At least one of your interests is now served by one of IRE's 29 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.

Aerospace and Navigational Electronics (G 11)	Fee $3
Antennas and Propagation (G 3)	Fee $6
Audio (G 1)	Fee $2
Automatic Control (G 23)	Fee $3
Bio-Medical Electronics (G 18)	Fee $3
Broadcast & Television Receivers (G 8)	Fee $4
Broadcasting (G 2)	Fee $2
Circuit Theory (G 4)	Fee $4
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 $4
Engineering Management (G 14)	Fee $3
Engineering Writing and Speech (G 26)	Fee $3
Geoscience Electronics (G 29)	
Human Factors in Electronics (G 28)	Fee $2
Industrial Electronics (G 13)	Fee $3
Information Theory (G 12)	Fee $4
Instrumentation (G 9)	Fee $3
Microwave Theory and Techniques (G 17)	Fee $3
Military Electronics (G 24)	Fee $2
Nuclear Science (G 5)	Fee $3
Product Engineering and Production (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 $3
Ultrasonics Engineering (G 20)	Fee $2
Vehicular Communications (G 6)	Fee $3

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 twice the cost-price to IRE members.

The Institute of Radio Engineers
1 East 79th Street, New York 21, N.Y.

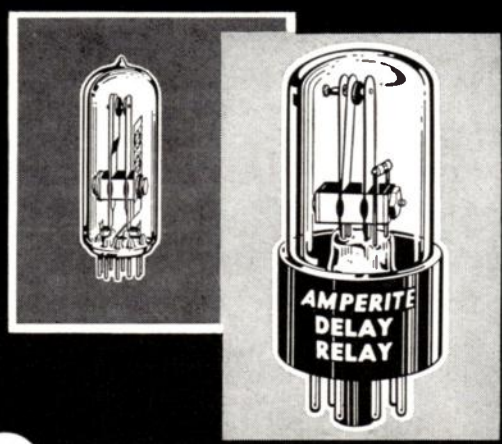
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AMPERITE

Thermostatic DELAY RELAYS



Only a glass seal offers true hermetic sealing ..assuring maximum stability and life!

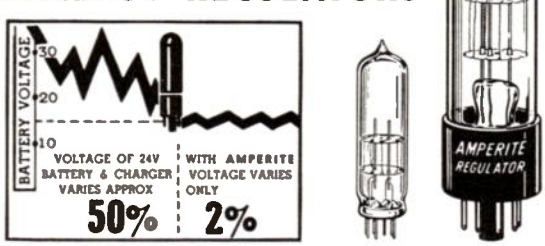
Delays: 2 to 180 seconds . . . Actuated by a heater, they operate on A.C., D.C., or Pulsating Current . . . Being hermetically sealed, they are not affected by altitude, moisture, or climate changes . . . SPST only—normally open or normally closed . . . Compensated for ambient temperature changes from —55° to +80° C. . . . Heaters consume approximately 2 W. and may be operated continuously . . . The units are rugged, explosion-proof, long-lived, and—inexpensive!

TYPES: Standard Radio Octal, and 9-Pin Miniature . . . List Price, $4.00. Also — Amperite Differential Relays: Used for automatic overload, under-voltage or under-current protection.

PROBLEM? Send for Bulletin No. TR-81

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IRE People

(Continued from page 60A)

Dr. Jan A. Narud (S'51–A'52–M'57) formerly with IBM Research Center at Yorktown Heights, New York, has accepted the position as Manager of Circuits Research for Motorola Semiconductor Products Division, Phoenix, Ariz.



J. A. Narud

At Motorola Dr. Narud will be responsible for circuit aspects of an expanded integrated circuits research program which was recently announced by the firm. Specifically his efforts will be directed toward the implementation of a set of compatible logic elements for computers, as well as integrated building blocks for communication circuits.

Before joining Motorola, Dr. Narud was engaged in the development of high-speed transistor logic circuits and tunnel diode memories for IBM. Previously, he had been an assistant professor in the Division of Applied Physics and Engineering at Harvard University. While at Harvard Dr. Narud also served as a consultant on a number of organizations including Bell Telephone Laboratories where he was working on various problems in conjunction with Pulse Code Modulation. He has published a number of papers on nonlinear circuit analysis and switching circuits.

Dr. Narud received his B.S. and M.S. degrees from California Institute of Technology in 1950 and 1951, respectively, and a Ph.D. from Stanford University in 1954, all in Electrical Engineering. He is a member of Sigma Xi.

❖

The appointment of **Richard M. Osgood** (SM'60) as Vice President and General Manager of the eastern operation of Sylvania Electronic Systems, Waltham, Mass., was announced recently.



R. M. Osgood

Mr. Osgood joined Sylvania in 1955 as Manager of Equipment Fabrication at Waltham, became Manager of the Avionics Laboratory in March, 1956, and in December of that year was appointed General Manager of the Waltham Laboratories. Before joining Sylvania, he was Chief of the Air Force's Electronic Defense Systems Division of the Air Materiel Command.

He received his Bachelor's degree from the U. S. Military Academy in 1941, and held the rank of Colonel in the U. S. Air Force. He has done graduate work in radio engineering at Harvard University, in microwave design at Massachusetts Institute of Technology, and has completed the program for senior executives conducted by M.I.T.

❖

The appointment of **Harold Rapaport** (M'54–SM'57) as vice-president—deputy to the president of the International Electric Corporation was announced recently.



H. Rapaport

Mr. Rapaport joined the International Telephone and Telegraph's U. S. defense group in May of 1960 as director of its Advanced System Center. Previously, he was deputy director of engineering with ITT Communications Systems, Inc., and before that had been with RCA, the Microwave Research Institute of the Polytechnic Institute of Brooklyn, and Westinghouse Electric Corporation.

Mr. Rapaport was graduated Summa Cum Laude from the University of Pittsburgh with a Bachelor of Science degree. He has served as a faculty member of the University of Pittsburgh. He received a Master of Electrical Engineering degree from the Polytechnic Institute of Brooklyn. He is also the author of several books and technical papers and has been awarded a number of patents.

❖

(Continued on page 124A)

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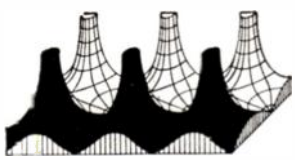
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April, 1962
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Proceedings of the IRE

Poles and Zeros



Opportunity. The following communication from Professor Herbert Reich of Yale University contains a valuable message to young members:

"College students and graduates in considering membership in technical societies frequently ask the question, What can this society do for me? In view of the many important functions served by the Institute of Radio Engineers and other professional societies, it has always seemed to me that a more valid question is, What can I, as a young engineer, do to contribute to the work of this society? In answering the last question, one must bear in mind that many of the vital activities of a professional society must be performed by its members and can not be delegated or bought. For this reason, as the student and the young engineer advance, they should realize that they have an obligation to the engineering profession, to the engineering societies, and to themselves to assume responsibilities in the technical societies. These responsibilities include participation in the work of technical committees.

"One of the major tasks of each technical committee of the Institute of Radio Engineers is the preparation of standard definitions, symbols, and methods of measurement. The importance of standardization of definitions and symbols first becomes apparent to the engineer as a student when he is obliged to learn, unlearn and relearn symbols in a field of standardization which has not been completed. Later, he learns by experience that lack of standardization results in ambiguities and misunderstandings which are expensive in time and money, and that serious problems arise when manufacturers and customers use specifications and methods of measurements that have not been standardized. In military procurement, the cost of lack of standardization may be the loss of life and ultimately, of a war. International recognition of the importance of standardization is evidenced by the standardizing activities of the more than fifty technical committees of the International Electrotechnical Commission. Many of the methods of measurements, symbols, and definitions prepared by the IRE technical committees have been incorporated in IEC Standards, which have legal status in a number of countries.

"Those who have attended recent conferences sponsored by the IRE Professional Groups can hardly have failed to be impressed with the fact that, so far as professional-group activities are concerned, IRE is a young man's organization. Yet, in spite of the importance of technical committee activities, many of our technical committees have a large percentage of members who have served for many years; and it is becoming increasingly difficult to replace these by younger members. This undesirable state of affairs must be altered if the Institute is to maintain its eminence in the field of standardization.

"In closing, I shall return to the original question, which I bypassed, and suggest that one of the benefits which the Institute offers to members is the privilege of working on its technical committees. The hours spent in IRE activities are amply repaid by the opportunity of working with other engineers who not only are experts in their fields, but who are wonderful people. From personal experience, I can say that the resulting professional and personal friendships—local, national, and international—are without doubt the most precious and lasting reward which the IRE can give its members."

Professor Reich identifies an area of considerable opportunity. Over 500 people are involved in permanent technical committees and some 125 subcommittees covering virtually all fields of IRE activity. Those who wish to pursue these opportunities to serve may contact L. G. Cumming at IRE headquarters, or the incoming chairman of the Standards Committee, H. R. Mimno, Harvard University, Cambridge, Massachusetts.

What Are Letters Made Of? Letters to the Editor is a fast growing section of the PROCEEDINGS that is becoming increasingly important in our rapidly developing technology. Although "The Letters" perform many functions, the most important function is that of a minimum-time-delay communication link. They permit the research engineer to "stake his claim" to a new discovery or result and they enable all of us to anticipate the directions in which our fields will develop. By scanning the letters in each issue each of us can find the guidance which we need in extending our plans for continuing study. Nor is the value of this guidance limited to the commercial practitioner—the educator, too, must lean heavily on sources of this sort, for he is directly responsible for launching the next generation on a timely, and effective, trajectory. A long lead time is imperative.

To make the Correspondence section most effective, the Editorial Board is continuing a policy of very limited review of all letters received, on the premise that speedy publication of valuable material will more than offset any possible effect of erroneous material. As a result some letters do get through that would not have survived a formal review procedure, but more importantly, other timely letters may appear in less than sixty days from receipt instead of being held up four to eight months.—T.F.J.



A. M. Angot

Vice President, 1962

André M. Angot (SM'51) was born in Le Puy, France, on February 15, 1905. He entered the Ecole Polytechnique, Paris, in 1926, and was promoted to Lieutenant in the Engineer Corps in 1928. He obtained his engineering degree from the École Supérieure d'Electricité, Paris, in 1933.

From the beginning of his career he has been active in military radio-communication research and development. He was first at the Section d'Etudes du Matériel de Transmission, Paris, from 1933; he then served as Director of the Service de Contrôle Technique des PTT, Lyon, from 1942, where studies of radar and communication systems, interrupted in 1940, were carried on in secret. After the Liberation of France he became Director of the Section d'Etude du Matériel des Transmissions, which had just re-opened. In 1946 he became Assistant Director of the Centre National d'Etudes des Télécommunications (C.N.E.T.) in Paris, and in 1952 was made Director of the Section d'Etude et de Fabrication des Transmissions (S.E.F.T.), also in Paris, where he was promoted to Ingénieur Général in 1956. The following year he left the government service to become Technical Director and Adviser of the Société des Télécommunications Radioélectriques et Téléphoniques (T.R.T.). He is Professor of Applied Mathematics at the Ecole Supérieure d'Electricité in Paris.

Mr. Angot is a member of the Société de Mathématiques de France, of which he was adviser-member in 1956. He has participated in meetings of the Comité Consultatif International des Radiocommunications (CCIR). He joined the Comité National Français de Radioélectricité Scientifique (URSI French Section), of which he was first a member, then an adviser-member, before being elected President in the years 1959–1961. In 1960 he was elected President of the Société Français des Electroniciens et Radioélectriciens.

Scanning the Issue

Propagation of the Low-Frequency Radio Signal (Johler, p. 404)—The communications field, broadly speaking is the oldest, and yet one of the most modern fields of activity within the IRE. Its modernity is evident in the sophistication of present-day modulation and signal processing methods, in the dramatic improvement in the performance of radio equipment, in the conquest of new regions of the frequency spectrum, and in the continuing evolution of new ways for transmitting a message from here to there, whether by means of a satellite, a meteor trail, or the knife-edge diffraction of a mountain top. In the frequency domain, while most of the attention has been directed toward extending the upper boundary of the usable spectrum, important work has also been going on in the lower end. The day is gone when the word "cycle" was always preceded by a number with at least six digits. Indeed, recent work in the geosciences strongly suggests that IRE members will soon be reading mc as "millicycle." This paper deals with that portion of the lower frequency domain which is currently of greatest interest to the practitioner and the most challenging to the theoretician. To the practitioner, the LF region has become a major radio thoroughfare for precision navigation systems, such as Loran-C, and for highly reliable communication systems, such as are needed in the Arctic. To the theoretician, the LF region calls for analytical methods substantially different from those usually employed at higher frequencies. As the author points out, this can be appreciated intuitively since at LF and VLF the wavelength approaches in magnitude certain critical dimensions of the propagation medium, such as the distance between ground and the ionosphere. Thus, as the frequency is decreased, the mathematical rigor required for a theory of propagation rapidly increases. On the other hand, as the frequency is increased the difficulties of maintaining full rigor also increase. As a consequence, in the LF region the theoretician is caught in the crux, where mathematical rigor is both required and difficult. It is the purpose of the present paper, which was specially solicited for the PROCEEDINGS, to review the theory of propagation for this important region of the spectrum, with particular emphasis on the propagation of a signal and propagation in the time domain.

Video Transmission by Delta Modulation Using Tunnel Diodes (Balder and Kramer, p. 428)—A little over a year ago the PROCEEDINGS reported an experiment in which television pictures were coded into binary pulses for transmission over telephone cable pairs. One of the important results of this work was to demonstrate the possibility of using binary pulse transmission for television systems having many links, such as transcontinental coaxial and microwave circuits. The advantage of this method is that it would avoid the cumulative effect of interference as the signal passes through many repeaters because in a pulse-code system the signal would be regenerated at each repeater, leading to substantial simplifications in repeater design requirements. This paper proposes using a different code modulation system known as delta modulation, which employs a 1-digit instead of a multidigit code to describe the sampled video signal amplitude. Until now the delta modulation system could only be used for speech transmission because of the high pulse-repetition rates required for video transmission. The authors have overcome this difficulty by employing tunnel diodes to obtain the desired repetition rates. The simplicity of the method of implementation is striking, the results are timely, and finally, this application should be welcomed by those who may have felt frustrated by the seemingly slow acceptance of tunnel diodes.

Construction and Performance of an ELF Display System (Sack, *et al.*, p. 432)—The availability of improved phosphors, plus the growing need for large-screen information displays for many complex data-handling systems, has stimulated considerable effort in the development of solid-state panel-type display screens during the past few years. In an earlier PROCEEDINGS paper an ELF display was proposed which employed a multi-element array of ferroelectric capacitors in conjunction with the electroluminescent screen. Having thus established the feasibility of the principle, work has since proceeded toward developing display panels up to 10 feet square for control center applications. Since displays of this size require over four million individual picture points, it can be appreciated that the interconnection problem alone represents a major task. In the work reported here, a smaller but complete experimental system was built and tested to evaluate the over-all feasibility of the full-scale display. The panel used was a 4-by-8-inch 8192-element subsection of a 10-foot-square screen. The results will bring a large number of people who are interested in display systems up to date regarding both the substantial progress and the difficulties being encountered in developing large, multi-element displays.

Duplexing and Switching with Multipactor Discharges (Forrer and Milazzo, p. 442)—A multipactor discharge consists of electrons in high vacuum which are driven back and forth between two electrodes by a synchronous RF electric field. Under appropriate conditions, the discharge can sustain itself by secondary emission. The discharge, being dependent on the applied voltage, represents a voltage sensitive impedance. The authors have found that a multipactor discharge can be employed as a new kind of duplexer and voltage-controlled high-power switch. They describe a developmental device capable of switching 5.5 Mw of peak power in 10 nsec. The results of this investigation offer important possibilities to radar systems and microwave device engineers and will likely give impetus to a substantial future effort in this field.

IRE Standards on Solid-State Devices: Definitions of Superconductive Electronics Terms (p. 451)—The announcement of the cryotron in 1956 opened up a new area of solid-state device development, namely, superconductive devices, which has been growing steadily in importance. The terminology spawned by this young field has now been standardized for the first time by the IRE Solid-State Devices Committee and the Standards Committee.

Design of a Microwave-Frequency Light Modulator (Blumenthal, p. 452)—Some years ago it was found that a suitably cut dihydrogen phosphate crystal would convert a plane polarized beam of light to an elliptically polarized one when a properly oriented electric field was applied to the crystal, and that the eccentricity of the ellipse could be changed by varying the field. Novel use has been made of this effect to develop a device which can intensity modulate a light beam at a microwave frequency rate. In view of the growing interest in the use of modulated light beams for guidance, control and communication systems, both the phenomenon and the device will be of interest to many engineers.

Upwind-Downwind Ratio of Radar Return Calculated from Facet Size Statistics of a Wind-Disturbed Water Surface (Schooley, p. 456)—This paper is concerned with radar return from one of nature's most complicated phenomena—a wind-swept ocean. Although considerable progress has been made in gaining an understanding of the physical principles involved, present theory does not explain the observed effects which wind velocity and direction have on radar sea return. The author presents the data needed to describe and calculate wind effects. The results will interest those working in sonar as well as those in radar.

Scanning the Transactions appears on page 505.

Propagation of the Low-Frequency Radio Signal*

J. RALPH JOHLER†, SENIOR MEMBER, IRE

The following paper was solicited for the PROCEEDINGS by the Tutorial Subcommittee of the IRE Wave Propagation Committee, and appears below as a part of a continuing program of presenting review and tutorial papers on subjects of general interest and importance.—*The Editor*

Summary—**The propagation of a radio signal and the propagation in the time domain is reviewed for linear amplitude systems. The particular case of the propagation of a ground wave pulse is considered in detail. A stretching in the form or shape of the pulse is noted as a result of the filtering action of the propagation medium. Theoretical transfer characteristics for the media of propagation of LF signals are introduced and methods of computation are considered. The particular case of a signal transmitted between two points on the earth's surface is considered from the viewpoint of propagation in the time domain.**

The field of LF waves propagated around the earth is, in large measure, influenced by the reflection and transmission processes at the ionosphere. Such processes are evaluated theoretically with the aid of Maxwell's equations together with an equation which describes the electron motion in the presence of a static magnetic field, a superposed electrodynamic field together with mechanical collisions between electrons and ions, such as the Langevin equation of motion of the electron. The use of full mathematical rigor in the application of these equations is feasible and indeed desirable at LF. Thus, the application of these equations to an electron-ion model plasma with arbitrary orientation of the superposed magnetic induction results in anisotropic transmission and reflection properties. The full rigor can be applied to model plasmas in which the electron density and collision frequency vary with altitude. This leads to the notion of reflection and transmission at a continuously stratified plasma.

Four distinct magneto-ionic propagation components exist in the ionosphere. These can be identified as ordinary and extraordinary, upgoing and downgoing waves. All of these propagation components are coupled to each other as the electron density changes with penetration depth into the plasma.

The anisotropy as a result of the electron gyration (Lorentz force) caused by the superposed static magnetic field of the earth clearly introduces a nonreciprocity in the propagation of the field between transmitter and receiver since the ionosphere reflection coefficient would not in general be the same if transmitter and receiver were interchanged.

The nature of the signal as a result of ionospheric propagation can be determined from the CW field with the aid of the Fourier transform-integral techniques employed on the ground wave in detail.

I. INTRODUCTION

THE ELECTRICAL properties of the ground, the ionosphere, the space between the ground and the ionosphere, and outer space determine the propagation of low-frequency (LF) electromagnetic waves in the vicinity of the earth. The electrical properties of these media (Fig. 1) are by convention described in concise form by means of the angular wave number $k=k_1, k_2, k_3, \cdots$, written $k=\eta\omega/c$, which involves the index of refraction $\eta=\eta_1, \eta_2, \eta_3 \cdots$, the angular frequency $\omega=2\pi f$, and the speed of light $c\sim 3(10^8)$ m/sec. A time-harmonic electromagnetic wave, *i.e.*, a wave which oscillates harmonically in time t from $t=-\infty$ to $t=+\infty$ (a wave uninterrupted in time) can be described in terms of the electric field $\overline{E}$, volts/meter,

$$E = |\overline{E}| \exp(i\omega t - ikD),$$

at a distance D when such a wave is propagated through a particular medium k of infinite extent. The principal task of the theoretician in the development of a description of the propagated field comprises the determination of the wave number or index of refraction from the electrical properties of the medium, applying Maxwell's equations for the propagation of electromagnetic fields $\overline{E}$, $\overline{H}$ ($\overline{H}$=electrodynamic magnetic field) to the boundaries between and within the various media and introducing the nature of the source of the radiation.

In the past, attention has been focused upon the propagation of these waves around the surface of the earth taking account of the ground, the ionosphere and the space between the ground and the ionosphere. Recently, as might be expected, considerable interest has developed in the propagation of LF waves in outer space, and there seems to be little doubt that interest in this type of propagation will increase with time.

The theoretical treatment of low frequencies apparently differs quite markedly from the theoretical treatment usually employed at high frequencies as to the degree of mathematical rigor. Indeed, the mathematical rigor required for a theory of propagation of radio waves in the vicinity of the earth increases rapidly as the frequency is decreased. This is not difficult to appreciate intuitively since the wavelength becomes quite long and even approaches in magnitude certain critical dimensions of the medium at LF/VLF, such as the altitude of the lower boundary of the ionosphere

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† National Bureau of Standards, Boulder, Colo.

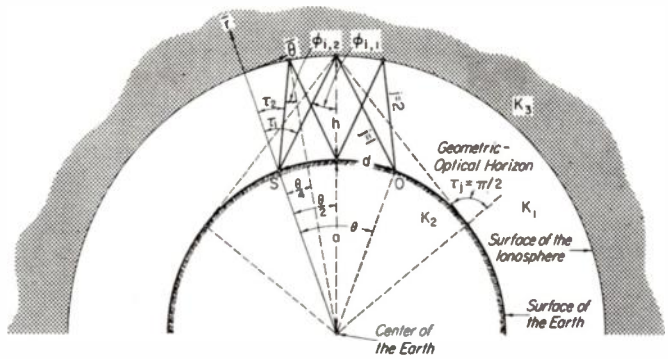


Fig. 1—Propagation media in the vicinity of the earth, illustrating propagation of waves about the earth.

(Fig. 1). Thus, for example, at 100 kc, $\lambda = f/c \sim 3000$ m at 10 kc, $\lambda \sim 30{,}000$ m. Therefore, the conventional geometric-optical treatment requires more rigorous corrections since such a treatment in the classical sense implies rays or waves of zero wavelength ($f = \infty$) or practically speaking, waves the length of which is small compared with the critical dimensions of the medium. Indeed, as the frequency under consideration is decreased to the VLF region and the distance between transmitter and receiver d (Fig. 1) is great, it seems to be quite necessary to abandon ray theory altogether and employ the full mathematical rigor to Maxwell's equations together with the appropriate boundary conditions and electrical description of the media. Such an approach is, of course, more difficult and the geometric-optical methods can be derived from this viewpoint [1], [2] as an approximate theory for higher frequencies and/or shorter distances. Whereas the full rigor results in a more satisfying mathematical treatment, the difficulties of maintaining full rigor increase with increasing frequency. Low frequencies are, therefore, on the one hand, in a part of the frequency domain where full rigor is difficult to apply and, on the other hand, complete confidence in the geometric-optical theory does not obtain. LF viewed from this perspective is, therefore, a difficult and challenging field of study for the particular species of investigator interested in the explanation of observed LF phenomena from the more penetrating viewpoint of electromagnetic theory.

Interest in LF waves has persisted from the early days of the radio science. More recently the requirement of precision radio navigation systems, such as the Loran-C pulsed radio navigation system [3], [4] and the requirements for high reliability in communications, especially in the Arctic, has stimulated interest in the favorable properties of these waves. Interest in these waves is also indicated by the extensive measurements of Belrose [5] and the theoretical work of Budden [6] and Barron [7].

This paper reviews the theory of propagation of LF waves with particular emphasis on the propagation of a signal and propagation in the time domain.

II. Propagation of LF Signals Near the Earth

Radio waves are employed to transmit information from point to point (Fig. 1), s to o (source to observer) around the earth. This is accomplished in a restricted sense as a form of modulation of the fields of time-continuous waves, $E(\omega, d)$ volts/meter which depend upon frequency, $f = \omega/2\pi$, cycles/second and distance d, meters. This is accomplished in a most general sense by means of an electromagnetic signal or transient electromagnetic field $E(t, d)$ volts/meter, which field depends upon time t and distance d, both reckoned from the transmitter.

The Hertz dipole [8] has been employed with remarkable success by theoreticians to represent a transmitter of such a signal in the LF frequency domain. Such a transmitter implies a point source (either vertical electric or vertical magnetic polarization) of radiation. But such a point source (except for fields very close to the transmitter) is not difficult to approximate experimentally at LF since the wavelengths are quite long relative to the dimensions of practical antennas. It is further implied that more complicated antennas could be synthesized by application of the superposition principle. A corresponding dipole probe has been utilized to define the field at a distance d from the source s (Fig. 1). Such a signal [$E(t, d)$ volts/meter] if it is to convey useful information, communication, or provide a radio navigation fix or time difference or indeed synchronize a system of clocks at different geographic locations to a common frame of reference [3], is varying in time (is modulated) and indeed is typically discontinuous in time. Thus, the signal $E(t, d)$ is an electromagnetic pulse in the quite general sense of the Fourier integral, assuming linear amplitude media of propagation

$$E(t' \ d) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \exp(i\omega t') E(\omega, d) f_r(\omega) f_s(\omega) d\omega, \qquad (1)$$

or using the symbol $\mathfrak{F}^{-1}$ for the inverse Fourier transform or Fourier integral

$$E(t' \ d) = \mathfrak{F}^{-1} f(\omega, d) \qquad (2)$$

where $f(\omega, d)$ is the complex Fourier transform of a signal. The source transform $f_s(\omega)$ is determined from the time domain $F_s(t)$ by the direct transformation

$$f_s(\omega) = \int_0^\infty \exp(-i\omega t) F_s(t) dt \tag{3}$$

or

$$f_s(\omega) = \mathfrak{F} F_s(t) \tag{4}$$

where the source $F_s(t)$ represents a Hertz dipole current moment, $I_o l$ ampere-meters as a function of universal source time t and the CW field $E(\omega, d)$ represents the complex transfer characteristic of the propagation medium. Since practical systems for the transfer of information affect the signal, it is necessary to introduce the complex transfer characteristic of the system (principally the receiver) $f_r(\omega)$. The local time t' [9] is reckoned locally from the beginning of the first precursor [10], [11] of the pulse, which can arrive at a point o (Fig. 1) no sooner than a signal propagated over the distance d at the speed of light c, but which will in general arrive later. Thus,

$$t' = t - \eta_1 d/c \tag{5}$$

where $\eta_1 \sim 1$ (for air, $\eta_1 \sim 1.000338$ typically at the surface of the earth).

The completely degenerate case of a signal varying harmonically in time from negative to positive infinity ($t = -\infty$ to $t = +\infty$) is a very special situation which can convey theoretically zero information between the point s, the transmitter, and the receiver o (Fig. 1),

$$E(t'd) \sim E(\omega, d), \tag{6}$$

but which is nonetheless frequently employed as an approximation for "narrow bandwidth" communication systems with the inference that such systems are satisfactorily described by the "zero bandwidth" asymptote and where the notion of bandwidth implies a finite spectrum of frequencies $f(\omega, d)$. Indeed, most theoretical calculations of the field $\bar{E}$ evaluate this transform $\bar{E}(\omega, d)$ with the implication that such a function, evaluated over all frequencies of concern in the Fourier integral (1) from negative to positive infinity, together with a specification of the source as a function of time $[f_s(t)]$ yield the nature of the propagated signal.

III. Pulses and Propagation in the Time Domain

The theoretical notion of the signal as a pulse implies important consequences as to the interpretation of propagation in the time domain. This can be more readily explained from the viewpoint of geometric-optics. Indeed, the use of full mathematical wave theory rigor would yield the same general conclusions as those which are reached with the aid of geometric-optics.

A signal transmitted around the earth between two points (Fig. 1) s to o, could arrive at the point o, according to the principle of relativity, no sooner than a signal transmitted at the speed of light over some ray length D. This point was established many years ago (1914) by Sommerfeld [10] and Brillouin [11] in a pair of memorable papers which established the consistency of electromagnetic theory with relativity. Whereas the CW concepts of phase velocity and group velocity in the presence of anomolous dispersion gave velocities which varied between positive and negative infinity, the full transient solution demonstrated that a light wave *signal velocity* properly defined was always less than the speed of light and thus consistent with the principle of relativity. Therefore, the shortest "ray" (Fig. 1) has a length $D = d$, the distance along the surface of the earth (since waves in the earth are completely absorbed). The first wave to arrive at the receiver o is then the ground wave $j = 0$. Other waves will arrive later as a result of propagation over some distance such as $D = D_j$ where $j = 1, 2, 3, \cdots$ (Fig. 1) and correspondingly arrive at the receiver at ever later times $t = t_j$. This fact is not obvious to the observer of a CW "signal" $[E(\omega, d)]$ since such a signal cannot resolve the individual ordered rays j which arrive at the receiver. Thus, the observer sees only the resultant vector field $E(\omega, d)$ of the sum of a number of individual fields $E_j(\omega, d)$ of each ordered ray j,

$$E(\omega, d) = \sum_{j=0}^{p} E_j(\omega, d), \qquad j = 0, 1, 2, 3, \cdots, \tag{7}$$

in which the zero order field $j = 0$ is the ground wave and each higher order field $j = 1, 2, 3, \cdots$ or $j \neq 0$ corresponds to ionospheric waves or waves reflected by the ionosphere [12],

$$E_j(\omega, d) = i\omega d D_j^{-1} C \exp(i\omega t_j') G_j' G_j' \alpha_j F_j C_j, \tag{8}$$

where

$$C = I_0 l b^2 / 4\pi\kappa d^3 = 10^{-7}/d, \quad I_0 l = 1, \quad \kappa = 1/c^2\mu_0, \tag{9}$$

and the local time for the ground wave t_0' is

$$t_0' = t - b, \tag{10}$$

$$b = \eta_1 d/c, \tag{11}$$

where $E_0(\omega, d) = |E_0(\omega, d)| \exp[-i(\omega b + \phi_c)]$, considering ϕ_c a phase lag or phase correction [13], and similarly, the local ionospheric wave time or ionospheric wave delay

t_j' $(j = 1, 2, 3, \cdots)$ is,

$$t_j' = t - b_j, \tag{12}$$

$$b_j = \eta_1 D_j / c, \qquad (j = 1, 2, 3, \cdots). \tag{13}$$

The quantity $b_j - b$, a time, is called the relative ionospheric wave delay, Fig. 2 (relative to the ground wave). The physical length of the particular type of ray D_j represented in Fig. 1 (other types of rays are feasible) can be evaluated geometrically for a reflection at an

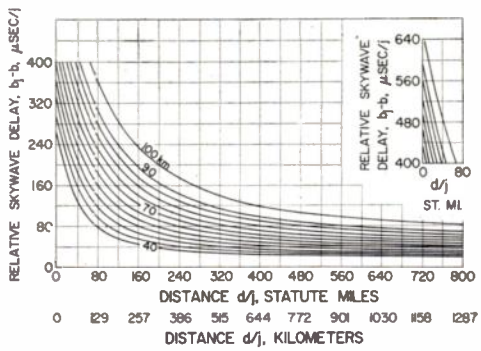


Fig. 2—Relative sky-wave delay for various altitude h of the lower ionosphere boundary.

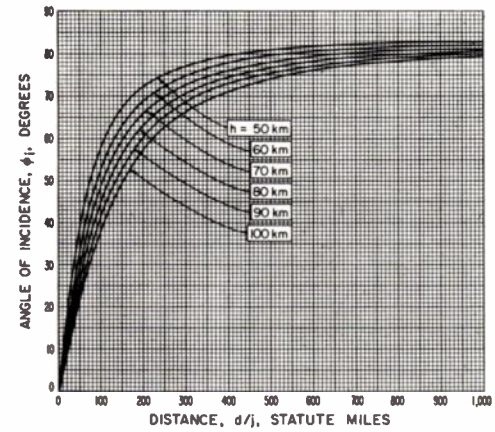


Fig. 3—Geometric-optical relation between the angle of incidence ϕ_i distance from the source d/j, $j=1, 2, 3, \cdots, j\neq 0$, and the altitude h of the lower boundary of the ionosphere.

altitude h above the surface of the earth of radius a,

$$D_j = 2j[(a + h)\cos\phi_{i,j} - a\cos\tau_j], \tag{14}$$

where (Fig. 1) ϕ_i is the angle of incidence of the ray on the ionosphere and τ_j is the corresponding angle of incidence on the earth and the subscript j reminds the reader that the equation refers to a particular ionospheric wave ($j=1, 2, 3, \cdots$) or ground wave ($j=0$) under consideration. The angles ϕ_i and τ_j are evaluated quite simply from the geometry. If,

$$\Delta_j = \left[2a(a + h)\left(1 - \cos\frac{\theta}{2j}\right) + h^2\right]^{1/2}, \text{ then} \tag{15}$$

$$\sin\phi_{i,j} = \Delta_j^{-1} a \sin\frac{\theta}{2j}. \tag{16}$$

$$\cos\phi_{i,j} = \Delta_j^{-1}\left[a\left(1 - \cos\frac{\theta}{2j}\right) + h\right], \tag{17}$$

$$\sin\tau_j = \Delta_j^{-1}(a + h)\sin\frac{\theta}{2j}, \tag{18}$$

$$\cos\tau_j = \Delta_j^{-1}\left[a\left(\cos\frac{\theta}{2j} - 1\right) + h\cos\frac{\theta}{2j}\right], \tag{19}$$

where θ (Fig. 1) is the angle at the center of the earth subtended by the distance d along the surface of a spherical earth, or simply $d=a\theta$. The relation between distance d/j, angle of incidence ϕ_i, and height h of the lower boundary of the ionosphere can therefore be quite simply illustrated as in Fig. 3.

The transmitting and receiving antenna factors G_j have been included to take account of antennas other than Hertz dipoles, where for the particular case of a vertical magnetic Hertz dipole $G_j=1$ in the equatorial plane of the dipole and $G_j=\sin\tau_j$ for the vertical electrical dipole.

The geometric-optical theory permits the use of plane reflection coefficients or Fresnel type reflection coefficients for rays reflected at the ground (Fig. 1) or the ionosphere. However, the ionosphere is not plane and it is necessary at low frequencies to introduce certain spherical corrections to the geometric-optical theory. The relation between plane and spherical reflections is defined by the convergence-divergence coefficient α_j which converts the former to the latter or from the viewpoint of the ray theory, takes account of ray focusing by the ionosphere and a corresponding defocusing of rays by the earth. Bremmer [1] has developed formulas for such a correction. A modification of this focusing or convergence correction A_j has been developed by Wait [14] to take account of rays near the geometric-optical horizon $\tau_j\sim\pi/2$ and beyond. The complete expression can be written

$$\alpha_j = \left(1 + h/a\left[\left(2j\sin\frac{\theta}{\partial j}\right)\Big/\sin\theta\right]^{1/2}\right. \times \left\{\left[a\left(1 - \cos\frac{\theta}{2j}\right) + h\right] \Big/ \left[(a + h)\cos\frac{\theta}{2j} - a\right]\right\}^{1/2} A_j, \tag{20}$$

in which A_j can be evaluated from the cylindrical Hankel function of order $n=\frac{1}{3}$ of the second kind, which for $j=1$ can be written

$$A_j \sim \left(\frac{\pi}{2}Z_j\right)^{1/2} H_{1/3}^{(2)}(Z_j)\exp\{-i[5\pi/12 - Z_j]\} \tag{21}$$

where

$$Z_j = k_1 a\cos^3\tau_j/3\sin^2\tau_j. \tag{22}$$

Wait [14] has developed numerous graphs of the function α_j and A_j and Johler [12] has detailed some computation methods, especially for the Hankel function $H_{1/3}^{(2)}(z)$.

The factor F_j is an antenna pattern factor since it describes a plane wave incident on a sphere with a receiver dipole antenna located on the surface of the sphere. The factor F_j accounts for the presence of the spherical earth at both the transmitter F_j^t and the receiver F_j^r, and if it can be assumed that the geometric-optical ray is not too close or beyond the geometric-optical horizon (Fig. 1), the Fresnel approximation again sufficies to determine F_j, or for vertical polarization

$$F_j \sim [1 + R_e^t(\tau_j)][1 + R_e^r(\tau_j)] \quad (23)$$

where the superscripts t and r refer to the transmitter and receiver respectively, and the subscript e refers to vertical electric polarization and

$$R_e(\tau_j) = \{k_2^2 \cos \tau_j/k_1^2 - [k_2^2/k_1^2 - \sin^2 \tau_j]^{1/2}\} / \{k_2^2 \cos \tau_j/k_1^2 + [k_2^2/k_1^2 - \sin^2 \tau_j]^{1/2}\}, \quad (24)$$

or for horizontal polarization

$$R_m(\tau_j) = \{\cos \tau_j - [k_2^2/k_1^2 - \sin^2 \tau_j]^{1/2}\} / \{\cos \tau_j + [k_2^2/k_1^2 - \sin^2 \tau_j]^{1/2}\} \quad (25)$$

where

$$k_2 = \frac{\omega}{c}\left[\epsilon_2 - i\frac{\sigma\mu_0 c^2}{\omega}\right]^{1/2}, \qquad k_1 = \frac{\omega}{c}\eta_1 \sim \frac{\omega}{c}, \quad (26)$$

which defines the wave number of the air and the ground in terms of the dielectric constant ϵ_2 relative to a vacuum, the conductivity, σ, mhos/m and the permeability $\mu_0 = 4\pi(10^{-7})$ h/m. The dielectric constant is $\epsilon_2 = 15$ for typical land and $\epsilon_2 = 80$ for sea water; also $\sigma = 0.005$ and 5 mhos/m for land and sea water respectively. Here again it has been found necessary to correct the rays near and beyond the geometric-optical horizon $\tau_j \sim \pi/2$. A contour integral developed by Wait [15] can be employed close to the geometric-optical horizon for the calculation of $F_j = F_j^t F_j^r$:

$$F_j^{t,r} \sim (\pi)^{-1/2} \exp[-ik_1 a\theta'] \cdot \int_{\infty \exp[-i2\pi/3]}^{\infty} \frac{\exp[-i(k_1 a/2)^{1/3}\theta'\rho]}{W_1'(\rho) - qW_1(\rho)}\, d\rho, \quad (27)$$

where $\theta' = (d - d_H)/a$, where d_H is the distance from transmitter to geometric-optical horizon ($\tau_j \sim \pi/2$) and

$$q = -i\frac{(k_1 a)^{1/3}}{2}\frac{k_1}{k_2}\sqrt{1 - \frac{k_1^2}{k_2^2}}. \quad (28)$$

$W_1(z)$ and $W_1'(z)$ are airy integrals related to the cylindrical Hankel Functions [12] (also see Appendix).

$$W_1(\rho) = \exp[-2\pi i/3]\sqrt{\pi/3}\,(-\rho)^{1/2} H_{1/3}^{(2)}[\tfrac{2}{3}(-\rho)^{3/2}], \quad (29)$$

$$W_1'(\rho) = \exp[-4\pi i/3]\sqrt{\pi/3}\,\rho H_{2/3}^{(2)}[\tfrac{2}{3}(-\rho)^{3/2}], \quad (30)$$

where

$$-\frac{\pi}{3} \leqq \arg \rho < \frac{5\pi}{3},$$

and

$$\arg(-\rho) = \arg \rho - \pi,$$

$$\arg \rho^{m/n} = \frac{m}{n}\arg \rho \text{ where } m \text{ and } n \text{ are integers.}$$

These restrictions on arg ρ make all functions involved single valued. Note that a separate conductivity σ and dielectric constant ϵ_2 can be ascribed to transmitter and receiver. Wait [15] has developed curves of this function and some computation methods have been outlined by Johler [12]. Close to, but beyond the geometric-optical horizon, the factor $F_j = F_j^r F_j^t$ can be evaluated as noted by Wait [15]. A residue series summation [12]

$$F_j^{r,t} \sim -2i\sqrt{\pi}\exp[-ik_1(d - d_H)] \cdot \sum_{s=0}^{\infty} \frac{\exp[-i(k_1 a)^{1/3}\theta'\tau_s]}{(2^{1/3}\tau_s - q^2)W_1(2^{1/3}\tau_s)} \quad (31)$$

where the permittivity lapse factor α, which takes ac- equation of Riccati, noted by Bremmer and tabulated by Johler, *et al.*, [16]

$$\frac{d\delta}{d\tau} - 2\delta^2\tau + 1 = 0, \quad (32)$$

where the factor δ (which depends on dielectric constant ϵ_2 and conductivity σ) for vertical electric polarization of the Hertz dipole $\delta = \delta_e$,

$$\delta_e = \frac{-ik_2^2\alpha^{1/3}/k_1^2}{(k_1 a)^{1/3}\left[\frac{k_2^2}{k_1^2} - 1\right]^{1/2}} \quad (33)$$

where the permittivity lapse factor α, which takes account of the variation in index of refraction of the atmosphere with altitude is $\alpha \sim 0.75$ to 0.85. Howe [17], Johler, Walters, and Lilley [16], and Walters and Johler [18] have developed methods for taking the special roots $\tau = \tau_s$ of (32), where the limiting roots $\delta = 0$, $\delta = \infty$ are found from

$$H_{2/3}^{(2)}[\tfrac{1}{3}(-2\tau_s)^{3/2}] = 0, \qquad \delta_e = \infty, \quad (34)$$

$$H_{1/3}^{(2)}[\tfrac{1}{3}(-2\tau_s)^{3/2}] = 0, \qquad \delta_e = 0, \quad (35)$$

$$s = 0, 1, 2, 3 \cdots.$$

The reflection process at the ground and the ionosphere is represented (8) in concise form C_j, according to Bremmer [1], for the case of a vertically polarized transmitter and receiver (Fig. 4).

$$C_j = \frac{1}{j!R_e}\frac{d^j}{dx^j}\left[\frac{1 + A_1 x}{1 - A_2 x - A_3 x^2}\right]_{x=0}, \quad (36)$$

where

$$A_1 = -R_m T_{mm}$$

$$A_2 = R_e T_{ee} + R_m T_{mm}$$

$$A_3 = R_e R_m[-T_{ee}T_{mm} + T_{em}T_{me}]$$

where R_e and R_m are the conventional Fresnel ground reflection coefficients for plane waves of angle of incidence τ_j (Fig. 1) of both vertical and horizontal polarization respectively, and the T's represent, the ionosphere reflection coefficients for plane waves with angle of incidence ϕ_s; thus, the essential nature of the propagation of the CW signal around the earth via the ionosphere can be described in terms of four reflection coefficients T_{ee}, T_{em}, T_{me}, T_{mm}. The reflection coefficient T_{ee} refers to vertical electric polarization of the incident

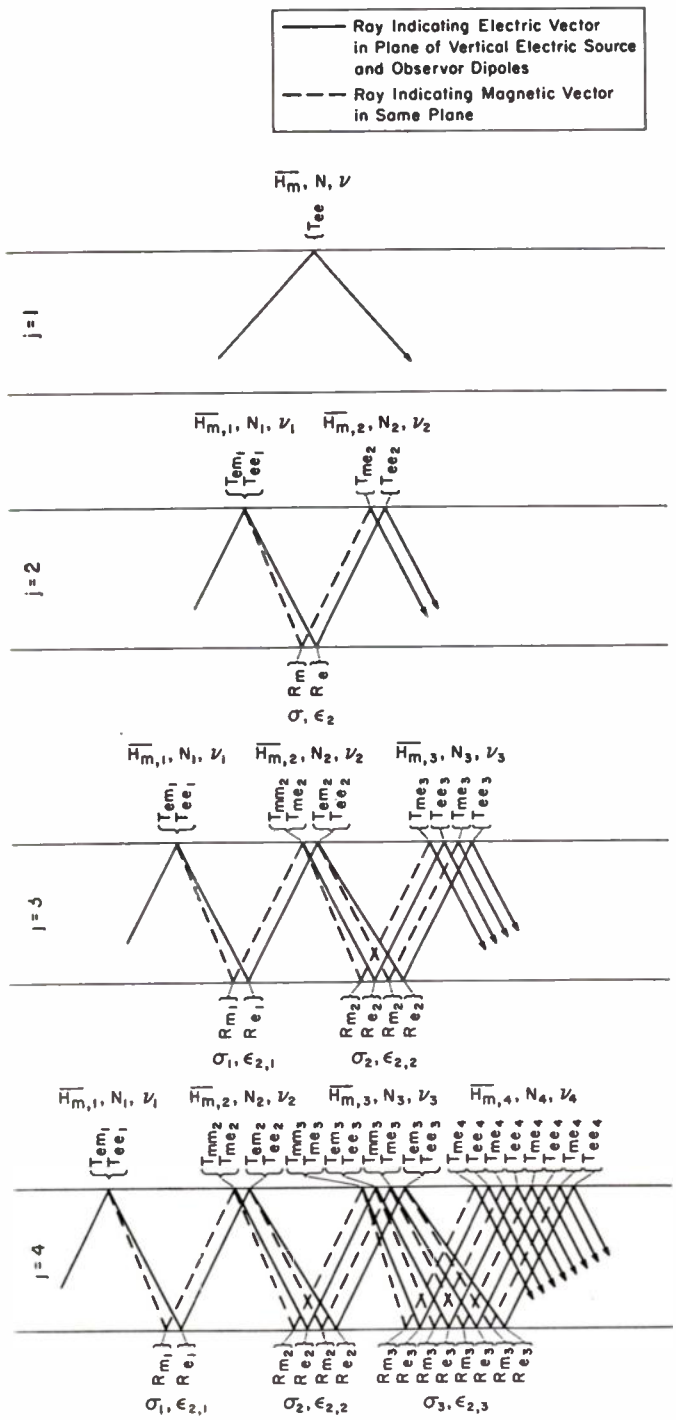


Fig. 4—Geometric-optical ray propagation mechanism, illustrating the development of the factor C_j and illustrating coupling exterior to the ionosphere as a consequence of the generation of the abnormal components.

plane wave and a similar vertical electric polarization of the reflected wave. The coefficient T_{em} describes the generation of the abnormal component by the incident vertical polarization (reflected horizontal electric polarization for vertical electric excitation). Similarly, T_{mm} refers to the incident horizontal electric polarization and the corresponding reflected horizontal electric polarization. Also, the abnormal component of the horizontal electric polarization (reflected vertical electric polarization for horizontal electric excitation) is described by the coefficient T_{me}. Referring these matters to a local coordinate system (Fig. 5) at the ionosphere lower boundary [12], [19], [20],

$$T_{ee} = E_{y'r}/E_{y'i}, \qquad T_{mm} = E_{x'r}/E_{x'i},$$
$$T_{em} = E_{x'r}/E_{y'i} \qquad T_{me} = E_{y'r}/E_{x'i}, \tag{37}$$

where the subscripts i or r refer to the incident and reflected wave, respectively, at the lower boundary of the ionosphere. The techniques for evaluating the reflection coefficients for an anisotropic model electron-ion plasma are quite complicated and will be discussed later.

The ground wave CW, $E_0(\omega, d)$ (*i.e.*, the zero order ray $j=0$ can be evaluated from the classical series of residues) formulated by Bremmer can be written in the form [1], [13], [23] for vertical electric polarization

$$E(\omega, d) = 2i\omega C\left[2\pi\alpha^{2/3}(k_1a)^{1/3}\frac{d}{a}\right]^{1/2} \times \sum_{s=0}^{\infty} \frac{\exp\left\{-i\left[(k_1a)^{1/3}\tau_s\alpha^{2/3}\frac{d}{a} + \frac{\alpha d}{2a} + \frac{\pi}{4}\right]\right\}}{[2\tau_s - 1/\delta_e]}, \tag{38}$$

where $s=0, 1, 2, 3, \cdots$, C is given by (9), and again $\alpha \sim 0.75$ to 0.85 and δ_e, τ_s have been defined (32), (33).

A horizontally-polarized Hertz dipole radiation field can also be found (vertical magnetic field, H_r, ampere-turns/meters) simply by replacing δ_e by δ_m. $\delta_m = \delta_e k_i^2/k_2^2$, re-evaluating τ_s and substituting in (38).

The notion of a CW signal $E(\omega, d)$ as the vector sum of individual rays ordered in time (7) is obscure to the observer of such a signal. However, a signal in the true sense, *i.e.*, one which can convey information and hence is interrupted in the time domain, manifests the individual propagation rays. The Fourier integral (1) for a pulse transmission can be rewritten as a consequence of propagation of such signals $E(t, d)$,

$$E(t', d) = \sum_{j=0}^{p} E_j(t'_j, d)$$
$$= \sum_{j=0}^{p} \frac{1}{2\pi}\int_{-\infty}^{\infty} \exp(i\omega t'_j) E_j(\omega, d) f_r(\omega) f_s(\omega) d\omega. \tag{39}$$

This merely represents the sum of separate Fourier integrals for each ray, separated in time by the ionospheric wave delay t'_j.

The signal $E(t', d)$, (1), (39) which has been described in the time domain, is in general complex if complex source functions $F_s(t)$, (3) are employed. The signal

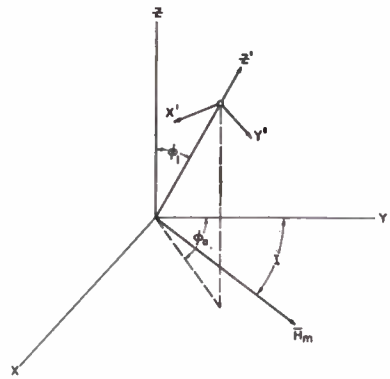


Fig. 5—Local coordinate system for ionosphere boundary.

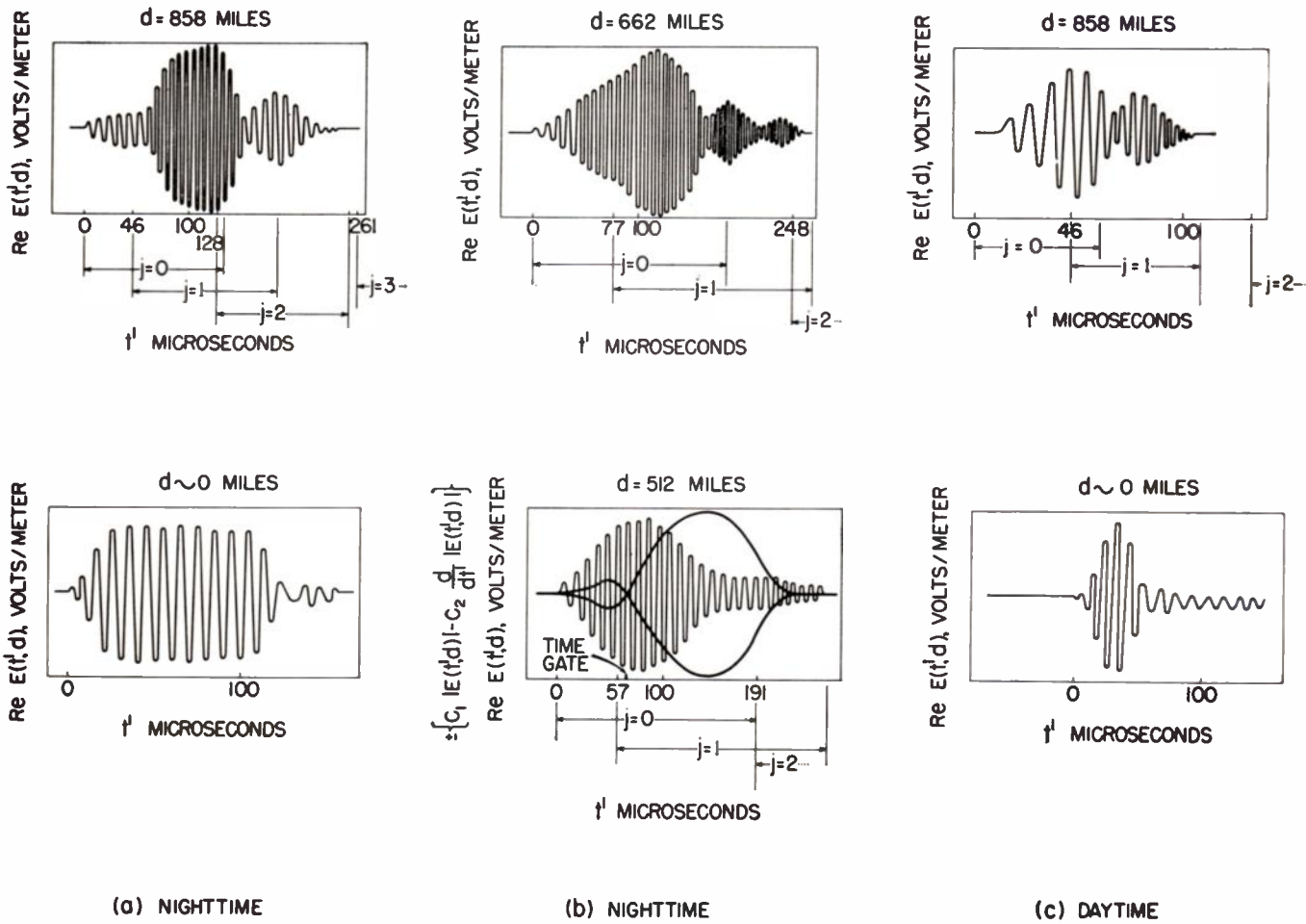


Fig. 6—Observations of propagated pulses of various lengths illustrating the time separation of the ground wave ($j=0$) and the various ionospheric reflections ($j=1, 2, 3, \cdots$). The measurement of a point in time on the leading edge of the pulse with the amplitude envelope minus the derivative of the amplitude envelope method is also illustrated (b, $d=512$). (Oscillograms traced from original photographs of July–August, 1953, CYTAC/Loran-C field tests).

which is observed and recorded as an oscillogram, for example, is typically the real part of the complex field, $\mathrm{Re}\, E(t', d)$, while the amplitude $|E(t', d)|$, can represent some sort of envelope detection process in the receiver. Thus, an envelope can be synthesized with the aid of a complex source and propagated with the signal as an index of the pulse dispersion (change in form or shape) as a result of the propagation.

The physical notion of a signal observed at a point o (Fig. 1) as the sum of ordered rays in the time domain is illustrated [21] in Fig. 6 for various length pulses employed during the development of the Cytac/Loran-C system [22]. The pulse radiated at the source, undisturbed by the ionospheric time rays (pure ground wave) is shown as oscillograms [Re $E(t', d)$] at short distances. The action of the propagation medium on the signal is demonstrated by the complicated, multiple ($j=0, 1, 2, 3, \cdots$), overlapping pulses observed at great distances. Thus, the oscillogram or amplitude-time function Re $E(t', d)$ observed at a great distance comprises the overlapping individual signals $E_j(t', d)$, $j=0, 1, 2, 3, \cdots$, apparently added together according to the complex field specification E_j of each and separated in time by the ionospheric wave delay t'_j of each ray j ordered in the time domain $j=0, 1, 2, 3, \cdots$. The approximate area in the amplitude-time plane occupied by each ordered ray is shown in Fig. 6. Areas of overlap in which both constructive and destructive interference between cycles of the multiple pulses produce notches. Enhancements in the composite pulse can be observed.

Notwithstanding the areas of overlap, the instrumentation has been developed which can sort out the individual ordered rays $E_j(\omega, d)$, $j=0, 1, 2, 3, \cdots$, in the time domain and study or measure the amplitude, phase and dispersion of these individually [3], [4], [22]. Thus cycles and minute fractions of a cycle can be measured by tagging a point in time on the pulse. One such method utilizes the amplitude envelope and hence employs amplitude envelope detection. In effect, the method forms the difference between the amplitude envelope $|E(t', d)|$ and the derivative $d|E(t', d)|/dt'$, and an elaborate null seeking device [4] seeks out a null point or zero crossing for the time function so desired, thus determining a time-root T_c of the differential equation

$$F(t', d) = c_1 |E(t', d)| - c_2 \frac{d}{dt'} |E(t', d)| = 0, \quad (40)$$

where c_1 and c_2 are constants which move the point in time which is to be tagged on the pulse, such as the time gate shown on Fig. 6(b), which can be set by the operator to pick out a particular point on the pulse. Both amplitude and time (phase) can be measured at such a point. Additional techniques are used to detect cycles and minute fractions of a cycle under the envelope on the leading edge (pure ground wave signal) or elsewhere on the pulse (a particular ionospheric ray signal can be selected). The existence of an ordered ($j=0, 1, 2, 3, \cdots$) sequence of signals $E_j(\omega, d)$ as a result of propagation over such rays as D_j (Fig. 1) has therefore been established both theoretically and experimentally.

IV. The Ground Wave Signal

The particular case of a ground wave pulse, $E(t', d) = E_0(t', d)$, $j=0$ has considerable theoretical and practical interest. The source dipole current $F_s(t)$ can be specified in a variety of forms. The complex damped cosine form has considerable theoretical interest [23].

$$\begin{aligned} \mathrm{Re}\, F_s(t) &= \mathrm{Re} \exp(-\nu t) \\ &= \exp(-c_1 t) \cos \omega_c t, \quad (0 < t < \infty) \\ &= 0, \quad (t < 0) \end{aligned} \quad (41)$$

or for the sine source,

$$\begin{aligned} -\mathrm{Im}\, F_s(t) &= \mathrm{Re}\, i \exp(-\nu t) = \exp(-c_1 t) \\ &\cdot \sin = 0, (t < 0)\, \omega_c t, (0 < t < \infty) \end{aligned} \quad (42)$$

where

$$\nu = c_1 + i\omega_c. \quad (43)$$

The direct transformation can be accomplished for this particular source by evaluating the integrals (3), (4) and inserting in the integrand of the Fourier integral (1),

$$E(t', d) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \exp(i\omega t') E(\omega, d) \cdot \int_0^{\infty} F_s(t) \exp(-i\omega t) dt d\omega \quad (44)$$

or upon evaluating the inner integral for the specified source $F_s(t)$, (41)–(43),

$$\begin{aligned} E(t', d) = \frac{1}{2\pi} \int_0^{\infty} |E(\omega, d)| \cdot \Bigg\{ \Bigg[& \frac{\cos\left[\omega_c t' - \phi_c' + \tan^{-1} \frac{-(\omega_c + \omega)}{c_1}\right]}{\sqrt{c_1^2 + (\omega_c + \omega)^2}} \\ & + \frac{\cos\left[-\omega t' + \phi_c' + \tan^{-1} \frac{-(\omega_c - \omega)}{c_1}\right]}{\sqrt{c_1^2 + (\omega_c - \omega)^2}} \Bigg] \\ & + i \Bigg[\frac{\sin\left[\omega t' - \phi_c' + \tan^{-1} \frac{-(\omega_c + \omega)}{c_1}\right]}{\sqrt{c_1^2 + (\omega_c + \omega)^2}} \\ & + \frac{\sin\left[-\omega t' + \phi_c' + \tan^{-1} \frac{-(\omega_c - \omega)}{c_1}\right]}{\sqrt{c_1^2 + (\omega_c - \omega)^2}} \Bigg] \Bigg\} d\omega, \end{aligned} \quad (45)$$

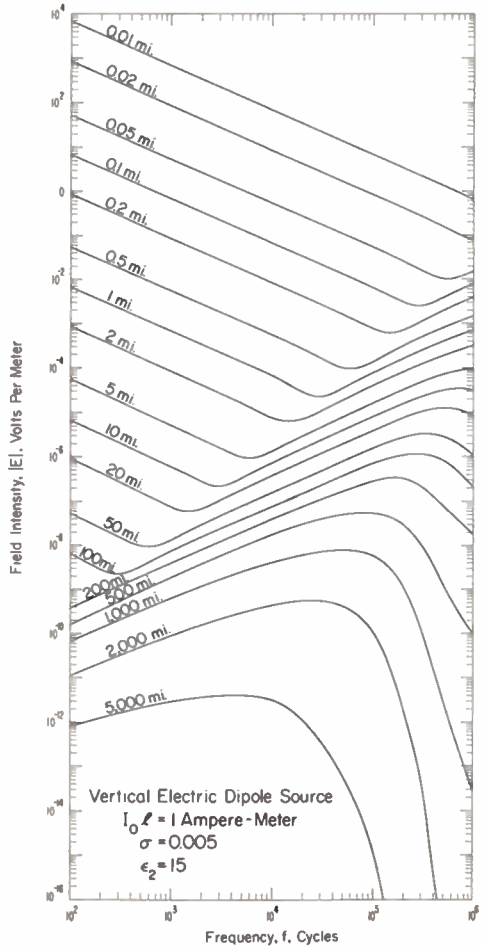


Fig. 7—Amplitude transfer characteristic of the ground wave.

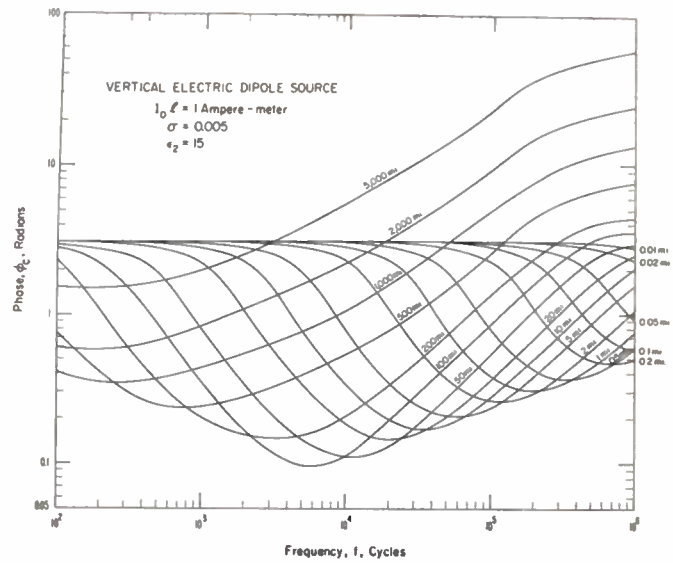


Fig. 8—Phase transfer characteristic of the ground wave.

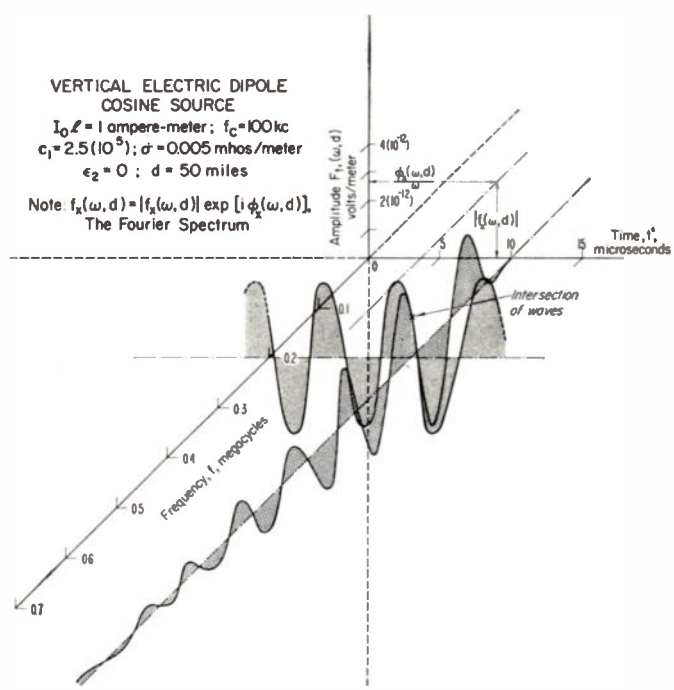


Fig. 9—Integrand of Fourier integral or image of pulse in the frequency-amplitude plane at small distance from the source, illustrating the relation of the integrand to the Fourier spectrum waves.

where $\phi_c' = -\varphi_c - \pi/2 = \arg\ [E(\omega,\ d)]$ and $E(\omega,\ d) = L_0(\omega,\ d)$.

The real part of the amplitude-time function (45) Re $L(t',\ d)$ is the desired function for the cosine source (41), and the imaginary part $-\text{Im}\ E(t',\ d) = \text{Re}\ [iE(t',\ d)]$ is the desired function for the sine source (42). This integral can be evaluated with the aid of quadrature techniques [23]. Thus, the problem has been reduced to the evaluation of a real integral

$$E(t',\ d) = \int_0^\infty F_t(\omega,\ d)d\omega$$

$$= \text{Re} \int_{-\infty}^{\infty} f(\omega,\ d)\ \exp\ (i\omega t)d\omega. \qquad (46)$$

The transfer function for the ground wave, $E(\omega,\ d)$, (38) which can now be inserted directly in the integrand of the Fourier integral is illustrated in Figs. 7 and 8. Since the transfer characteristic $E(\omega,\ d) = E_0(\omega,\ d)$ is complex, both amplitude and phase are presented as a function of frequency for various distances. The phase is presented as the phase lag ϕ_c where the total true phase $\arg\ [E(\omega,\ d)] = -[k_1 d + \phi_c + \pi/2]$. The effect of the conduction currents in the earth on the propagation has been introduced as the conductivity for typical land, $\sigma = 0.005$ mho/m. The effect of the displacement currents in the earth on the propagation has been introduced by the dielectric constant $\epsilon_2 = 15$ (relative to a vacuum). The permeability $\mu_0 = 4\pi(10^{-7})$ henry/meter has been assumed. The use of the series of residues applicable to propagation about a spherical earth takes account of the vertical lapse of the index of refraction of the earth's atmosphere [1] by the factor α (38) where $\alpha \sim 0.75$. Although it has been assumed that both transmitter and receiver are located on the surface of the earth, the effect of elevating transmitter and/or receiver can be introduced by multiplying *each* term of the series of residues (38) by the factor $f_s(h_1)f_s(h_2)$ where h_1 and h_2 are the height of the transmitter and receiver, respectively, above the surface of the earth, and (1), (13), (18)

$$f_s(h) = \frac{hv_2\left\{\left(\frac{1}{2}\right)^{2/3}\left[(k_1 a)^{2/3}\frac{2h\alpha^{1/3}}{a} - 2\tau_s\right]\right\}}{hv_2\left\{-(2)^{1/3}\tau_s\right\}}, \qquad (47)$$

in which $hv(z)$ is the modified Hankel function tabulated by Furry [24].

The integrand of the Fourier integral (Fig. 9) in the frequency-amplitude plane at some given local time t' can be related to the more conventional notion of the Fourier spectrum $f_x(\omega,\ d)$ by eliminating the notion of a negative frequency ω. Thus, the amplitude spectrum is

$$|f_x(\omega,\ d)| = |f(\omega,\ d) + f(-\omega,\ d)| \quad (\omega \geq 0) \quad (48)$$

and the phase spectrum is

$$\phi_x(\omega,\ d) = \arg\ [f_x(\omega,\ d)]$$

$$= \arg\ [f(\omega,\ d) + f(-\omega,\ d)] \quad (\omega \geq 0). \quad (49)$$

The phase, $\phi_x(\omega,\ d)$ can be reckoned (Fig. 9) from the origin $t' = 0$ to the crest of the continuous wave or Fourier spectrum wave at a certain frequency (0.2 Mc, Fig. 9). The corresponding amplitude $|f_x(\omega,\ d)|$ does not correspond to the amplitude of the integrand $F_t(\omega,\ d)$. The two waves do intersect, however, at the point $t' = 10$ μsec, (see, *e.g.*, Fig. 9), at which point the Fourier spectrum wave enters the integration (45) with a phase shift beyond the crest of the wave. Thus, the Fourier spectrum waves will all be phase advanced by different amounts between the zero and infinite frequency limits of integration. The Fourier spectrum wave, $f_x(\omega,\ d)$, could, therefore, represent exactly the signal observed through a receiver, if and only if the receiver transfer function, $f_r(\omega)$, as shown in (1), (39), introduced an "infinite Q" or zero bandwidth circuit into the transform, $F_t(\omega,\ d)$, such that only a single frequency was admitted. But this is another way of saying the receiver circuit rings or oscillates indefinitely as a result of the "high Q" of the circuit. Thus, in general, it is necessary to perform the integration (1), (39) for each time t' from zero to infinite frequency to describe the signal $E(t',\ d)$. Fortunately the wave (Fig. 9) $F_t(\omega,\ d)$ damps out rapidly as the frequency f is increased. Indeed, the particular wave illustrated (Fig. 9) applies to short distances ($d = 50$ statute miles) whereas for greater distances [23] the integrand for the case of the ground wave pulse is rather severely mutilated by the transfer function (Figs. 7, 8) such that the wave $F_t(\omega,\ d)$ damps out in a cycle or fraction thereof, which is another way of saying the integral $E(t',\ d)$, (1) converges rapidly. This convergence phenomenon, together with any further mutilation introduced by the receiver transfer characteristic $f_r(\omega)$, can be exploited in the application of quadrature techniques on the integral [23].

The detailed structure of the transient for various combinations of characteristic frequency $f_c = \omega_c/2\pi$ and damping c_1 for both sine and cosine source functions are illustrated in Figs. 10–13 (pp. 414–415). The dispersion of the pulse at great distance is evident in the illustrations. The most noteworthy attribute of this dispersion was an increase in the natural period of the pulse or a stretching of the pulse in the time domain. The propagation medium thus illustrated, assuming a perfect (infinite bandwidth) receiver $f_r(\omega) = 1$ filters the signal, and indeed at the greater distances the exact form of the source becomes obscured by the filtering action.

The cosine source (Figs. 11 and 13) employs an abrupt initial current. The radiated field therefore propagated an impulse type of function which is superposed upon the sinusoid. This can be explained quite simply for the case of an infinitely conducting earth with the

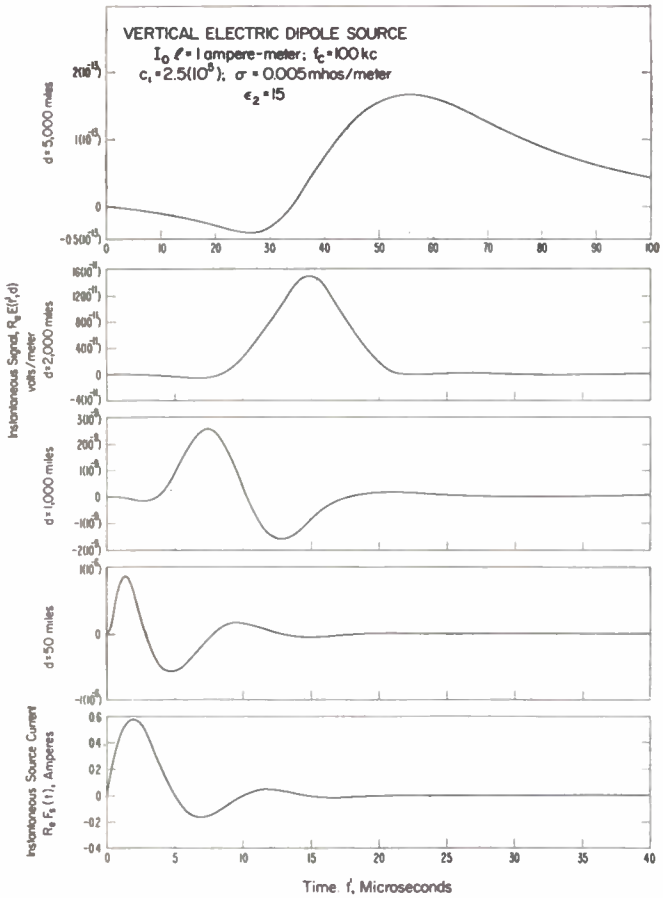


Fig. 10—Instantaneous signal and corresponding damped LF sine wave source current of a propagated ground wave pulse.

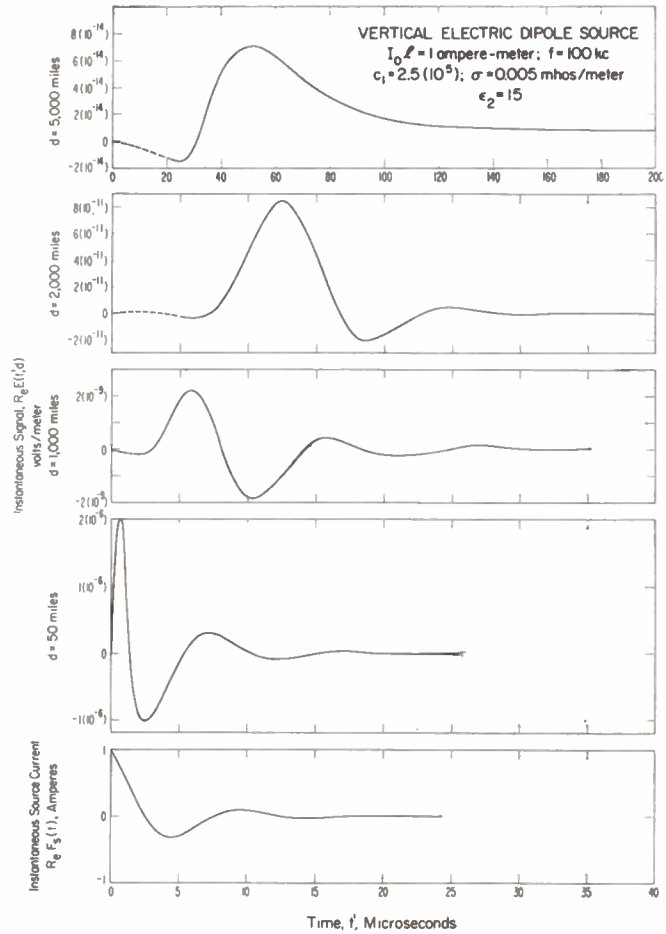


Fig. 11—Instantaneous signal and corresponding damped LF cosine wave source current of a propagated ground wave pulse.

aid of the convenient Laplace transform

$$E(s) = 1 \qquad (\nu = 0) \tag{50}$$

where $s = i\omega$. The inverse Laplace transform $\mathfrak{L}^{-1}$ is

$$E(t', d) = \mathfrak{L}^{-1}E(s) = \delta(t') \tag{51}$$

where the Dirac impulse function $\delta(t')$ can be defined in relation to the step function $u(t)$; thus,

$$\int_0^t \delta(t)dt = u(t), \tag{52}$$

where

$$u(t) = 1, \qquad t > 0$$
$$u(t) = 0, \qquad t < 0. \tag{53}$$

The impulse is, of course, finite in the damped cosine wave (amplitude and duration finite) as a result of the finite conductivity of the ground, the displacement currents in the ground and the effect of the earth's curvature. The transient response of the ground wave at great distances illustrates (Figs. 12–14, pp. 415–416) the stretching of such pulses in the time domain.

The finite bandwidth of a radio receiver or filter, $f_r(\omega) \neq 1$, can be introduced by a mutilation of the Fourier transform with one or more frequency selective networks. Perhaps the simplest network is the following series network:

$$f_r(\omega) = \frac{\frac{R}{L}(i\omega)}{-\omega^2 + \frac{R}{L}(i\omega) + \frac{1}{CL}}, \tag{54}$$

where R is a resistive element (ohms) L is an inductive element (henry) and C is a capacitive element (farads). The modification of the pulse by the finite bandwidth so described (54) for particular values of R, L and C is illustrated in Figs. 15 and 16, p. 416). The ringing of the circuit becomes evident (Fig. 16) as the constants R, L and C are changed so that the bandwidth becomes quite narrow, *i.e.*, the Fourier spectrum wave, $f_z(\omega, d)$ is approached asymptotically.

The damped sine-squared pulse, of which the envelope shape, defined by $\sin^2 \omega_p$, can serve as a useful model for the type pulse employed in radio navigation systems. Such a pulse can be synthesized quite simply by redefining the source function $F_s(t)$, (41), (42),

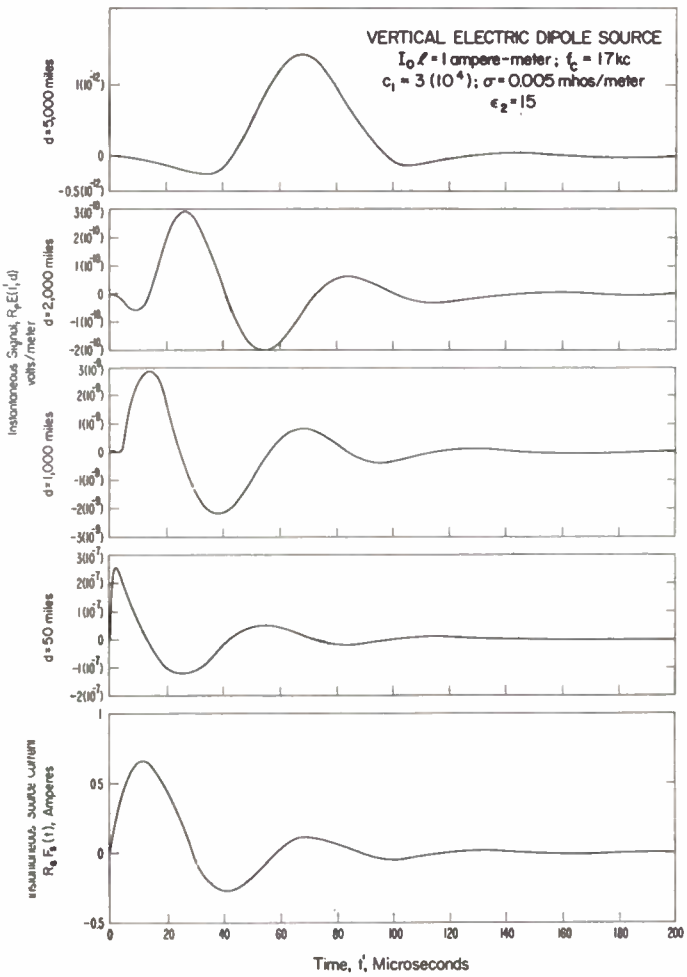


Fig. 12—Instantaneous signal and corresponding damped VLF sine wave source current of a propagated ground wave pulse.

$$\text{Re } F_s(t) = \exp(-c_1 t) \sin^2 \omega_p t \sin \omega_c t \tag{55}$$

$$\text{Re } F_s(t) = \tfrac{1}{2} \exp(-c_1 t) \sin \omega_c t - \tfrac{1}{4} \exp(-c_1 t) \sin(\omega_c + 2\omega_p)t - \tfrac{1}{4} \exp(-c_1 t) \sin(\omega_c - 2\omega_p)t. \tag{56}$$

$$F_s(t) = \frac{i}{2} \exp(-\nu t) - \frac{i}{4} \exp(\nu_1 t) - \frac{i}{4} \exp(-\nu_2 t), \tag{57}$$

where

$$\nu = c_1 + i\omega_c \text{ (as before)}$$
$$\nu_1 = c_1 + i(\omega_c + 2\omega_p)$$
$$\nu_2 = c_1 + i(\omega_c - 2\omega_p).$$

The typical radio navigation type pulse has a value for c_1 of the order of ω_p. It is quite obvious, however, that the amplitude time function $E(t', d)$ for the damped sine-squared pulse is merely the sum of three waves calculated as previously described (45).

$$E(t', d) = A_1 E_\nu(t', d) + A_2 E_{\nu_1}(t', d) + A_3 E_{\nu_2}(t', d), \tag{58}$$

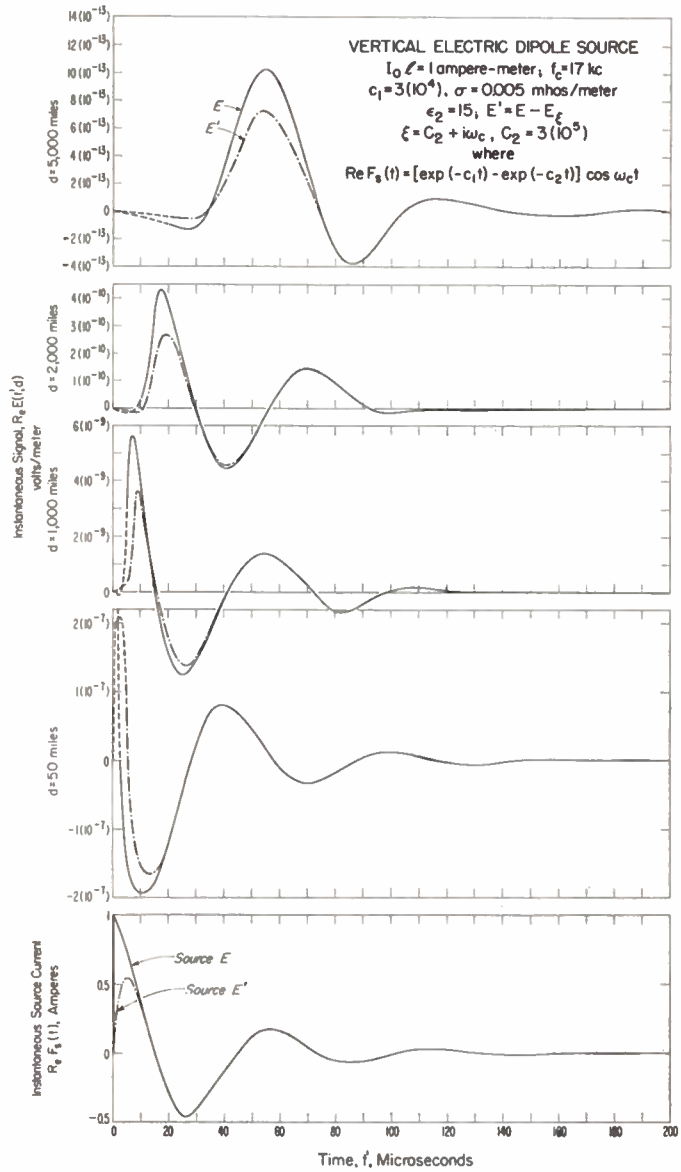


Fig. 13—Instantaneous signal and corresponding damped VLF cosine wave source current of a propagated ground wave pulse illustrating the introduction of a less abrupt initial source current.

where $A_1 = i/2$, $A_2 = -i/4$, $A_3 = -i/4$. A particular sine-squared pulse Re $E(t', d)$ is illustrated in Fig. 17 (p. 417) together with the amplitude envelope $|E(t', d)|$.

The source functions which represent natural phenomena, such as sferics (the electromagnetic radiation from thunderstorms), will not, in general, have the precise mathematical form of a damped sinusoid, impulse function or step function. Since the application of the superposition principle is not always practical, another approach to the general problem is appropriate [23], [25]. Indeed, it is quite possible to extend the theory to complicated waveforms. Consider an experiment in which the signal Re $E(t', d)$ is observed and recorded at some distance d_1 from the source. The theory is then required to predict the form of the signal recorded at some other distance d_2. The theory is also required to determine the form of the source $F_s(t)$.

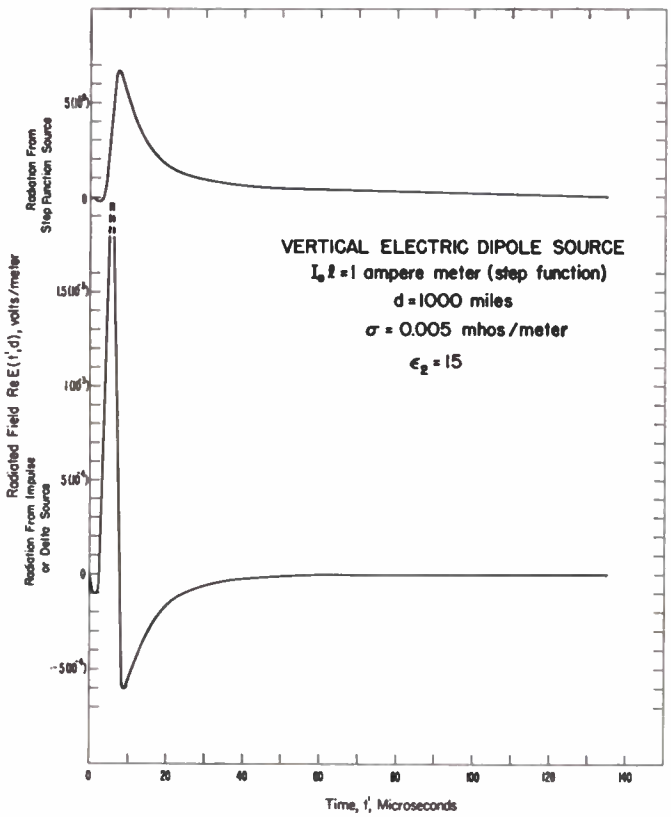


Fig. 14—The step and impulse source current radiation of the ground wave.

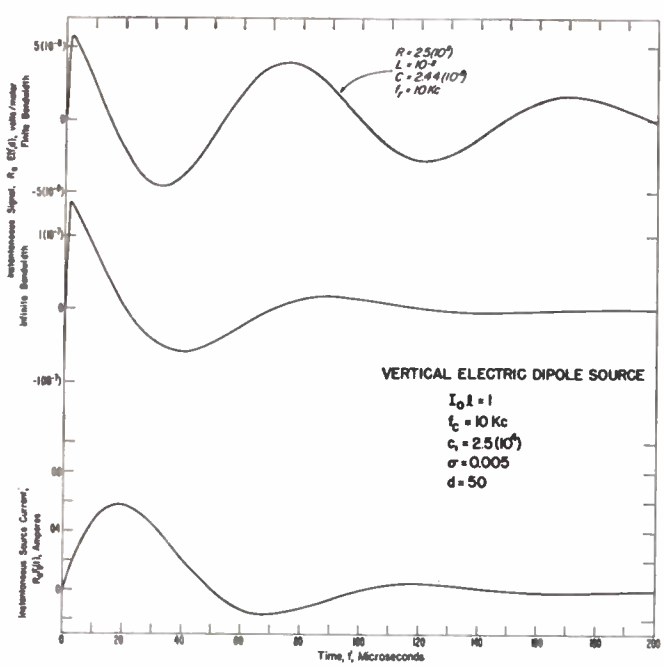


Fig. 15—Comparison of the calculation of the pulse observed through an infinite bandwidth receiver $[f_r(\omega) = 1]$ with the calculation of the same pulse observed through a finite bandwidth receiver $[f_r(\omega) \neq 1]$, illustrating the effect of "narrow-band" as compared with "broad-band" receiver.

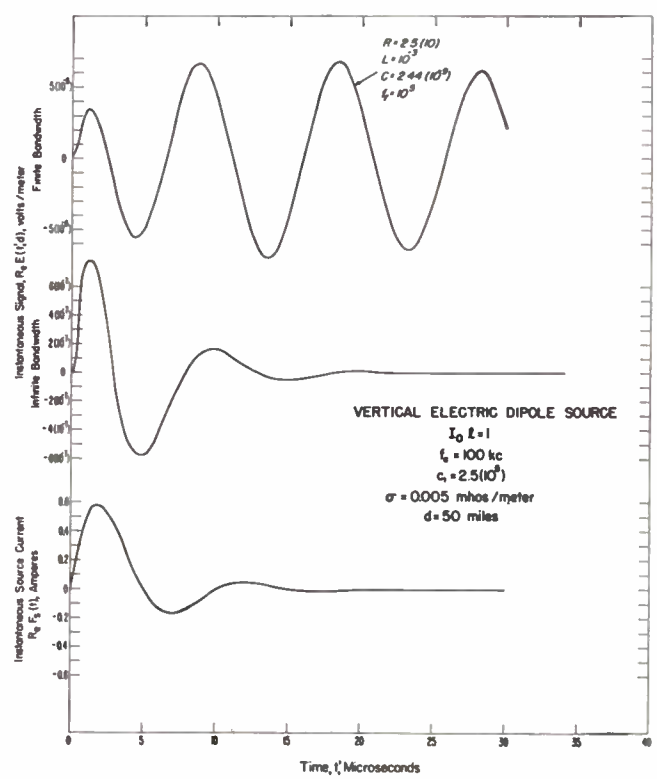


Fig. 16—Comparison of the calculation of the pulse observed through an infinite bandwidth $[f_r(\omega) = 1]$ receiver with the calculation of the same pulse observed through a finite bandwidth receiver $[f_r(\omega) = 1]$.

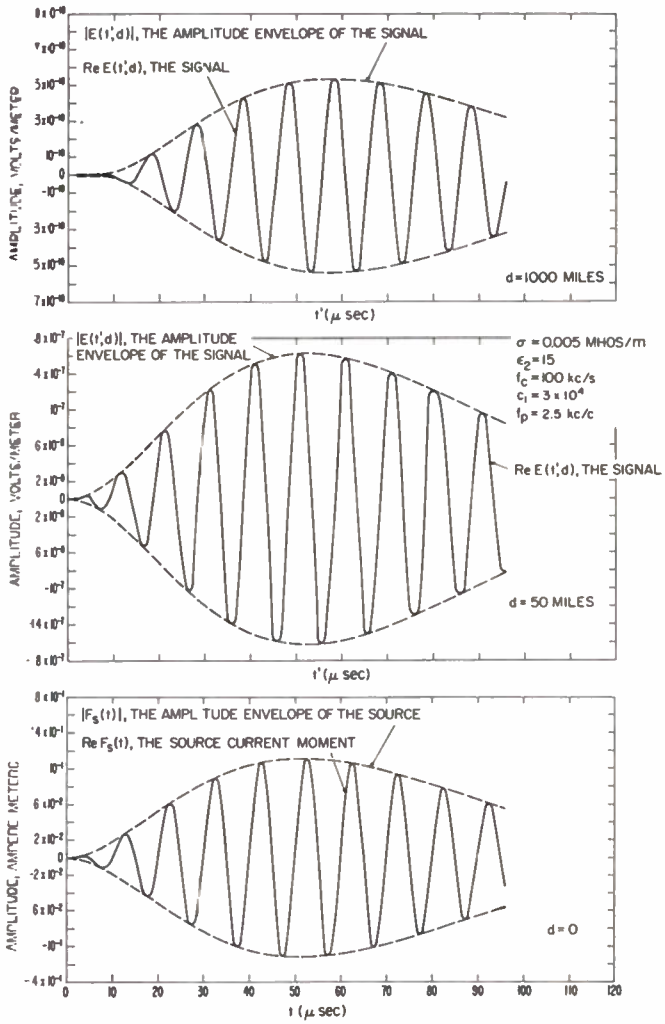


Fig. 17—The damped sine-squared pulse, illustrating synthesis of a radio-navigation system-type pulse with corresponding amplitude envelope.

The complex spectrum (48), (49) can be determined directly from the observed signal Re $E(t', d)$:

$$f_x(\omega, d) = \int_0^\infty \exp(-i\omega t') \text{ Re } E(t', d)dt'. \quad (59)$$

The complex spectrum of the source $f_{x,s}(\omega)$ can then be determined

$$f_{x,s}(\omega) = \frac{f_x(\omega, d)}{E(\omega, d)}. \quad (60)$$

Since the real part of the signal Re $E(t', d)$ was employed, the source function Re $F_s(t)_\infty$ can be described

$$F_s(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \exp(i\omega t) f_{x,s}(\omega)d\omega, \quad (61)$$

or

$$F_s(t) = \frac{1}{\pi}\int_0^\infty |f_{x,s}(\omega)| \{\cos[\omega t + \phi_{x,s}(\omega)]\}d\omega, \quad (62)$$

also

$$f_x(\omega, d_2) = \frac{f_x(\omega, d_1)}{E(\omega, d_1)} E(\omega, d_2) \quad (63)$$

and

$$E(t', d_2) = \frac{1}{\pi}\int_0^\infty |f_x(\omega, d_2)| \cos[\omega t' + \phi_x(\omega, d_2)]d\omega. \quad (64)$$

Thus, with the aid of quadrature techniques [24], [26], the analysis of the detail of transient signals could be continued ad infinitum.

V. Ionospheric Waves

The essential nature of the propagation of the ionospheric waves is described by the four reflection coefficients (36), (37) T_{ee}, T_{em}, T_{mm}, T_{me}. These reflection coefficients can be employed in VLF mode calculations in a method developed by Wait [26]. These reflection coefficients have been employed directly in geometric-optical calculations [12]. In the latter the angle of incidence ϕ_i is real. In either case a form of polarization coupling between vertically and horizontally polarized waves *external* to the ionosphere can be noted. This is most obvious in the calculation of the effective reflection coefficient of the geometric-optical theory C_j (Fig. 4). Notice that each reflection from the ionosphere gives rise to both horizontal and vertical polarization as a consequence of the generation of the abnormal component, in spite of the fact that the incident wave comprises pure vertical or horizontal polarization. Thus, the abnormal component cannot be ignored in the case of vertically polarized transmitter and receiver for the ordered propagation rays, $j>1$, *i.e.*, $j=2, 3, 4, \cdots$. This is a form of coupling between wave polarizations quite distinct from the coupling between the magneto-ionic propagation components within the ionosphere to be described subsequently.

The evaluation of the reflection and transmission processes at the ionosphere is the most complicated part of the problem of describing the transform of the signal $E_j(\omega, d)$ for any individual time-ordered ionospheric propagation ray $j=1, 2, 3, \cdots$. The index of refraction of the ionosphere is first determined. The lower boundary of a model electron-ion plasma (Fig. 5) below which ($z<0$) the ionization is nil ($N=0$) or zero electron density, is considered to be the xy plane. The region above the xy plane ($z>0$) is characterized by an electron density N and a collision frequency ν which vary with respect to altitude z. A plane wave $\bar{E}_i$ gives

$$E_i = |\bar{E}_i| \exp\left[i\omega t - \frac{\omega}{c}\eta D\right], \quad (65)$$

where the index of refraction ($z<0$), $\eta=\eta_0=1$, c is the speed of light $c\sim3(10^8)$ m/sec and the quantity D is related to other parameters (Fig. 5) [19], [20], [27].

$$D = x \sin\phi_i \sin\phi_a + y \sin\phi_i \cos\phi_a + z \cos\phi_i, \quad (66)$$

is varying harmonically in time t at a frequency $f=\omega/2\pi$ and is assumed to be incident upon the xy plane at an angle of incidence ϕ_i and a magnetic azimuth ϕ_a is measured clockwise from the yz plane for the direction of propagation. The earth's magnetic field vector H_m ampere-turns/meter is contained in the yz plane at a dip or inclination angle I (measured from the horizontal).

A resultant wave E_t transmitted into the ionosphere model ($z>0$) (Figs. 5 and 18) is then assumed to have the form

$$E_t = |\bar{E}_t| \exp\left[i\left(\omega t - \frac{\omega}{c}\eta D\right)\right] \tag{67}$$

where, in the plasma model,

$$\eta D = x \sin\phi_i \sin\phi_a + y \sin\phi_i \cos\phi_a + z\zeta \tag{68}$$

in which ζ is, in general, a complex number, the value of which will depend upon altitude z, $\zeta=\zeta(z)$.

The quantity ζ is determined by a simultaneous solution of Maxwell's equations

$$\bar{\nabla}\times\bar{E} + \mu_0\frac{\partial\bar{H}}{\partial t} = 0,$$

$$\bar{\nabla}\times\bar{H} - \bar{J} - \epsilon_0\frac{\partial\bar{E}}{\partial t} = 0, \tag{69}$$

and the equation of motion of an electron (Langevin equation)

$$m\frac{d\bar{V}}{dt} + mg\bar{V} + \mu_0 e(\bar{V}\times\bar{H}_m) + e\bar{E} = 0 \tag{70}$$

with the electric field $\bar{E}$, the magnetic field $\bar{H}$ (electrodynamic as distinguished from $\bar{H}_m$ the static field of the earth), the convection current $J=-NeV$ for N electrons per cubic meter (usually expressed as electrons/cc) with charge e, mass m, and vector velocity $\bar{V}$, where μ_0 and ϵ_0 are the permeability and permittivity of space, respectively. The collision frequency factor g is assumed to be a constant real number with respect to frequency; $g\sim\nu$ is the classical magneto-ionic theory.

After eliminating the vectors $\bar{V}$ and $\bar{H}$, it can be concluded that field $\bar{E}$ exists in the medium if a quartic equation in ζ is satisfied [1], [19], [20], [28],

$$a_4\zeta^4 + a_3\zeta^3 + a_2\zeta^2 + a_1\zeta + a_0 = 0 \tag{71}$$

where the coefficients of this quartic are defined in the Appendix. The roots of this equation (ζ) are quite simply related to the index of refraction of the medium η or the wave number $k=(\omega/c)\eta$, since

$$\eta^2 = \zeta^2 + \sin^2\phi_i. \tag{72}$$

The existence of a quartic equation in the index of refraction as a direct consequence of the simultaneous solution of Maxwell's equations, (69) and the equation of motion of the electron (70) was first noted by Booker and the Booker quartic is more or less equivalent to (71).

Two pairs of roots ζ can be found [19] where each root can be identified as either ordinary or extraordinary, upgoing or downgoing magneto-ionic propagation component within the model ionosphere plasma.

Since the electron density and collision frequency can vary with respect to altitude z, a model plasma which can be deformed to fit most any measured or theoretical electron-ion profile, $N(h)$, $N(z)$, is desirable from the theoretical viewpoint to completely describe the reflection and transmission process at the ionosphere. Several approaches to this problem have been utilized by various authors such as Budden [6] and Barron [7]. The notion of a continuously varying medium

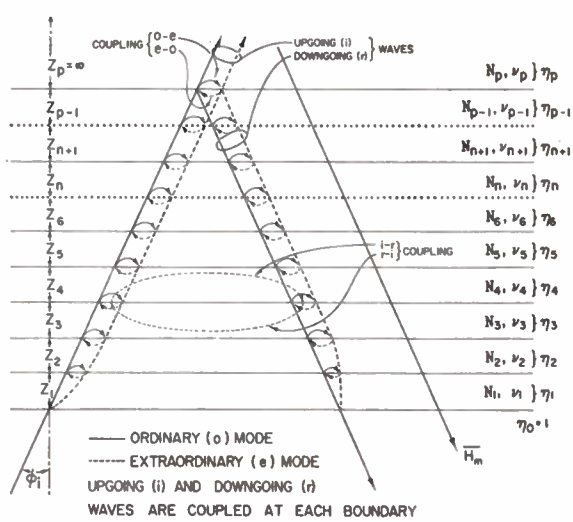


Fig. 18—Structure of the flexible plasma model, illustrating ordinary and extraordinary propagation components, coupled at the boundaries. Each slab (z_n, $n=1, 2, 3, \cdots, p$) becomes smaller as the number of slabs (p) is increased, until a stable reflection is obtained. z is always infinite where each $N=N_n$, $\nu=\nu_n$ corresponds to median values of the intervals (Z_p), respectively, of the particular profile under investigation.

has been treated by approximating the medium with one or more slabs of uniform composition as exemplified by the works of Brekhovskikh [29], Hines [30], Ferraro and Gibbon [31]. Such methods have been exploited by Johler and Harper [27], and carried to the limit, such that the number of slabs p for each calculation depends upon the computation precision required and the particular values of the electric and geometric parameters.

The detailed structure of such a flexible model is illustrated in Fig. 18 as a stack of plasma slabs of arbitrary thickness (but consistent with computation efficiency) z_n except the topmost slab of thickness $z_p = \infty$. The number of such slabs p is also quite flexible, since the notion is implied in such a model that the measured electron density-altitude, $N(h)$ or $N(z)$ profile, and collision frequency altitude, $\nu(h)$ or $\nu(z)$ profile, can be approximated to any desired accuracy by decreasing z_n and increasing p simultaneously until a stable reflection process is obtained.

A constant electron density and collision frequency with respect to altitude z is of course assumed for each slab. A set of four roots $\zeta = \zeta_n$ of (71) are found to exist in each slab. Two of the roots will exhibit a negative imaginary (Im ζ negative) corresponding to an upgoing wave ($+z$ direction, Figs. 5 and 18) and two of these roots will correspond to a positive imaginary (Im ζ positive) corresponding to a downgoing wave ($-z$ direction, Figs. 5 and 18). It is necessary to consider both upgoing and downgoing waves in the analysis of either the reflection or transmission process at the ionosphere, except for the topmost slab, where only the upgoing waves are considered.

It is necessary to distinguish between the ordinary and extraordinary magneto-ionic components of propagation for both the upgoing and downgoing waves. This is accomplished by an examination of the form of the index of refraction function with respect to frequency and altitude (or electron density and collision frequency which varies with respect to altitude). Thus, the index of refraction η [as defined by (71), (72)] is detailed for each frequency and slab z_n, $\eta = \eta_n$. The upgoing ordinary and extraordinary $\eta_{i,o,e}^{(n)}$ and the downgoing ordinary and extraordinary $\eta_{r,o,e}^{(n)}$ function continuity is examined in detail as a function of frequency to determine, if any, the crossover points of the functions for each slab or electron density under consideration. The absolute distinction between ordinary and extraordinary magneto-ionic wave components [19], [27] remains quite arbitrary, but the analysis must be consistent between each slab and consistent within each slab for upgoing and downgoing waves.

The reflection and transmission coefficients are determined by the boundary conditions which express at the boundary of each slab the principle of continuity of the tangential $\overline{E}$ and $\overline{H}$ and the normal $\overline{H}$ fields (Figs. 5 and 18) of the model plasma. These fields are equated immediately above and below each boundary and after considerable ado, a matrix equation is obtained [27],

$$
\begin{bmatrix}
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\
a_{p,p+4} & \cdots & a_{p,p+9} & & & & & & & & & & & \\
b_{p,p+4} & \cdots & b_{p,p+9} & & & & & & & & & & & \\
c_{p,p+4} & \cdots & c_{p,p+9} & & & & & & & & & & & \\
d_{p,p+4} & \cdots & d_{p,p+9} & & & & & & & & & & &
\end{bmatrix}
\begin{bmatrix}
T_{em,} & T_{mm} \\
T_{ee,} & T_{me} \\
U_{eio,}^{(1)} & U_{mio}^{(1)} \\
U_{eie,}^{(1)} & U_{mie}^{(1)} \\
U_{ero,}^{(1)} & U_{mro}^{(1)} \\
U_{ere,}^{(1)} & U_{mre}^{(1)} \\
U_{eio,}^{(2)} & U_{mio}^{(2)} \\
U_{eie,}^{(2)} & U_{mie}^{(2)} \\
U_{ero,}^{(2)} & U_{mro}^{(2)} \\
U_{ere,}^{(2)} & U_{mre}^{(2)} \\
\cdot & \cdot \\
\cdot & \cdot \\
\cdot & \cdot \\
U_{eio,}^{(p-1)} & U_{mio}^{(p-1)} \\
U_{eie,}^{(p-1)} & U_{mie}^{(p-1)} \\
U_{ero,}^{(p-1)} & U_{mro}^{(p-1)} \\
U_{ere,}^{(p-1)} & U_{mre}^{(p-1)} \\
U_{eio,}^{(p)} & U_{mio}^{(p)} \\
U_{eie,}^{(p)} & U_{mie}^{(p)}
\end{bmatrix}
+
\begin{bmatrix}
a_{oe,} & a_{om} \\
b_{oe,} & b_{om} \\
c_{oe,} & c_{om} \\
d_{oe,} & d_{om}
\end{bmatrix}
= 0, \quad (73)
$$

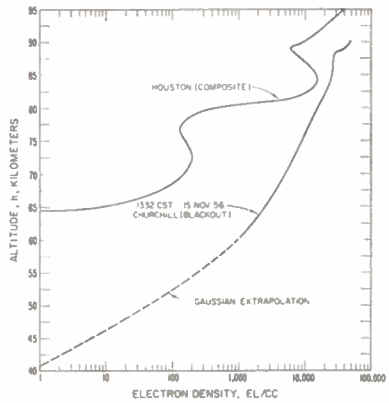


Fig. 19—Electron density-altitude [$N(h)$ or $\nu(z)$] (quiescent and disturbed) profiles.

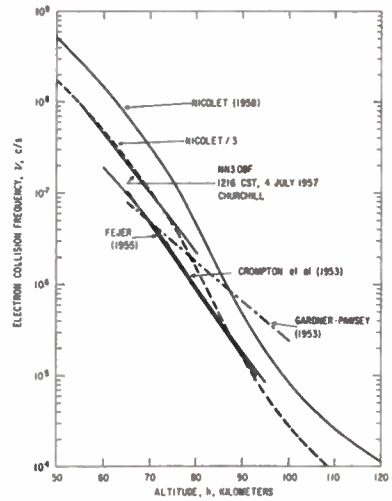


Fig. 20—Collision frequency-altitude [$\nu(h)$ or $\nu(z)$] profiles (Nicolet/3 was employed in calculations).

where the elements of the matrix $a_{1,1} \cdots$ are defined in the Appendix.

The upgoing ordinary and extraordinary and the downgoing ordinary and extraordinary magneto-ionic components of propagation are coupled within the ionosphere (Fig. 18) as a result of the introduction of the boundary conditions described in concise form in the matrix equation (73). Thus, at the upper and lower boundary of each slab, energy is transferred between the four magneto-ionic components of propagation [four roots of the quartic equation (71)]. This type of coupling is distinct from the coupling of the polarization components, external to the ionosphere described previously [beginning of Section V—see also Fig. 4 and (36)].

The continuously stratified technique can be illustrated by evaluating reflections from an ionosphere model determined by actual measured profiles of electron density (Fig. 19) and collision frequency (Fig. 20). A typical daytime-room profile $N(h)$ presented by Waynick [32] (Fig. 19) and a corresponding disturbed profile of Seddon and Jackson [33], indicative of the intensity of ionization during a local auroral zone ionosonde blackout, were selected for purposes of illustrating application of the described continuous stratification techniques. The region of the ionosphere on the latter curve, below 1000 electrons/cc, was represented (dashed curve, Fig. 19) with a Gaussian distribution [6],

$$N = N_{\max} \exp\left[-(z - z_{\max})^2/k'\right],$$

where the constants $N_{\max}$, $z_{\max}$, and k' were determined by the measured profile >1000 electrons/cc. In particular, $N_{\max} = 26{,}000$, $z_{\max} = 85{,}000$, $k' = 1.92$ (10^8).

The Nicolet/3 collision frequency [34], [35] was employed in this analysis. These collision frequencies are applicable to the classical magneto-ionic theory employing the approximation $g \sim \nu$ [27], [36] in the equation of motion of the electron (70).

The reflection coefficients T_{ee}, T_{em}, T_{me}, and T_{mm} were evaluated (Figs. 21–28, pp. 421–422). The reflection coefficients for the quiescent profiles are illustrated in Figs. 19–25. The disturbed profiles reflection coefficients are illustrated in Figs. 26–28.

The reflection coefficients $|T_{ee}|$, $|T_{mm}|$ show a steady decrease in amplitude as the frequency is increased. A small perceptible rise is noted near the gyrofrequency, however. This was a result of the approximation $g \sim \nu$ [27] and the assumed model, whereas the use of a complex collision frequency g could exhibit higher attenuation near the gyrofrequency. Such a complex collision frequency can be deduced from the work of Phelps [36], Molmud [37], Jancel and Kahan [38], where a collision frequence $\nu = \nu(u)$ proportional to the electron energy or temperature is derived. Johler and Harper [27] have introduced electron collisions proportional to energy as a modification of the coefficients of the quartic equation (71). This, of course, introduces some changes in the detail of the reflection coefficients, but the general form of the reflection coefficients of the classical magneto-ionic theory remains unaltered at LF/VLF.

The magnitude of the abnormal components $|T_{em}|$, $|T_{me}|$ also shows a decrement as a function of frequency. These components are quite small for the assumed model (<0.1 at 10 kc, for example). The corresponding disturbed blackout reflection coefficients imply a slight change in the angle of incidence ϕ_i as a result of a lowering of the ionosphere. However, the principal cause of change as a result of this profile is, nevertheless, the redistribution of the electron density-altitude profile. It is interesting to note an increased attenuation at the higher frequencies 100 kc to 1000 kc. However, the high attenuation or total ionosonde blackout which characterizes high frequencies does not seem to exist at LF. Indeed, an enhancement in the field is anticipated from this profile at VLF (<30 kc).

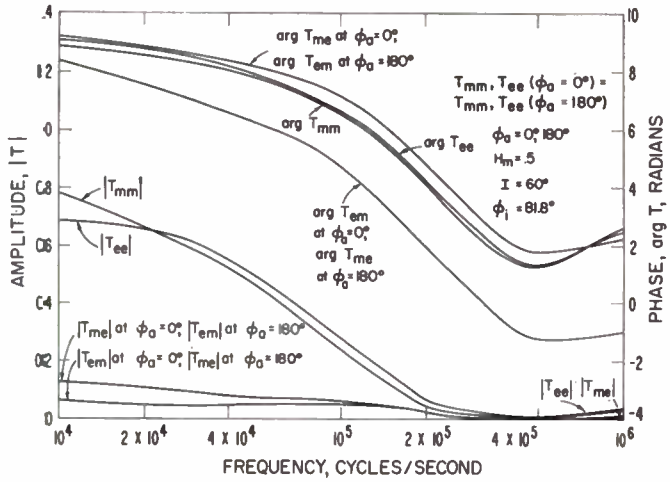


Fig. 21—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's, illustrating the frequency dependence of the classical magneto-ionic theory ($\phi_a = 0, 180°$).

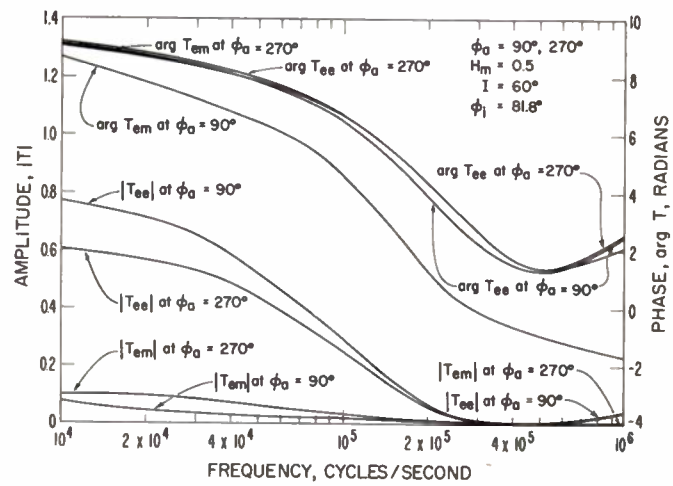


Fig. 22—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's, illustrating the frequency dependence of the classical magneto-ionic theory ($\phi_a = 90°, 270°$), vertical polarization (T_{ee}, T_{em}).

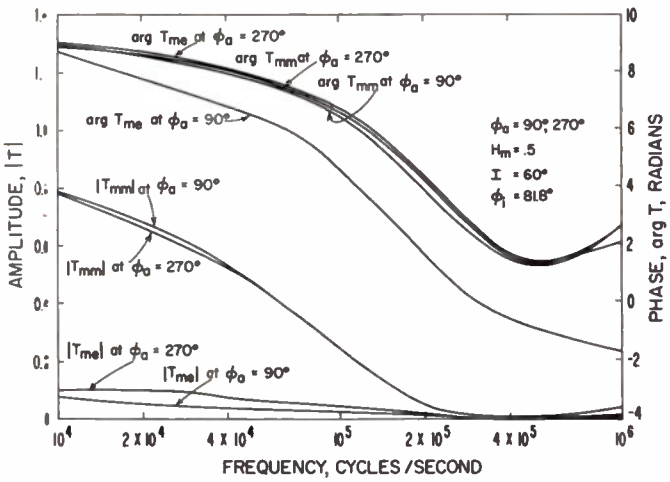


Fig. 23—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's, illustrating the frequency dependence of the classical magneto-ionic theory ($\phi_a = 90°, 270°$), horizontal polarization (T_{mm}, T_{me}).

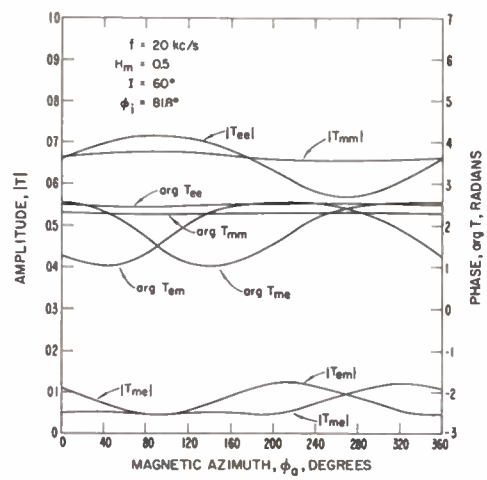


Fig. 24—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's, illustrating the action of the Lorentzian force (earth's magnetic field) in the classical magneto-ionic theory ($f = 20$ kc).

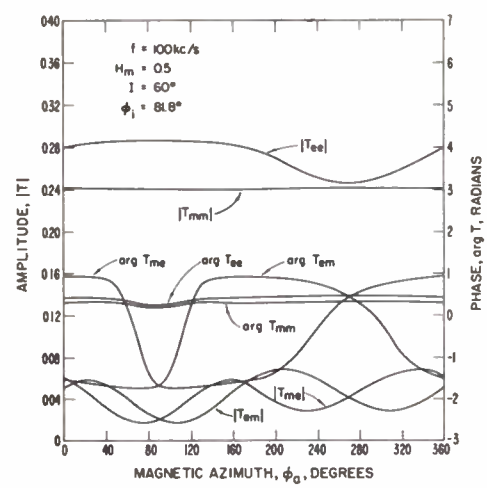


Fig. 25—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's, illustrating the action of the Lorentzian force (earth's magnetic field) in the classical magneto-ionic theory ($f = 100$ kc).

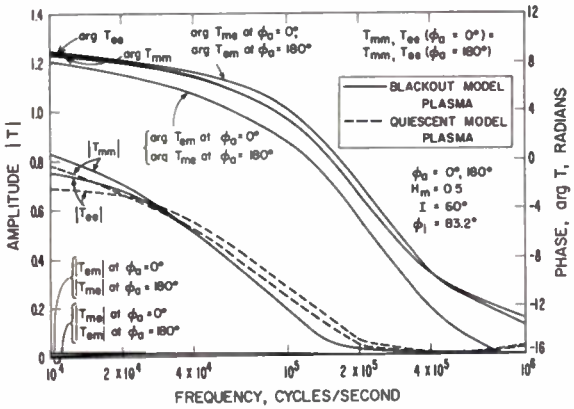


Fig. 26—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's during disturbed conditions, illustrating the frequency dependence of the classical magneto-ionic theory. $|T_{ee}|$ and $|T_{mm}|$ are also illustrated for comparison with the quiescent conditions (see Figs. 21–25 for complete reflection coefficients). ($\phi_a = 0$, 180°.)

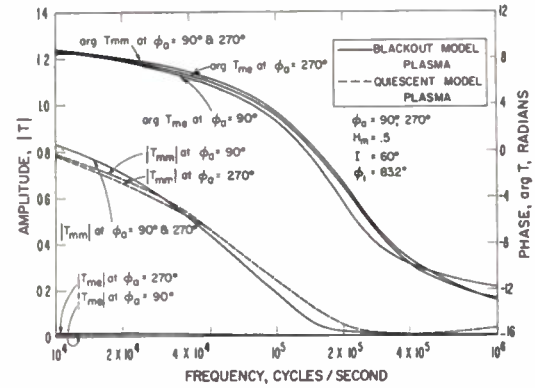


Fig. 27—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's during disturbed conditions, illustrating the frequency dependence of the classical magneto-ionic theory. $|T_{ee}|$ and $|T_{mm}|$ are also illustrated for comparison with quiescent conditions (see Figs. 21–25 for complete reflection coefficients). ($\phi_a = 90°$, 270°, vertical polarization T_{ee}, T_{em}.)

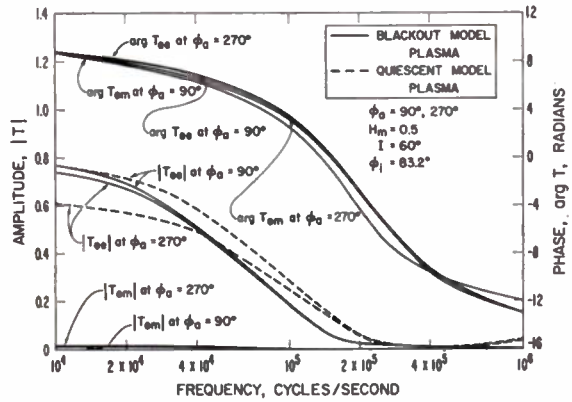


Fig. 28—Reflection coefficients (amplitude and phase) of the lower ionosphere for LF's during disturbed conditions, illustrating the frequency dependence of the classical magneto-ionic theory. $|T_{ee}|$ and $|T_{mm}|$ are also illustrated for comparison with quiescent conditions (see Figs. 21–25 for complete reflection coefficients). ($\phi_a = 90°$, 270°, horizontal polarization, T_{mm}, T_{me}.)

The effect of the Lorentzian force, $\mu_0 e(\overline{V} \times \overline{H}_m)$, [see (70)], or the action of the earth's magnetic field on the reflection process is also illustrated in Figs. 24 and 25. The reflection coefficients are illustrated here as a function of magnetic azimuth ϕ_a (Fig. 5). Note the propagation into the west, $\phi_a = 270°$, shows a smaller reflection coefficient than the propagation into the east, $\phi_a = 90°$, for the particular example illustrated. This seems to be quite generally valid for grazing incidence type transmission, $\phi_i \sim 82°$. This clearly indicates a nonreciprocity in the transmission, *i.e.*, the interchange of transmitter and receiver would not produce the same field.

Although the ionosphere reflections are quite intricate, it is quite feasible to evaluate the field of each ionospheric propagation ray, $E_j(\omega, d)$, (7), (8) or the total field, $E(\omega, d)$. The application of the transformation techniques (1)–(4), (39), (41)–(46) can then be applied to particular signal sources (as was illustrated for the ground wave, Section IV), $F_s(t)$. The propagated ionospheric signals $E_j(t', d)$ will thus be determined.

VI. Conclusions

Low frequencies exhibit properties which are quite favorable to high reliability and precision radio navigation-timing. In particular, the ground wave signal is especially favorable at distances less than 2000 statute miles (3200 km), *i.e.*, the pulse type transmissions resolve or sort out the individual propagation rays. At greater distances the signals propagated via ionospheric propagation rays also exhibit favorable properties, provided again the individual ionospheric propagation rays are sorted in the time domain. The detailed investigation of these properties is now required as a result of the economic and scientific importance of the navigation timing and communications systems now operating at LF.

Appendix

The coefficients of the quartic equation (71) are

$$a_0 = (a^2 - 1)^2\left[1 - \frac{s}{s^2 - h^2}\right] + (a^2 - 1)\left[\frac{1}{s} + \frac{s - 2}{s^2 - h^2} + \frac{a_L{}^2 h_T{}^2}{s(s^2 - h^2)} + \frac{s - 1}{s(s^2 - h^2)}\right], \tag{74}$$

$$a_1 = 2\,\frac{h_L h_T a_L}{s(s^2 - h^2)}\,(a^2 - 1), \tag{75}$$

$$a_2 = \left\{2\left[1 - \frac{s}{s^2 - h^2}\right] + \frac{h_L{}^2}{s(s^2 - h^2)}\right\}(a^2 - 1) + \frac{h_T{}^2 a_L{}^2}{s(s^2 - h^2)} + \frac{s - 2}{s^2 - h^2} + \frac{1}{s}, \tag{76}$$

$$a_3 = 2\,\frac{h_L h_T a_L}{s(s^2 - h^2)} = -\,a_1 \sec^2 \phi_i = -\,a_1/(1 - a^2), \tag{77}$$

$$a_4 = 1 - \frac{s^2 - h_L{}^2}{s(s^2 - h^2)}, \tag{78}$$

$$s = \frac{\omega^2}{\omega_N{}^2}\left[1 - i\,\frac{\nu}{\omega}\right], \tag{79}$$

where (Fig. 18) $\nu = \nu_n$, the collision frequency of the particular altitude n under investigation is

$$h = \frac{\omega_H \omega}{\omega_N{}^2}, \tag{80}$$

$$h_L = -\,h \sin I, \tag{81}$$

$$h_T = h \cos I, \tag{82}$$

$$a_L = \sin \phi_i \cos \phi_a, \qquad a_T = \sin \phi_i \sin \phi_a, \tag{83}$$

$$a = \sin \phi_i, \tag{84}$$

$$\omega_N{}^2 = Ne^2/\kappa m, \tag{85}$$

and the electron density of the particular slab n (Fig. 18) under investigation is

$$\omega_H = \mu_0 e H_m/m, \tag{86}$$

$$\kappa = 1/c^2\mu_0 = \epsilon_0. \tag{87}$$

The elements of the matrix equation (73) are defined:

$$a_{1,1} = \cos \phi_a \qquad b_{1,1} = -\sin \phi_a$$

$$a_{1,2} = -\cos \phi_i \sin \phi_a \qquad b_{1,2} = -\cos \phi_i \cos \phi_a$$

$$a_{1,3} = -\,Q_{io}^{(1)} \qquad b_{1,3} = -1$$

$$a_{1,4} = -\,Q_{ie}^{(1)} \qquad b_{1,4} = -1$$

$$a_{1,5} = -\,Q_{ro}^{(1)} \qquad b_{1,5} = -1$$

$$a_{1,6} = -\,Q_{re}^{(1)} \qquad b_{1,6} = -1$$

$$a_{2,3} = -\,a_{1,3} \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{io}^{(1)}\right] \qquad b_{2,3} = \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{io}^{(1)}\right]$$

$$a_{2,4} = -\,a_{1,4} \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{ie}^{(1)}\right] \qquad b_{2,4} = \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{ie}^{(1)}\right]$$

$$a_{2,5} = -\,a_{1,5} \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{ro}^{(1)}\right] \qquad b_{2,5} = \exp\left[-i\,\frac{\omega}{c}\,z_1 \zeta_{ro}^{(1)}\right]$$

$$a_{2,6} = -a_{1,6}\exp\left[-i\frac{\omega}{c}z_1\zeta_{re}^{(1)}\right] \qquad b_{2,6} = \exp\left[-i\frac{\omega}{c}z_1\zeta_{re}^{(1)}\right]$$

$$a_{2,7} = -Q_{io}^{(2)} \qquad b_{2,7} = -1$$
$$a_{2,8} = -Q_{ie}^{(2)} \qquad b_{2,8} = -1$$
$$a_{2,9} = -Q_{ro}^{(2)} \qquad b_{2,9} = -1$$
$$a_{2,10} = -Q_{re}^{(2)} \qquad b_{2,10} = -1$$

$$a_{3,7} = -a_{2,7}\exp\left[-i\frac{\omega}{c}z_2\zeta_{io}^{(2)}\right] \qquad b_{3,7} = \exp\left[-i\frac{\omega}{c}z_2\zeta_{io}^{(2)}\right]$$

$$a_{3,8} = -a_{2,8}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ie}^{(2)}\right] \qquad b_{3,8} = \exp\left[-i\frac{\omega}{c}z_2\zeta_{ie}^{(2)}\right]$$

$$a_{3,9} = -a_{2,9}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ro}^{(2)}\right] \qquad b_{3,9} = \exp\left[-i\frac{\omega}{c}z_2\zeta_{ro}^{(2)}\right]$$

$$a_{3,10} = -a_{2,10}\exp\left[-i\frac{\omega}{c}z_2\zeta_{re}^{(2)}\right] \qquad b_{3,10} = \exp\left[-i\frac{\omega}{c}z_2\zeta_{re}^{(2)}\right]$$

$$a_{3,11} = -Q_{io}^{(3)} \qquad b_{3,11} = -1$$
$$a_{3,12} = -Q_{ie}^{(3)} \qquad b_{3,12} = -1$$
$$a_{3,13} = -Q_{ro}^{(3)} \qquad b_{3,13} = -1$$
$$a_{3,14} = -Q_{re}^{(3)} \qquad b_{3,14} = -1$$
$$\cdots\cdots \qquad \cdots\cdots$$

$$a_{p,p+4} = -a_{p-1,p+4}\exp\left[-i\frac{\omega}{c}z_{p-1}\zeta_{io}^{(p-1)}\right] \qquad b_{p,p+4} = \exp\left[-i\frac{\omega}{c}z_{p-1}\zeta_{io}^{(p-1)}\right]$$

$$a_{p,p+9} = -Q_{ie}^{(p)} \qquad b_{p,p+9} = -1$$

$$c_{1,1} = -\cos\phi_i\sin\phi_a \qquad d_{1,1} = -\cos\phi_i\cos\phi_a$$
$$c_{1,2} = -\cos\phi_a \qquad d_{1,2} = \sin\phi_a$$
$$c_{1,3} = -\left[a_L P_{io}^{(1)} - \zeta_{io}^{(1)}\right] \qquad d_{1,3} = -\left[\zeta_{io}^{(1)}Q_{io}^{(1)} - a_T P_{io}^{(1)}\right]$$
$$c_{1,4} = -\left[a_L P_{ie}^{(1)} - \zeta_{ie}^{(1)}\right] \qquad d_{1,4} = -\left[\zeta_{ie}^{(1)}Q_{ie}^{(1)} - a_T P_{ie}^{(1)}\right]$$
$$c_{1,5} = -\left[a_L P_{ro}^{(1)} - \zeta_{ro}^{(1)}\right] \qquad d_{1,5} = -\left[\zeta_{ro}^{(1)}Q_{ro}^{(1)} - a_T P_{ro}^{(1)}\right]$$
$$c_{1,6} = -\left[a_L P_{re}^{(1)} - \zeta_{re}^{(1)}\right] \qquad d_{1,6} = -\left[\zeta_{re}^{(1)}Q_{re}^{(1)} - a_T P_{re}^{(1)}\right]$$

$$c_{2,3} = -c_{1,3}\exp\left[-i\frac{\omega}{c}z_1\zeta_{io}^{(1)}\right] \qquad d_{2,3} = -d_{1,3}\exp\left[-i\frac{\omega}{c}z_1\zeta_{io}^{(1)}\right]$$

$$c_{2,4} = -c_{1,4}\exp\left[-i\frac{\omega}{c}z_1\zeta_{ie}^{(1)}\right] \qquad d_{2,4} = -d_{1,4}\exp\left[-i\frac{\omega}{c}z_1\zeta_{ie}^{(1)}\right]$$

$$c_{2,5} = -c_{1,5}\exp\left[-i\frac{\omega}{c}z_1\zeta_{ro}^{(1)}\right] \qquad d_{2,5} = -d_{1,5}\exp\left[-i\frac{\omega}{c}z_1\zeta_{ro}^{(1)}\right]$$

$$c_{2,6} = -c_{1,6}\exp\left[-i\frac{\omega}{c}z_1\zeta_{re}^{(1)}\right] \qquad d_{2,6} = -d_{1,6}\exp\left[-i\frac{\omega}{c}z_1\zeta_{re}^{(1)}\right]$$

$$c_{2,7} = -\left[a_L P_{io}^{(2)} - \zeta_{io}^{(3)}\right] \qquad d_{2,7} = -\left[\zeta_{io}^{(2)}Q_{io}^{(2)} - a_T P_{io}^{(2)}\right]$$
$$c_{2,8} = -\left[a_L P_{ie}^{(2)} - \zeta_{ie}^{(2)}\right] \qquad d_{2,8} = -\left[\zeta_{ie}^{(2)}Q_{ie}^{(2)} - a_T P_{ie}^{(2)}\right]$$
$$c_{2,9} = -\left[a_L P_{ro}^{(2)} - \zeta_{ro}^{(2)}\right] \qquad d_{2,9} = -\left[\zeta_{ro}^{(2)}Q_{ro}^{(2)} - a_T P_{ro}^{(2)}\right]$$
$$c_{2,10} = -\left[a_L P_{re}^{(2)} - \zeta_{re}^{(2)}\right] \qquad d_{2,10} = -\left[\zeta_{ie}^{(2)}Q_{ie}^{(2)} - a_T P_{re}^{(2)}\right]$$

$$c_{3,7} = -c_{2,7}\exp\left[-i\frac{\omega}{c}z_2\zeta_{io}^{(2)}\right] \qquad d_{3,7} = -d_{2,7}\exp\left[-i\frac{\omega}{c}z_2\zeta_{io}^{(2)}\right]$$

$$c_{3,8} = -c_{2,8}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ie}^{(2)}\right] \qquad d_{3,8} = -d_{2,8}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ie}^{(2)}\right]$$

$$c_{3,9} = -c_{2,9}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ro}^{(2)}\right] \qquad d_{3,9} = -d_{2,9}\exp\left[-i\frac{\omega}{c}z_2\zeta_{ro}^{(2)}\right]$$

$$c_{3,10} = -c_{2,10}\exp\left[-i\frac{\omega}{c}z_2\zeta_{re}^{(2)}\right] \qquad d_{3,10} = -d_{2,10}\exp\left[-i\frac{\omega}{c}z_2\zeta_{re}^{(2)}\right]$$

$$c_{3,11} = -\left[a_L P_{io}^{(3)} - \zeta_{io}^{(3)}\right] \qquad d_{3,11} = -\left[\zeta_{io}^{(3)} Q_{io}^{(3)} - a_T P_{io}^{(3)}\right]$$

$$c_{3,12} = -\left[a_L P_{ie}^{(3)} - \zeta_{ie}^{(3)}\right] \qquad d_{3,12} = -\left[\zeta_{ie}^{(3)} Q_{ie}^{(3)} - a_T P_{ie}^{(3)}\right]$$

$$c_{3,13} = -\left[a_L P_{ro}^{(3)} - \zeta_{ro}^{(3)}\right] \qquad d_{3,13} = -\left[\zeta_{ro}^{(3)} Q_{ro}^{(3)} - a_T P_{ro}^{(3)}\right]$$

$$c_{3,14} = -\left[a_L P_{re}^{(3)} - \zeta_{re}^{(3)}\right] \qquad d_{3,14} = -\left[\zeta_{re}^{(3)} Q_{re}^{(3)} - a_T P_{re}^{(3)}\right]$$

. . . . . .

$$c_{p,p+4} = -c_{p-1,p+4}\exp\left[-i\frac{\omega}{c}z_{p-1}\zeta_{io}^{(p-1)}\right] \qquad d_{p,p+4} = -d_{p-1,p+4}\exp\left[-i\frac{\omega}{c}z_{p-1}\zeta_{io}^{(p-1)}\right]$$

$$c_{p,p+9} = -\left[a_L P_{ie}^{(p)} - \zeta_{ie}^{(p)}\right] \qquad d_{p,p+9} = -\left[\zeta_{ie}^{(p)} Q_{ie}^{(p)} - a_T P_{ie}^{(p)}\right]$$

$$a_{oe} = \cos\phi_i \sin\phi_a$$

$$b_{oe} = \cos\phi_i \cos\phi_a$$

$$c_{oe} = -\cos\phi_a$$

$$d_{oe} = \sin\phi_a$$

$$a_{om} = \cos\phi_a$$

$$b_{om} = -\sin\phi_a$$

$$c_{om} = \cos\phi_i \sin\phi_a$$

$$d_{om} = \cos\phi_i \cos\phi_a$$

and

$$P = E_z/E_y, \qquad Q = E_x/E_y.$$

Both transmission coefficients U and reflection coefficients T previously introduced (37) are determined by the matrix. The U's are defined as

$$U_{eio}^{(n)} = \frac{E_{yio}^{(n)}}{E_{y'i}} \qquad U_{ero}^{(n)} = \frac{E_{yro}^{(n)}}{E_{y'i}}$$

$$U_{mio}^{(n)} = \frac{E_{yio}^{(n)}}{E_{x'i}} \qquad U_{mro}^{(n)} = \frac{E_{yro}^{(n)}}{E_{x'i}}$$

$$U_{eie}^{(n)} = \frac{E_{yie}^{(n)}}{E_{y'i}} \qquad U_{ere}^{(n)} = \frac{E_{yre}^{(n)}}{E_{y'i}} \tag{88}$$

$$U_{mie}^{(n)} = \frac{E_{yie}^{(n)}}{E_{x'i}} \qquad U_{mre}^{(n)} = \frac{E_{yre}^{(n)}}{E_{x'i}}.$$

The analytic expressions for the complex numbers $P_{io}^{(n)}$, $P_{ie}^{(n)}$, $P_{ro}^{(n)}$, $P_{re}^{(n)}$, $Q_{io}^{(n)}$, $Q_{ie}^{(n)}$, $Q_{ro}^{(n)}$, $Q_{er}^{(n)}$ can be derived from the definitions by a simultaneous solution of Maxwell's equation (69) and the equation of motion of the electron (70) with the following result:

$$P = \frac{-\left[a_L\zeta + \frac{h_T h_L}{s(s^2-h^2)}\right]\left[1 - a_L{}^2 - \zeta^2 - \frac{s}{s^2-h^2}\right] + \left[a_L a_T - i\frac{h_L}{s^2-h^2}\right]\left[a_T\zeta - i\frac{h_T}{s^2-h^2}\right]}{\left[1 - a^2 - \frac{s^2-h_L{}^2}{s(s^2-h^2)}\right]\left[1 - a_L{}^2 - \zeta^2 - \frac{s}{s^2-h^2}\right] - \left[a_T\zeta + i\frac{h_T}{s^2-h^2}\right]\left[a_T\zeta - i\frac{h_T}{s^2-h^2}\right]}, \tag{89}$$

$$Q = \frac{-\left[1 - a^2 - \frac{s^2-h_L{}^2}{s(s^2-h^2)}\right]\left[a_L a_T - i\frac{h_L}{s^2-h^2}\right] + \left[a_T\zeta + i\frac{h_T}{s^2-h^2}\right]\left[a_L\zeta + \frac{h_L h_T}{s(s^2-h^2)}\right]}{\left[1 - a^2 - \frac{s^2-h_L{}^2}{s(s^2-h^2)}\right]\left[1 - a_L{}^2 - \zeta^2 - \frac{s}{s^2-h^2}\right] - \left[a_T\zeta + i\frac{h_T}{s^2-h^2}\right]\left[a_T\zeta - i\frac{h_T}{s^2-h^2}\right]}. \tag{90}$$

where the particular slab (Fig. 18) $n=1, 2, 3, \cdots, p-1, p$ under consideration is designated by the notation $\zeta=\zeta^{(n)}$, $P=P^{(n)}$, $Q=Q^{(n)}$, and *io*, *ie*, *ro*, and *re* refer to the four roots of the quartic in ζ for upgoing, downgoing, ordinary, and extraordinary waves, respectively, in the particular part z_n of the electron-ion plasma under consideration.

The factor $F_j{}^{t,r}$ can be written [12]

$$F_j{}^{t,r} = (\pi)^{-1/2}\exp\left[-ik_1a\theta'\right] \cdot\left\{\int_0^\infty \frac{\exp\left[-i(k_1a/2)^{1/3}\theta'\alpha\right]}{W_1'(\alpha) - qW_1(\alpha)}\,d\alpha - \int_0^\infty \frac{\exp\left[-i(k_1a/2)^{1/3}\theta'\alpha' - i2\pi/3\right]}{W_1'(\alpha') - qW_1(\alpha')}\,d\alpha\right\},$$

where $\alpha' = \alpha\exp\left[-i2\pi/3\right]$ and

$$W_1(\alpha') = -i\sqrt{\pi/3}\,(\alpha)^{1/2}H_{1/3}{}^{(2)}\left[\tfrac{2}{3}i\alpha^{3/2}\right]$$

$$W_1'(\alpha') = \sqrt{\pi/3}\,\alpha H_{2/3}{}^{(2)}\left[\tfrac{2}{3}i\alpha^{3/2}\right],$$

where α is a positive real number.

The following explicit form for the equation $F_j{}^{t,r}$ has been suggested [39]:

$$F_j{}^{t,r} = (\pi)^{-1/2}\exp\left[-ik_1a\theta'\right] \cdot\left\{\int_0^\infty \frac{\exp\left[-i(k_1a/2)^{1/3}\theta'\alpha\right]}{W_1'(\alpha) - qW_1(\alpha)}\,d\alpha + \int_0^\infty \frac{\exp\left[-\frac{(\sqrt{3}-i)}{2}(k_1a/2)^{1/3}\theta'\alpha\right]}{W_2'(\alpha) - q\exp\left[-i2\pi/3\right]W_2(\alpha)}\,d\alpha\right\},$$

where $W_2(\alpha)$ and $W_2'(\alpha)$ are airy integral functions appropriate to the rotation $\alpha' = \alpha\exp(-2\pi i/3)$.

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Video Transmission by Delta Modulation Using Tunnel Diodes*

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Summary—**A method is described which enables video signals to be transmitted by the pulse code modulation system known as delta-modulation. A tunnel-diode balanced pair (Goto pair) is used for converting the video signal into a binary signal. With a new and very simple circuit, operating at a bit rate of 100 Mc, a ratio of signal-to-quantizing noise of 42 db is obtained. A more conventional circuit, that combines tunnel-diodes with transistors, makes an even lower quantizing noise possible.**

Introduction

TO REDUCE the cumulative effect of interference in communication systems having many links, the input signal may be coded into some binary pulse pattern. A pulse code system for the transmission of video signals over telephone cable pairs has recently been reported[1] where an n-digit binary number is used to represent the sampled video signal amplitude. The particular code modulation system known as delta-modulation[2,3] uses a 1-digit code to represent the rate of change of the signal amplitude. Until now this system could only be used for speech transmission and not for video transmission because of the high pulse repetition rates involved. In this paper, methods will be described for overcoming this difficulty by using tunnel-diodes. Two circuits are presented, one of which is derived from the feedback loop as given by Schouten, de Jager and Greefkes. The other one is new, very simple, and can be used over a wide range of pulse repetition rates.

Delta Modulation

In principle the delta-modulation system converts a continuous signal into a binary signal by means of quantized feedback. The modulator consists of a clipping differential amplifier, a pulse generator, a pulse modulator and an integrating network as shown in Fig. 1.

The differential amplifier compares the input signal with a reconstructed signal, which is obtained by integrating the binary output from the delta-modulator. If the input signal is larger than the integrator output, the modulator produces a positive pulse; if it is smaller, a negative pulse is produced. The resulting output pattern of positive and negative pulses is applied to the integrating network. The integrated signal is fed back to the differential amplifier where it is compared with the input signal, as described.

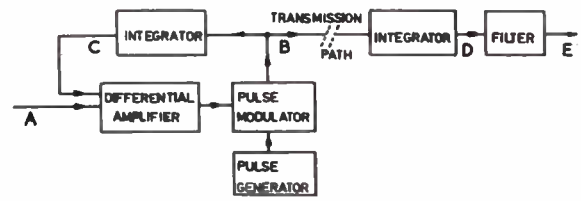


Fig. 1—Block diagram of a delta-modulation system.

The binary output can be transmitted directly or can be modulated on a high-frequency carrier.

At the end of each transmission link the signal is regenerated to remove the effects of interference. At the receiving end the regenerated signal is applied to an integrating network that has the same frequency characteristics as the one on the transmitting side. All frequencies higher than the signal frequencies are suppressed. The result then will be a reconstruction of the original signal.

The waveforms at points A, B, C, D and E of Fig. 1 are shown in Fig. 2. Because a continuous signal can never be exactly represented by a binary code signal there will always be a difference between the input and the reconstructed signal.

These differences may be considered as a particular kind of noise, called quantizing noise. The amount of noise will depend on the characteristics of the integrating network and on the frequency of the pulse generator.

When a single RC-integrating network is used the amplitude of the quantizing noise can be shown[3] to vary with the pulse frequency as $f^{-3/2}$. When two cascaded RC networks are used, one integrating over the complete frequency range of the signal and the other only over a range above the signal frequencies, the quantizing noise varies as $f^{-5/2}$.

For a signal-to-quantizing noise ratio of 40 db, using a single integrating network, the pulse generator frequency has to be about 20 times the highest signal frequency. A television video signal in this case will require a pulse frequency of 100 Mc. When a double integrating network is used a pulse frequency of 40 Mc will suffice.

* Received by the IRE, September 28, 1961.
† Philips Research Laboratories, N. V. Philips' Gloeilampenfabrieken, Eindhoven, The Netherlands.
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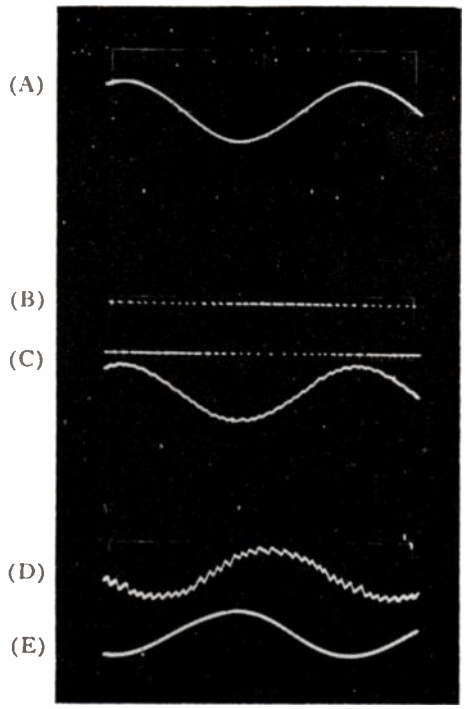


Fig. 2—Waveforms as indicated at A–E in Fig. 1. (A) Original sine wave. (B) Binary output signal. (C) Reconstructed signal in transmitter. (D) Reconstructed signal in receiver. (E) Output signal of receiver.

The Tunnel-Diode Delta-Modulator

The functions of the differential amplifier and the pulse modulator in the delta-modulator block diagram can be combined into one balanced pair of tunnel diodes (Goto pair).[4]

This circuit (Fig. 3) consists of two tunnel diodes in series fed by two synchronous pulse sources of opposite polarity. At the start of a supply pulse the circuit is biased by a signal at the connecting point of the diodes. The polarity of this bias determines the polarity of the output pulse.

The behavior of the pair will be explained with the aid of Fig. 4. When the bias signal is positive, tunnel-diode T_1 is biased in the reverse direction and tunnel-diode T_2 in the forward direction. At the start of the supply pulses both points P_1 and P_2 shift over the tunnel-diode characteristic. Point P_2 goes over the top first and reaches position P_2' in the valley; point P_1 shifts to position P_1'. To insure this operation each supply voltage must be equal to $(V_p+V_v)/2$. Because $V_v \gg V_p$ the output voltage is nearly equal to the positive supply voltage. It appears that the polarity of the output pulse is the same as that of the bias signal. The sensitivity is determined by the minimum bias required for overcoming the hysteresis of the tunnel-diode pair. One way of using the balanced pair in the delta-modulator is shown in Fig. 5. In this case the input signal fed to the pair is the difference between the signal to be modulated and the reconstructed signal, that is the output of the integrator. The output of the tunnel-diode pair consists of positive or negative pulses, depending on the polarity of the difference signal at its input. In this way the tunnel-diode pair combines the actions of the differential amplifier and the pulse modulator as mentioned above. The pulse supply of the tunnel-diode pair serves as the pulse generator.

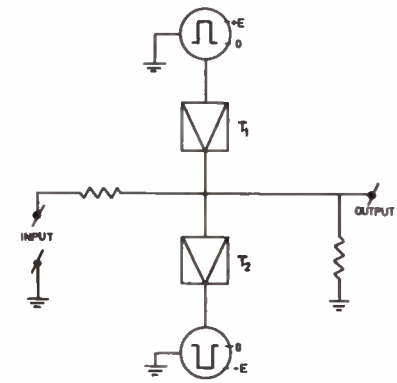


Fig. 3—Tunnel-diode balanced pair.

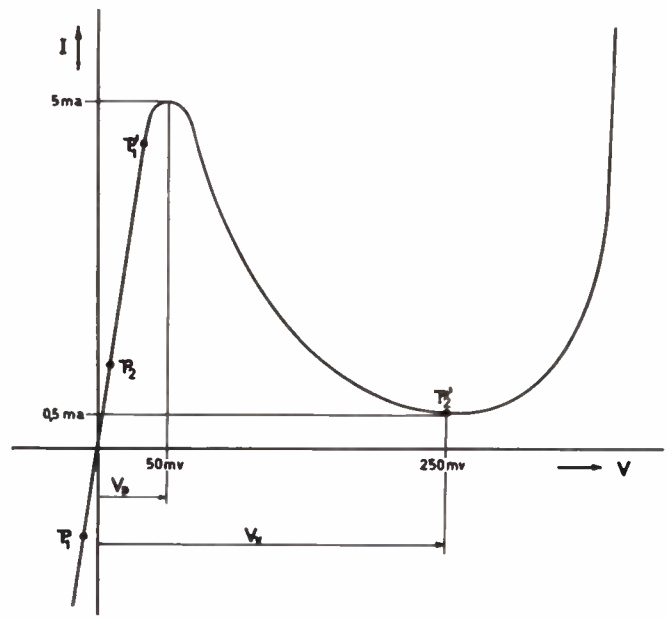


Fig. 4—Tunnel-diode characteristic. Points P_1 and P_2 represent bias of the pair at the start of the supply pulses. During the supply pulses points P_1 and P_2 move to points P_1' and P_2'.

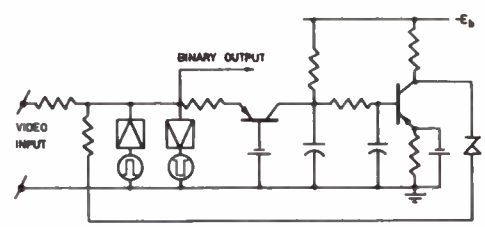


Fig. 5—Tunnel-diode delta-modulator with external loop and double integrating network.

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The output pulses of the tunnel-diode pair have to be fed back to the input through an integrating circuit. This circuit has to be unilateral, because input and output are indistinguishable in the tunnel-diode pair. Unilaterality is provided by a transistor pulse amplifier. For correct operation the loop delay has to be smaller than the time interval between successive pulses. This requires that the switching delay of the transistor be small. An advantage of this form of the circuit is that double integration can be employed.

A second and very simple way of using the tunnel-diode pair is shown in Fig. 6. Here again the diodes act as a combined pulse differential amplifier and pulse modulator; an inductance is added as the integrator. After each output pulse of the tunnel-diodes, the inductance acts as a current source $i = -1/L \int e dt$ of opposite polarity. In the absence of an input signal, this current will bias the tunnel-diode pair, thereby determining the polarity of the next output pulse. This results in a pattern of alternating positive and negative pulses (Fig. 7), as is the case with all delta-modulators in the absence of an input signal.

When an input signal is present, the bias of the tunnel-diode pair is the sum of the input signal current and the inductor current. Each output pulse causes the current through the inductor to change by a definite amount, either in a positive or in a negative sense. Because the voltage on the inductor is opposite to the rate of change of the current through it, the polarity of each pulse will be such as to counteract the current in the inductor. Between the pulses the common point of the tunnel-diodes will thus be at virtual earth potential.

The pulse pattern at the output of the circuit is then the same as would be obtained by a delta-modulator with a single integration loop. Only single integration is possible here as no two-terminal network can exist of which the admittance has the same frequency characteristic as the transfer impedance of a double integrating network.

The magnitude of the current step in the inductor follows from

$$e = -L \frac{di}{dt}.$$

In the circuit tested, a shifted sine wave is used instead of the rectangular supply pulses (Fig. 8). The current step in the inductor is

$$-\Delta i = \int_0^T \frac{e dt}{L} = \int_0^T \frac{\hat{e}(1 - \cos \omega t) dt}{wL} = \frac{2\pi \hat{e}}{L} = \frac{\hat{e}}{f \cdot L}.$$

This current step must be larger than the sensitivity of the tunnel-diode pair. When the sensitivity is 5 μa, the supply voltage is 0.1 v and the pulse frequency is 100 Mc, the inductance must be smaller than 100 μh. A value of 60 μh is used. The parallel capacitance of the inductor has to be low, in this case about 1 pf. This was obtained by using a ferrite core having a small number of turns.

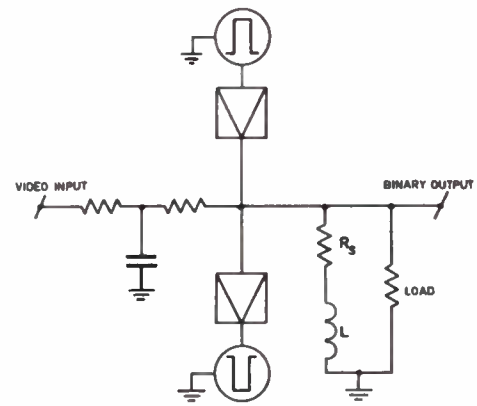


Fig. 6—Tunnel-diode delta-modulator with an inductor as integrator.



Fig. 7—Binary pattern of delta-modulator in the absence of input signal.

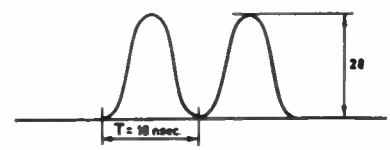


Fig. 8—Supply pulses for a tunnel-diode balanced pair.

In the circuit under discussion the input signal is differentiated with a time constant determined by the series resistance of the inductor. This time constant has been chosen as 100 μsec. An integrator with the same time constant is inserted between the signal source and the modulator input. At the receiving end only a low-pass filter is needed.

Regenerators and Converters

The tunnel-diode balanced pair as described above can also be applied for regeneration of binary signals. In this case the received binary signal is applied to the tunnel-diode pair. The supply pulses are locked to the received signal by a narrow-band device, *e.g.*, a phase-locked oscillator. At the output of the tunnel-diode pair a regenerated binary signal will then be available.

For several applications it is necessary to have a plus-zero binary signal, instead of a plus-minus signal as used here.

This can be obtained by adding a series of positive pulses, obtained from a second synchronously operated tunnel-diode pair, to the plus-minus signal (Fig. 9).

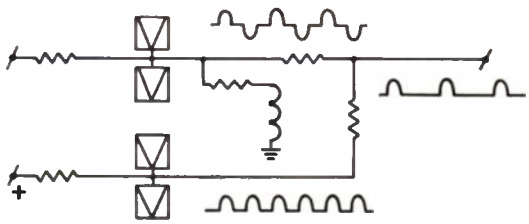


Fig. 9—Use of a second tunnel-diode pair for suppressing negative pulses.

Results

A delta-modulator using a tunnel-diode pair and an inductor has been built. A photograph of this circuit is shown in Fig. 10.

The tunnel-diodes used were of the germanium type with a peak current of 5 ma and a capacitance of 5 pf. The video signal was coded into a binary signal with a bit rate of 100 Mc. After regeneration in a second diode pair the binary signal was applied to a video amplifier with a cutoff frequency of 5 Mc serving as a low-pass filter. Pictures obtained with the original signal and with the demodulated signal are shown in Figs. 11 and 12 respectively. They are of limited value due to the photographic processing. A better insight into the quality of the system is given by the ratio of signal-to-quantizing noise. For this ratio a value of 42 db has been measured.

A second circuit consisting of a tunnel-diode pair combined with two experimental UHF transistors in an external feedback loop with double integration gives a signal-to-quantizing noise ratio of 39 db, using a 40-Mc bit rate. The signal-to-quantizing noise ratio was measured in the following way. The maximum signal amplitude possible with overloading the delta-modulator was determined without an oscilloscope. For the measurement of the quantizing noise, a signal of 50 cps was applied to the delta-modulator. The r.m.s.-voltage of the resulting noise was measured with the aid of a thermocouple. The quantizing noise is independent of the amplitude of the 50-cps signal.

Conclusion

In the foregoing it has been shown that by using a tunnel-diode balanced pair in a delta-modulation system a video signal can be converted into a binary signal with a 100-Mc bit rate having a more than sufficient ratio of signal-to-quantizing noise.

The advantages of the circuit are its simplicity and the possibility of using very high bit rates. The quality of the resulting picture is good. A further advantage of delta-modulation as compared with other pulse code modulation systems is that no lines of constant brightness (isophots) are visible on the received picture, because there are no fixed quantizing levels.

Limitations are the slightly higher bit rate in comparison with normal pulse code modulation at 70 Mc, and the rather low output voltage of the tunnel-diodes (0.2 v).

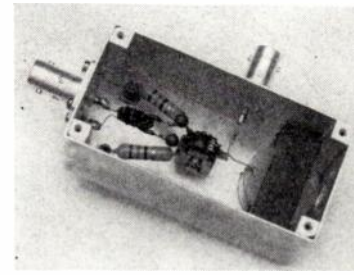


Fig. 10—Photograph of tunnel-diode delta-modulator with an inductor as integrator.



Fig. 11—Original television picture.



Fig. 12—Reconstructed television picture after transmission by a single integrator delta-modulator with a pulse frequency of 100 Mc.

The system is particularly suited for those cases where a communication channel is available that has a large bandwidth, but also a high level of interference and distortion. Examples of such channels are microwave systems using circular waveguides in the TE_{01} mode, and in the future possibly optical systems using lasers.

Acknowledgment

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Construction and Performance of an ELF Display System*

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Summary—An experimental display system featuring a solid-state display screen has been constructed and evaluated. The system includes a 256-cell-per-square-inch electroluminescent panel, row and column drivers for the panel distribution matrix, and character generation equipment to form target images on the display in accordance with a computer-word input. The brightness pattern on the 4-by-8-inch electroluminescent panel is controlled and stored by a ferroelectric microarray. A matrix of gaseous discharge elements called ionic switches distributes the control signals to the ferroelectric structure.

Both conventional and novel techniques were used to fabricate the panel. Less than 2 per cent of the 8192 cells of the completed panel are faulty. Highlight brightness is 2.8 foot-lamberts and contrast is 25:1; both figures are below design objectives due to limits set on panel excitation for this model. Image storage time is more than adequate for the 5 seconds frame time of the system, and the electronic scanning matrix performs as required. The general appearance of target images on the panel is satisfactory although uniformity can be improved by better mechanical design and fabrication process control.

Introduction

A CONSISTENT requirement of many complex data-handling systems is means for large-screen electronic display of highly processed information. The display is needed to provide supervisory personnel with quick access to large amounts of interrelated data, with the objective of enhancing decisions which cannot be left to the system computer. The inadequacies of conventional approaches, such as projection and electromechanical writing, have given impetus to the development of a variety of electroluminescent display panels based on widely differing operating principles.[1–3] One of the approaches, the ELF screen, utilizes a multielement array of ferroelectric capacitors to form the brightness image on the electroluminescent panel.

The application to which ELF is addressed is typified by the control center shown in Fig. 1. This center requires status display panels up to 10 feet square with over four-million individual picture points. Image storage, gray scale, rapid rewrite and moderate brightness are necessary in addition to selective erasure capability. The information to be displayed consists primarily of target data and appropriate reference outlines.

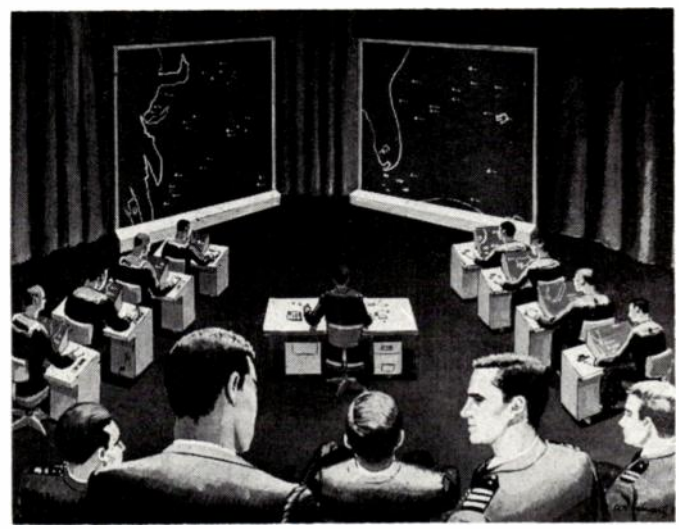


Fig. 1—Artist's conception of a control center with 10-foot-square ELF display panels.

Obviously, a multicell display with several million picture points, however simple in concept, represents a major development task. There are many questions concerning technical and economic feasibility which appear to be best answered by building small subsections of the full size panel. Initial research and development in the ELF program was devoted to the demonstration of the feasibility of the principle.[4] Subsequently, materials research provided improved electroluminescent and ferroelectric materials and switching elements for the distribution of image information to the panel.[5] In the work reported here, a complete experimental system, from information source to the ELF panel, was designed, built, and tested to evaluate the over-all feasibility of the full-scale display. The ELF panel for this system represents a 4-by-8-inch subsection of a 10-foot-square screen and has equal resolution, 256 cells per square inch. The 4-by-8-inch size was selected as the minimum necessary to give a good representation of the target information.

A block diagram of the experimental system is shown in Fig. 2. Target information, in the form of a computer word, is fed from an information source to a translator, which generates the characters for the display.[6] The

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[1] R. K. Orthuber and L. R. Ullery, "Solid-state image intensifier," *J. Opt. Soc. Am.*, vol. 44, pp. 297–299; April, 1954.

[2] J. A. Rajchman, G. R. Briggs, and A. W. Lo, "Transfluxor controlled electroluminescent display panels," PROC. IRE, vol. 46, pp. 1808–1824; November, 1958.

[3] R. T. Loewe, R. L. Sisson, and P. Horowitz, "Computer generated displays," PROC. IRE, vol. 49, pp. 185–195; January, 1961.

[4] E. A. Sack, "ELF—A new electroluminescent display," PROC. IRE, vol. 46, pp. 1694–1699; October, 1958.

[5] E. A. Sack, "Advances in screen structure and data distribution for the ELF display system," 1960 IRE INTERNATIONAL CONVENTION RECORD, pt. 3, pp. 23–33.

[6] This equipment was provided by the Maico Corp., Minneapolis, Minn.

computer word contains the X and Y coordinates of the target location, a heading vector, and identifying information to be displayed in alphanumeric characters adjacent to the target vector. The translator stores the target data in a local memory for quick access during the display scanning cycle. Information is supplied to one row of ELF panel cells at a time, starting at the top and stepping consecutively toward the bottom of the screen. The translator selects from its memory all of the targets which touch the top row of the panel and generates a spatial geometry of signals which represent the target character forms. Information for the first row of the screen is then fed to the display column drivers. Immediately after the column driver states are established, the translator supplies a row-select signal to the row driver, causing it to trigger the column signals into the top row of the screen. The cycle is then repeated for each successive row until the entire panel has been scanned and all targets which fall into the panel area are displayed. Due to the excellent storage characteristics of the ELF panel, the target images may be retained until update information becomes available. In the experimental system, however, all targets are rewritten every 5 seconds.

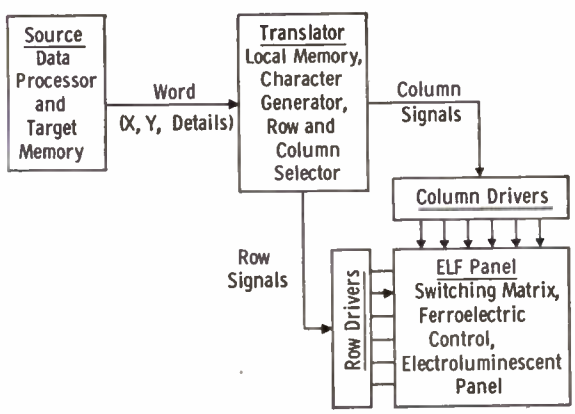


Fig. 2—Experimental ELF display system.

Although the ELF panel constructed for the experimental system has gray-scale capabilities, the translator and drivers are designed to provide only full ON or full OFF information for the target characters. Gray-scale levels for display of background images are to be included in subsequent modifications of the system.

Panel Design Considerations

The design of the experimental ELF display panel follows certain general considerations. The panel is a multicell device, having 64 rows and 128 columns of cells. Within each cell, excitation to an electroluminescent layer is controlled by a pair of nonlinear capacitive elements, whose operating point is set by a stored charge established by a signal distribution system.

In the screen-row-at-a-time process of signal distribution, brightness information signals are supplied on column buses and switching signals on row buses, to enable a switching element associated with each cell to transfer control charge for that cell. Switching time allotted to each row is based on a 5-second frame time for a 10-foot-square prototype panel. Since the latter would have 2048 rows, a switching time of 2.44 msec is available.

Cell Equivalent Circuit and Element Requirements

An equivalent circuit diagram for an individual cell is shown in Fig. 3. Bus connections A and B are common to all cells of the panel and provide excitation potentials with respect to bus connection N, the common transparent electrode for all electroluminescent elements. The bridge control configuration comprised of the common excitation source and nonlinear capacitors C_{NA} and C_{NB} was selected in preference to simpler series control circuits[4] because of its superior control capabilities and because of the wider flexibility that results from the additional adjustable operating parameters.

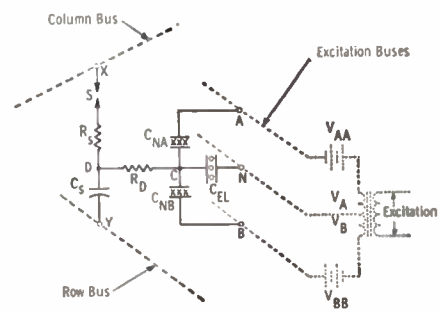


Fig. 3—Equivalent circuit of a single ELF cell.

The particular mode of operation employed utilizes dc biases on each of the nonlinear capacitors and unequal ac potentials on buses A and B. The introduction of a control charge at point C results in equal and opposite changes in the dc potentials appearing across C_{NA} and C_{NB}, with a consequent shift in the ac balance condition of the bridge. A change of 200 v in the dc control potential at point C was determined to be within the capability of economical signal distribution systems. This control voltage is sufficient to change the ac potential applied to the electroluminescent element, C_{EL}, from approximately 400 v peak-to-peak to 140 v peak-to-peak. With typical electroluminescent layers, this variation permits a single cell on-to-off brightness ratio in excess of 50 to 1.

By proper choice of the screen operating potentials, it is possible to eliminate the dc control potential on the electroluminescent element under the condition of maximum ac potential, thus relieving the breakdown voltage requirements on that element. Under this condition, the electroluminescent layer must be capable of withstanding the dc control potential of 200 v in the presence of a small ac voltage. In addition, of course, it must provide the required highlight brightness at approximately 400 v peak-to-peak. As a compromise among considera-

tions of electroluminescent brightness, maintenance, and ferroelectric temperature rise, an excitation frequency of 400 cps is employed. A final requirement of the electroluminescent layer is that it have a low dc leakage, in order to prevent premature decay of the stored control charges.

Typically, the capacitance for an electroluminescent layer of this type is 1500 pf per square inch. At a cell resolution of 256 per square inch, the capacitance of each EL element is then approximately 6 pf. Analysis of bridge performance under various conditions of loading by C_{EL} shows that nonlinear capacitors C_{NA} and C_{NB} should each have a capacitance on the order of 50 pf.[7] These values of capacitance, in turn, determine the values required for the decoupling resistor, R_D, and the indirect storage capacitor, C_S. The latter circuit elements serve the purpose of preventing the ac potential present at point C from appearing on the switch, S, at point E and thus affecting the firing time of the switch element.

In the information storage process, capacitor C_S is charged to the desired potential through switch S, during the 2.44-msec row writing time. A portion of the charge on C_S is then transferred through R_D to the bridge capacitors, C_{NA}, C_{NB} and C_{EL}. The requirement on C_S is that it be sufficiently large to prevent a significant change in its potential in the process of charging the bridge capacitors. A capacitance on the order of 2000 pf meets this criterion.

The value of the decoupling resistor R_D must be great enough to make the time constant R_DC_S long relative to the period of the 400-cps screen excitation, and must be small enough to make the time constant $R_D(C_{NA}+C_{NB}+C_{EL})$ a small fraction of a second. This last requirement results from the undesirability of any visual perceptibility of the cell writing process. A value for R_D of approximately 200 megohms is employed in the model.

Switching Elements

The remaining elements of the equivalent cell circuit are switch S and its associated suppressor resistor R_S. The function of the switch is to connect the cell to the peripheral drivers when brightness information is to be changed, and to isolate the cell from the drivers at all other times in order to permit satisfactory retention of stored information. Because of the rather unusual nature of this element, its characteristics and operation are described in some detail.

The switch element employed in the model utilizes an ionic discharge between two closely-spaced electrodes surrounded by air at atmospheric pressure; for this reason it is called an *ionic switch*. The potential-current characteristic of the switch has two stable regions on each side of the origin, as illustrated in Fig. 4. In the zero current region, for potentials below the breakdown potential, V_B, the ionic switch exhibits a resistance greater than 10^{14} Ω. In the second region, it maintains a constant potential, V_S, of approximately 320 v over the current range 2×10^{-4} to 3×10^{-2} a, with a dynamic resistance of less than 100 Ω. Separating these stable regions is a third, unstable region in which the switch exhibits negative dynamic resistance.

In the ELF panel the ionic switches are operated as bidirectional clamps by utilizing the stable portions of their characteristics. A symmetric switching burst, shown in Fig. 5, is applied to the row bus for the screen row to be written. Simultaneously, brightness information potentials for the respective cells are applied to the column buses.

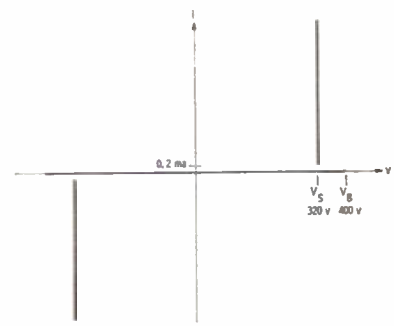


Fig. 4—Current-vs-voltage for an ionic switch.

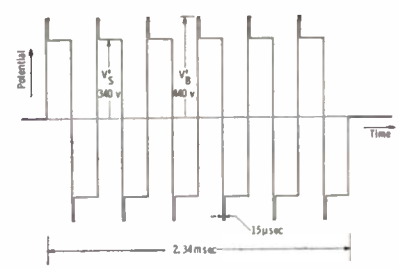


Fig. 5—Signal distribution switching burst.

The duration of the switching burst is slightly less than the available 2.44 msec. Its basic amplitude, V_S', and the height of its leading edges, V_B', are somewhat greater than the corresponding ionic switch sustaining and breakdown potentials, V_S and V_B, in order to insure reliable operation. To reduce statistical variations in the potential stored at point D (Fig. 3), six complete cycles are employed in each burst.

Brightness information potentials supplied on the column buses are 200 or 0 v, depending on whether the corresponding cells are to be OFF or ON. In the absence of a switching burst, the ionic switch remains in its zero current region. When a burst is present, however, the switch alternates between its negative and positive constant potential regions, clamping the potential at point D to the contemporary level at point X.

[7] For present purposes, the capacitance of a nonlinear capacitor is defined to be peak-to-peak charge, measured at panel operating conditions, divided by peak-to-peak voltage.

To determine the total allowable resistance, R, in series with each ionic switch, the time constant, RC_S, is set equal to $\frac{1}{3}$ of the time available for charging C_S in either direction, so that the indirect storage capacitor charges to within 5 per cent of the potential at point X. Since charging (or discharging) occurs only on alternate half cycles of the switching burst, the available charging time is 1.17 msec, so that R is $1.8\times10^6\ \Omega$. Of this, $3\times10^4\ \Omega$ is allocated to the suppressor resistor, R_S, which is associated with each ionic switch to prevent interactions between the storage circuits of separate cells in the matrix. Of the remaining resistance, $9\times10^4\ \Omega$ and $6\times10^4\ \Omega$ are allocated to the drivers connected to points X and Y, respectively. Because all 128 ionic switches in a row are energized simultaneously, the maximum source resistance for the row driver is then $6\times10^4\ \Omega$ divided by 128, or 470 Ω.

Screen Structure

Except for the electroluminescent capacitor, the various elements comprising the circuit of Fig. 3 are fabricated in sheets, or *fins*, stacked on edge behind a segmented electroluminescent panel, one 8-inch-long fin for each row of 128 screen cells. This arrangement has the distinct advantage of providing ample space for circuit elements for each cell. Because of the experimental nature of the model, the structure was made demountable, to permit modifications after initial assembly.

Demountability is achieved by providing a toothed structure on the edge of each fin, with one tooth for each cell of the screen. Contact between the conductively coated tooth and the corresponding segment of the electroluminescent panel is obtained by means of a helical metal spring. As shown in Fig. 6, these springs are held in position by a perforated retainer plate.

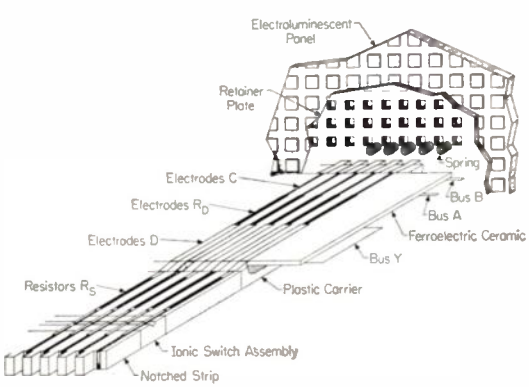


Fig. 6—ELF panel fin structure.

The various control and switching elements may be identified by reference to the fin shown in the figure. Capacitors C_{XA} and C_{XB} are formed on a 10-mil-thick ferroelectric ceramic sheet by electrodes C on one surface and excitation bus electrodes A and B on the opposite surface. All of these electrodes are 7 mils wide. Capacitors C_S are similarly formed by electrodes D and row bus electrode Y. Buses A and B, being common to the whole screen, are connected to similar buses of other fins at the edge of the screen. Bus Y is common only to the cells of a single fin, and is brought out at the edge of the screen individually for each fin as a distribution matrix bus. The decoupling resistors, R_D, are deposited directly on the ferroelectric ceramic, overlapping electrodes C and D.

The ceramic structure is mounted in a slot provided in a toothed plastic carrier, and electrically conducting paths are provided from the ceramic onto the carrier teeth. Suppressor resistors, R_S, are deposited on separate carriers of steatite in a manner similar to that employed for the decoupling resistors. These carriers are fastened to the plastic carrier and appropriate conducting paths are formed across the junctures.

Adjacent to the suppressor resistor carriers are the ionic switch assemblies. Two platinum-iridium strips, having cross sections of 5 by 15 mils and separated by 0.2 mils, form the electrodes of each switch. These are mounted on a steatite substrate. In order to prevent the ionic discharge from occurring along the substrate surface and to minimize leakage current, a V-shaped groove is provided in the substrate directly beneath the electrode gap.

The control fin is completed by the addition of a notched strip along the rear edge of the ionic switch assemblies. The notches of this strip are placed to coincide with the free ends of the switches. A conducting path is provided from each notch to the corresponding switch tab. When the array of fins is assembled, the notches form a set of channels into which soft conducting material is packed to provide the distribution matrix column buses.

Panel Construction

Because of limitations in ceramics technology, the 8-inch-long control fins for the experimental ELF display panel were fabricated from a number of one-inch-long segments. Considerations of process compatibilities dictated that these segments, in turn, be comprised of three separate assemblies, one containing the ferroelectric elements, one the suppressor resistors, and one the ionic switches. An advantage of this approach is that it permits testing of the individual parts prior to final assembly to determine that they will properly fulfill their respective functions in the completed device.

Throughout this section, reference to Figs. 3 and 6 will aid the reader's comprehension of the descriptions.

Ferroelectric Assemblies

Ferroelectric ceramics having the required electrical nonlinearity and loss characteristics were specially fabricated for this application in the form of flat 10-mil-thick wafers, 0.6 by 1.0 inch.[8] Vapor-deposited silver is employed for the electrode patterns on both faces of

[8] These were supplied by the Erie Resistor Corp., Erie, Pa.

the wafers. The use of this electrode material results in superior nonlinear elements with lower electrical losses than would be obtained with other metals, such as gold or aluminum. A potential problem in the use of silver, that of surface migration, is overcome by the protective coating applied in a later stage of processing.

The remaining elements located directly on the ferroelectric ceramic wafer are the decoupling resistors R_D. A filled phenolic composition is applied by a squeegee technique to form these elements.[8]

In order to facilitate electrical connections to the *A*, *B*, and *Y* buses, leads are attached to the corresponding electroded areas of the ferroelectric ceramic wafer. This is accomplished by stretching 3-mil-diameter wires in contact with each of the three buses and applying a coat of epoxy resin to that surface of the ceramic wafer. Curing of the resin secures the wires in reliable permanent contact to the electroded areas. This technique is considerably easier to employ than one utilizing a conductive adhesive, since it is not necessary to confine the adhesive to the 7-mil-wide electroded area. At the same time, it provides the necessary corona and silver migration inhibition for the surface of the ferroelectric. The several stages in the processing of the ceramic are shown in Fig. 7.

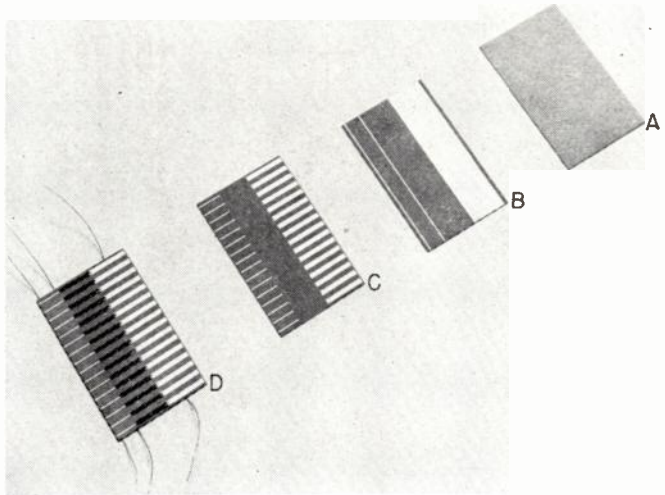


Fig. 7—Ferroelectric ceramic fabrication: A—ceramic; B—bus electrodes; C—electrodes *C* and *D*; and D—decoupling resistors and bus leads.

Completion of the fabrication of the one-inch-long ferroelectric assembly is accomplished by laminating the ferroelectric ceramic to a carrier as shown in Fig. 8. The carriers employed are a toothed structure containing a slot for the ceramic and provided with notches on each end for the lead wires. An injection-molded, fiberglass-filled polycarbonate resin was chosen for this part,[8] primarily because of its superior match to the coefficient of thermal expansion of the ceramic, as compared to other plastic materials. The ceramic is secured in the carrier slot by an adhesive. Narrow stripes of vapor-deposited metal form bridging connections from the electroded areas of the ceramic to the faces of the corresponding carrier teeth. On the *C*-electrode edge of the carrier a "stamp pad" technique was employed to continue these conducting paths onto the ends of the teeth with air-drying silver paint. The bridging connections are strengthened by a final protective coat of epoxy resin on the exposed face of the ferroelectric.

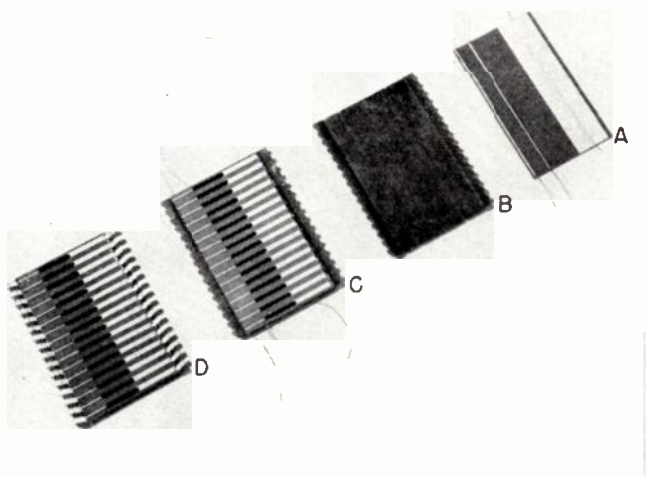


Fig. 8—Assembly of a ferroelectric ceramic to a plastic carrier: A—ferroelectric ceramic with leads; B—carrier; C—lamination; and D—bridging connections.

The completed ferroelectric assembly was tested to verify its performance under actual operating conditions. In this test, appropriate ac and bias voltages were applied to the *A* and *B* buses. Each tooth on the *C*-electrode edge of the carrier was terminated in a capacitance to simulate the load of the electroluminescent element; dc control potentials were then applied to the teeth along the *D*-electrode edge of the assembly, and performance was judged by measuring the ac voltages appearing across the dummy loads. In addition, a breakdown test was performed on each one-inch assembly by applying ac and dc voltages somewhat in excess of operating values. Although uniformity of performance from element to element and from one assembly to another was less than desired, the breakdown testing showed virtually no defective assemblies among the 1000 pieces that were fabricated.

Ionic Switch Assemblies

Each ionic switch assembly is fabricated from two mirror halves. As shown in Fig. 9, beveled steatite carriers are employed as supports for the platinum-iridium electrodes. The fabrication process begins with the attachment of 16 lengths of metal ribbon to a number of one-inch-long steatite carriers. The resulting array is then cut apart to form the subassemblies shown in the figure. By means of surface grinding and lapping, a reference plane common to both the carrier and the electrode ends is established on each subassembly. Subse-

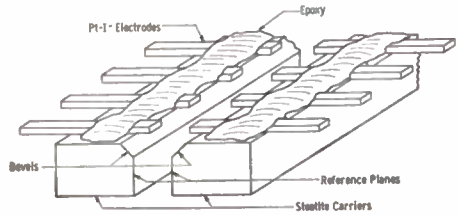


Fig. 9—Ionic switch assembly detail.

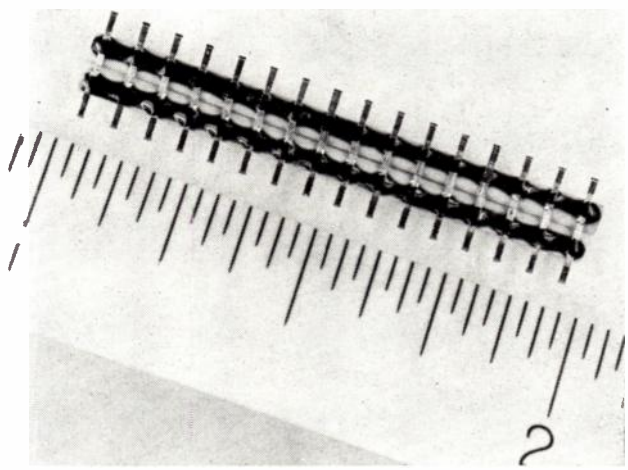


Fig. 10—Completed ionic switch assembly.

quent electropolishing removes any remaining burrs and results in the depression of the electrode ends by 0.1 mil below the reference plane. When two subassemblies are placed with their reference planes in contact, the desired 0.2-mil spacings between electrodes are obtained. Capillary action is used to convey liquid adhesive along the reference planes to bond the two steatite carriers. A typical completed assembly is shown in Fig. 10.

After a short period of break-in operation, each ionic switch was tested under panel operating conditions. In this test, the element was connected in series with a capacitor to simulate the decoupling capacitor of the cell equivalent circuit. Performance of each switch was determined by applying standard brightness information potentials and switching bursts to the circuit. Stored potentials appearing across the capacitor were sensed by an electrometer and automatically recorded. An assembly of 16 ionic switches was considered acceptable if the potentials stored by each element did not deviate from the desired values by more than 20 v in 90 per cent of the storage periods.

Including the technique development period, the total yield of acceptable ionic switch assemblies (*i.e.*, assemblies of 16 acceptable switches) was 63 per cent. In the fabrication of the last 10 per cent of the assemblies, however, the yield improved to 87 per cent. This last figure implies that the yield of acceptable individual switches is greater than 99 per cent.

Eight-Inch Control Fins

To facilitate final assembly of the panel, eight ferroelectric, suppressor resistor, and ionic switch assemblies are combined into a single structure eight inches long. This fin, shown in Fig. 11, serves for an entire row of 128 cells and can be installed in the panel as a unit. To make the fin, the eight ferroelectric control assemblies are joined end-to-end by epoxy resin. Three 10-inch lengths of wire are placed in the slots in the plastic face of the structure to serve as common connections for the *A*, *B*, and *Y* leads of each one-inch segment. After the addition of the suppressor resistors,[8] the ionic switch assemblies, and an eight-inch-long notched plastic piece, bridging connections are established between the various parts by means of conductive epoxy resin.

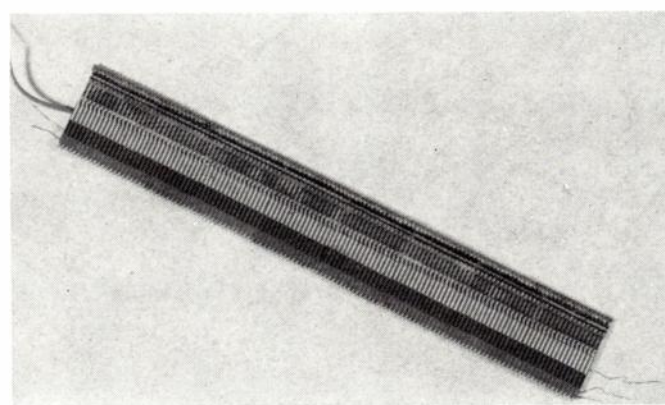


Fig. 11—8-inch control fin.

Electroluminescent Plate

The electroluminescent plate for the experimental panel is an adaptation of the conventional phosphor-in-plastic construction. Flat pyrex glass forms the transparent support. A tin oxide conductive coating serves as the common electrode, *N*, for all cells of the panel. In order to improve the breakdown and dc leakage properties of the electroluminescent layer, a 1-micron-thick film of magnesium fluoride is deposited over the tin oxide coating. A sufficient number of coats of electroluminescent phosphor suspended in polyvinyl chloride acetate lacquer are then applied to produce a layer approximately 30 microns thick. For further dc leakage protection, this is covered with a coat of clear lacquer approximately 1.5 microns thick. Application of an electrode pattern of vapor-deposited aluminum, consisting of 8192 squares 50 mils on a side, completes the plate. Its appearance is shown in Fig. 12.

The plate was tested for both brightness and leakage by contacting 8-by-8-element groups. Brightness was measured at 400 v peak-to-peak, 400 cps; in addition, a higher voltage was applied to assure adequate breakdown strength. Dc leakage was evaluated at 200 v dc, with an ac potential of 140 v peak-to-peak, 400 cps,

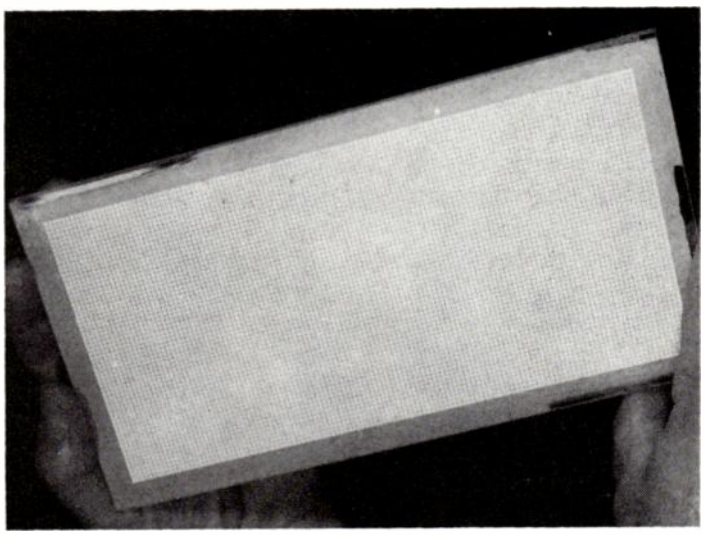


Fig. 12—4-by-8-inch electroluminescent plate.

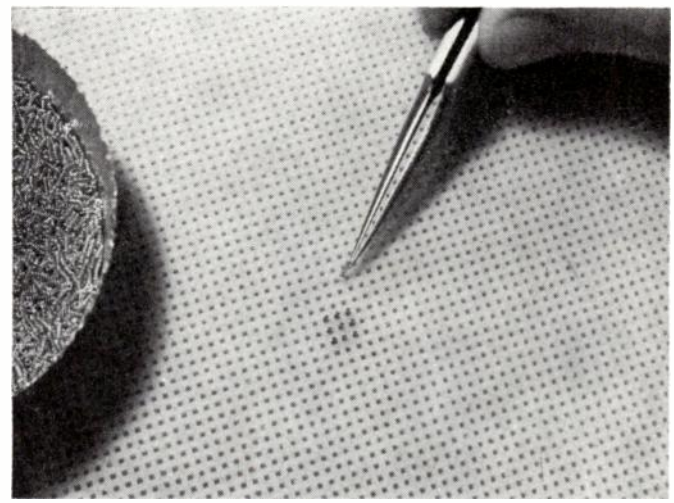


Fig. 14—Insertion of helical contact springs into a silastic retainer plate.

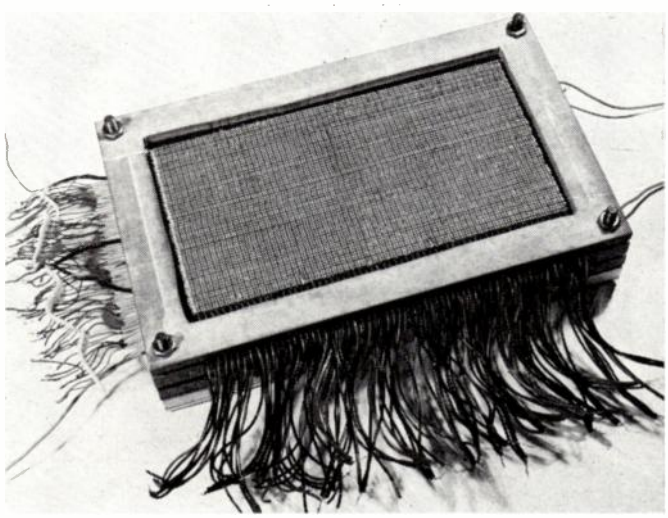


Fig. 13—Rear view of panel with 8-inch controls fins and X-bus leads in position.

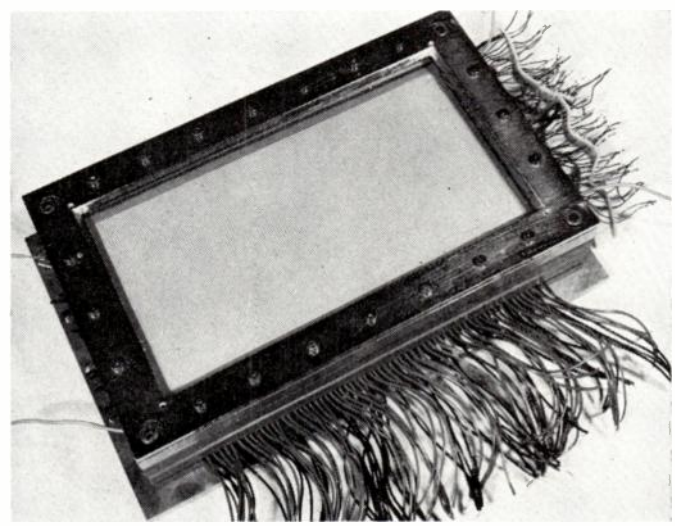


Fig. 15—Front view of completed ELF display panel.

superimposed to simulate conditions of actual screen operation.

Final Panel Assembly

The electroluminescent plate and 64 eight-inch control fins are assembled in a metal frame. To begin the assembly process, a glass plate and the retainer plate for the helical springs are placed at the front of the frame. The retainer plate is of cast silastic and contains square holes to accept the teeth of the control fins. The control fins are stacked into the retainer plate to form the structure shown in Fig. 13. Along both of the 4-inch edges of the frame, two metal strips, separated and clamped by resilient insulating material, contact the A and B bus leads of the control fins. The Y bus leads are insulated and similarly clamped in place.

The figure shows the set of 128 channels, each 4 inches long, in the face formed by the notched plastic strips mounted on the ionic switch assemblies. These channels are each packed with soft aluminum foil, on top of which is placed a bare wire lead to establish the corresponding X bus connection. The remaining depth of the channels is packed with soft insulating material, and a 4-by-8-inch metal pressure plate is placed in position over the structure.

The frame is next inverted, its front flange removed, and the glass plate taken out. The exposed surface of the silastic retainer plate is then loaded with helical contact springs, Fig. 14, and the electroluminescent plate is placed in contact with the springs. Two additional clips secured to the frame provide contact to the common tin oxide electrode. A protective plate of tempered Pyrex glass is positioned over the electroluminescent plate. Finally, the front flange is replaced, and the frame is tightened to insure contact by all of the helical springs to the respective electrodes of the electroluminescent plate. The completed device is shown in Fig. 15.

A hermetically-sealed capsule houses the experimental

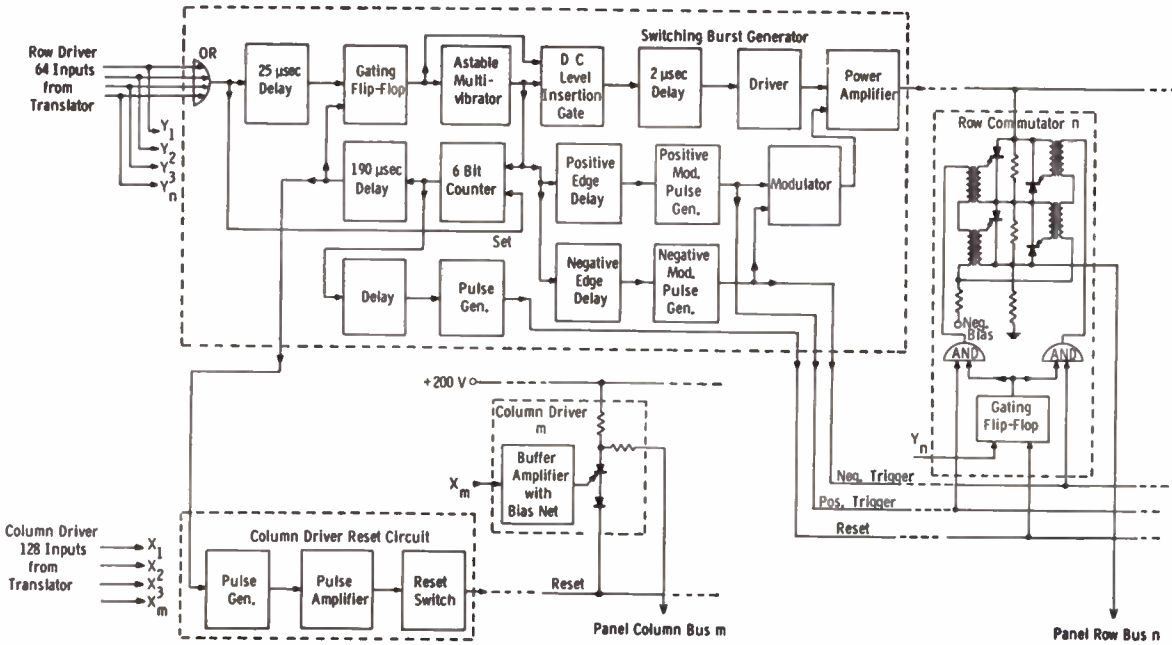


Fig. 16—Block diagram of row and column driver circuitry.

ELF display panel in order to protect against the effects of a possibly humid or dusty ambient. The controlled environment insures against premature permanent degradation of the electroluminescent and ionic switch elements. In addition, information storage time is not reduced in humid weather by the effects of increased surface leakages within the screen structure.

Peripheral Circuitry

Excitation, bias, brightness information, and switching signals for the experimental ELF display panel are provided by compact auxiliary equipment. Solid-state devices are employed exclusively in order to conserve space and to minimize power requirements.

Bias potentials for the panel are obtained from dc supplies of conventional design. An oscillator-amplifier circuit is employed to furnish the 400-cps excitation voltages. Special requirements placed on this supply by the high-capacitance nature of its load are considerably reduced by partially resonating the panel.

The translator supplies inputs to the 128 column and 64 row drivers in the form of 10-v, 10-msec pulses. In response to these signals, the drivers generate brightness information potentials and switching bursts of the amplitudes and waveforms required by the display panel. A block diagram of the system employed for this purpose is shown in Fig. 16.

A single generator supplies the switching burst of Fig. 5 when a signal appears at any one of the 64 row driver inputs. This burst is transferred to the proper row bus by one of the 64 row commutators. These are enabled by the row driver inputs and reset by the switching burst generator.

Approximately 30 msec prior to the start of the switching burst, the column drivers corresponding to the ON cells in the screen row to be written are triggered from the quiescent state (+200 v output) to the ON state (0 v output) by pulses at their respective inputs. In the absence of an input pulse, a column driver remains in the quiescent state. After the termination of the switching burst, all 128 column drivers are reset to their quiescent state by the column driver reset circuit, triggered from the switching burst generator.

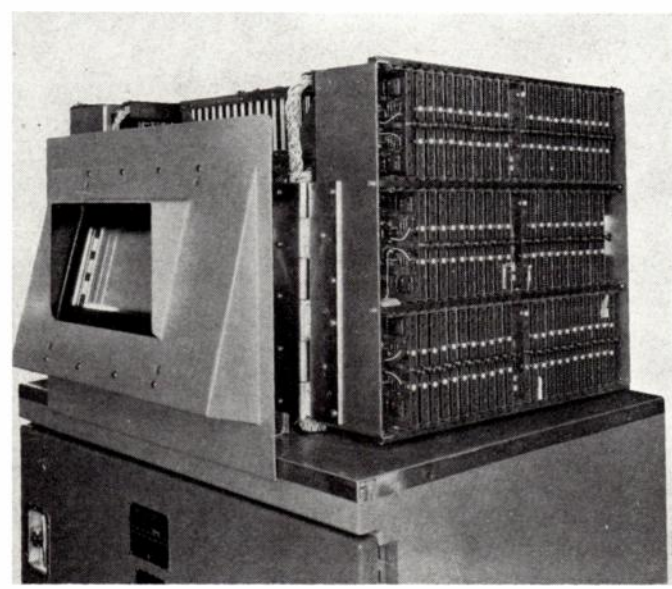


Fig. 17—ELF display cabinet with cover removed.

The screen capsule, drivers, and power supplies are packaged in the cabinet shown in Fig. 17. The driver cards are stacked directly behind the display panel in the upper section of the cabinet to minimize the length

of the column and row connections. All power supplies are located in the base. The target word source, translator and control equipment are combined in a separate console.

Performance

As noted in the Introduction, the experimental system was built to provide more complete information on the feasibility of the ELF approach to large screen status display. The system represents a step in development toward eventual construction of a prototype 10-foot-square panel. Due to its experimental nature, numerous modifications have been made in the system in the course of evaluation. Certain general conclusions are possible from data accumulated to date.

In confirmation of the over-all system design, the experimental ELF panel does display the target information received from the translator. Fig. 18 is a photograph of the screen in operation. The detailed behavior of the panel has been evaluated with respect to the following:

Highlight Brightness

The screen was designed to operate at supply potentials of $V_A = 400$ v rms, $V_B = 200$ v rms, $V_{AA} = -200$ v dc and $V_{BB} = 400$ v dc; all of the fins were tested under these conditions before assembly into the screen. After assembly, however, it was found that the supply voltages had to be considerably reduced to avoid internal sparkovers. Breakdown in the screen could generally be traced to an overflow of conductive epoxy, which reduced the spacing between the excitation buses.

A set of reduced operating conditions was established which avoided the danger of sparkover but which also considerably reduced the highlight brightness of the display. Under these conditions, the brightness is no greater than 2.8 foot-lamberts, whereas the design value had been 5 foot-lamberts. Tests showed that the design figure would be achieved if full excitation could be applied.

Contrast

There are two different contrast figures which are of interest. One is the ratio between the ON and the OFF brightnesses of a given area of the screen. The other is the ratio between the brightness of an ON area and an adjacent OFF area of the display. These numbers will be generally somewhat different due to light scattering and to adjacent cell interaction within the ferroelectric ceramic. In the experimental system, the best contrast between an area ON at 2.8 foot-lamberts and an adjacent OFF area was approximately 25:1. Visually this appeared to be adequate for target display, but the contrast is lower than would be desired for good gray scale presentation. The reduction in contrast from the design value of 50:1 is primarily traceable to the reduced operating conditions, although there is some evidence that the switching elements are not providing the full 200 v control potential range.



Fig. 18—Typical target displayed by the experimental panel.

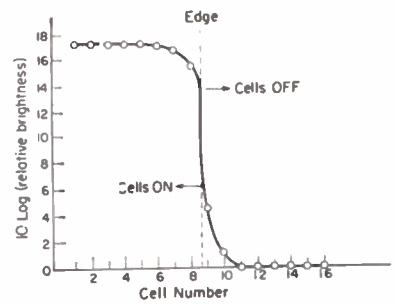


Fig. 19—Brightness distribution across an image boundary (experimental).

Resolution

If resolution is defined as the largest number of lines which may be discerned on the screen without regard to contrast between lighted and unlighted bars, then the experimental model evidenced its maximum possible resolution of 16 lines per inch. However, electrical interaction between adjacent cells and optical halation tend to degrade the crispness of target outlines. Fig. 19 shows the light distribution across a boundary between ON and OFF cells.

Faulty Cells

Since this was the first attempt at a moderately large ELF array, there was considerable interest in the number, and visual effect, of faulty cells. A count made after 25 hours of screen operation showed the failures listed in Table I. While the total number of failures represents only 1.7 per cent of the cells, the visual effects are not negligible. The most annoying blemishes are those due to cells which remain ON at all times. Cells which are always OFF are noticeable only when they occur at a critical point in a target figure. While this small percentage of cell failures does not significantly reduce the target readability, it does disturb the viewer who looks at the screen for the first time.

TABLE I

Fault	Number of Cells
Open Contact Between Ferroelectric Control Structure and Electroluminescent Plate	100
Misregistration Between Ferroelectric Control Structure and Electroluminescent Plate	18
Ionic Switches Not Firing	12
Poor Contacts Within the Ferroelectric Control Structure	10
Ionic Switches Shorted	3
Total Faults	143
Total Cells	8196
Faults Percentage	1.7

Uniformity

The brightness-vs-control-potential characteristic for an ELF cell tends to saturate at the highlight value. This reduces the visual effect of cell-to-cell nonuniformity in the ON condition. Nonuniformity in OFF brightnesses is masked by the ambient light level. When breakdown forced operation of the panel considerably below saturation brightness, cell-to-cell nonuniformities were apparent. No quantitative measurements were made of this effect, but it is evident that improved uniformity is highly desirable. This can be achieved by better control in the fabrication of the array.

Storage

During the first 70 hours of system operation, the image storage capabilities of the screen were excellent and frame-to-frame flicker was negligible. If a target configuration was written on the screen and the scanning system was then disabled, negligible image degradation was experienced for times up to 5 minutes.

As testing continued, however, the storage capabilities of the screen became progressively worse until frame-to-frame flicker was noticeable. Electrical tests carried out from external access points indicated that the ionic switches had developed excessive leakage. The screen was disassembled and it was found that this leakage was attributable to decomposition products of silicone vapor from the silastic parts of the panel which had deposited on the ionic switch electrodes. Greater care is being taken in the selection of materials for use in future models.

Write-Erase Performance

Before leakage became a problem, the rewrite between successive frames was unnoticeable (except on faulty cells). However, it appeared that two scan cycles were needed to complete a change in the target pattern. The previous information was erased in one scan, but newly written targets did not reach full brightness until the second scan cycle.

Conclusions

The 8192 Cell ELF system represents one of the most ambitious multicell display projects completed to date; the experimental panel has a component density exceeding two-million elements per cubic foot. The completion of an operating model having less than 2 per cent faulty elements illustrates that the critical interconnection problem has been successfully met, if not completely solved, in the ELF array.

Under the reduced operating conditions dictated by breakdown considerations, the highlight brightness is 2.8 foot-lamberts. The measured contrast ratio of 25:1 is adequate for target character display but must be improved for adequate gray scale rendition. Cell-to-cell uniformity is degraded by the reduced operating conditions but remains adequate to present entirely intelligible target patterns. The model is scanned at a rate which will permit the 10-foot-square panel to be rewritten in 5 seconds. Image storage times in excess of 5 minutes were obtained before the ionic switches were contaminated.

The deficiencies which are apparent from evaluation of the model do not result from theoretical limitations of the ELF approach. Rather, they accrue from mechanical difficulties in the complex panel structure. Better mechanical design and improved quality control in the fabrication processes should result in a panel with a highlight brightness of 5 to 10 foot-lamberts, contrast exceeding 50:1, excellent cell uniformity, and less than 1 per cent cell failures. The construction of another panel, based on an improved design, is now in progress.

Acknowledgment

The authors would like to thank the many people who have been active in the development and fabrication of the experimental display system. B. R. Canty and A. A. Schwenkler were responsible for panel fabrication, T. Hamburger and Dr. H. L. Cox designed the peripheral equipment, and Dr. W. J. Harper developed the electroluminescent panel. Z. L. Collins and G. R. Brainerd of the Westinghouse Electronics Division were responsible for the system coordination. The significant contributions of the Erie Resistor Corporation are gratefully acknowledged.

Duplexing and Switching with Multipactor Discharges*

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Summary—**Multipactor discharges in high vacuum are employed as switching mechanism for high-power microwave duplexers and voltage controlled switches. The devices described handle peak powers up to 5.5 Mw at nanosecond switching speed. Further characteristics include freedom from spike leakage and practically instantaneous recovery times. A survey is given of the underlying multipactor theory. Developmental *S*-band multipactor duplexers and switches are described. Their advantages, limitations and potential improvements are discussed.**

Introduction

THE SECONDARY electron resonance phenomenon, commonly known as multipactor, has been known for many years. It was first described by P. T. Farnsworth [1], who intended to use it for electron beam amplification. Later, excessive loading effects in klystrons and other microwave high-power tubes were explained by the multipactor phenomenon [2]–[5]. Extensive studies of the multipactor discharge have been made by E. W. B. Gill and A. von Engel [6], G. Francis and A. von Engel [7], K. Krebs and H. Meerbach [8], A. J. Hatch [9]–[12], H. Tamagawa [13] and Fu Fang [14]. In addition to these, special aspects of the phenomenon have been described, among them nonlinear properties [15], [16] and the distribution of electron density and velocity [17]. Experimental investigations described in these references were carried out in the 10-Mc and 80-Mc regions as well as at *S* band.

A multipactor discharge consists of electrons in high vacuum which are driven back and forth between two electrodes by an RF electric field. This electron motion is in synchronism with the applied electric field. In the simplest case, each transit occurs in one half RF period, but higher order modes are also possible where one transit requires any odd number of half RF periods. Upon impact of the electrons, secondary electrons are emitted to reconstitute the discharge. It is evident that such a discharge may sustain itself if the secondary emission ratio is larger than one and if the frequency, voltage, and gap spacing are such that synchronous motion is possible. The multipactor discharge, being dependent on the voltage, represents a voltage sensitive impedance. It therefore suggests itself to switching applications and duplexing.

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Consider, for example, an evacuated transmission type cavity providing reflectionless transmission at the frequency of operation. Let it be of the coaxial or reentrant type so as to provide a high electric-field gap suitable for multipactor to occur at high power level. The multipactor discharge impedance will load the cavity as well as detune it, thus causing most of the incident power to be reflected. This cavity performs the functions of a TR tube.

By application of a dc control voltage between the multipactor electrodes, the discharge may be quenched or inhibited. This mechanism may be exploited in a voltage-controlled high-power switch.

Prime advantages of multipactor duplexing and switching devices are their high speed, their practically instantaneous recovery, freedom from spike leakage, long life and high-power capabilities.

S-band duplexers and voltage-controlled switches will be described which employ the multipactor principle. These developmental devices are switching up to 5.5 Mw of peak power at switching times less than 10 nsec and yield isolation in excess of 20 db.

Theoretical Considerations

Three types of analyses, of successively increased complexity, prove helpful for the understanding of high-power multipactor discharges:

1) kinematic theory,
2) tight electron bunch theory, neglecting electron repulsion,
3) space-charge theory.

The kinematic theory provides a basic understanding of the multipactor at low discharge currents, strictly speaking, at the starting conditions. The second theory yields voltage-current relationships at intermediate discharge strengths, while the third attempts to predict discharge limitations due to space-charge saturation effects.

The kinematic theory consists of the solution of Newton's equation of motion for a single electron traversing the RF gap. The multipactor starting conditions are found by stipulating transit times of odd multiples of half RF periods and by observing phase stability. For the basic one-half cycle mode, the multipactor starting conditions are given by

the gap voltage amplitude $V_g = 5.4 \times 10^6 (d/\lambda)^2$ volts,
the electron impact energy $V_i = 0.4 V_g$ electron volts.

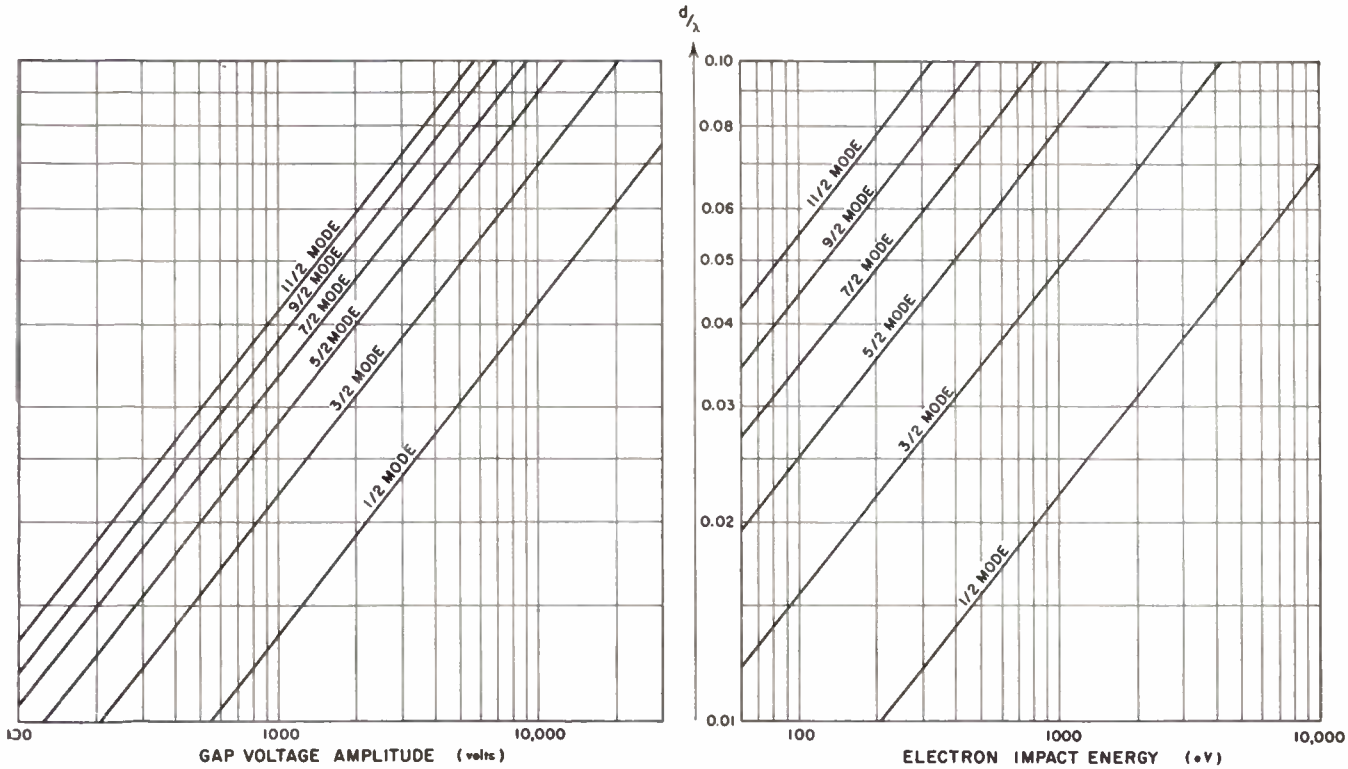


Fig. 1—Multipactor starting voltages for various gap lengths, d, as determined from kinematic theory.

These results, and the corresponding ones for higher multipacting modes, are plotted in Fig. 1. For a given gap length, d, and wavelength, λ, the operating conditions are confined to a horizontal line across the diagrams. The left-hand chart shows the discrete synchronism conditions (in order of descending mode numbers) as the driving power and thus the applied gap voltage is raised. The fundamental one-half cycle mode requires the highest voltage. Whether or not these intersection points really represent multipactor starting conditions depends on the secondary emission properties of the electrodes. The right-hand diagram shows the associated impact energies. Where they are such as to give rise to a secondary emission ratio larger than unity, the corresponding multipactor mode may be expected to occur.

Considerable work has been done in the past with small gaps, *i.e.*, $d/\lambda = 0.01$–0.015. In this range only the fundamental one-half cycle mode occurs. However, the discharges occur at relatively low levels; that is, gap voltages of the order of 1000 volts, incident power levels between tens of watts and tens of kilowatts, depending on cavity parameters. For high-power operation, it was found necessary to choose larger gaps, for example, $d/\lambda = 0.05$. Here, several modes may occur.

The kinematic theory furthermore predicts the phenomenon of phase focusing, meaning that electrons of a variety of initial time-phase relations with the electric field are focused during subsequent traversals into an unique time phase, the steady-state or synchronous phase. Phase focusing leads to the concept of a tightly bunched electron sheet traversing the gap.

The build up of the discharge follows a rapid exponential. If N_0 chance electrons are available at the start, and if the secondary emission ratio δ is larger than unity, $N_0\delta$ electrons will participate during the second half cycle, and, after m half cycles, there will be $N_0\delta^m$ electrons. For S band, the electron population will increase ten orders of magnitude during seven cycles, or approximately 2.5 nsec if we assume $\delta = 5$. The number 10^{10} corresponds to the number of electrons observed in a saturated discharge. Since the rise time of most radar transmitter pulses is much larger than 2.5 nsec, the discharge may follow the transmitter pulse "instantaneously," with the result that a multipactor duplexer is free from any spike leakage.

The kinematic theory fails to describe multipactor behavior as the gap voltage is increased from the starting condition and as the electron space-charge becomes appreciable. A space-charge theory has been developed [18], where an infinitely thin charge sheet, as predicted by the phenomenon of phase focusing, is taken into account. Again the equation of motion can be solved exactly, and the multipactor conditions can be described as a function of participating charge, *i.e.*, the discharge current. It turns out that the charge sheet decreases the

effectiveness of the electric field. In other words, higher discharge current requires increased gap voltage in order to maintain synchronism. This phenomenon helps in providing dynamic range. However, this theory still fails to predict the maximum or saturation value of the discharge current.

The maximum value of the discharge current attainable is of prime interest for practical applications. It determines peak power performance and isolation achievable in a given circuit configuration.

The maximum value of discharge current is determined in the third type of analysis, where space-charge debunching effects are considered [18].

The electron sheet is assumed to have finite thickness in the longitudinal direction. As it traverses the gap, space-charge repulsion increases the sheet thickness as well as the lateral extent of the cloud. This lateral diffusion causes electrons to miss the opposite electrode, and may be described quantitatively by an electron loss factor defined by the number ratio of electrons starting a traversal to electrons completing the traversal on the opposite electrode. Fig. 2 shows this loss factor as a function of the discharge current.

Much more important is the longitudinal space-charge spreading. It causes a dispersion of electron arrival times. Thus, many electrons arrive either too early or too late, and their secondaries cannot effectively participate in the discharge. Again, the situation may be quantitatively expressed by an electron loss factor as seen on Fig. 2. The total electron losses occurring each transit must be counterbalanced by the electron gain through secondary emission. The maximum possible discharge current occurs when the electron loss just equals the available secondary emission ratio. Beyond this point, the discharge collapses.

The space-charge theory has succeeded in predicting experimental discharge strengths within a factor of two. A more accurate theory would have to consider velocity distributions.

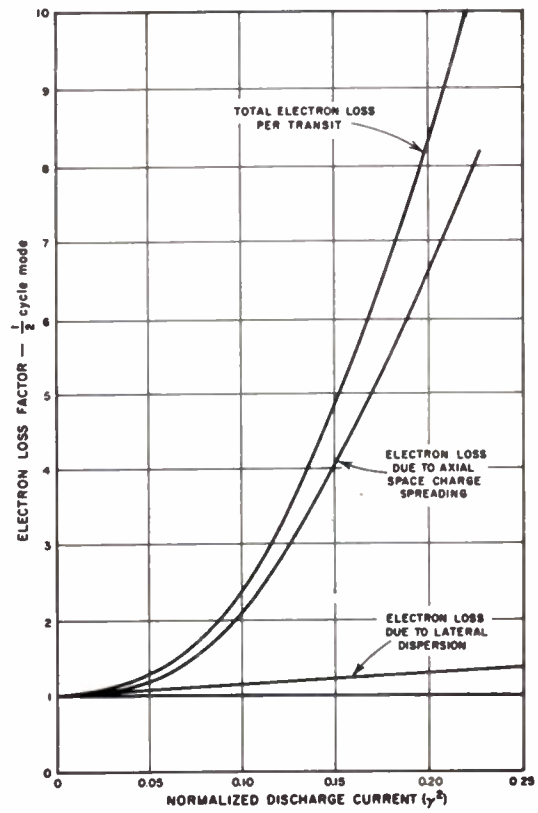


Fig. 2—Electron loss per transit as a function of discharge current.

A Developmental Multipactor Duplexer

The prime problem in the development of practical multipactor switching devices was that of achieving strong, dependable discharges at high power levels. The main parameters involve the choice of secondary emission material, surface treatment, gap spacing and vacuum processing.

Prior work on high density secondary electron emission has been published by V. K. Zworykin [20], *et al.*, and by D. A. Jenny [21]. From among many experiments it was found that an alloy of silver and magnesium works best. Gap spacings between 0.2 and 0.25 inch were used for operation at 2.8 kMc. The cavities were evacuated using ion pumps. Bakeout proceeded at 550°C for several hours. It was terminated when the pressure was below 10^{-7} mm Hg. After cooling, the vacuum achieved was better than 10^{-8} mm Hg.

A small hole in one multipactor electrode allows convenient monitoring of the discharge current using an electron collector (Faraday cup). Under the assumption of a constant current density throughout the multipactor discharge, one may obtain a measure of the total discharge current. On this basis, the best cells yielded an rms current of 20 amperes. This corresponds to a density of 7 amperes (rms) per cm², and compares favorably with oxide cathodes. The number of electrons participating in the discharge is approximately 4×10^{10} electrons, and the volume density is 3×10^{10} electrons per cubic centimeter.

Fig. 3 shows a sketch of an experimental multipactor cavity that operates up to 3.5 megawatts incident power. The coaxial cavity is machined out of a copper block. Electrical connections to the input and output waveguides occur through symmetrical irises and ceramic vacuum windows. The cavity cover, shown removed from the cavity, is assembled by a heli-arc welding process.

A photograph of this cavity is shown in Fig. 4. The cavity is equipped with a klystron-type ring tuner, of which the flexible bellows are visible. The electrodes and the tuner are water cooled, the visible plastic hoses providing water connections. Further details include

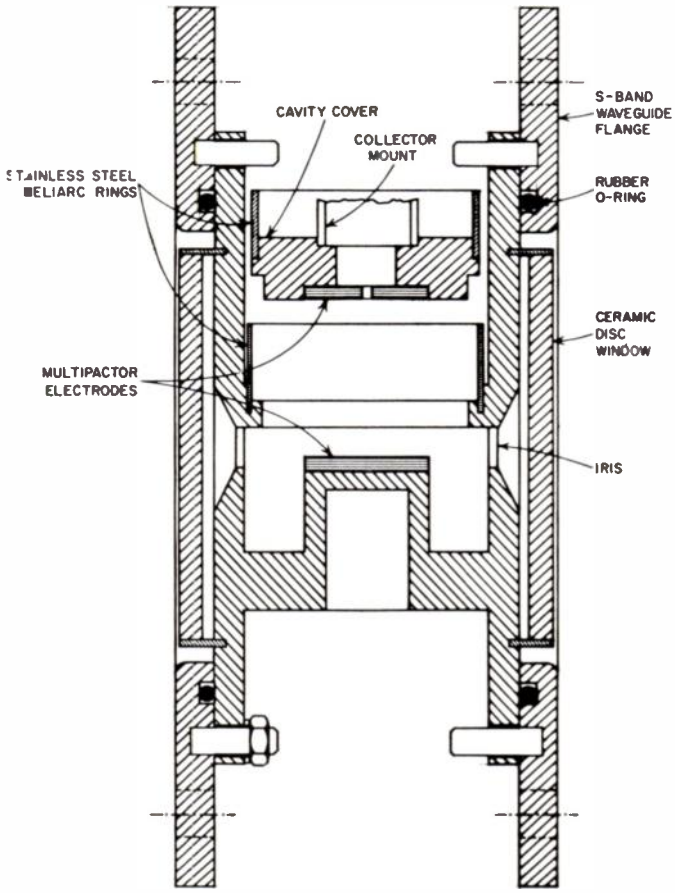


Fig. 3—Sketch of *S*-band multipactor TR cavity.

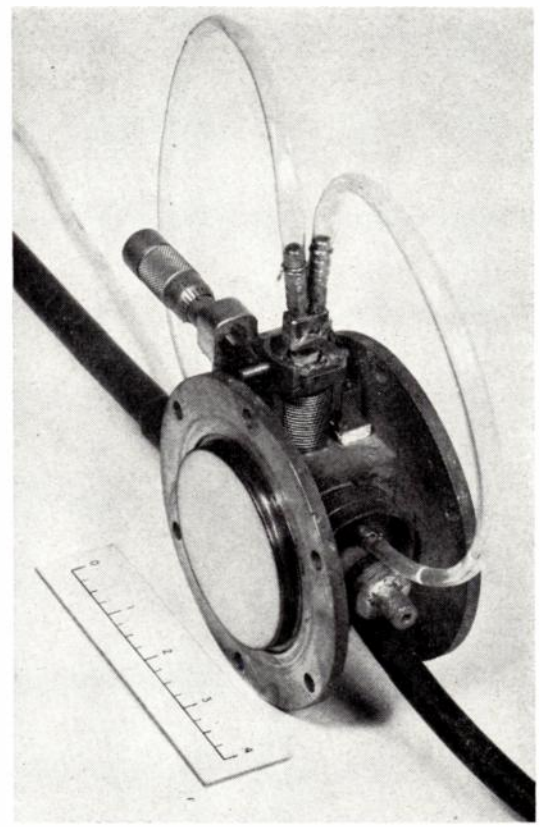


Fig. 4—Experimental *S*-band TR cavity.

the electron monitoring collector and the pump-out tubing.

Test results are shown in Fig. 5, which represents a plot of transmitted power versus incident power. The straight 45-degree line is the unity transmission characteristic applicable in the absence of discharge, in particular, for very low power levels. The points shown represent experimental transmission measurements in the presence of discharge. For the cavity under discussion, the discharge starts between 50 and 100 w peak and exists up to 3.5 Mw peak incident power. The amount of isolation achieved increases for higher powers, reaching 23 db at the upper limit.

The amount of power dissipated by the discharge has been measured calorimetrically to be 250 kw, which represents an "arc loss" of 0.35 db. The recovery time is extremely short, of the order of one-half RF cycle. Measurements have been performed which confirm that, for all practical purposes, the TR cavity becomes fully transmitting as soon as the high power pulse disappears. The resolution of the instrumentation available for this work was 10 nsec.

The life performance of this type of multipactor tube appears to be good. Life tests over 1000 hours have shown no degradation in electrical characteristics.

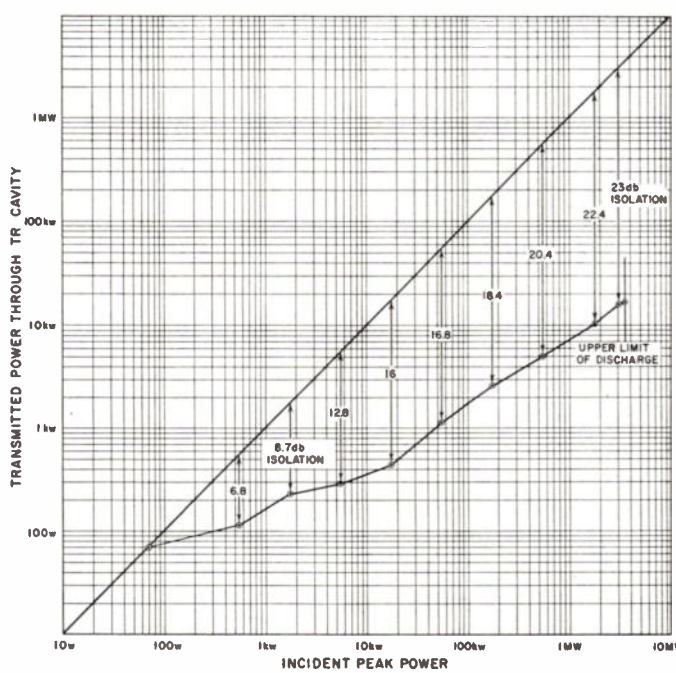


Fig. 5—Test results of developmental TR cavity.

A balanced multipactor duplexer has been built for which a dual TR tube as shown in Fig. 6 was built. Two cavities similar to that of Fig. 3 were machined out of a single copper block and connected to a common vacuum exhaust. The dual TR cavity is mounted between two side-wall hybrids to form a balanced duplexer configuration (Fig. 7).

The low-power characteristics of this duplexer are described by the following:

Frequency range	2650 to 3050 Mc (tunable)
Fixed bandwidth	1.5 to 2.5 per cent
Insertion loss	0.4 db
Voltage standing-wave ratio	1.2

Under high-power conditions, the cavities sustain discharges up to 5.5 Mw of incident power, and the duplexer provides 46 db of transmitter-receiver isolation.

A Developmental Multipactor Voltage Controlled Switch

The objective of this effort was to provide a dc voltage controlled multipactor switch. To accomplish this, the TR cavity design described earlier was modified so as to dc isolate one of the secondary emitting electrodes. The essentials of the cavity design are shown in Fig. 8. Input and output coupling irises, ceramic vacuum windows, and a ring tuner are shown. The break in the cavity wall, to allow dc isolation of one electrode, is on the diameter of the electrode, making it the input plane of a coaxial filter. The highly attenuating reactive filter is associated with the cavity design to prevent serious loss of power through the break in the cavity walls. The filter is a choke design, one which presents a well defined equivalent short-circuit plane which does not move relative to the filter input plane over a large frequency range. Because it was found necessary to use at least two choke sections in the filter, the second section was also designed to form the ceramic holder, making the over-all design compact and sturdy. Note that the filter center conductor is hollow, and that a coaxial system carries cooling near the electrode.

Test results are shown in Fig. 9. The transmission through the cavity is plotted as a function of the incident peak power level. In the absence of control voltage the discharge starts at approximately 50 w and increases in strength up to an incident power level greater than 2.5 Mw. At the upper limit the isolation is 20 db, and essentially all the incident power is being reflected. The horizontal line shows the insertion loss through the cavity in the other operating state; that is, with sufficiently high control voltage to inhibit the discharge. In this case the insertion loss is 0.6 db.

Of interest is the cavity isolation as a function of control voltage for voltages between zero and the value re-

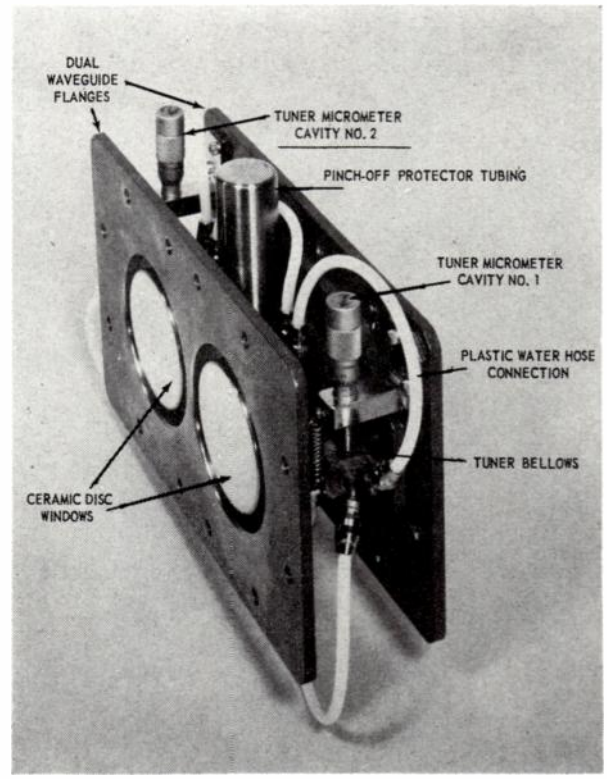


Fig. 6—*S*-band multipactor dual TR tube.

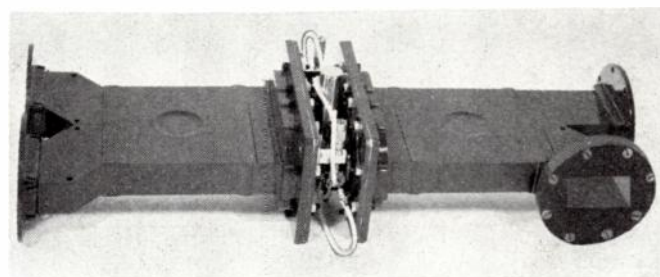


Fig. 7—*S*-band multipactor duplexer.

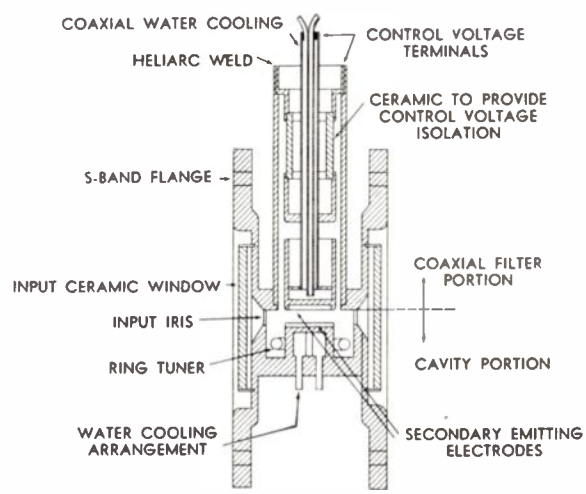


Fig. 8—Sketch of multipactor switch cavity.

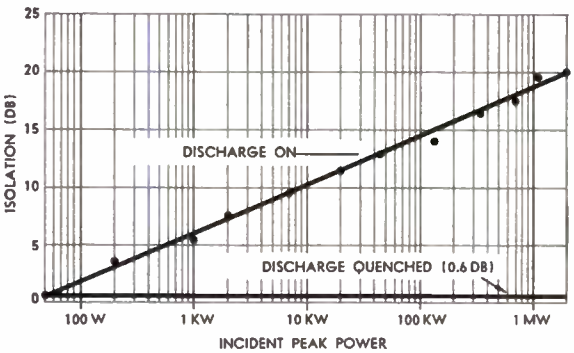


Fig. 9—Single-cavity transmission characteristics.

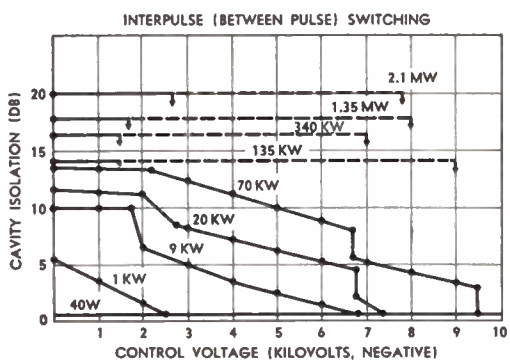


Fig. 10—Single-cavity isolation vs control voltage, interpulse (between-pulse) switching.

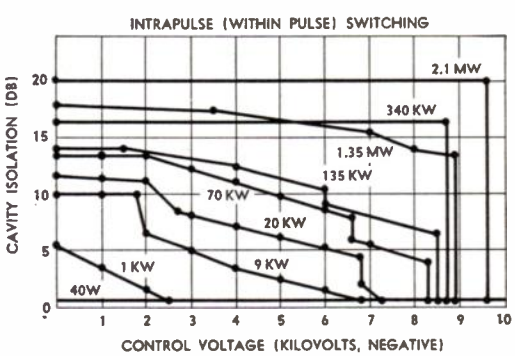


Fig. 11—Single-cavity isolation vs control voltage, intrapulse (within-pulse) switching.

quired to completely quench the discharge. These data are plotted separately in Figs. 10 and 11 for interpulse and intrapulse switching. In interpulse switching the control voltage is applied and exists over the full duration of the RF pulse. Intrapulse switching, on the other hand, implies changes in control voltage conditions within the RF pulse duration.

Consider first the case of interpulse switching. As can be seen from Fig. 10, the behavior as a function of power level changes at about the 100-kw peak power level. For higher power levels the transmission characteristic is abrupt as a function of control voltage; that is, the discharge is either on or off. Furthermore, it was found that the exact value of control voltage required to switch the cavity varied from pulse to pulse in what appeared to be a random manner. This is indicated by the dotted portion of the curves. For power levels around one kilowatt, the transmission characteristic is a smooth function of control voltage. For intermediate power levels, a combination of the previous characteristics is seen: for certain values of control voltage, abrupt jumps in the transmission characteristic are seen; for other ranges of the control voltage, smooth changes in cavity transmission occur.

In the case of intrapulse switching (Fig. 11), the behavior observed is identical for the low power range. Above 700 kw, the abrupt switching characteristic is again seen. However, for this case, as contrasted with interpulse switching, it was observed that the control voltage required to switch the discharge off was well defined. In other words, as the control voltage is raised from zero, little or no change in cavity transmission occurs until a critical control voltage is reached, at which time the discharge becomes completely quenched.

An interesting property of the intrapulse switching time at high input power levels is apparent from Fig. 11. Since essentially no switching takes place until the control voltage exceeds a critical value, the switching takes place in a shorter time than the rise time of the control voltage pulse. This point is verified experimentally; the measured switching time of the final developmental model was less than 10 nsec, whereas the rise time of the control voltage waveform was approximately 40 nsec.

The detailed behavior can be understood as follows: in the absence of space charge, *i.e.*, at very small currents, the simple kinematic theory predicts that there will be a discrete set of voltages for which synchronous electron motion is possible. Each mode corresponds to a mode characterized by a different number of odd multiples of the RF half period in the transit time. A more detailed analysis shows that the presence of space charge tends to decrease the electric field in the gap. At zero current a certain voltage will provide synchronism, but as the current in the discharge builds up, a higher and higher voltage is required to maintain synchronism. Each mode has a certain dynamic range of RF gap voltage over which the discharge operates and, in fact, the various ranges overlap. For example, for the cavity shown, at the lowest power (and hence the lowest RF voltage) for which a discharge appears, the discharge is operating in a long transit time mode such as the five-half-cycle mode. At a higher incident power level, it would correspond to the three-half-cycle mode. At the highest incident power level it would correspond to the one-half-cycle mode. Referring back to Figs. 10 and 11, it is probable that the abrupt jumps in isolation which occur for control voltages around 2 and 7 kv are related to mode changes in the total discharge current.

To produce a waveguide switch with two output terminals, a dual cavity was designed and fabricated for use between two 3-db, short-slot hybrid junctions, as shown in Fig. 12.

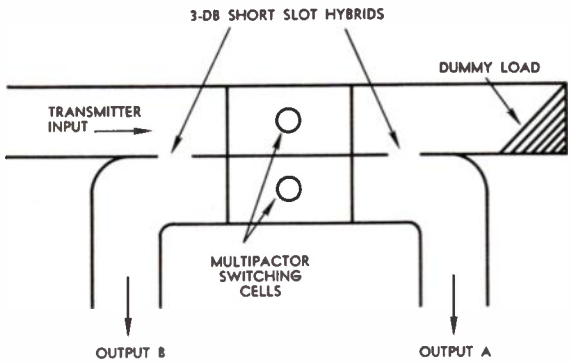


Fig. 12—Multipactor switching circuit.

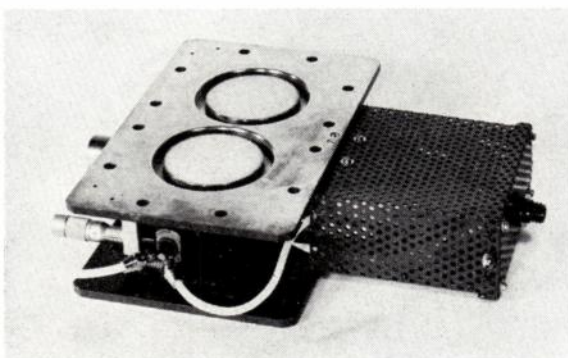


Fig. 13—Dual-switch cavity.

The circuit transfers power in the following manner: with zero control voltage, a multipactor discharge takes place in the cavities, causing the transmitter power to appear at output B. If a sufficiently high control voltage is applied, the discharge cannot take place. In this case the power is transferred to output terminal A.

The cavity assembly is shown in Fig. 13.

The dual cavity is tunable over the range of 2700 to 3000 Mc with an instantaneous bandwidth of 1 per cent. The electrical characteristics, measured at a frequency of 2800 Mc, a power level of 5 Mw peak, and 0.001 duty, are as follows:

ELECTRICAL CHARACTERISTICS OF WAVEGUIDE SWITCH

	Switch in Position A (Discharge Off)	Switch in Position B (Discharge On)
Input VSWR	1.10	1.14
Insertion Loss	0.5 db	0.6 db
Isolation to Unused Output Terminal	36 db	20 db

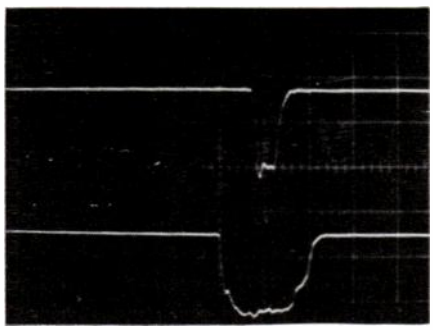
Oscilloscope photographs demonstrating intrapulse switching were taken with this model of the switch (Fig. 14). The time scale is 1 μsec/cm. In this test, a one-half microsecond control voltage pulse of -7 kv amplitude was applied to the cells. The control voltage pulse was located (in time) within the RF pulse. The input power was approximately 140 kw. The rise time of the oscilloscope was 40 nsec. Note that the discharge is quenched at the instant the control voltage is applied, and that it appears again during the decay of the control voltage pulse. Thus the transmitter power is switched from output terminal B to A and back to B again, all within the 2-μsec transmitter pulse.

The same time relationships are shown in Fig. 15, which demonstrates switching at 2.2 Mw peak power. Here, as in the previous case, during approximately the first third of the transmitter pulse the switch is in position B, because the control voltage is zero. Again application of control voltage switches the power to terminal A, but now when the control voltage is removed the switch remains in position A for the remainder of the RF pulse. What is happening is that the discharge will not start again, once it has been turned off, during the remainder of any RF pulse.

The explanation of this one-way-only switching phenomenon is as follows: at high operating power levels the discharge is initiated and reaches a steady state during the rise of the RF pulse, because only a few RF cycles are required to achieve a large discharge current through the multipactor mechanism. In the steady state, this large current is detuning the cavity to the extent that almost all of the incident RF power is being reflected. The small portion of power not reflected determines the cavity gap voltage, and hence the gap is at a relatively low voltage. When the discharge is quenched, the gap voltage will rise by orders of magnitude to a value determined by the full incident power. If the control voltage is now removed, the gap finds itself at too high a voltage to initiate a discharge, and remains quenched for the remainder of that RF pulse.

The power level beyond which the intrapulse switching can be accomplished in one direction only is a function of the cavity parameters. In particular, the gap spacing, the loaded Q and the R/Q factor set the exact power level which separates the regions of two-way and one-way-only switching. For the cavity described here, two-way switching could be accomplished only for power levels less than approximately 200 kw peak.

Measurements of switching times were performed on this final developmental model of the switch (using a Hewlett-Packard Model 185 sampling oscilloscope at power input levels of approximately 300 kw, 1 Mw, and 3 Mw. The specifications of the oscilloscope indicate a rise time of 0.7 nsec. Due to the nature of the measurement (that is, the sampling techniques), the oscilloscope tracings were subject to considerable time jitter, apparently due to pickup from electric fields in the area. As a result of this jitter, it was not possible to resolve the switching time to better than approximately 10 nsec. Changing the input power level did not result in any noticeable change in switching time. The switching time measured was the decay of the RF pulse at output terminal B with the application of the control voltage pulse. The switching time is probably on the order of a few RF cycles, which are 0.33 nsec long at a frequency of 3000 Mc.



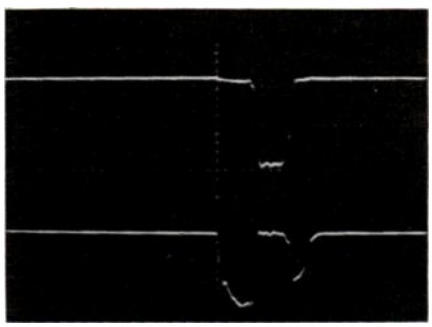
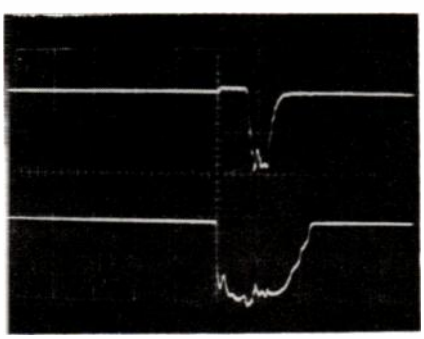


Fig. 14—Oscillographs demonstrating intrapulse two-way switching.



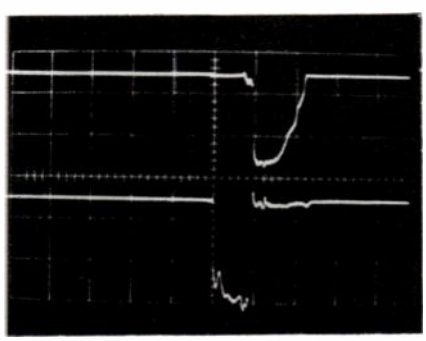


Fig. 15—Oscillographs demonstrating intrapulse one-way switching.

A theoretical analysis [19] (which is essentially the solution of the equations of motion), has been carried out for the multipactor in the presence of a dc voltage, for the small-current case. The results of this work show that as the dc voltage is increased, the RF gap voltage required for synchronism is increased. In the limit at the highest value of dc voltage under which synchronous transits can still occur, the RF voltage V_g necessary for synchronism has been increased by approximately 44 per cent. Good agreement between theoretical and experimental quenching voltages has also been found. The theory predicts a quenching voltage of 5.4 kv; the experimentally measured value was approximately 6.5 kv at the appropriate RF input power, *i.e.*, at the RF input power corresponding to the starting power for the one-half mode of operation.

Conclusion

Prime advantages of multipactor switching devices over conventional devices are:

1) Extremely short recovery time of the order of one-half RF period,
2) No spike leakage,
3) Long life of as yet undetermined limitation,
4) Low noise due to absence of gas (and residual ions),
5) High peak and average power capability.

Life tests performed on an early developmental model multipactor TR cell indicated no change in electrical characteristics at the end of 1000 hours.

A comparison of the present state of the art of multipactor duplexers with gas duplexers is afforded by Table I.

Furthermore, the development of a high power multipactor discharge has made possible an entirely new, voltage-controlled, high power switch since the multipactor may be quenched or inhibited by application of a dc control voltage. There is presently no other device available that has comparable characteristics.

The advantages available from multipactor duplexers presently have to be paid for with some drawbacks. The multipactor cavities are of relatively high Q (50–100), so that the bandwidth available is between one and two per cent. This has made it necessary to incorporate a mechanical tuning arrangement which may be objectionable in certain applications. The transmit insertion loss (arc loss) of a high power duplexer is also of importance and measurements have shown that the arc loss is approximately 0.35 db for $Q=125$ and ranges up to approximately 1.0 db if the Q factor of the TR cavities is lowered to 50.

It is of interest to estimate ultimate duplexer capabilities that could reasonably be expected from further development of the multipactor principle:

1) *Peak Power:* It is possible that the multipactor peak power performance can be increased through improved secondary emission surfaces. It also appears pos-

TABLE I
COMPARISON OF MULTIPACTOR AND GAS DISCHARGE DUPLEXERS

	Conventional Duplexer	Multipactor Duplexer
Active Medium	Discharge of Argon Gas with Water Vapor (Ionized Gas)	Electrons Synchronized with RF Voltage
Pressure	Several Millimeters of Hg	Hard Vacuum (10^{-8} mm Hg)
Recovery Time	10 μs to 100 μs	Approximately 1 RF Cycle (*i.e.*, 0.0003 μs at *S*-Band)
Bandwidth	Moderate to Wide (10 per cent)	Narrow to Moderate (2 per cent)
Operable Life	Several Hundred Hours	Expected to be in Excess of 5000 hours
Noise Contribution During Receive	Through Residual Ions in Gas	None
Presence of Spike Leakage	Yes	No
Arc Loss	Small to Moderate	Moderate
Cooling	Heat Generated Within the Gas Volume	Heat Generated on Electrodes Exclusively
	Cooling Difficult	Convenient Cooling

sible, through a drastic redesign of the TR cavities, to operate two multipactor discharges in series, which, in the first approximation, should quadruple the peak power capability and thus lead to a 20-Mw device.

2) *Average Power:* It is felt that multipactor devices offer great promise for high average power applications of the order of several hundred kilowatts. Since the heat of the arc-loss is generated exclusively on the multipactor electrodes rather than throughout a volume of gas as in a conventional duplexer, effective water cooling may be applied.

3) *Bandwidth:* Increasing the fixed bandwidth from the one to two per cent into the five to ten per cent range would go far in making multipactor devices more attractive. If one attempts to increase the bandwidth in a single cavity, as used in this program, one:

a) decreases the isolation,
b) decreases the peak power capability,
c) increases the arc-loss, and
d) decreases the receive insertion loss.

All but the last point are undesirable, and it becomes mandatory to search for some radically new circuit configurations. These might very likely consist of band-pass filter structures (or periodic structures) containing a plurality of multipactor discharges.

Multipactor duplexers should find application in high resolution radars employing high pulse repetition frequency and high average power. The voltage controlled switch is uniquely suited for channelling transmitter power into various antennas either on a pulse-to-pulse or on an intrapulse switching basis. It may find application also for high-power pulse shaping, for the generation of high-power nanosecond pulses and possibly for high-level RF modulation.

ACKNOWLEDGMENT

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IRE Standards on Solid-State Devices: Definitions of Superconductive Electronics Terms, 1962*

62 IRE 28.S1

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Critical Controlling Current (of a cryotron). That current in the control which just causes dc resistance to appear in the gate, in the absence of gate current and at a specified temperature.

Critical Current (of a superconductor). That current in a superconductive material above which the material is normal and below which the material is superconducting, at a specified temperature and in the absence of external magnetic fields.

Critical Magnetic Field (of a superconductor). That field below which a superconductive material is superconducting and above which the material is normal, at a specified temperature and in the absence of current.

Critical Temperature (of a superconductor). That temperature below which a superconductive material is superconducting and above which the material is normal, in the absence of current and external magnetic fields.

Control (of a cryotron). An input element of a cryotron.

Cryotron. A superconductive device in which current in one or more input circuits magnetically controls the superconducting-to-normal transition in one or more output circuits, provided the current in each output circuit is less than its critical value.

Gate (of a cryotron). An output element of a cryotron.

Normal (state of a superconductor). The state of a superconductor in which it does not exhibit superconductivity.

Example: Lead is normal at temperatures above a critical temperature. See *Superconducting.*

Persistent Current (in a superconducting material). A magnetically-induced current which flows undiminished in a superconducting material or circuit.

Superconducting. The state of a superconductor in which it exhibits superconductivity.

Example: Lead is superconducting below a critical temperature and at sufficiently low operating frequencies. See *Normal (state of a superconductor).*

Superconductive. Pertaining to a material or device which is capable of exhibiting superconductivity.

Example: Lead is a superconductive metal regardless of temperature. The cryotron is a superconductive computer component.

Superconductivity. A property of a material which is characterized by zero electrical resistivity and, ideally, zero permeability.

Superconductor. Any material which is capable of exhibiting superconductivity.

Example: Lead is a superconductor.

Trapped Flux (in a superconducting material). Magnetic flux which links with a closed superconducting loop.

Design of a Microwave-Frequency Light Modulator*

RALPH H. BLUMENTHAL†

Summary—**A device is described which intensity modulates a light beam at modulating frequencies in the microwave region. A high-Q re-entrant capacity-loaded coaxial-line resonator employing a properly oriented slab of uniaxial crystal of the dihydrogen phosphate variety as its dielectric medium is coupled to a microwave-frequency generator tuned to the fundamental cavity mode. A light path is provided through the resonator so that a beam of plane polarized light can pass through the crystal into a suitably oriented analyzer. The intensity of the light beam emerging from the latter varies at the same rate as the cavity frequency.**

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Introduction

THE USE of modulated light beams in guidance and control systems has several advantages over conventional microwave-radar systems. First, a light beam can more accurately discriminate between targets than a radar beam, and second, less power is required as the result of a minimum of diffusion. Although there are numerous methods of modulating light beams at low frequencies, most of these methods are not feasible in the microwave region. A practical device capable of intensity-modulating light at microwave frequencies has been developed which employs a properly cut electro-optic retardation crystal of the dihydro-

gen phosphate variety, $NH_4H_2PO_4$ (ADP).

The development is physically more versatile in its applications than the usual liquid Kerr cell employed, with its inherent power dissipation at microwave frequencies, in addition to leakage, decomposition, and toxicity problems. Historically, Rupp[1] modulated green light at frequencies of about 10^8 cps using a Kerr cell in the 1920's. More recently crystalline modulators have been built, but these are operationally limited to frequencies on the order of a few megacycles per second because of their conventional design. Although the new device is not designed for low-frequency application, it is potentially useful well into the microwave-frequency region.

Electro-Optic Properties of $NH_4H_2PO_4$ (ADP)[2-4]

With no applied electric field, an ADP crystal is uniaxial. Using standard crystallographic terminology the z axis and optic axis are parallel. When an electric field is applied, the crystal becomes biaxial and the crystallographic axes xyz are no longer coincident with the axes $x'y'z'$ of the crystal's index ellipsoid. The results of an electric field in the z direction are of special significance in the design of a light modulator. For this case x' and y' are rotated $-45°$ from x and y while z' remains coincident with z. Further, the indices of refraction and birefringences are given by

$$\begin{aligned} n_x' &= n_o + 1/2n_o^3 r_p E_z \\ n_y' &= n_o - 1/2n_o^3 r_p E_z \\ n_z' &= n_e \end{aligned} \tag{1}$$

$$\begin{aligned} B_x' &= n_y' - n_z' = n_o - n_e - 1/2n_o^3 r_p E_z \\ B_y' &= n_z' - n_x' = n_o - n_e + 1/2n_o^3 r_p E_z \\ B_z' &= n_x' - n_y' = n_o^3 r_p E_z, \end{aligned} \tag{2}$$

in which n_o and n_e denote ordinary and extraordinary index of refraction, and r_p represents the electro-optic coefficient. $n_o = 1.4798$ and $n_e = 1.5254$ at 22°C for light of wavelength 556 millimicrons. If E_z varies with the time, it has been shown that r_p depends upon the frequency range, being lower for frequencies above piezoelectric resonance (40 kc). For relatively high frequencies, r_p is approximately six-tenths of its constant or static value of 0.847×10^{-11} m per volt, a fact explainable on the basis of crystal inertia.

It is apparent that induced birefringence is greatest for light passing in the z direction. In addition, for the latter condition, natural birefringence is not a factor. It is reasonable, therefore, to employ the crystal such that the light beam to be modulated is made to pass in the z direction. Then the retardation through the crystal is given by

$$\Gamma = \frac{B_z' t}{\lambda} = \frac{n_o^3 r_p V}{\lambda}, \tag{3}$$

in which t is the crystal thickness, V the difference of potential and λ the wavelength of the light beam. Thus, for a given Γ, the voltage required is proportional to wavelength. In terms of phase difference ϕ in radians (3) may be rewritten as

$$\phi = 2\pi \frac{n_0^3 r_p V}{\lambda}. \tag{4}$$

Principles of Operation of Dihydrogen Phosphate Light Modulators

Fig. 1 is a schematic diagram showing the electro-optic effects which take place in a dihydrogen phosphate light modulator. A source of light in combination with a converging lens or lens system produces a collimated beam of light which is normally incident upon the polarizer. Representations are shown of the various stages of polarization of the light as it proceeds from the source into a detector for the condition of crossed polarizer and analyzer. In Fig. 2 are shown representations of the polarization planes of the polarizer and analyzer and the induced electro-optic axes of the crystal for this case.

For the arrangement described, with no electric field in the crystal, a minimum of light is passed to the detector. Sighting back through the analyzer toward the source one can see the circular ring pattern with brushes characteristic of a uniaxial crystal placed between crossed polaroids. With a modulating voltage applied between the crystal faces, elliptically-polarized light in general emerges from the crystal because the incident plane-polarized beam is split into two mutually perpendicular components which travel with different velocities within the crystal, as indicated previously. As the voltage alternates the eccentricity of the resulting ellipse changes. Consequently the analyzer passes a periodically varying amount of light, over a cycle, to the detector.

Plots of relative light intensity transmitted by the analyzer vs applied voltage across the crystal (electric field in the z direction) are shown in Fig. 3(a) and (b) for crossed polaroids and two conditions of bias. If ϕ equals the crystal retardation, I_0 the maximum in-

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[3] —— "The electro-optic effect in uniaxial crystals of the type XH_2PO_4. II. Experimental," *J. Opt. Soc. Am.*, vol. 39, pp. 802–808; October, 1949.

[4] R. O'B. Carpenter, "The electro-optic effect in uniaxial crystals of the dihydrogen phosphate type. III. Measurement of coefficients," *J. Opt. Soc. Am.*, vol. 40, pp. 225–229; April, 1950.

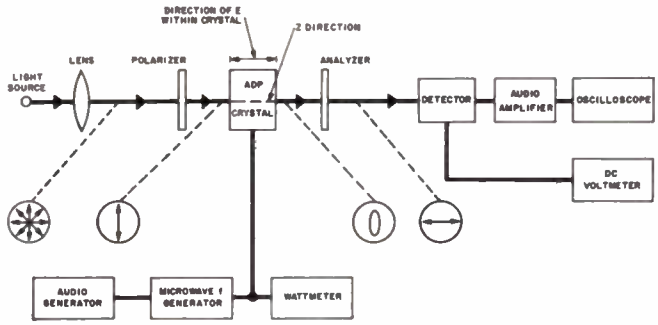


Fig. 1—Electro-optic light modulation and detection.



Fig. 2—Orientation of polarization planes and induced electro-optic axes for crossed polaroids.

tensity transmitted by the analyzer, V_0 the voltage required for 100 per cent modulation, I and V instantaneous intensity and voltage, respectively, then the relative transmission may be shown to equal

$$I/I_0 = \sin^2(\phi/2) \tag{5}$$

or

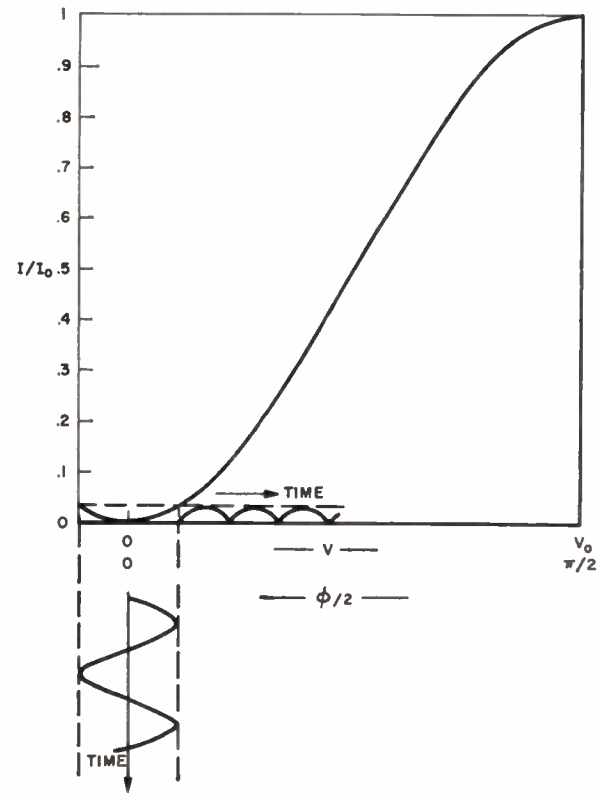
$$I/I_0 = \sin^2\left(\frac{\pi}{2}\,\frac{V}{V_0}\right). \tag{6}$$

Generally the linear operating condition depicted in Fig. 3(b) may be obtained by employing the dc bias $V_0/2$ across the crystal faces. Since a dc bias is impractical in the microwave device, a quarter-wave ($\lambda/4$) plate between crystal and either polaroid with its principal axes of refraction parallel to the birefringent axes of the crystal achieves, optically, practically the same effect. The voltage required for half-wave retardation (V_0) is approximately 15 kv at the edge of the ultraviolet region.

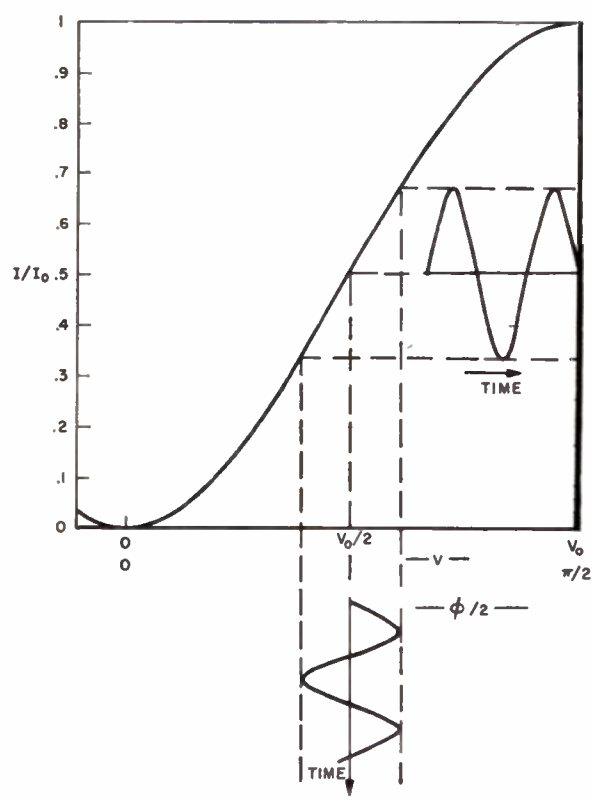
Limitations Imposed by Polaroids and ADP Crystal

Because of the brittle and hygroscopic nature of ADP, great care must be exerted in cutting, polishing, and subsequent handling. As a further complication, a constant optical check must be made during cutting and polishing to insure that the crystal is on axis. An optical technique has been developed at the Sperry Gyroscope Company which yields reasonably well-polished crystals of optical quality.

The maximum transmission of an optical modulator



(a)



(b)

Fig. 3—Relative intensity vs crystal voltage for (a) zero bias and (b) quarter-wave bias.

is dependent upon the transmission of the crystal and the polaroids, and reflection losses. Minimum transmission is determined by the efficiency of the crossed polaroids and the angular field employed. Because the crystals are naturally birefringent, there is some retardation with consequent transmission for rays directed off the optic axis. Limitation of the angular field to a few degrees results in high maximum to minimum (contrast) ratio.

The crystal should operate with ambient temperatures in the 10 to 40°C range. Unwanted elasto-optic effects are readily observable if the upper temperature is exceeded. Thermal shock can result in destruction of the crystal.

Design of a Microwave Light Modulator

In order to apply voltages to the crystal on the order of several thousand volts at a microwave frequency, it is necessary to employ microwave techniques[5] as opposed to low-frequency procedures. A high-Q re-entrant capacity-loaded coaxial-line resonator employing a cylinder of the electro-optic crystal as its dielectric medium ($K=14$) was decided upon because of its function in concentrating an extremely high electric field in the limited region in which the crystal is placed. At the same time the electric field and optical path through the crystal must be parallel to the z or optic axis. A schematic diagram of an experimental resonator is shown in Fig. 4. Its resonant frequency may be determined to a reasonable approximation by setting the susceptance of the capacitor formed by the crystal equal to the susceptance of the coaxial transmission line formed by the outer and center conductors. Although the loss tangent of ADP is low (on the order of 10×10^{-4} for a field parallel to the z axis at 25°C) for high voltages at frequencies close to 1000 Mc, the dielectric loss can be high enough to produce unwanted thermo-optic effects in the crystal and even permanent damage. A very low crystal capacitance is therefore mandatory.

Because of the necessity of drilling holes through the cavity in order to provide an optical path, the following approximate equations should be interpreted in terms of a particular geometrical configuration. The resonant wavelength Q and shunt impedance of the cavity are given by

$$\lambda_0 = 2\pi\left(\frac{Lr_1}{2t'}\ln\frac{r_2}{r_1}\right)^{1/2} \tag{7}$$

$$Q = \frac{2L}{\delta}\,\frac{\ln r_2/r_1}{2\ln r_2/r_1 + L(1/r_1 + 1/r_2)} \tag{8}$$

[5] For a more complete treatment of microwave cavity resonators, the reader is referred to a standard work such as the one by T. Moreno, "Microwave Transmission Design Data," Dover Publications, Inc., New York, N. Y., 1958.

$$R = \frac{60\pi}{\delta}\,\frac{(2L)^2(\ln r_2/r_1)^2}{\lambda_0[2\ln r_2/r_1 + L(1/r_1 + 1/r_2)]}, \tag{9}$$

in which t', the thickness of an equivalent air capacitor, equals $t/14$, the actual thickness divided by the dielectric coefficient. r_1, r_2 and L are inner-conductor radius, outer-conductor radius, and outer-conductor length. r_1 is, in addition, the crystal radius. Further, since the cavity is coupled to a transmission line, λ_0 and Q are again altered.

The regions through which the light passes on either side of the crystal may be treated as circular waveguide segments. In order to limit microwave energy losses from these regions, their dimensions should be such that cutoff occurs below the resonant frequency of the cavity. As may be seen in Fig. 4, the polaroid holders and the deep axial path on one side, in combination with a relatively small cross-sectional opening can provide adequate attenuation. In a silver-plated resonator (not shown) a resonant frequency of 800 Mc with a Q of approximately 500 was obtained. The modulation ratio was estimated to be 0.24 using a quarter-wave plate, as discussed below.

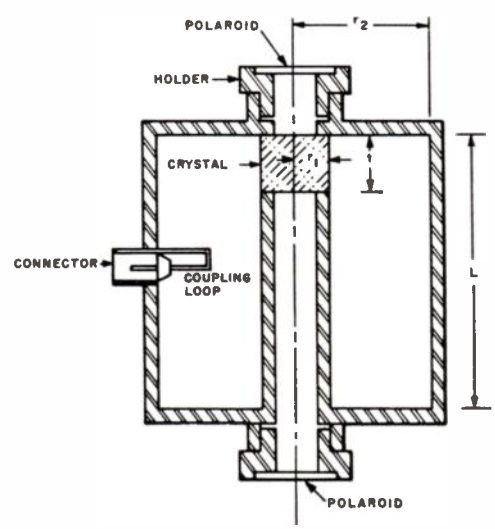


Fig. 4—Schematic diagram of microwave electro-optic light modulator.

Modulation Measurements at Microwave Frequency

A 1P21 multiplier phototube and associated circuitry were used to detect the modulated light beam. Because the circuitry used did not respond to microwave frequencies, modulation ratio at these frequencies was determined using average photomultiplier voltage readings taken with the dc voltmeter shown in Fig. 1. If V_{av} represents the voltmeter reading for incident modulated light using crossed polaroids, and if V_{av}' represents the voltmeter reading for the same operating conditions, but with parallel polaroids, then the modulation

ratio for zero bias can be shown to equal

$$\text{Mod Ratio} = \sin^2 \phi/2 = \frac{\pi/2V_{av}}{V_{av} + V_{av}'}. \qquad (10)$$

A value of 1.8 was obtained using a white light source for the 800-Mc modulator. Referring to Figs. 3(a) and (b) this corresponds to a value of about 0.24 if a quarter-wave plate were interposed.

The audio generator shown in Fig. 1 is used to modulate the high-frequency source which acts as a carrier for some preset audio frequency. The latter is amplified and displayed on the oscilloscope, thus facilitating alignment and orientation of the optical system as well as detection.

Conclusions

A method of designing a practical crystalline microwave-frequency light modulator has been described. Some areas still to be investigated involve operation at reduced temperature, use of other crystalline materials with similar electro-optic properties, and use of high-intensity monochromatic light sources with shorter wavelengths.

Upwind-Downwind Ratio of Radar Return Calculated from Facet Size Statistics of a Wind-Disturbed Water Surface*

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Summary—**A wind tunnel with water as a lower surface has been used to obtain experimental data on the statistical distributions of facet size in relationship to wind velocity, facet slope, and flatness tolerance. Flatness tolerance is defined as one-tenth of the radar wavelength.**

Using the above experimental data, calculations are presented which, for the first time, relate the upwind-to-downwind ratio of radar return with radar beam depression angle for various wind velocities and radar wavelengths. Comparison with available sea-clutter measurements are made. It is concluded that the concept of facet size in relationship to flatness tolerance and slope distribution is useful for describing a rough surface from which radar waves are reflected.

I. Introduction

RADAR RETURN from the rough surface of the sea is a complicated phenomenon that depends upon a number of parameters. These are principally the depression angle (angle below the horizontal at which the sea is viewed), the frequency, the polarization, and the roughness of the sea surface. Goldstein[1,2] was probably the first to systematically study the phenomenon and introduced the valuable concept of the dimensionless quantity σ°, defined as the back-scattering cross section per unit area of the sea.

Katzin[3] advanced the understanding of the physical principles involved in radar sea return by developing a theory in which the elemental scatters in the sea surface were assumed to be small patches, of "facets," having statistical distributions of slope and facet size. Katzin's theory, though successful in most respects, failed to explain the observed upwind-downwind ratio of radar return. This is not particularly surprising because he had no measurements of facet size distributions and relatively few measurements of slope distributions[4,5] upon which to base his calculations.

The only statistical measurements of facet size distributions that are now available have been made using a short fetch (distance over which the wind blows) wind tunnel having water as the lower surface.[6] The present

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[1] D. E. Kerr, Ed., "Propagation of Radio Waves," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 13, pp. 481–587; 1951.

[2] H. Goldstein, "Frequency dependence of the properties of sea echo," *Phys. Rev.*, vol. 70, pp. 938–946; December 1 and 15, 1946.

[3] Martin Katzin, "On the mechanisms of radar sea clutter," PROC. IRE, vol. 45, pp. 44–54; January, 1957.

[4] A. H. Schooley, "A simple optical method for measuring the statistical distribution of water surface slopes," *J. Opt. Soc. Amer.*, vol. 44, pp. 37–40; January, 1954.

[5] C. S. Cox and W. H. Munk, "Measurement of the roughness of the sea surface from photographs of the sun's glitter," *J. Opt. Soc. Am.*, vol. 44, pp. 838–850; November, 1954.

[6] A. H. Schooley, "Relationship between surface slope, average facet size, and facet flatness tolerance of a wind-disturbed water surface," *J. Geophys. Res.*, vol. 66, pp. 157–162; January, 1961.

paper uses this statistical data to calculate the upwind-to-downwind ratio of radar return and compare the calculations with available experimental data.

II. 'Oceanographic' Data

Flatness tolerance is defined in Fig. 1. The heavy irregular line represents a water-wave profile with the wind blowing from left to right. The light solid line at an angle $-\theta$ with respect to the mean surface level is drawn tangent to one point on the wave profile and represents the slope at this point. Very short electromagnetic wavelength waves striking the surface at right angles to the tangent would be reflected back from a small facet of the water surface centered at this point. The size of the facet would be determined by its flatness, measured in terms of a fraction of a wavelength. In this paper *flatness tolerance* will be defined as $\frac{1}{16}$ of a wavelength. In Fig. 1 flatness tolerance (a) and (b) are indicated, together with the corresponding facet lengths. In the data to be presented, four flatness tolerances have been used: 1 mm, 3 mm, 5 mm, and 10 mm, which correspond, by definition, to 1-cm, 3-cm, 5-cm, and 10-cm wavelengths.

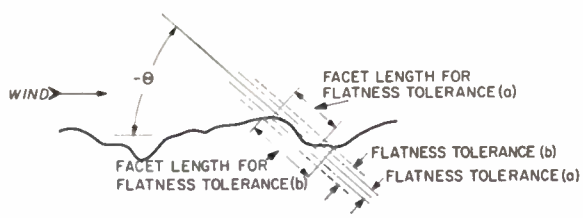


Fig. 1—Flatness tolerance determines facet length.



Fig. 2—Profile of a wave in a transparent water-wind tunnel with a 16-knot wind blowing from left to right.

Fig. 2 shows the profile of a water wave created by a 16-knot wind blowing from left to right. The channel is about 10-cm wide and 70 cm long. This length corresponds to 70 1-cm wavelengths and 7 10-cm wavelengths. In Fig. 2 the boundary between the air, the water, and the front transparent wall of the channel has been retouched to make it more visible in the illustration. Full-size pictures similar to this were used in taking the experimental measurements. The slope and facet lengths for the chosen flatness tolerances were measured graphically at $\frac{1}{2}$-cm intervals along many wave profiles for various wind velocities.

Fig. 3 shows the results for wind velocities of 10, 15, and 20 knots, and for a 1-mm flatness tolerance. Figs. 4–6 are similar except that the flatness tolerances are 3 mm, 5 mm, and 10 mm, respectively. The individual curves do not seem to be simple mathematical functions and the families of curves are apparently not related by simple mathematical relationships. Attempts to fit them empirically to statistical distribution formulas and to solutions of second-order differential equations led to much work and a not very precise fit.

It is difficult to estimate the total experimental errors that may enter into the presentations of the data given in Figs. 3–6. First, there is the fact that the profiles of the waves at the channel boundary are not identical with what they would be away from the boundary. Visual examination of Fig. 2 indicates that the difference is probably not serious. Next, the graphical determination of the facet length for various flatness tolerances introduces errors. However, individual random errors probably largely balance out in the averaging process. Errors due to the finite length of the channel probably are larger for the 10-mm flatness tolerance than for the lesser flatness tolerances. Finally, statistical averaging errors depend upon the number of samples. Each curve shown in Figs. 3–6 is based on experimental data consisting of between 50 and 100 experimental points.

Figs. 7–9 are smoothed experimental water-wind tunnel curves which relate the probability of various slopes for wind velocities of 10, 15, and 20 knots, respectively.[7] These three figures represent an upwind-downwind slice of the distribution function. The distribution function is really three dimensional because facets of the water surface tilt in the cross-wind direction as well as in the upwind-downwind direction. For this paper, however, only the upwind-downwind slice of the distribution will be considered.

III. Calculations

The approximate calculations to be described were made on a step-by-step basis at intervals of one degree of facet slope (s). The step-by-step calculations were repeated twelve times for the combinations of three wind velocities (w); 10, 15, and 20 knots; and four radar wavelengths (λ); 1 cm, 3 cm, 5 cm, and 10 cm. It is to be remembered that $\lambda = 10\tau$ where (τ) is the facet flatness tolerance.

Any given facet of a particular slope (s), wind velocity (w), and flatness tolerance (τ) has its length (l) determined by referring to the proper curve in Figs. 3, 4, 5, or 6. The curves may be expressed as $l = f(w, \tau; s)$.

It will now be assumed that the facets of the surface can be considered to be circular in shape with a radius (a) of one-half the length (l). Fig. 10 shows a picture

[7] A. H. Schooley, "Mean roughness factor as a function of wind velocity," *J. Geophys. Res.*, vol. 66, pp. 2863–2866; September, 1961.

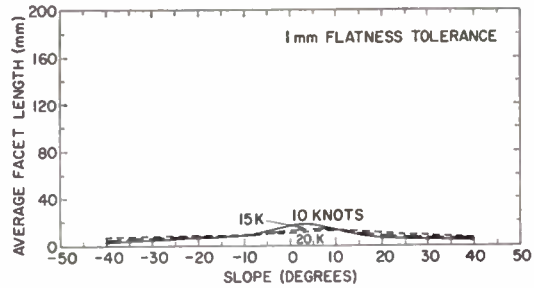


Fig. 3—Average facet length vs slope for 1-mm flatness tolerance which corresponds to a radar wavelength of 1 cm.

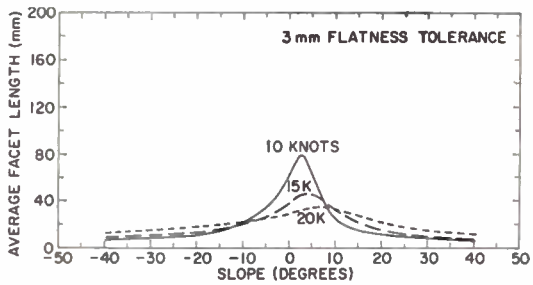


Fig. 4—Average facet length vs slope for 3-mm flatness tolerance which corresponds to a radar wavelength of 3 cm.

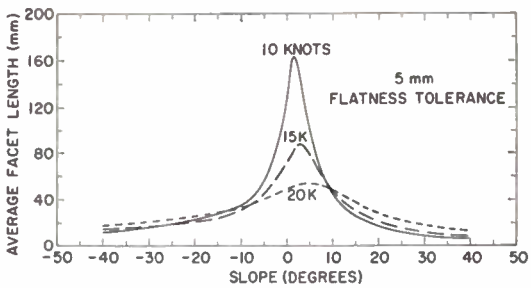


Fig. 5—Average facet length vs slope for 5-mm flatness tolerance which corresponds to a radar wavelength of 5 cm.

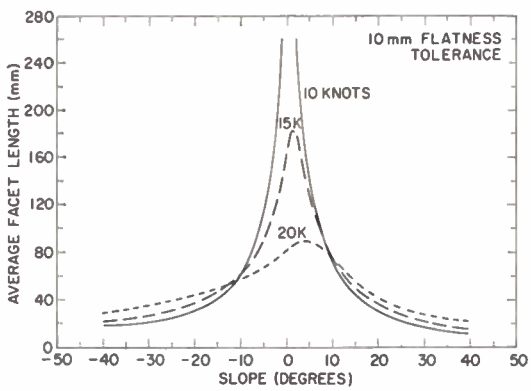


Fig. 6—Average facet length vs slope for 10-mm flatness tolerance which corresponds to a radar wavelength of 10 cm.

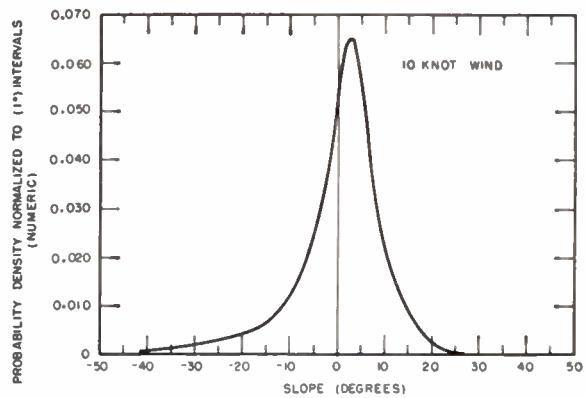


Fig. 7—Slope probability for a 10-knot wind.

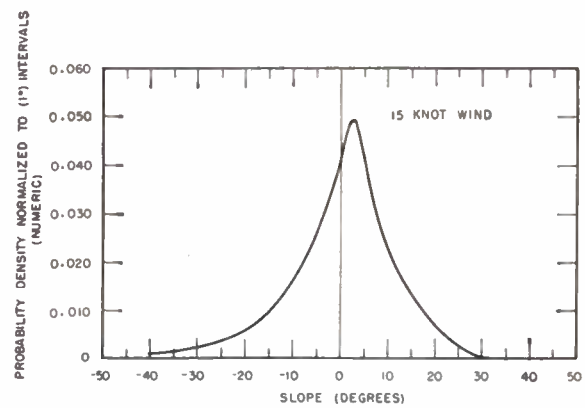


Fig. 8—Slope probability for a 15-knot wind.

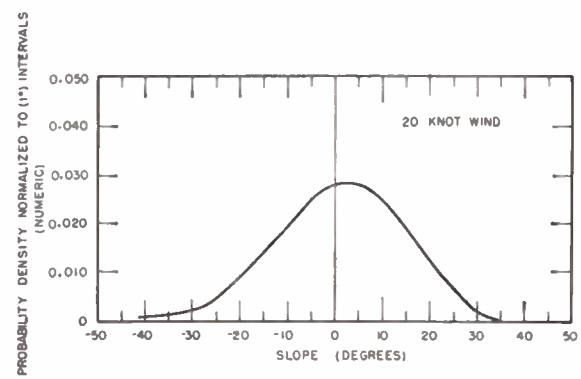


Fig. 9—Slope probability for a 20-knot wind.

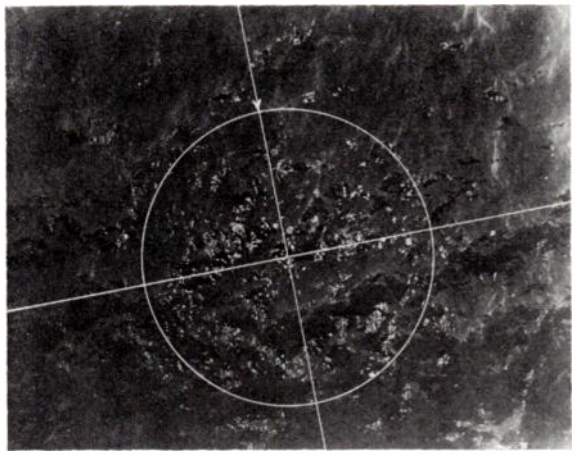


Fig. 10—Light reflected from facets of a wind-swept water surface.

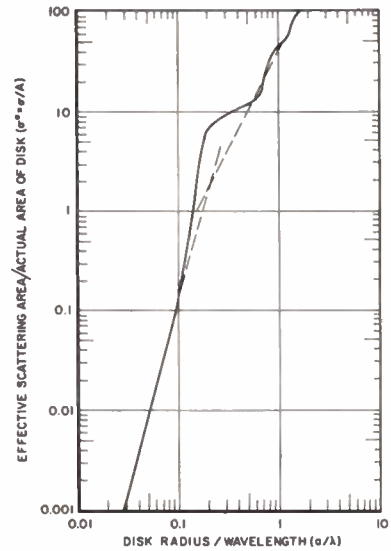


Fig. 11—Relationship between the effective radar scattering area of a round conducting disk divided by its actual area and the ratio of disk radius to radar wavelength. The curve is for normal incidence and for all polarizations.

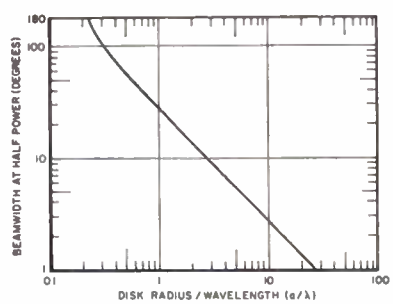


Fig. 12—Relationship between the beamwidth reradiated by an illuminated conducting disk and the ratio of disk radius to radar wavelength. The curve is for normal incidence and for all polarizations.

that presents some justification for this approximation. In this picture the "highlights" are reflections from facets of a wind-swept water surface that are oriented to reflect light back into a vertically held camera that has a flash bulb discharged adjacent to the camera. It is evident by close examination of the facets that they are irregular in shape but on the average can best be approximated as having circular shape.

If a facet is assumed to have a radius $(a)=l/2$, then the actual area of a single facet disk $(A)=\pi(a)^2$. The effective radar scattering area (σ) of a single facet disk will in general be different than the actual geometrical area (A) of the disk. Fig. 11 shows the effective scattering area of a disk per unit actual area of the disk (σ°) as a function of the ratio of disk radius (a) to radar wavelength (λ).[8] This is a theoretical curve that has been verified experimentally and holds for radar waves impinging on a disk at normal incidence. Under these circumstances the direction of polarization is immaterial. The relationship shown in Fig. 11 may be expressed as $\sigma^\circ=f(a/\lambda)$. To determine the effective radar scattering area of a single disk (σ) the relationship $\sigma=\sigma^\circ\ (A)$ may be used.

Through the process just described, let it be assumed that a table has been prepared giving the effective radar scattering area (σ) for every degree of facet slope (s) from $s=+40°$ to $-40°$ for a particular value of wind velocity (w) and facet flatness tolerance (τ). Now it is necessary to take into account that the probability of having facet slopes in the region of zero degrees is greater than for positive and negative slopes of higher values. Figs. 7–9 give the probability (p) of the surface having various slopes, in the upwind-downwind direction, for $w=10$ knots, 15 knots, and 20 knots, respectively. These curves can be expressed as $p=f_w(s)$. Using the proper probability curve, the probability for each degree increment of slope may be determined and multiplied by the value of (σ) for that slope. This gives a table of values for the effective area of the facets (σ_p) when the probability density of the various slopes are considered. In symbolic form $\sigma_p=\sigma P$ for each one degree slope interval from $s=+40°$ to $-40°$.

It is next necessary to consider the effective beamwidth of the facets. Each facet will receive and reradiate radar energy over a limited angle. Reradiation will be greatest at normal incidence, 90°, and less for other angles. The effective beamwidth (ψ) will be defined as the beamwidth at half power and it is a function of the facet size and the radar wavelength. Fig. 12 shows this relationship in graphical form.[9] In symbolic form it is $\psi=f_1(a/\lambda)$. From this relationship it is possible to identify an effective beamwidth for each value of (σ_p) and note it on the table for each degree interval of slope. It was assumed that the maximum beamwidth for a/λ less than about 0.22 was 180°. In other words, a

[8] H. J. Schmitt, "Back-Scattering Measurements with a Space-Separation Method," Cruft Lab., Harvard Univ., Cambridge, Mass., Scientific Rept. No. 14; November, 1957.

[9] S. Silver, "Microwave Antenna Theory and Design," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 12, p. 194; 1951.

facet of a surface cannot receive or reflect energy over an angle greater than 180°.

Now the term radar depression angle (θ) is introduced. This is the angle that the center of a radar beam makes with respect to the horizontal. For pointing straight down $\theta = 90°$. When pointing at the horizon $\theta = 0°$. This paper considers only the upwind and downwind directions. Thus for the upwind direction θ_u may range from zero to 90°. $\theta_u = 0°$ is for the case when the radar is directed towards the horizon in the upwind direction. Likewise θ_d may range from zero to 90° and $\theta_d = 0°$ corresponds to the case where the radar antenna is pointed towards the horizon in the downwind direction.

The next step is to examine the table of (σ_p) with associated values of facet beam angles for identical values of (θ_u) and (θ_d) in order to determine which facets are oriented and have sufficient beam angle (ψ) to contribute to the total radar return from the water surface. This was done for each one degree slope (s) intervals and for each 10° of beam depression angle (θ). The values of (θ_u) and (θ_d) that were used were 10, 20, 30, 40, 50, 60, 70, 80, and 90°. With this data it was possible to sum up the effective scattering area for all facets that are effective at each particular radar beam depression angle in the upwind and also the downwind directions. Symbols for these summations are $\sum[\sigma_{p(u)}]$ and $\sum[\sigma_{p(d)}]$. Thus the ratio of the effective scattering area in the upwind direction to that in the downwind direction is $\sum[\sigma_{p(u)}]/\sum[\sigma_{p(d)}]$. This ratio in decibels is $(R) = 10 \log_{10}\sum[\sigma_{p(u)}]/\sum[\sigma_{p(d)}]$.

After having repeated this process for the twelve tables necessary to examine the range of all the variables, it is possible to plot $R = f(w, \lambda; \theta)$ which is the end that is sought.

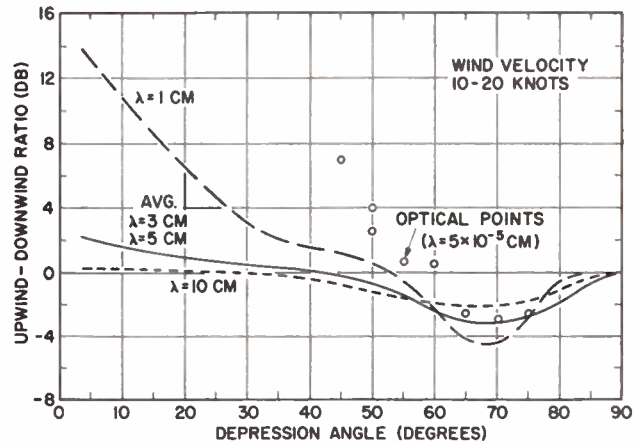


Fig. 13—Relationship between the upwind-downwind ratio of radar return from a wind-swept water surface and various radar beam depression angles and radar wavelengths.

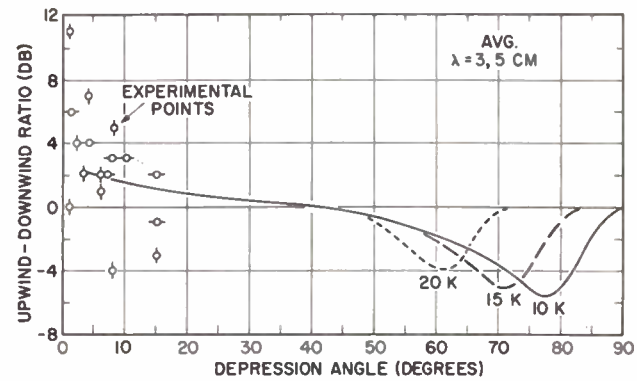


Fig. 14—Relationship between the upwind-downwind ratio of radar return from a wind-swept water surface and various radar beam depression angles, three wind velocities, and for radar wavelengths in the region of three to five centimeters. The experimental points are 3-cm wavelength measurements taken in the open sea. The points marked (◇) are for vertical polarization and the ones marked (-o-) are for horizontal polarization.

IV. Results

Since the calculations were based on the experimental statistical data of Figs. 3–9, it is expected that inaccuracies in these data will be reflected in the results of the calculations. Thus some averaging of the results appeared to be in order to show the major trends as accurately as possible. Fig. 13 shows the upwind-downwind ratio of radar return as ordinate with radar beam depression angle as abscissa. The curves are averages for all wind velocities including 10, 15, and 20 knots. The solid curve is further averaged from 3- and 5-cm radar wavelengths. Three things of major significance are apparent from Fig. 13. First, for low depression angles, the radar return from the wind-swept water surface is greater when the radar is pointing into the wind than when it is pointing at the same angle downwind. Second, this phenomena is more pronounced for short wavelengths than for long wavelengths. Third, in the region of depression angle between about 50° and 80° the radar return is greater when looking downwind than when looking upwind at the same angle. This has not been shown before, and there are no known accurate radar measurements at large depression angles to check this prediction experimentally. However, the effect appears reasonable and is probably due to large specular reflections off the broad gentle slopes on the left part of the waves that are shown in Fig. 2. Optical measurements conducted in a water-wind tunnel confirm this prediction as indicated by the circle points in Fig. 13.

The optical points, where the wavelength was about $5(10^{-5})$ cm, not only appear to confirm the negative upwind-downwind ratio in the region around 70°, but also fit in with the pattern of increasingly positive upwind-downwind ratio in the region of radar beam depression angles less than about 50°.

Fig. 14 repeats the solid curve of Fig. 13 except that the principal effect of wind velocity is shown. This is averaged out in Fig. 13. Also are shown the available

experimental points on upwind-downwind ratio of radar sea return taken at 3-cm wavelength.[10] The experimental points are widely scattered but seem to more or less confirm the calculations. The experimental data includes vertical and horizontal polarization points. There is no evidence in the original experimental data that polarization is an important variable above a very few degrees depression angle. In the calculations it has been tacitly assumed that polarization is not a significant parameter.

V. Conclusions and Discussion

The statistical relationships between surface slope, average facet size, facet flatness tolerance, and wind velocity have been experimentally determined by using a wind tunnel with water as its lower boundary.

Using this experimental data as a basis, approximate calculations have been made relating the following variables: upwind-downwind ratio of radar return from the wind-swept water surface, depression angle of the radar beam, radar wavelength, and wind velocity.

For radar beam depression angles less than about 40°, the upwind-downwind ratio expressed in db is positive and is greater for the shorter radar wavelengths. Available measurements of the upwind-downwind ratio of radar return from the surface of the open sea, for a radar wavelength of three centimeters, tend to confirm the calculations.

For beam depression angles in the general region around 70° the upwind-downwind ratio in db is negative. Optical measurements in a water-wind tunnel have confirmed this region of negative upwind-downwind ratio of return.

It is concluded that the concept of assuming that the sea surface is a distribution of facets having statistically measurable diameters (related to the radar wavelength being used) and slopes is valid as an approximation.

The calculations of upwind-downwind ratio of radar return are not reliable below a few degrees of depression angle because the available statistical data on the distributions of slope and facet size are not particularly accurate in this region and also this is the region where destructive interference sets in and the sea becomes a few discrete scatterers instead of a random distribution.

Over the range of wind velocity from 10 to 20 knots, wind velocity seems less critical than the other variables. The calculations show that the principal effect of higher wind velocity is to move the peak of the negative ratio of upwind-to-downwind radar return to slightly lower values of depression angle.

There are indications that the distributions of facet slope and facet size determined by using a short fetch (70 cm) laboratory water-wind tunnel are reasonably accurate for describing the situation in the open sea for radar wavelengths in the region of one to ten centimeters. Longer wavelengths will require that the slope and the facet size distributions be determined under circumstances where the fetch is long compared to the radar wavelength.

The results of the calculations presented herein should also be applicable to sonar surface reverberations. Since a sonar beam looks up to the surface rather than down on the surface, the abscissa of Figs. 13 and 14 should be relabled "Elevation Angle (Degrees)." Also, the curves should be mirror images around the zero ordinate. Because of the underwater geometry, the upwind-to-downwind ratio for sonar surface reverberation should be negative at the low elevation angles and should become positive in the general region around 70°.

Acknowledgment

The author wishes to thank S. F. George for his help with the calculations.

[10] F. C. Macdonald, "The correlation of radar sea clutter on vertical and horizontal polarization with wave height and slope," 1956 IRE National Convention Record, pt. 1, pp. 29–32.

Correspondence

Ferroelectric Parametric Amplifier*

It is known that in ferroelectrics[1,2] the small signal dielectric constant increases many times during the switching. Based on this effect, a ferroelectric parametric amplifier was designed and built. The basic circuit used for this amplifier is illustrated in Fig. 1: B is a battery, F_1, F_2, F_3, F_4 are four ferroelectric crystals, S is a signal generator, D a diode and L the load. The generator S switches the ferroelectric crystals with a frequency f_0. From basic studies on switching[1,2] one knows that during switching the dielectric constant and hence the capacitance of each crystal increases many times, independently of the direction of switching. The stray signals due to the switching and due to the voltage from S are equal at the points A and B and therefore do not appear across the load L. The equivalent circuit of Fig. 1 can thus be obtained by substituting the four ferroelectrics F_1, F_2, F_3, F_4 and the generator S with only *one capacitor* C which varies periodically with time.

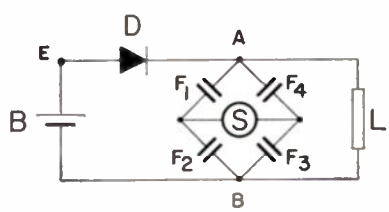


Fig. 1—Circuit of the ferroelectric amplifier.

This equivalent circuit works as follows: when the capacitance C increases (due to the switching) a current flows from the battery B to the condenser C, through the diode D, while the voltage across the condenser C remains equal to the battery voltage V_0. When the capacitance C decreases, after switching, no current can flow back to the battery, due to the diode D. Since the charge on the condenser C remains constant, the drop in capacitance causes an increase of the voltage across C. During the next increase in capacitance, the voltage decreases to the battery voltage V_0; during this half cycle the battery supplies a current which restores the charge lost through the load L during the previous half cycle. The device works as an upconverter. The output voltage, however, can be passed through a low-pass filter to obtain a dc output. If, instead of the dc voltage of the battery B, a variable ac signal is used, it will be amplified, provided that the frequency of the signal is considerably smaller than the frequency of the generator S. It can be seen that the circuit of Fig. 1 works as a parametric amplifier, the generator S acting as the pump, the battery B (or ac signal), as the signal. The basic circuit of Fig. 1 can be varied slightly by connecting the load between the points A and E. A second diode, of opposite polarity than D, must then be connected in series with the load.

In order to demonstrate the principle, a ferroelectric parametric amplifier was built and tested. The ferroelectric used was a plate of triglycine sulfate, about 0.2 mm thick and with 5 mm² electrode area. Voltage amplifications up to 40 were obtained. The input and output resitances R_{in} and R_{out} (at $V_0=+6$ volts and $V_{pump}=250$ volts) were measured and were found to be $R_{in}=22$ KΩ; $R_{out}=1$ MΩ. A flat response with frequency is found up to about 5 kc; at higher frequencies the amplification starts to drop.

The question of how the pump provides the energy for signal amplification can be answered by examining Fig. 1. At each half cycle the output voltage opposes the switching voltage of the pump, in two of the four ferroelectrics. This results in an apparent increase of the coercive field of the ferroelectric and hence in an increase of the area covered by the hysteresis loop. This increase in area is proportional to the work done in order to amplify the signal during each cycle.

To check this mechanism of power amplification we studied the hysteresis loop of the ferroelectrics (as seen by the pump S) when the input signal was -3 volts (device not amplifying) and when it was $+3$ volts (device amplifying). The results are shown in Fig. 2. Similar results can be obtained by varying the load L. When L is very large, the hysteresis loop appears as shown in Fig. 2(a) (no power dissipated); when L equals the output impedance (maximum power dissipated), the loop appears as shown in Fig. 2(b). It can be shown theoretically (and proved numerically in practical cases) that the work corresponding to the shaded area of Fig. 2(b) equals the work done at each cycle, to amplify the signal.



Fig. 2—(a) Hysteresis loop when $V_0=-3$ volts (device not amplifying). (b) Hysteresis loop when $V_0=+3$ volts (device amplifying). The shaded area represents the energy necessary to amplify the signal at each cycle.

In conclusion it should be noted that this parametric amplifier is of a new type, based on the property exhibited by ferroelectrics that the small signal dielectric constant *increases* substantially *during switching*. This mode of operation is fundamentally different from that employed in previously described dielectric amplifiers,[3] in which the amplification is a consequence of the *decrease* of the dielectric constant with applied voltage.

In the amplifier described herein the ferroelectric crystals absorb energy from the pump through an enlarged ferroelectric hysteresis loop. This extra energy of the hysteresis loop is then used to amplify the signal. The frequency range of the amplifier is from dc to about 50 kc.

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[1] M. E. Drougard, H. L. Funk, and D. R. Young, "Dielectric constant and loss measurements on barium titanate single crystals while traversing the hysteresis loop," *J. Appl. Phys.*, vol. 25, pp. 1166–1169; September, 1954.

[2] E. Fatuzzo, "Increase in dielectric constant during switching in lithium selenite and triglycine sulfate," *J. Appl. Phys.*, vol. 32, pp. 1571–1579; August, 1961.

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A Backward Wave in Plasma Waveguide*

It has been shown[1–3] that a plasma column may be used as a slow waveguide in which the propagation takes place in the form of propagating space-charge disturbances. One interesting aspect of the plasma waveguide is its backward-wave characteristics. In the presence of a finite magnetic field in the axial direction, there are two pass bands, the upper branch representing a backward wave. Trivelpiece[2] has pointed out further that, even in the absence of the magnetic field, there exists a backward wave if the plasma column is surrounded by a thin dielectric cylinder. The possibility of a backward-wave interaction between these backward-wave modes and an electron beam has been considered as means of making a structureless backward-wave oscillator. Such an oscillator would be particularly useful in the millimeter range where considerable difficulty is encountered in the fabrication of the slow-wave structure.

In this note we will introduce another plasma structure having a backward-wave mode. The structure to be considered consists of a cylindrical plasma column and a cylindrical conducting rod placed at the axis of the column, as shown in Fig. 1. The

* Received by the IRE, January 9, 1962.

[1] A. W. Trivelpiece and R. W. Gould, "Space charge waves in cylindrical plasma columns," *J. Appl. Phys.*, vol. 30, pp. 1784–1794; November, 1959.

[2] A. W. Trivelpiece, "Slow Wave Propagation in Plasma Waveguides," TR. No. 7, Electron Tube and Microwave Lab., Calif. Inst. of Tech., Pasadena, Calif.; May, 1958.

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structure resembles the Goubau line, except that the dielectric is replaced by the plasma. In fact, in the absence of a magnetic field, one can consider the plasma as a homogeneous isotropic dielectric with a dielectric constant of

$$\epsilon = \epsilon_0[1 - (\omega_p^2/\omega^2)].$$

Consider a TM mode of propagation of the lowest order, *i.e.*, no azimuthal variation of fields. (It can be readily shown that no TE mode can propagate on such a structure.) Assuming slow waves, *i.e.*, $v_p/c < 1$, we can write the electric field components in each region in the following form: for the region $a < r < b$

$$E_{z1} = AI_0(\gamma r) + BK_0(\gamma r)$$
$$E_{r1} = (j\beta/\gamma)[AI_1(\gamma r) - BK_1(\gamma r)], \quad (1)$$

and for the region $r > b$

$$E_{z2} = CK_0(\gamma_0 r)$$
$$E_{r2} = (-j\beta/\gamma_0)CK_1(\gamma_0 r), \quad (2)$$

where γ_0 and γ are the radial propagation constants for each region,

$$\gamma_0^2 = \beta^2 - \omega^2/c^2$$
$$\gamma^2 = \beta^2 - (\omega^2/c^2)[1 - (\omega_p^2/\omega^2)]$$
$$= \gamma_0^2[1 + (\omega_p^2/\gamma_0^2c^2)].$$

The boundary conditions are, at $r = a$,

$$E_{z1}(a) = 0, \quad (3)$$

and at $r = b$,

$$E_{z1}(b) = E_{z2}(b)$$
$$[1 - (\omega_p^2/\omega^2)]E_{r1}(b) = E_{r2}(b). \quad (4)$$

The determinantal equation obtained from these boundary conditions is as follows:

$$1 - (\omega_p^2/\omega^2) = (\gamma/\gamma_0)$$
$$[K_1(\gamma_0 b)G_{00}(\gamma a, \gamma b)/K_0(\gamma_0 b)G_{01}(\gamma a, \gamma b)], \quad (5)$$

where

$$G_{mn}(x, y) = I_m(x)K_n(y) - (-1)^{m-n}K_m(x)I_n(y).$$

Eq. (5) can be simplified considerably if we assume $\gamma = \gamma_0$. This assumption is valid under the condition $(k_p/\gamma)^2 \ll 1$. If we consider cases where the plasma frequencies are such that $k_p b \ll 1$, then we can assume $\gamma = \gamma_0$ for the range of γb's above 1.0.

With this assumption, and making use of a Bessel identity

$$K_n(y)G_{n,n+1}(x, y) - K_{n+1}(y)G_{n,n}(x, y) = K_n(x)/y,$$

we obtain the following simple solution:

$$\omega/\omega_p = [(\gamma b)K_0(\gamma b)G_{01}(\gamma a, \gamma b)/K_0(\gamma a)]^{1/2}. \quad (6)$$

In Fig. 1, ω/ω_p is plotted as a function of γb from (6), for various values of b/a. Fig. 1 shows the propagating mode of the "plasma Goubau line" to have pronounced backward-wave characteristics.

A qualitative physical explanation for this behavior can be given along the same line of argument that Trivelpiece[2] uses for his backward-surface-wave. For low values of γb the field extends far out away from the structure, and thus, the mode of propagation is close to that of a single-wire transmission line. For very large values of γb, the

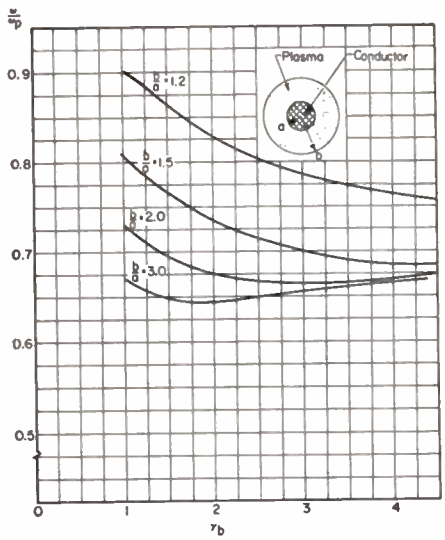


Fig. 1—Phase characteristics of plasma column with center conductor.

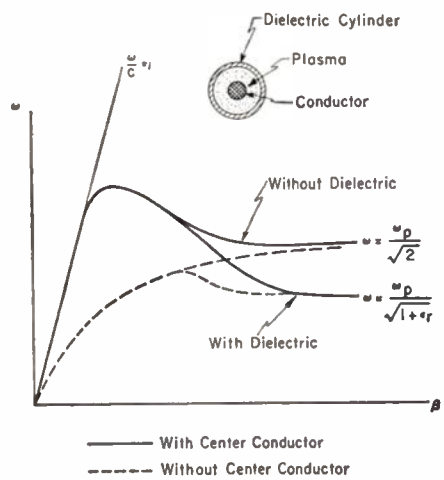


Fig. 2—Approximate phase characteristics of plasma waveguide.

presence of the inner conductor has a negligible effect, and, thus, the mode of propagation follows closely the surface-wave mode of the plasma column. In the intermediate range of γb's, the dispersion curve must go from one asymptotic case to the other, which results in the group velocity being negative.

One can consider many variations of this structure, *e.g.*, external shields, dielectric tubes, etc. One particular variation of interest is the one with a thin dielectric cylinder surrounding the plasma column, since this structure would tend to enhance the backward wave as in the case of the surface-backward-wave described by Trivelpiece. For this case, the dispersion curve will approach the frequency $\omega = \omega_p/\sqrt{1+\epsilon_r}$ asymptotically for large β, ϵ_r being the relative dielectric constant of the surrounding cylinder. The resulting dispersion curve is sketched qualitatively in Fig. 2.

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WWV and WWVH Standard Frequency and Time Transmissions*

The frequencies of the National Bureau of Standards radio stations WWV and WWVH are kept in agreement with respect to each other and have been maintained as constant as possible with respect to an improved United States Frequency Standard (USFS) since December 1, 1957.[1] The corrections reported here were arrived at by means of improved measurement methods based on NBS LF and VLF transmissions. The values given are 5-day running averages of the daily 24 hour values beginning at 1800 UT of each day listed.

The WWV and WWVH time signals are also kept in agreement with each other. Since they are locked to the frequency of the transmissions, a continuous departure from UT2 may occur. Corrections are determined and published by the U. S. Naval Observatory. The broadcast signals are maintained in close agreement with UT2 by properly offsetting the broadcast frequency from the USFS at the beginning of each year when necessary. This new system was commenced on January 1, 1960.

Subsequent changes were as follows:

Frequency Offset, with Reference to the USFS
January 1, 1960, −150 parts in 10^{10}
January 1, 1962, −130 parts in 10^{10}

Time Adjustments, with Reference to the Time Scale UT2
December 16, 1959, retardation, 20 milliseconds
January 1, 1961, retardation, 5 milliseconds
August 1, 1961, advancement, 50 milliseconds.

Adjustments were made at 0000 UT on the foregoing dates; an advancement means that the signals were adjusted to occur at an earlier time than before.

WWV Frequency
With Respect to U. S. Frequency Standard

1962 January	Parts in 10^{10}†
1‡	−130.2
2	−129.8
3	−129.5
4	−129.2
5	−129.2
6	−129.1
7	−129.1
8	−129.1
9	−129.1
10	−129.1
11	−129.0
12	−128.9
13‖	−129.0
14	−130.1
15	−130.2
16	−130.4
17	−130.4
18	−130.4
19	−130.4
20	−130.4
21	−130.3
22	−130.3
23	−130.2
24	−130.0
25	−130.0
26	−130.1
27	−130.2
28	−130.2
29	−130.1
30	−130.1
31	−130.1

† A minus sign indicates that the broadcast frequency was below nominal. The uncertainty associated with these values is $\pm 5 \times 10^{-11}$.
‡ Frequency adjusted $+19.5 \times 10^{-10}$ at 0000 UT on January 1, 1962.
‖ Frequency adjusted -1.0×10^{-10} at 1900 UT on January 13, 1962.

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* Received by the IRE, February 23, 1962.
[1] Refer to "National Standards of Time and Frequency in the United States," Proc. IRE, vol. 48, pp. 105–106; January, 1960.

Observations on the Pump-Light Intensity Distribution of a Ruby Optical Maser with Different Pumping Schemes*

Among the pumping schemes for pulsed ruby optical masers that have been devised and tried, the helical lamp in a circular cylindrical reflector[1,2] and the linear lamp in an elliptical cylindrical reflector[3] have found wide usage. In the former case the pumping light fills more or less uniformly the cavity containing the ruby rod, while in the latter case the highly polished elliptical reflector images the flash lamp onto the ruby rod. Because of this focussing action a higher pumping efficiency can be achieved with the elliptical reflector configuration. For the same reason the distribution of pump-light intensity inside the ruby rod may not be as uniform as could be obtained with the helical lamp configuration, thus resulting in maser action being concentrated in intensely pumped areas only.

In order to observe the effects of the nonuniform distribution of pumping light inside the ruby rod, photographs of the output end of the ruby were taken for various input energies above threshold for both pumping schemes. Fig. 1 shows a series of such photographs of a 0.6-cm diameter ruby rod pumped by an FT-524 helical lamp in a cylindrical magnesium oxide reflector. This particular rod is relatively free from strain as evidenced by the following observations. At threshold, which is approximately 1500 joules input, the maser action is confined to a thin filament near the center of the rod. A very small increase in input energy immediately spreads the maser action over a coaxial circular cylinder of radius equal to approximately six-tenths of the radius of the rod. Subsequent increase in input energy produces a relatively slower growth of the extent of maser action, which eventually spreads over the entire rod. These observations suggest that the pump-light intensity is fairly uniform around the central axis but decreases radially near and outside a cylinder of radius equal to six-tenths of the radius of the rod. This is in agreement with Devlin *et al.*,[4] who computed the theoretical intensity distribution for such a case, taking into account the higher index of refraction of the ruby.

Fig. 2 shows a similar series of enlarged photographs taken of the same ruby rod pumped by an FX-100 linear lamp in a highly polished elliptical reflector. At threshold, which is approximately 190 joules input, the maser action is concentrated in a thin central filament coincident with one of the focal lines of the elliptical cylinder. As input energy is increased the bright spot on the end of the rod showing the extent of maser action becomes proportionately larger, always remaining oval in shape and having its axis of elongation perpendicular to the major axis of the elliptical reflector. Thus it appears that the distribution of pump-light intensity is now quite nonuniform. The central high intensity area is very much smaller and the rapid radial decrease of intensity starts much closer to the axis of the rod. This is presumably due to the focussing action of the elliptical reflector. The shadows cast by the ruby and by the lamp appear along the major axis of the ellipse and result in a noncircular elongated pump-light intensity contour over the cross section of the rod. This is manifested in the form of the oval masing areas in Fig. 2.

Because of the focussing action of the elliptical reflector, maser action can be induced in different parts of the ruby simply by displacing either the flash lamp or the ruby off the focal lines of the ellipse. Fig. 3 shows the result of such an experiment in which the ruby rod is displaced from perfect alignment by an amount slightly less than the radius of the rod. However, due to the refraction that occurs in ruby, the masing filament is not shifted by the same amount but is shifted by a smaller amount.

Since for a given per cent of the input energy above threshold, the helical lamp configuration yields a larger masing volume than does the linear lamp in the elliptical reflector, we should expect the output energy to be correspondingly greater. This has been observed experimentally. Therefore, until a suitable high-energy linear lamp be-

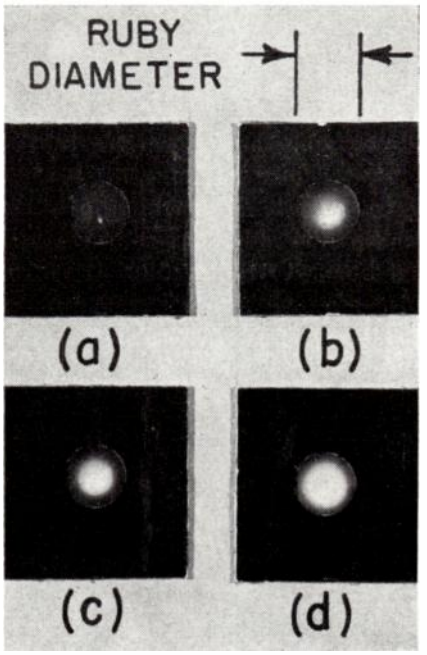


Fig. 1—Photographs of the output end of the ruby maser rod pumped by an FT-524 helical lamp in an MgO reflector. (a) 1500 joules input (threshold). (b) 1550 joules input. (c) 1600 joules input. (d) 1700 joules input.

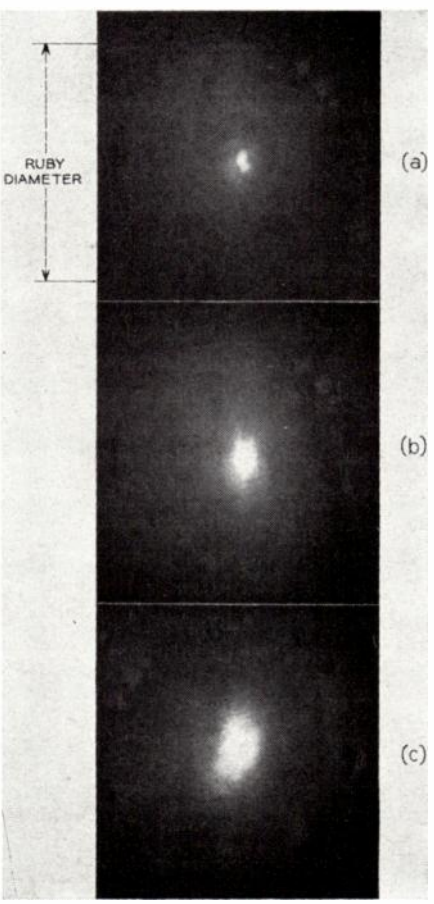


Fig. 2—Photographs of the output end of the ruby maser rod pumped by an FX-100 linear lamp in an elliptical reflector. (a) 190 joules input (threshold). (b) 210 joules input. (c) 240 joules input.

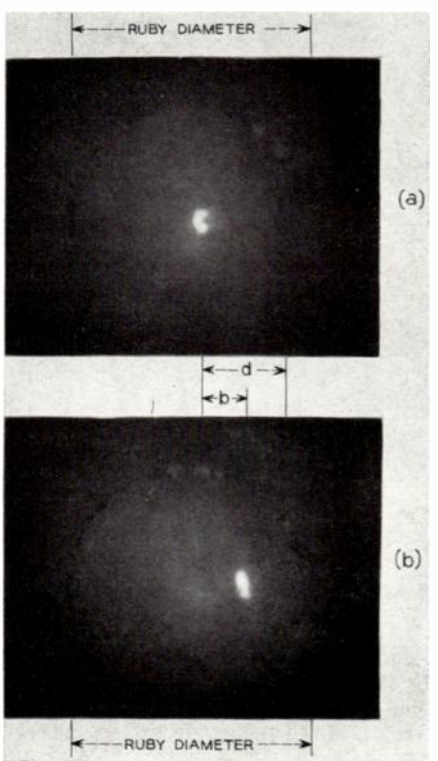


Fig. 3—Photographs showing the results of the experiment in which the ruby rod is displaced from perfect alignment in the elliptical reflector. (a) Ruby rod placed at the focus (195 joules input). (b) Ruby rod shifted off the focus by *d*. The masing area is shifted only by *b* (290 joules input).

* Received by the IRE, February 5, 1962.

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[4] G. E. Devlin, J. McKenna, A. D. May, and A. L. Schawlow, "Composite rod optical masers," *Appl. Optics*, vol. 1, pp. 11–15; January, 1962.

...mes available, the helical lamp appears to ...e more suited for applications requiring ...igh-energy maser beams.

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Simulation of Third-Order Systems with Simple-Lead Using One Operational Amplifier*

In a previous communication,[1] a particular case of the general third-order linear system was considered. The purpose here is to discuss another particular type, that is, a third-order system with a simple-lead whose transfer function is of the form

$$F(s) = -\frac{b_1 s}{(a_3 s^3 + a_2 s^2 + a_1 s + 1)}, \quad (1)$$

which can be simulated with the network of Fig. 1. The transfer function of the network of Fig. 1 can be shown to be

$$\frac{E_0}{E_1} = -\frac{Y_1 Y_3 Y_5}{Y_6(Y_1+Y_2+Y_3)(Y_3+Y_4+Y_5+Y_7) + Y_3 Y_6(Y_4+Y_5+Y_7) + Y_5 Y_7(Y_1+Y_2+Y_3+Y_8) + Y_3 Y_5 Y_8}, \quad (2)$$

and it is possible to simulate the system of (1) with the network of Fig. 1 if the admittances (Y's) are suitably chosen.

Of the possible six circuits only three are discussed, for the simple reason that the other three and their validity conditions can be determined easily by the process of reasoning similar to that outlined here.

Simulation of the system characterized by (1) with the network of Fig. 1 would require at least three capacitors. A possible choice, as shown in Fig. 2(a), is to make

$$\begin{aligned} Y_1 &= sC_1 \\ Y_4 &= sC_4 \\ Y_6 &= sC_6 \end{aligned} \quad (3)$$

$$Y_2 = Y_5 = Y_7 = Y_8 = \frac{1}{R}$$

and

$$Y_3 = \frac{1}{aR}.$$

Substituting (3) in (2) and simplifying, we have

$$\frac{E_0}{E_1} = -\frac{\frac{RC_1 s}{2(a+1)}}{\frac{a}{2(a+1)} R^3 C_1 C_4 C_6 s^3 + \left[\frac{(2a+1)}{2(a+1)} R^2 C_1 C_6 + \frac{(2a+1)}{2(a+1)} R^2 C_4 C_6\right] s^2 + \left[\frac{a}{2(a+1)} RC_1 + 2RC_6\right] s + 1}. \quad (4)$$

Eqs. (1) and (4) will be identical if

$$b_1 = \frac{T_1}{2(a+1)} \quad (5)$$

$$a_1 = \frac{a}{2(a+1)} T_1 + 2T_3 \quad (6)$$

$$a_2 = \frac{(2a+1)}{2(a+1)} T_3(T_1 + T_2) \quad (7)$$

$$a_3 = \frac{a}{2(a+1)} T_1 T_2 T_3, \quad (8)$$

where

$$\begin{aligned} T_1 &= RC_1 \\ T_2 &= RC_4 \\ T_3 &= RC_6. \end{aligned} \quad (9)$$

Simulation of the system of (1) with the network of Fig. 2(a) is possible only if the values of a, T_1, T_2, T_3 obtained as the solution of (5) through (8) are real and positive. It is therefore required to determine the values of a, T_1, T_2 and T_3 in terms of the known real and positive constants b_1, a_1, a_2, and a_3.

Eliminating T_1, T_2 and T_3 from (5) through (8) gives a quartic

$$2b_1^2 a^4 - b_1(2a_1 - 3b_1)a^3 + (2a_2 - 3a_1 b_1 + b_1^2)a^2 - (2a_3 - 2a_2 + a_1 b_1)a - a_3 = 0 \quad (10)$$

which will have at least one real and positive root, and for which corresponding values of T_1, T_2 and T_3 will also be real and positive if

$$\frac{a_1}{b_1} > \frac{(a_3 - a_2) + \sqrt{a_2^2 + a_3^2}}{2a_2}. \quad (11)$$

The value of a can be obtained by solving the quartic of (10) by methods that are well known and discussed at length in textbooks on higher algebra. Substituting a so obtained in (5) gives T_1; T_3 and T_2 can now be obtained conveniently by solving (6) and (8). The values of the resistors and capacitors may be obtained with the aid of (9) by choosing a suitable value for one of the capacitors.

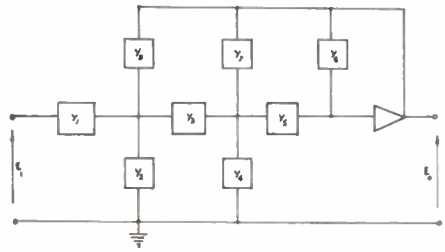


Fig. 1—Networks for the simulation of $\frac{E_0}{E_1} = -\frac{b_1 s}{a_3 s^3 + a_2 s^2 + a_1 s + 1}$.



$$b_1 = \frac{RC_1}{2(a+1)}, \quad a_1 = 2RC_6 + \frac{a}{2(a+1)} RC_1,$$

$$a_2 = \frac{(2a+1)}{2(a+1)} R^2 C_6(C_1 + C_4),$$

$$a_3 = \frac{a}{2(a+1)} R^3 C_1 C_4 C_6,$$

$$\frac{a_1}{b_1} > \frac{(a_3 - a_2) + \sqrt{a_2^2 + a_3^2}}{2a_2}$$

(a)



$$b_1 = \frac{1}{2} RC_3, \quad a_1 = \frac{a}{2} RC_2 + \frac{(a+1)}{2} RC_3 + 3RC_6,$$

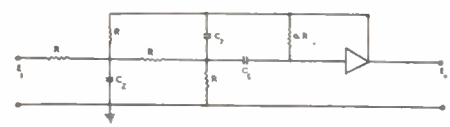
$$a_2 = \frac{3}{2} aR^2 C_2 C_6 + \frac{(3a+2)}{2} R^2 C_3 C_6,$$

$$a_3 = \frac{a}{2} R^3 C_2 C_3 C_6, \quad a_2 < \left(\frac{3a_1 - b_1}{6}\right)^2,$$

$$a_3 < \frac{b_1}{6}(a_1 - b_1)^2,$$

$$\frac{b_1(a_1 - b_1) + \sqrt{b_1^2(a_1 - b_1)^2 - 6b_1 a_3}}{3} > \frac{(2a_2 b_1 - 3a_3)}{2b_1} > \frac{b_1(a_1 - b_1) - \sqrt{b_1^2(a_1 - b_1)^2 - cb_1 a_3}}{3} > 0$$

(b)



$$b_1 = \frac{a}{5} RC_5,$$

$$a_1 = \frac{2}{5} RC_2 + \frac{(a+3)}{5} RC_5 + \frac{3}{5} RC_7,$$

$$a_2 = \frac{1}{5} R^2 C_2 C_5 + \frac{1}{5} R^2 C_2 C_7 + \frac{3a}{5} R^2 C_5 C_7,$$

$$a_3 = \frac{a}{5} R^3 C_2 C_5 C_7, \quad a_3 < \frac{25}{24} b_1(a_1 - b_1)^2,$$

$$\frac{5b_1(a_1 - b_1) + \sqrt{25b_1^2(a_1 - b_1)^2 - 24a_3 b_1}}{2} > \frac{(5b_1 a_2 - a_3)}{5b_1} > \frac{5b_1(a_1 - b_1) - \sqrt{25b_1^2(a_1 - b_1)^2 - 24a_3 b_1}}{2} > 0$$

(c)

Fig. 2—Block diagram of an operational amplifier and its associated input feedback networks for simulating third-order systems.

The other two possible circuits and the validity conditions for each are shown in Fig. 2(b) and (c).

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* Received by the IRE, October 10, 1961.

[1] L. K. Wadhwa, "Simulation of Third-Order Systems with One Operational Amplifier," PROC. IRE, vol. 50, pp. 201–202; February, 1962.

Deduction of Satellite Orientation from Faraday Fading Measurements*

It is well known[1] that satellite signals on the lower frequencies (20–56 Mc) received on linear antennas show a characteristic periodic fading due to the rotation of the plane of polarization of the arriving wave. This is due to the so-called Faraday effect, caused by magnetoionic splitting in the ionosphere. It will be shown that it is possible to deduce satellite orientation from the depth of this fading,[2] especially when the satellite transmits circular polarization, as is the case, for instance, with '59 iota 1 (Explorer 7).

The circular polarization transmitted by the satellite will generally be received as an elliptically polarized wave. The eccentricity of the polarization ellipse depends on the angle ϕ between the direction of circular polarization (which is nearly the same as the satellite spin axis) and the direction of the ray leading to the receiver. It is independent of satellite spin. The small semi-axis of the ellipse will be $E_{min} = E_{max} \cos \phi$ where E_{max} is the large semi-axis (Fig. 1). When $\phi = 90°$ the arriving wave is linearly polarized. When $\cos \phi$ changes sign, the sense of polarization rotation changes.

In this case of elliptical polarization of the received wave, the Faraday effect will rotate the whole ellipse around the ray. A receiver using a linear antenna will record a fading, the rate of which is as usual a measure of ionization in the ionosphere.[3] The depth of the fading, however, measures the angle ϕ at the satellite as follows:

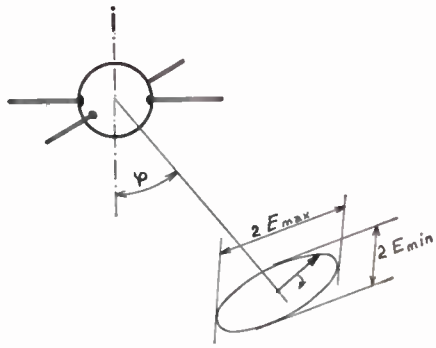


Fig. 1.

$$\cos \phi = \frac{\text{signal strength at a minimum}}{\text{average of signal strengths of the two adjacent maxima}}$$

when $\phi = 0$, the fading disappears (Fig. 2).

Simultaneous measurement of ϕ from two receiving sites defines the instantaneous orientation of the satellite axis in space, providing its orbit is known.

A single station can deduce satellite orientation assuming that the spin-axis direction is almost fixed in space or nutates around a fixed direction. This is so because there is a one-to-one correspondence between the axis directions and the functions $\phi(t)$ for a known orbit. Plotting ϕ vs i, the angle of incidence at the receiver, calculated for the orbit in question, one gets characteristic curves of the type shown in Fig. 3, drawn for a zenithal pass and $B = 25°$. A is the angle between the satellite axis and the orbital plane, B the angle between the local vertical and the projection of the satellite axis on the orbital plane, at closest approach. The measured values of ϕ will either follow one of these characteristic lines, oscillate around it or deviate in a consistent manner.

As an example, satellite orientation was calculated for revolutions 8165 and 10172 of '59 iota 1 (Explorer 7) transmitting on 19.991 Mc (Fig. 2), viewed from the receiving station of Val-Joyeux, France. On revolution 8165 the satellite axis was less than 10° from the orbital plane and at 20° to the vertical at closest approach. The axis seemed to be precessing at the rate of 0.23° per sec, almost in the orbital plane. At revolution 10172 the axis seemed to be less stable in space, tumbling at a rate of 0.45° per sec in a plane at 45° to the orbital plane. At closest approach the satellite axis was inclined about 74° to the vertical.

Care must be taken that the receiving antenna system is purely linearly polarized. This can be verified when receiving satellites with a dipole transmitting antenna, in which case the Faraday minima should always be zero.

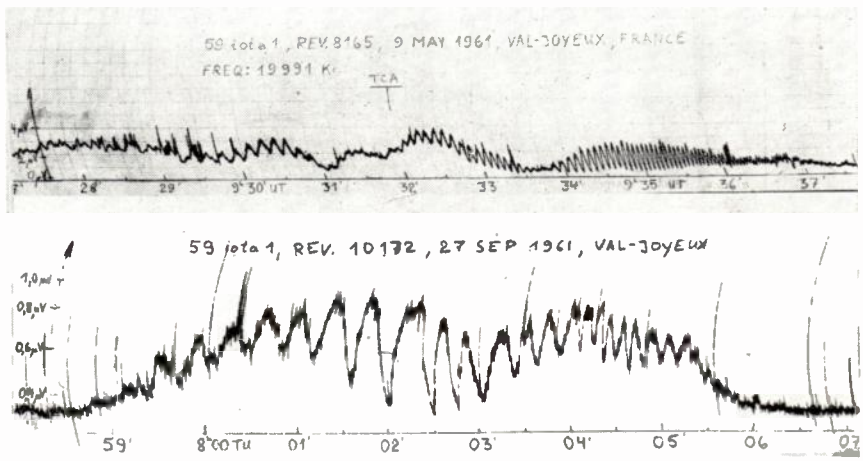


Fig. 2.

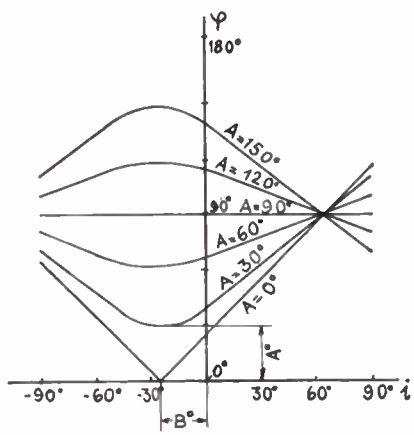


Fig. 3.

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Correction to "Bandwidth of Hybrid-Coupled Tunnel-Diode Amplifier"

In the above paper[1] the author would like to make the following correction.

The sentence "This must be equated to ½ to determine the value of θ at the half-power points." should read "$|2S_{12}S_{14}|^2$ must be equated to ½ to determine the value of θ at the half-power points."

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[1] R. M. Kurzrok, PROC. IRE (*Correspondence*), vol. 50, pp. 226–227; February, 1962.

* Received by the IRE, January 22, 1962. Experimental work has partly been carried out under United States Air Force Contract No. AF 61(052) through the European Office of Aerospace Research and partly under contract for the French Committee of Space Research.

[1] W. T. Blackband, B. Burgess, I. L. Jones, and G. J. Lawson, "Deduction of ionospheric electron content from the Faraday fading of signals from artificial earth satellites," *Nature*, vol. 189, pp. 1172–1174; April 25, 1959.

[2] J. Mass, "Nouvelles possibilités offertes par la mesure de l'amplitude des signaux radioélectriques des satellites artificiels," *Comptes Rendus des séances de l'Académie des Sciences*, vol. 253, pp. 1832–1833; October 23, 1961.

[3] K. C. Yeh and G. W. Swenson, Jr., "Ionospheric electron contents and its variation deduced from satellite observations," *J. Geophys. Res.*, vol. 66, pp. 1061–1067; April, 1961.

A Tunnel Emission Device*

This note describes an active solid-state triode device which achieves gain by means of a form of controlled internal field emission. Consider a structure consisting of two metallic stripes in contact with a single crystal of n-type germanium, and separated from each other by a thin insulating spacer, *e.g.*, aluminum oxide. A cross-sectional view is shown in Fig. 1. The surface barriers existing at the metal germanium interface are reverse biased in operation, and if the insulating spacer is thin compared to the depletion layers, a potential distribution like that shown in Fig. 2 results. The electric field E_i existing in the insulator when a bias is applied between the metal stripes fringes over into the germanium, and produces fields there approximately equal to E_i. E_i is limited only by the breakdown strength of the insulator, and can be made as high as 10^6–10^7 v/cm. Thus interband or metal to semiconductor tunneling can occur under the insulator, injecting electrons into the germanium. Such electrons would then experience the total field in the semiconductor, which has a small but nonvanishing component in the direction so that these electrons will flow out the germanium contact.

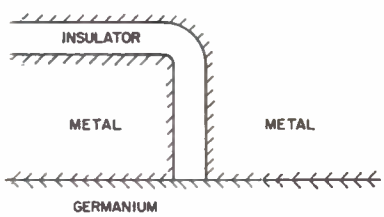


Fig. 1—Cross-sectional view of edge-effect device.

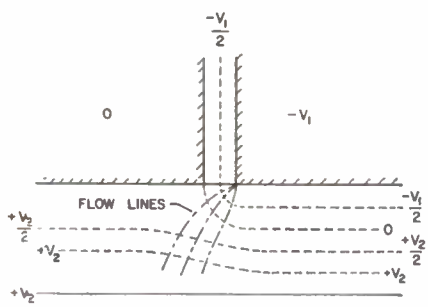


Fig. 2—Potential distribution in edge device (right-angle edge).

This current will be controlled by the maximum field occurring in the germanium, *viz.*,

$$\mathcal{E}^2_{\max} \approx \frac{V_{EB}^2}{d^2} + \frac{2qN_D}{K}(V_{EB} + V_{CB}) \quad (1)$$

where d is the thickness of the insulator, K is the dielectric constant and N_D the donor concentration of the germanium. The relative importance of V_{EB} and V_{CB} in controlling the tunneling current can be estimated from (1) as

$$\left.\frac{\partial V_{EB}}{\partial V_{CB}}\right| E_{\max} \approx \frac{\dfrac{-2q\bar{N}_D}{K}}{\dfrac{2qN_D}{K} + \dfrac{2V_{EB}}{d^2}}. \quad (2)$$

This voltage feedback factor is less than 10^{-4} if $V_{EB} \approx 1$ volt, $d \approx 100$ A, and $N_D \approx 10^{15}$. Hence, the generated current is controlled almost solely by V_{EB} while flowing in the emitter to collector loop, thereby resulting in active behavior.

This device is characterized by 1) a low, relatively temperature insensitive input impedance, 2) a high output impedance, 3) an active transconductance above a threshold value of V_{EB}, and 4) reversibility of the roles of the emitter and base films, *i.e.*, depending on the bias arrangement, either metal film may be used as the emitter and the other as base. (However, the complete electrical symmetry expected in an ideal structure, *e.g.*, Fig. 1, would not be expected where geometrical deviations occur.) Structures simulating this device have been fabricated by partially overlapping two films of aluminum, spaced by a 20 Å oxide. Fig. 3 shows the common base characteristics where the last film deposited is used as the emitter, while Fig. 4 shows the common base characteristics where the first film is used as the emitter. Studies are currently under way to determine to what extent this mechanism might have been present in the devices used to study hot electron transport in metal films.[1,2]

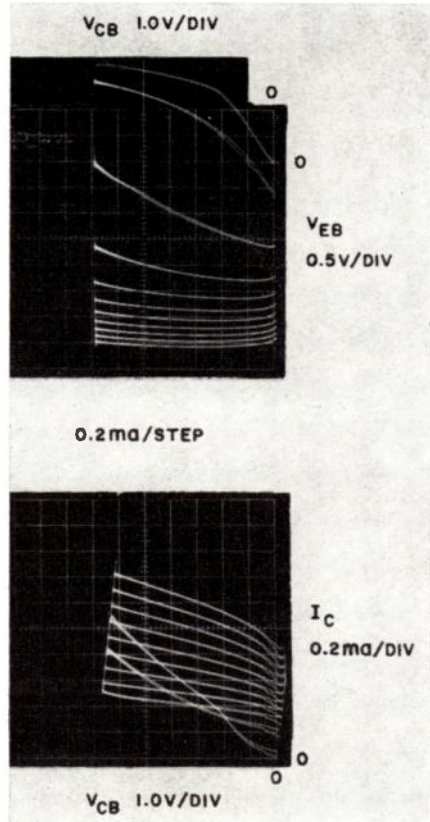


Fig. 3—$I_C - V_{CB}$ and $V_{EB} - V_{CB}$ curves for thin film device "normal" bias.

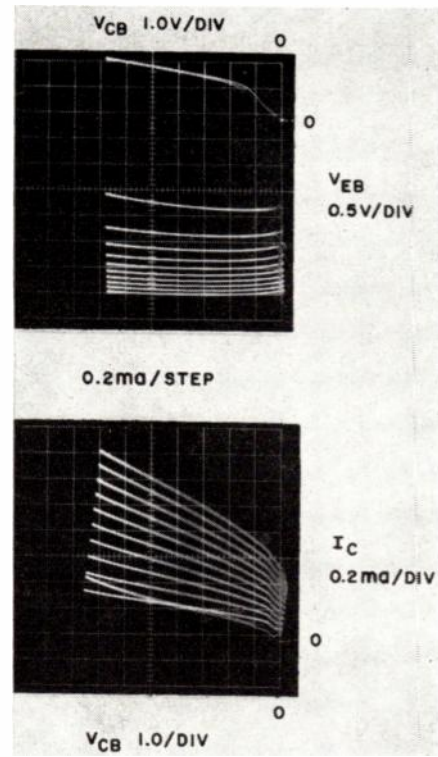


Fig. 4—$I_C - V_{CB}$ and $V_{EB} - V_{CB}$ curves for thin film device "reverse" bias.

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[1] J. P. Spratt, R. F. Schwarz and W. M. Kane, *Phys. Rev. Letts.*, vol. 6, pp. 341–342; April 1, 1961.
[2] J. P. Spratt, R. F. Schwarz and W. M. Kane, presented at Solid-State Device Res. Conf.; June, 1961.

* Received by the IRE, February 21, 1962.

Compatible Single Sideband*

I appreciate the opportunity to comment on Mr. Bruene's recent letter.[1]

I do not want to argue too much on his apparent displeasure with the name Compatible Single-Sideband. He points out that it does not follow the IRE definition for a single-sideband wave, which is not surprising, because Compatible Single-Sideband is not a *conventional* single-sideband wave, and this is why it is not just called "single-sideband." Furthermore, the system was not in existence in 1948, thus the 1948 IRE definition could not take the system into consideration.

There is, however, a definition officially adopted by the CCIR: "A single-sideband

* Received by the IRE, March 9, 1962.
[1] W. B. Bruene, "Comments on compatible single sideband," Proc. IRE (*Correspondence*), vol. 50, pp. 333–334; March, 1962.

transmission is considered to be compatible if it can be received on the existing conventional double-sideband receivers without any modifications whatsoever and with satisfactory quality of reception."[2] This definition was specifically written for the CSSB system. Furthermore, it forms the basis of a study question to which the United States, Australia, and other countries, are submitting answers. I believe that since CCIR is a division of ITU, which is a specialized agency of the United Nations, this definition is authoritative.

A number of astute engineers have used slightly different names for Compatible Single-Sideband. Mr. Harmon of the Westinghouse Broadcasting Company has called this system "Compatible Single-Sideband" in some of his writings, but he also has expressed his preference for the more detailed name "Full Carrier Compatible Single-Sideband." The Russians have called such systems "Optimum Modulation," and in other articles the "Kahn System." I prefer the use of the term "Compatible Single-Sideband" because it indicates the type of spectrum transmitted and the fact that it is compatible with existing AM receivers. However, I feel that it is unrewarding to argue definitions and I do not wish to take further space in so doing.

As to Bruene's point concerning the SNR, the article indicated that, because of economic considerations, present AM receivers are too narrow for good quality AM reception and do not pass all of the desired signal components. A CSSB wave, because it is a more compact wave, allows more signal energy to pass through the receiver and, therefore, the signal power increases. In this manner, although the noise is not altered, the SNR is improved. This has been reported by a number of independent engineers and others during actual on-the-air tests.

Regarding his comments on the *communications* applications, there is no question that suppressed carrier operation has severe limitations when used with high-speed aircraft because of the Doppler shift. We have maintained that a 20-cycle frequency translation error is the limit that should be accepted under operating conditions, because it greatly degrades intelligibility under poor SNR conditions. It should be noted that AT&T has used this specification of 20 cycles for their carrier telephone work over the years, despite the fact that at the time of their specification was formulated it was very difficult and expensive to maintain such stability. Even a 20-cycle error is intolerable for many data links and selective calling systems.

Other groups, both here and abroad, have agreed with this specification, and surely, in this day of extremely high-speed aircraft, it seems quite shortsighted not to recognize this ever increasing problem. Compatible Single-Sideband and conventional amplitude modulation systems do not suffer from Doppler shift.

Regarding the clipping question, square waves are generally used to analyze clipping systems and also to measure equipment performance. This is a long accepted practice, just as the sine wave is used to test conventional AM transmission systems. Most engineers recognize the limitations of both tests, but each test reveals many equipment problems. Furthermore, it is well known that conventional SSB systems cannot utilize clipping to full advantage.[3] Compatible single-sideband and amplitude modulation, as well as double-sideband suppressed carrier systems take full advantage of clipping.

An automatic load-control circuit is similar to a limiter used in broadcasting. It is well known that neither device operates on the waveshape of the modulation and, therefore, both are incapable of reducing the crest factor which is the function of a clipper.

I hope that the does not overstate the case for Compatible Single-Sideband, because it is not our intention to give the impression that Compatible Single-Sideband is a universal panacea. CSSB does, however, have certain advantages for applications, such as broadcasting and mobile communications services. For a full discussion of the advantages and disadvantages of Compatible Single-Sideband, see the October, 1961, issue of PROCEEDINGS.

Also, it should be noted that a most interesting analysis of the 1.4 phase stretch system of Compatible Single-Sideband has been published in the *Australian Proceedings of the IRE*.[4] A detailed discussion of the CSSB paper appeared in the *European Broadcasting Union Journal*.[5]

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[2] "Resolutions, Questions, and Study Programes," CCIR, 9th Plenary Assembly, Los Angeles, Calif., vol. 2, pp. 165–166; 1959.

[3] L. R. Kahn, "The use of speech clipping in single-sideband communications systems," PROC. IRE (*Correspondence*), vol. 45, pp. 1148–1149; August, 1957.

[4] J. M. Dixon, "Envelope modulation," *Proc. IRE, Australia*, pp. 481–486; August, 1961.

[5] Some noteworthy articles, "Compatible Single-Sideband," *EBU Rev.*, pp. 274–275; December, 1961.

A Comparison of Error Rates for Coherent and Phase-Comparison Detection of Two- and Four-Phase Digital Signals in the Presence of Rayleigh Carrier Fading*

The theoretical performance of various detecting schemes in the presence of additive white noise is well established. With the increasing need to transmit digital data via HF radio channels, it is important to have available some estimate of the effects of fading. This note is the result of an extension of previously published work and provides a basis for comparison of probability of element error as a function of average signal-to-noise power ratio for commonly known phase detection methods when Rayleigh distributed signal fluctuations are present.

In a previous correspondence, Cahn [1] has indicated that a four-phase signal such as Collins Kineplex requires slightly less than a 3 db better SNR to maintain a specified error rate when phase-comparison[1] rather than coherent detection is used in the presence of white noise. In contrast, the binary phase-comparison demodulation technique suffers a smaller disadvantage in required SNR especially when the ratio is large, with respect to the coherent two-phase system [2]. This degradation becomes small, approaching zero db, for large SNR's. These results, for both the two- and four-phase cases, have been substantiated experimentally [2], [3]. If Rayleigh fading occurs, the relative locations of the resulting curves, in comparison to those without fading, undergo noticeable change. It has been shown that for coherent phase-reversal detection with Rayleigh fading, the probability that a signal element will be received incorrectly is given by [4]

$$P_e = \frac{1}{2}\left[1 - \sqrt{\frac{R}{R+1}}\right], \qquad (1)$$

where R is the average (S/N) power ratio which alternatively may be taken as the received signal energy per bit divided by the noise power per cycle of bandwidth.

For differentially coherent phase-reversal modulation, the error probability with fading is found directly from similar equations

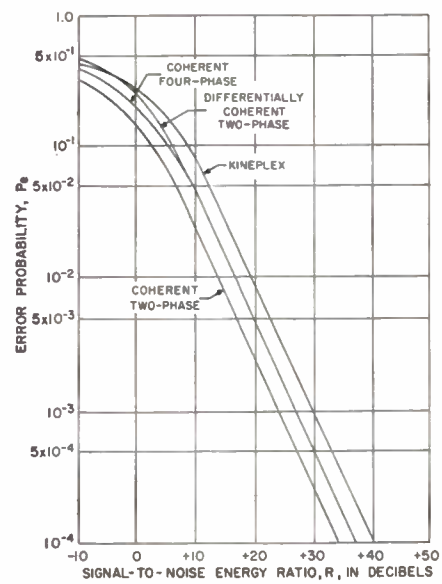


Fig. 1—Error probability vs average SNR with Rayleigh Fading.

[1] The phase comparison, or differentially coherent, detector as discussed here is one which derives its reference phase for each pulse from the phase of the immediately preceding pulse. Another scheme whereby the reference is obtained by integration over two or more previous pulse time intervals which can further improve performance is not considered here.

* Received by the IRE, November 1, 1961.

for frequency modulation [4], [5]. The result is

$$P_e = \frac{1}{2(R+1)}. \qquad (2)$$

The expressions derived by Montgomery [4] for phase modulation provide an equation for the four-phase coherent system when the maximum deviated phase angle is adjusted to $\pi/4$ radians. The error rate then becomes

$$P_e = \frac{1}{2}\left[1 - \sqrt{\frac{R/2}{R/2+1}}\right], \qquad (3)$$

which shows close agreement with Fig. 3 of Cahn [5]. In the derivation of a companion equation for the phase-comparison Kineplex technique, Mosier and Clabaugh [3] degrade the SNR by 3 db compared to the coherent four-phase system. This is thought to give a useful, although not exact, indication of performance. The appropriate error rate is thus given as

$$P_e = \frac{1}{2}\left[1 - \sqrt{\frac{R/4}{R/4+1}}\right] \qquad (4)$$

The above equations are plotted in Fig. 1.

From the foregoing, it is apparent that with fading the separation between the coherent and the phase-comparison detector curves in both the two- and four-phase cases is fixed and is not dependent upon the SNR, except at low values. Thus, the performance of the differentially coherent detector will not approach that of the coherent device, even for very-high SNR's. The four-phase coherent system shows an improvement over the binary phase-comparison technique at low SNR's. Intuitively, this is to be expected because the former system has only the signal corrupted by noise, whereas in the latter system both signal and reference are randomly disturbed. With high SNR's, the performance of the ideal four-phase detector is identical with that of the binary phase-comparison system. That (2) and (3) do, in fact, yield the same values in this case is verified as follows: For large R, the term under the radical in (3), can be approximated (after inverting) as

$$\sqrt{\frac{R/2+1}{R/2}} = \sqrt{1+\frac{2}{R}} = 1 + \frac{1}{2}\left[\frac{2}{R}\right], \qquad R \gg 1.$$

Then (3) becomes

$$P_e = \frac{1}{2}\left[1 - \frac{1}{1+\frac{1}{R}}\right] = \frac{1}{2(R+1)}$$

which is (2).

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[1] C. R. Cahn, "Comparison of coherent and phase-comparison detection of a four-phase digital signal," Proc. IRE (*Correspondence*), vol. 47, p. 1562; September, 1959.
[2] J. G. Lawton, "Theoretical error rates of 'differentially coherent' binary and 'kineplex' data transmission systems," Proc. IRE, vol. 47, pp. 333–334; February, 1959.
[3] R. R. Mosier and R. G. Clabaugh, "Kineplex, a binary transmission system," *Trans. AIEE, (Commun. and Electronics)*, pp. 723–727; January, 1958.
[4] G. F. Montgomery, "A comparison of amplitude and angle modulation for narrow-band communication of binary-coded messages in fluctuation noise," Proc. IRE, vol. 42, pp. 447–454; February, 1954.
[5] C. R. Cahn, "Performance of digital phase-modulation communication systems," IRE Trans. on Communication Systems, vol. CS-7, pp. 3–6; May, 1959.

Harmonic Generation Using the Ammonia Inversion Transition*

A molecular system with two quantized energy levels can be used for amplification of signals if its equilibrium population is inverted by some means. A less familiar property of two-level systems is that under strong field excitation they can act as nonlinear elements having frequency-mixing properties. This effect does not require population inversion and is characterized by power levels of operation much above the usual ones for maser amplification. The frequencies at which these nonlinear phenomena are significant are related to the energy separation between levels and, consequently, depend on the material used, of which there are many choices available, giving interaction from microwave up to infrared and optical frequencies.

An analysis of harmonic generation using this effect[1] predicts that an induced electric dipole, two-level system, with a positive temperature population distribution will emit third harmonic of the driving frequency when subjected to strong RF fields at approximately one-third of the natural transition frequency. Since there exists an effective detuning or shift of the natural resonance due to the strong fields (similar to the Bloch-Siegert shift)[2] the driving frequency for maximum interaction occurs at a value somewhat higher than one-third the natural frequency:

$$\omega_{\text{drive}} = \frac{\Omega_0}{3}\left[1 + \frac{9}{8}\left(\frac{\mu E}{\hbar\Omega_0}\right)^2\right], \qquad (1)$$

where Ω_0 is the natural transition frequency, μ is the electric dipole moment and E is the intensity of the applied field. The harmonic power output per cubic centimeter of interaction volume is

$$P = \frac{1}{4096}\frac{\hbar^2 N\tau}{kT}\left(\frac{\mu E}{\hbar}\right)^6 \frac{\Omega_0^2}{\omega^4} \cdot \frac{1}{1+\frac{1}{1024}\left(\frac{\mu E}{\hbar}\right)^6 \frac{\tau^2}{\omega^4}}, \qquad (2)$$

where N is the total number of molecules per unit volume, τ is the relaxation time due to collisions, T is the temperature, k is Boltzmann's constant and ω is the drive frequency.

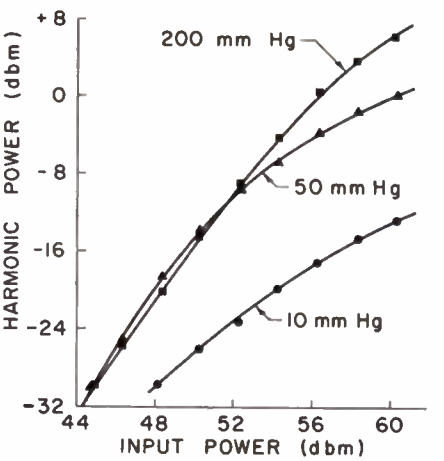


Fig. 1—Harmonic output power vs incident power for various pressure ranges. Power levels are in decibels above one milliwatt.

An experiment has been performed to observe this effect in the inversion transition of ammonia using a detuning of approximately 7 per cent. The experimental configuration consisted of a reentrant cavity, completely filled with ammonia gas, which was resonant at 8530 Mc and $8530\times3 = 25{,}590$ Mc with a gap in which the electric fields of both modes were strong and parallel. A 2J51 magnetron was the power source, with a low pass filter to reject the magnetron harmonics.

Output powers of the order of 10 milliwatts were obtained with input powers slightly in excess of 1 kilowatt. In Fig. 1

* Received by the IRE, February 5, 1962. The research in this document was supported jointly by the U. S. Army Signal Corps, the U. S. Air Force, and the U. S. Navy (Office of Naval Research).

[1] J. R. Fontana, R. H. Pantell and R. G. Smith, "Advances in Quantum Electronics," Jay R. Singer, Ed., Columbia University Press, New York, N. Y., p. 612 ff.; 1961.

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the harmonic power output measured is shown as a function of input power and ammonia pressure. For a pressure of 200 mm, cube law behavior is observed, with saturation starting to set in at about 1 kilowatt. At lower pressures, saturation occurs at lower power levels.

In addition to saturation, there is another effect which tends to cause the input-output characteristics to vary from cube law because of the frequency detuning and of the inhomogeneity of the fields, there is a variation of the effective natural resonance of each molecule according to its position within the cavity. At lower pressures where the line width is narrow this causes a volume effect, superimposed on the saturation effect, which tends to change the harmonic power output. At higher pressures where the line is quite wide the volume effect is small and saturation predominates. The data are qualitatively consistent with these predictions.

The driver frequency field in the gap was approximately 25,000 v/cm for the highest points shown on the curves. The power required to produce such a field (about 1 kilowatt) is much greater than necessary in a well designed system, and is due to the loss present in the input coupling system used. Loss also existed in the output coupler.

At power levels higher than the range of the curves, a plasma was observed to form and harmonic generation from this was noted. The characteristics were different from the above effect, and the two were easily distinguishable.

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Hilbert Transforms and Positive-Real Functions*

In a recent note[1] Schwarz's lemma was used to derive certain properties of positive-real (p.r.) functions. In the following we shall show that such properties can be established with the use of an important but neglected formula relating the Laplace transform $F(p)$ of a causal function with the real part $R(\omega)$ of its Fourier transform. This formula states that

$$F(p) = \frac{2}{\pi}\int_0^\infty \frac{p}{p^2+y^2} R(y)dy \qquad (1)$$

and will be proved at the end of this note. If $F(p)$ has no imaginary poles then $R(\omega) = \text{Re } F(j\omega)$. If $F(p)$ has such poles then appropriate impulses must be added to Re $F(j\omega)$ to obtain $R(\omega)$.[2]

For example, if

$$F(p) = \frac{K}{p - j\omega_0}$$

then

$$R(\omega) = K\pi\delta(\omega - \omega_0). \qquad (2)$$

Using (1) we shall prove that:

1) If $F(p)$ is p.r. then

$$|\arg F(p)| \leq |\arg p| \quad \text{for Re } p \geq 0. \qquad (3)$$

2) If $F(p)$ is p.r. then

$$\frac{F(p_1)}{p_1} \leq \frac{F(p_2)}{p_2} \quad \text{for } p_1 > p_2 > 0. \qquad (4)$$

3) If $F(p)$ is analytic for Re $p>0$ and $R(\omega)\geq 0$ then $F(p)$ is p.r. (In the usual formulation of this theorem one imposes the additional requirement that the imaginary poles of $F(p)$ must be simple with positive residues. However, this is implicit in our definition of $R(\omega)$ and condition $R(\omega)\geq 0$.)

Proof: with y a constant, the function $p/(p^2+y^2)$ satisfies (3) and (4) as one can see by easy inspection. Since $R(\omega)\geq 0$ and properties 1) and 2) are additive, we conclude from (1) that they must be true for any $F(p)$. To prove 3) we observe that from r.h. plane analyticity of $F(p)$ expansion (1) follows and since $p/(p^2+y^2)$ is p.r. and $R(\omega)\geq 0$, $F(p)$ must also be p.r.

Q.E.D.

The known proofs of 1) and 2) make use of Schwarz's lemma and are rather lengthy.[3,4]

We close with a simple proof of 1). This equation is usually derived from the r.h. plane analyticity of $F(p)$ and Cauchy's theorem; however, it can be formally established from the identity

$$R(\omega) = \int_{-\infty}^{\infty} R(y)\delta(\omega - y)dy. \qquad (5)$$

Indeed, for $R(y) = \delta(\omega - y)$ we have [see (2)] $F(p) = 1/\pi(p - jy)$; hence, for an arbitrary $R(\omega)$ as in (5) the corresponding $F(p)$ is given by

$$F(p) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{R(y)dy}{p - jy} \qquad (6)$$

and (1) follows from (6) and the evenness of $R(\omega)$.

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* Received by the IRE, January 10, 1962.

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A Temperature-Stabilized Microwave Power Limiter for Communication Satellite Use*

A ferrimagnetic microwave power limiter has been developed for use in an experimental active communication satellite repeater. At a given frequency the limiting level can be varied with the magnetic bias field in contrast to coincidence limiters.[1–4] Temperature stability of the device characteristics was achieved over a temperature range $55°\leq T\leq 120°$F required for satellite operation. This limiter uses as its nonlinear element a large single crystal sphere of yttrium iron garnet (YIG) biased to the subsidiary absorption,[5,6] and placed in a transmission microwave cavity. Limiting occurs when the power level exceeds the threshold for the subsidiary absorption (parametric excitation of half-frequency spin waves) in the garnet. The losses associated with this absorption increase with power above the threshold, lowering the unloaded cavity Q and increasing the cavity insertion loss.

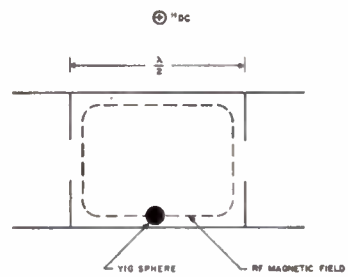


Fig. 1—Schematic diagram of subsidiary absorption limiter.

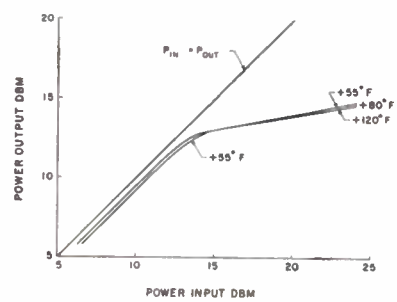


Fig. 2—Measured characteristics of the 4-kMc limiter at 3 temperatures. The dc magnetic field was 1100 oersteds.

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A limiter using this principle can be constructed at any frequency, depending only on the availability of an adequate dc magnetic field, whose amplitude is somewhat smaller than the ferrimagnetic resonance value. Theoretical considerations show that the filling factor, which is proportional to the sample volume divided by the cavity volume, must be large in order to achieve limiting over a significant range of power. The availability of large single crystals of yttrium iron garnet now makes it possible to obtain these large filling factors along with narrow linewidths.

Fig. 1 is a schematic of a 4 kMc model of this limiter which used a polished sphere of single crystal YIG, 0.260 inches in diameter. The desired limiting value was 14 dbm. This level can be adjusted to as low as 3 dbm with the dc magnetic field. A reduced-height (0.400 in) transmission cavity with a loaded Q of 200 was operated in the TE_{101} mode with the sample placed in the maximum RF magnetic field close to the side wall of the cavity. At low power levels the sample has very little effect on cavity transmission properties. Above a well-defined threshold level sample losses increase rapidly and limit the transmission power level.

Temperature changes can have large effects on the characteristics of this device. The limiting power level changes with $4\pi M$, ΔH_k, H_{dc} and H_a, the anisotropy field.[7] In addition, there are low-level insertion loss variations due to thermal cavity detuning effects. These include cavity expansion and RF susceptibility variations dependent on $4\pi M$, ΔH_k, H_{dc}, and H_a. A major source of thermal changes in limiter performance can be avoided by the use of a spherical sample, for which the ferromagnetic resonance frequency is independent of the saturation magnetization and its associated temperature variation. It can also be shown that orientation of the anisotropy field can be used to minimize further the temperature sensitivity. The samples used here were of a purity such that ΔH_k had only a slightly negative temperature coefficient at room temperature. For these samples orientation of the magnetically hard [100] crystallographic axis along the biasing field gave optimum temperature characteristics.

The limiter performance over the design temperature range from 55° to 120°F is shown in Fig. 2. The sharp break in characteristic at the threshold is important for efficient power leveling. It is dependent on the use of single-crystal narrow-linewidth material and the surface polish. In this case ΔH_k was approximately 0.15 oe at 4 kMc. Spike leakage was observed but not investigated; however, this limiter should have characteristics similar to the coincidence limiter[2] in this respect.

Because of weight limitations in the satellite application, the cavity was fabricated from silver-plated magnesium resulting in a total weight, including magnet, of 11 ounces. While the limiter was designed at a particular frequency with particular requirements, it should prove useful in other applications at different frequencies requiring precise control of power level.

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Power-Aperture and the Laser*

The author has heard frequent reference to the power-aperture product criterion for radar surveillance, but has not yet seen in print a reasonably general proof of the relation, as simple as it is. The situation is particularly important at present with the development of the laser, its very narrow beamwidth and the consequent possibility of a very long range optical radar with a small aperture. It is necessary, therefore, to consider the limitations of this device, particularly for surveillance purposes. To anticipate the result: the surveillance of a given number of square degrees of coverage per second out to some range with a given input noise, requires at least the same average power-aperture product at optical as at microwave frequencies.

Large Spot Size

We consider first the usual radar case in which the beamwidth is much larger than the target (large spot size). $E_T = P_T\tau$ is the transmitted energy in an element of solid angular resolution $\Delta\Omega$ during a total coherent time of integration τ; the total coherent time τ may be broken up and distributed over a longer time interval provided the returns from an individual target can be processed coherently. P_T is the average transmitted power during time τ and corresponds to the peak pulse power if the power is emitted in uniform rectangular pulses. For a CW fence radar, τ would ideally correspond to the time of passage of the target through the fence. The transmitting antenna gain $G_T = 4\pi/\Delta\Omega$.

The basic radar equation, in terms of the returned energy, E_R, in time τ, is

$$E_R = \frac{E_T G_T \sigma A_R}{(4\pi R^2)^2} = \frac{E_T \sigma A_R 4\pi}{(4\pi)^2 R^4 \Delta\Omega},$$

where A_R = receiving antenna aperture area.

At the output of a matched filter, the signal-to-noise energy or power ratio is $2E_R/N$, where N is the input noise power per cps of bandwidth (noise spectral density). Therefore, if we denote by C the signal-to-noise power margin required for some preassigned probability of detection,

$$C = \frac{2E_R}{N} = \frac{2E_T \sigma A_R}{4\pi N R^4 \Delta\Omega}.$$

If n is the total number of elements of angular resolution of the transmitting antenna swept out during a surveillance scan interval t and if E_G is the total energy radiated during t, then $nE_T = E_G$, and

$$C = \frac{2E_G \sigma A_R}{4\pi N R^4 n\Delta\Omega} = \frac{2E_G \sigma A_R}{4\pi N R^4 \Omega}; \quad n\Delta\Omega = \Omega.$$

$E_G = P_A t$, where P_A is the average transmitted power in a scan interval, so

$$C = \frac{2P_A t \sigma A_R}{4\pi N R^4 \Omega} \text{ or } 2\pi NC \frac{R^4}{\sigma}\left(\frac{\Omega}{t}\right) = P_A A_R.$$

This is the surveillance equation for large spot size, and shows that the solid angular coverage swept out per second is proportional to the product of the average transmitted power and the receiving aperture.

There are, of course, other limitations not expressed in the previous equation, such as mechanical limitations on speed of solid angular coverage, and assurance that the receiving aperture is in the correct angular position to receive the return echo at the time of arrival.

In an actual radar there will be losses, which can be lumped in with C. An important corollary is obvious from the above theorem, by virtue of the fact that $(\Sigma P_i)\cdot(\Sigma A_i) > \Sigma P_i A_i$, for $i > 1$. For a given rate of coverage out to a given range for the case of separate radars, not synchronized or coherent with one another, the smaller the number of radars, the smaller the total power-aperture requirements; in fact, if line-of-sight requirements permit, one radar is the most efficient. For example, if we took an extreme case of 100 radars, then the system would require ten times as much total aperture area and ten times as much total average power as would the single radar installation.

With a laser radar, in the case of large spot size, the same fundamental coverage considerations apply as for a microwave radar. Therefore, unless the assumptions of the foregoing analysis can be controverted for the laser, since we will need as high power and as large aperture for the optical as for microwave radar, there is little advantage to the laser for long range surveillance, and we will probably continue into the indefinite future with radars in the general microwave region for this purpose. Of course, in tracking with large spot size, it is true that a laser radar with a small aperture can track to the same range as a microwave radar with equal power and noise and much larger aperture.

Small Spot Size

It has been pointed out that the laser is capable of such narrow beamwidth that the spot size can be smaller than the target, so that all the power in the transmitted beam is intercepted by the target, resulting in an inverse-square optical radar range relation as compared to the inverse-fourth for the microwave radar. This inverse-square relation may be true for relatively short ranges, but at a long range such as 1000 nautical miles, for an optical-wavelength laser radar with a 1-cm aperture, the spot size due to the diffraction-limited beamwidth is about 300 feet across. A large percentage of space objects will be considerably less than this. Thus, for space applications over appreciable ranges, for the most part, with the small

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apertures presently discussed for laser radars, the spot sizes will be large, and the conventional inverse-fourth power radar equation holds. Laser radar apertures will have to be raised to linear dimensions of the order of meters rather than centimeters to derive what advantages there are from small spot size. However, once we get to the larger dimensions cited, one of the main advantages of the optical radar, small size, is lost. However, for shorter ranges, such as 10 nautical miles, a tremendous power or aperture advantage is theoretically available over a microwave radar subject to the inverse-fourth power restriction.

It is important, though, to realize that in the whole preceding discussion we have given minimum attention to target cross section as a function of wavelength and spot size, and the effect of motion and consequent fluctuations The whole subject is too involved to be treated sketchily as it must in a contribution such as the present one. However, one simple example will be given, to bring out the kind of problem that exists with small spot size.

Suppose that one had a 100-foot perfectly-reflecting smooth sphere. The only region of the sphere which would reflect back to the source would be a small area surrounding the radius vector from the source to the center of the sphere. Any other region of the sphere would be at such an angle to the radius vector that it would reflect signal away from the source. With large spot size, because of beamwidth much greater than the target, as long as the sphere is within the beam there will always be a radius vector within the beam perpendicular to some part of the sphere, so that some portion of the radiated energy is bound to be reflected back. However, with small spot size, unless the spot is in the region of the sphere perpendicular to the radius vector, there will be essentially no reflection back to the source; the energy will be specularly reflected in some other direction. The return signal strength is tremendous when the beam is exactly centered on the sphere, but goes essentially to zero when off-center.

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Parametric Amplification and Oscillation at Optical Frequencies*

Recent experimental work[1] using intense optical fields produced by a maser has indicated that it is possible to obtain variable parameter interaction in a solid. It follows that the processes of amplification and oscillation utilized in microwave devices may be extended to the optical frequency range. Specifically, we propose that coherent optical energy may be generated at subfrequencies if a nonlinear dielectric material is driven by an optical maser "pump," such as a ruby. Here we derive the conditions for oscillation in a simple resonant system based on the observed experimental data for second harmonic generation.[1-3]

Consider a resonant structure composed of two parallel, highly reflecting surfaces bounding a medium of nonlinear dielectric material, such as quartz. We shall excite the medium with a traveling-plane wave of frequency f_p and by parametric excitation produce standing waves in the medium at frequencies f_s and f_i subject to the condition that $f_p = f_s + f_i$. Here it is assumed that the thickness of the medium l is such that there exist resonant modes at f_s and f_i. It is also assumed that the reflectivity of the walls is small at the pump frequency so that the pump wave may propagate through the structure without appreciable reflection. Under these conditions, it may be shown[4] that the rate of change of amplitude of the signal wave E_s due to interaction of the "idler" wave E_i with the pump is given by

$$\frac{\partial E_s}{\partial t} = \frac{1}{4\epsilon l}\int_0^l e^{-jk_s z}\left(\frac{\partial P_s}{\partial t}\right)dz = \frac{j\omega_s\gamma_{si}E_i^*E_p}{4\epsilon l}\int_0^l e^{j(k_p-k_s-k_i)z}dz \quad (1)$$

where k_s, k_i, and k_p are the respective wave vectors $(2\pi/\lambda)$ for the signal, idler, and pump; and it has been assumed that the polarization of the nonlinear medium at frequency f_s is

$$|P_s| = \gamma_{si}|E_i||E_p| \quad (2)$$

where γ_{si} is a function of the three frequencies. Taking into account the Q of the cavity at the frequency f_s we obtain the equation,

$$\frac{\partial E_s}{\partial t} = \alpha_{si}E_i^* - \frac{\omega_s}{2Q_s}E_s, \quad (3)$$

and a similar equation for the idler wave,

$$\frac{\partial E_i}{\partial t} = \alpha_{is}E_s^* - \frac{\omega_i}{2Q_i}E_i \quad (4)$$

where

$$\alpha_{si} = \frac{j\omega_s\gamma_{si}E_p}{4\epsilon l}I_{si}(l) \quad (5)$$

and $I_{si}(l)$ is the "coherence" integral of (1). Now for oscillation, the rate of growth of the signal and idler waves should be zero or greater, and setting (3) and (4) equal to zero yields

$$\alpha_{is}\alpha_{si}^* - \frac{\omega_i\omega_s}{4Q_sQ_i} = 0. \quad (6)$$

Using the Q of a planar cavity with power reflectivity R given by

$$Q_s = \frac{k_s l}{1-R}, \quad (7)$$

and setting $\omega_s \cong \omega_i \cong \omega_p/2$, we obtain

$$\frac{\omega_s^2\gamma_{si}^2E_p^2I_{si}^2(l)}{4\epsilon^2 l^2} > \frac{\omega_s^2(1-R)^2}{k_s^2l^2} \quad (8)$$

or

$$\gamma_{si}^2E_p^2I_{si}^2(l) > \frac{4\epsilon^2\omega_s^2(1-R)^2}{k_s^2} \quad (9)$$

as the condition for oscillation at the frequencies f_s and f_i.

In a similar manner we may calculate the second harmonic electric field for a traveling wave of frequency f_p obtaining

$$E_{2p} = j\omega_p\sqrt{\frac{\mu}{\epsilon}}\gamma_{2p}E_p^2\int_0^l e^{j(2k_p-k_{2p})z}dz \quad (10)$$

where the polarization at frequency $2f_p$ is given by

$$|P_{2p}| = \gamma_{2p}|E_p|^2, \quad (11)$$

and the generation takes place over a path length l. We now define the efficiency of second harmonic power generation as

$$\eta = |E_{2p}|^2/|E_p|^2 = \omega_p^2\frac{\mu}{\epsilon}\gamma_{2p}^2E_p^2I_{2p}^2(l) \quad (12)$$

with $I_{2p}(l)$, the "coherence" integral of (10). For a practical experiment, with the proper choice of materials, the values of γ and the coherence integral $I(l)$ should be approximately the same for second harmonic generations as for parametric mixing. Thus, the inequality of (9) reduces to

$$\eta > (1-R)^2 \quad (13)$$

for the same length, l, and pump amplitude E_p. Recent experiments[1-3] indicate that η can be of the order of 10^{-6} indicating that the reflectivity of the cavity walls should be 99.9 per cent or higher for oscillation. This reflectivity should be obtainable using multiple dielectric layer films; higher pump fields using advanced techniques should relax the above requirements.

We have here considered a special case of subfrequency generation using a simple cavity geometry and a traveling pump wave. There are many other possible configurations for such cavities utilizing a standing wave pump, for example, or taking advantage of the tensor properties of the crystal to obtain longer interaction lengths, such as described by Giordmaine[2] and Maker.[3] It is felt that the possibility of coherent generation of lower frequencies as shown by this calculation offers great promise as an alternative source of long wavelength energy at frequencies where direct maser action is not feasible. In addition, upon the availability of continuous high-power maser sources, amplifiers may also be built using the above techniques. Experiments are now underway to verify the above predictions.

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Tunnel Diode Shift Register*

Shift circuits are used in information handling systems for storing data, converting it from serial to parallel (and vice versa), counting, and the like. These commonly include a chain of bistable storage stages connected in cascade. It is generally desirable that the shift operation be accomplished at high speed and with a minimum of power consumption. The circuit shown in Fig. 1 performs the function of storage and shifting by employing a tunnel diode TD as the bistable element and a series combination of resistor R and conventional diode D as the interstage coupling network. Fig. 2 illustrates a tunnel diode volt-ampere characteristic and the operating points α and β for the low and high state, respectively. All states of the shift circuit are structurally the same; each stage

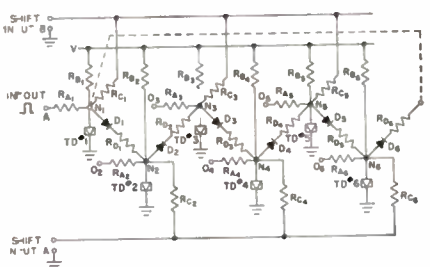


Fig. 1—Tunnel diode shift circuit diagram.

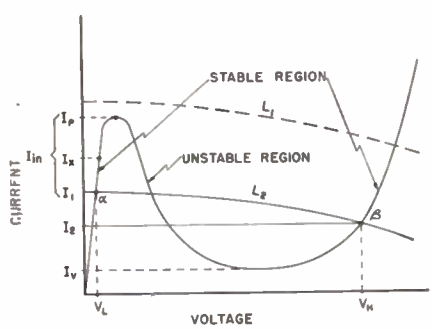


Fig. 2—Tunnel diode V-I characteristic and the nonlinear load line of the coupling network.

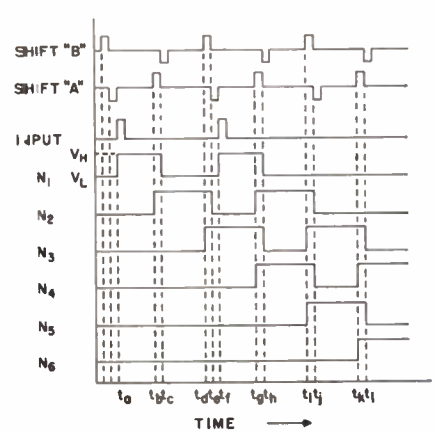


Fig. 3—Timing diagram.

* Received by the IRE, November 2, 1961.

has a tunnel diode TD which is biased with a dc current through resistor R_b and an input terminal O, connected to TD by means of resistor R_a, where information to be shifted may be applied. Since the impedance of the tunnel diode is negligibly small compared to the interstage coupling network, the load line seen by each tunnel diode is essentially that of D in series with R_d, as indicated in Fig. 2. Operation of the circuit could best be described with reference to the timing diagram of Fig. 3. Initially all the tunnel diodes are in the reset or low voltage state having a dc current bias I_1 flowing through each of them. Since all junctions N are at essentially the same potential, no current flows in the coupling network. When a pulse $I>I_p-I_1$ is applied at the input terminal of any odd numbered stage ith at $t=t_a$ it causes the tunnel diode TD_i to switch over to its high voltage stage and shift to the operating point β after the input pulse is removed. The dc current flowing through TD_i is now I_2 and a "one" has been stored in that stage. The excess current $I_1-I_2=\Delta I$ is essentially taken up by the tunnel diode of the next succeeding stage TD changing its bias current to $I_X=2I_1-I_2$; all other tunnel diodes remain unaffected. To shift the bit one more stage, one applies a positive advance pulse $I_p-I_1>I_A>I_p-I_X$ to terminal A at $t=t_b$ which causes only TD_{i+1} to switch to its high state but none of the others. Each advance pulse at A is followed by a negative reset current pulse I_R at terminal B of sufficient amplitude to reset all odd-numbered tunnel diodes. The next positive advance pulse is applied at terminal B at time t_d causing each of the odd-numbered stages to assume the operating state of its immediately preceding even-numbered stages. The shifting cycle is completed and a bit stored in the odd $(i+2)$th stage. To store a bit in an even-numbered location, one performs the same operation with the shift pulses at A and B interchanged. For subsequent storing or shifting, one repeats the same sequence. Each advance and reset pulse pair is effective in shifting the stored information one position to the right in the shift circuit. The information is shifted from the odd-numbered main stages to the next succeeding even-numbered, temporary storage stages, when the advance pulse is applied at terminal A and conversely the information is shifted from even- to odd-numbered stages by applying an advance shift pulse at terminal B. Thus a bit entered into the first stage will reach the nth location after n advance pulses. The stored information may also be read out of the shift circuit in parallel form by sampling the outputs at the terminals O. To operate this circuit as a parallel-to-serial shift register, one enters the information at the terminals O of the odd-numbered stages, respectively, and then reads the same information out serially from the last stage as advance reset pair pulses are applied at terminals A and B. Clearly by interconnecting the last stage back to the first stage one obtains a ring counter (commutator). A six-stage shift circuit was constructed and tested in the laboratory using germanium tunnel diodes IN 2939 and conventional diodes IN 279 with $R_A=1K$ and $R_D=1.5K$. The operating dc bias current I_1 and I_X were 440 μa and 660 μa, respectively, and the advance and reset pulses were 420 μa. Resistors R_B and R_C were chosen large enough to make these currents independent of the voltage across the tunnel diode. The advance and reset pulses were generated with conventional digital circuitry. This shift circuit offers the advantages of simplicity, low power drain, potential high-speed operation and low cost.

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Comments on "Electrodeless Measurements of Semiconductor Resistivity at Microwave Frequencies"*

H. Jacobs, *et al.*,[1] have described a method, employing microwaves, that determines the conductivity of semiconductors. This method is of particular interest in those cases where four-point probe techniques may be difficult. However, the authors fail to mention the limitations imposed by measurements at microwave frequencies when the measurements are used to obtain data at dc and low frequencies.

In general, the conductivity, as measured at any frequency, is composite. It consists of the desired dc conductivity plus the conductivity due to dispersion (not considering the interfacial-polarization contribution of inhomogeneous materials). The microwave method is applicable, then, to those substances that do not have a dispersion region of the order of magnitude of the dc conductivity at the frequency of measurement. This limitation may not be of significance for a great many semiconductors, such as some oxides and sulfides where the lowest dispersion frequency lies in the infrared,[2] but this is not necessarily known, *a priori*.

The measured conductivities for some ferromagnetic semiconductors rise appreciably between 10^9 and 10^{11} cps indicating absorption spectra lying in the 10^{11} to 10^{12} cps range which move toward lower frequencies as the temperature decreases.[3] Similar behavior is observed for glasses when they contain loosely bound cations.[3] In these cases the measured conductivities at microwave frequencies arise, for the most part, from the absorption spectra. Measurements at more than one frequency may be helpful in determining the presence or absence of an absorption region, but then, at the lower frequencies that may be required,

* Received by the IRE, October 19, 1961.

[1] H. Jacobs, *et al.*, "Electrodeless measurement of semiconductor resistivity at microwave frequencies," Proc. IRE, vol. 49, pp. 928–932; May, 1961.

[2] N. B. Hanny, "Semiconductors," Reinhold Publishing Corp., New York, N. Y., p. 548; 1959.

[3] P. A. Miles, *et al.*, "Dielectric spectroscopy of ferromagnetic semiconductors," *Rev. Mod. Phys.*, vol. 29, pp. 279–307; July, 1957.

other difficulties such as interfacial polarization may need to be considered. However, these are just the difficulties that the method is trying to avoid.

One other point in regard to the choice of frequency should be mentioned. Jacobs, *et al.*, used the 9.546 kMc frequency at *X* band and suggested that when a new material was not available in larger size crystals, a higher frequency would be applicable. Even assuming that the only loss mechanism is due to the dc conductivity, such high frequencies would be suitable only for semiconductors having high conductivities. Those semiconductors having conductivities in the lower region would be difficult, if not impossible, to measure since the quantity measured, σ/ω, could be beyond the detectability of the equipment at the very high frequencies suggested.

It is hoped that cognizance will be taken of the limitations of the microwave method since this method is an excellent one in those cases where it is applicable and where other methods leave much to be desired.

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Technique for the Dynamic Measurement of Differential Phase Shift at Microwave Frequencies*

The block diagram of Fig. 1 illustrates a well-known method of measuring differential phase shift through two parallel microwave paths. The example used is that of two traveling-wave tubes, but applies equally well to other devices, passive or active. Reflections should be minimized by pads or isolators at the ends of the slotted line. The two traveling waves in the line set up a standing wave with minima whose positions depend on the phase relation between the traveling waves. Differential phase shift can result from a change in frequency, operating voltages, input level, environment, etc. This shift causes a change in the position of the minimum in the slotted line, according to the relation

$$\Delta\phi = \frac{720\Delta x_{\min}}{\lambda_0} \text{ degrees.}$$

The method has the following limitations:

1) Only steady-state shifts in phase can be observed.
2) Phase resolution is dependent on a sharp null, *i.e.*, on approximately equal power levels at the two ends of the slotted line.
3) Ultimate sensitivity is of the order of a few degrees, due to null position uncertainty.

* Received by the IRE, November 13, 1961.

This note describes a straightforward extension of the above method which overcomes these limitations. The technique is illustrated in the block diagram of Fig. 2. Phase shift through one of the tubes is caused to vary sinusoidally at an audio rate. The amount of variation is of the order of a few tens of degrees, and is caused by applying a sweep voltage from an audio oscillator to one of the tube electrodes through a coupling capacitor. In the case illustrated, the sweep is applied to the helix, which has a phase sensitivity of approximately 40° per volt. The same sweep voltage is applied to the horizontal input of the oscilloscope. The varying phase length through one path sweeps the null position sinusoidally in the slotted line. If the probe is set at the nominal center position of the null, the output of the crystal detector rises and falls with the sweeping of the null. Feeding the detector output to the vertical input of the oscilloscope results in a V-shaped trace. With the probe centered on the null, the two ends of the V appear at the same level, as in the upper trace of Fig. 3. Displacement of the null by changing phase length through either path (or repositioning the probe with the null remaining fixed) causes unbalance in the V, as illustrated in the lower trace of Fig. 3. This trace represents 30° of unbalance, caused by changing the helix voltage on one tube. The scale sensitivity is 10° per square. By increasing the vertical channel gain, sensitivity can be increased to the point at which resolution of the ends of the trace is limited by residual phase jitter. The appearance of the trace with a scale sensitivity of 1° per square is shown in Fig. 4, with the V inverted and only the ends of the trace visible. The lower trace represents 4° of unbalance.

Areas in which this technique can be usefully applied are illustrated by the following examples:

1) Differential phase shift between two traveling-wave tubes (or other microwave amplifiers or networks) resulting from changes in frequency, power level, or operating voltage is generally a steady-state type of measurement. Balancing of the V-trace by sliding the detector probe can be used as an accurate means of locating the null, or the graticule can be calibrated to

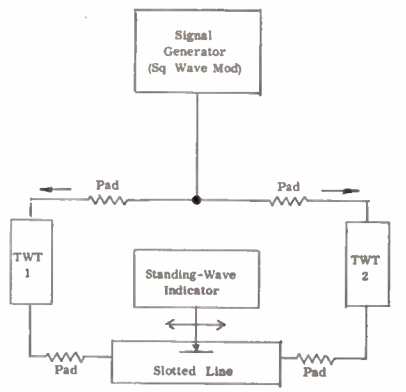


Fig. 1—Block diagram showing a conventional method of measuring differential phase shift between two microwave paths, here shown as traveling-wave tubes.

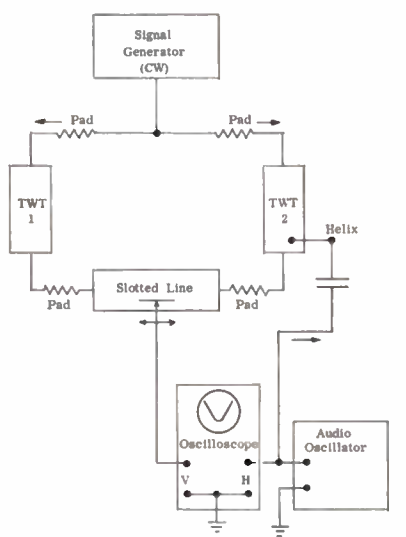


Fig. 2—Block diagram of setup for measuring differential phase shift which allows dynamic measurements and finer resolution than the conventional method.

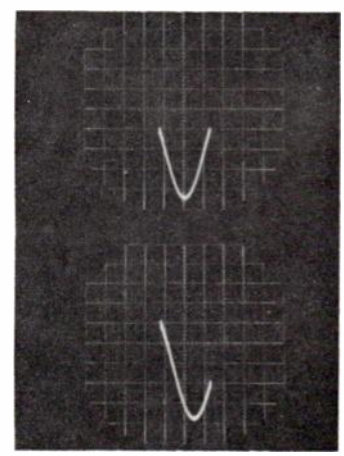


Fig. 3—Oscillogram showing V-trace which results from sweeping the null by varying the phase length through one path. Sensitivity is 10° per square, hence the lower trace represents 30° of phase unbalance.

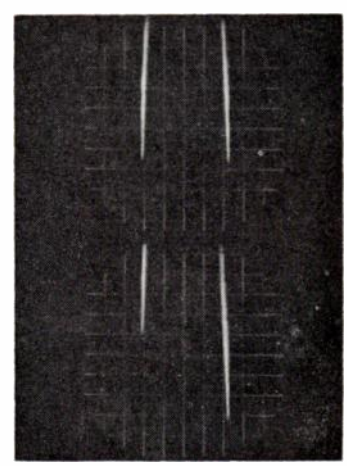


Fig. 4—In this oscillogram, the sensitivity was increased to one degree per square. The upper trace shows phase balance, while the lower trace represents 4° of unbalance.

read $\Delta\phi$ directly in degrees, with the probe position fixed. Resolution is approximately 0.1° of phase shift.

2) Residual phase jitter at a fixed frequency (*e.g.*, 60 cps) between two tubes can be measured by setting the audio oscillator at a frequency close to that of the jitter. The beat-frequency shifting of the V-trace can be read out as differential phase shift.

3) Phase shift resulting from mechanical vibration can be measured by synchronizing the audio oscillator to almost the shake frequency, and observing the beat-frequency unbalance of the V-trace, as in measuring phase jitter.

These examples emphasize the utility of the technique as both a dc and an ac phase meter, provided only that the phase length through one path is electronically variable.

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Comments on "Reflections of a Communication Engineer"*

Dr. Golay is to be congratulated for his thought provoking paper.[1] He has avoided the recurrent objections to a universal entropy principle that 1) question the validity of the principle itself, 2) postulate an unobserved energy source, 3) dismiss entropy as a subjective quantity, 4) seek a remote reversal of time, 5) grasp for a rare chance concourse of atoms, or 6) criticize its universal application as an unwarrented extrapolation. However, two of his "reflections" bring some religious or philosophical dissatisfactions. In order that such comment may not be overlooked by these Proceedings, my dissatisfactions are given herewith.

First, Dr. Golay suggests a Creator to "trigger" an exchange between negative gravitational energy and positive energy in the form of mass and radiation. This highly intelligent act would necessarily contain the pattern for all subsequent events in the universe, including those astronomical, atomic, biological and even intellectual. The author agrees with Eddington[2] that "a single winding-up at some remote epoch is not really the kind of relation between God and His world that brings satisfaction to the mind." Moreover, if the Creator acted once, why should He not act a second time or even sustain a continual relationship with the universe?

Second, I cannot become excited about the universe experiencing what many cosmologists refer to as a "heat-death." It is as religiously objectionable to assume that the present order will continue into the future without limit as it is to assume its existence from the infinite past. It is truly more satisfying to believe that the present order has a direction and a purpose and that a new order, "a new heaven and a new earth," will be established by the Creator. Let us expend our energies promoting the new order, as we envision it, instead of maintaining the present order. This is where science ends and faith begins.

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* Received by the IRE, October 25, 1961.

[1] M. J. E. Golay, "Reflections of a communication engineer," Proc. IRE, vol. 49, pp. 1378–1382; September, 1961.

[2] A. S. Eddington, "New Pathways in Science," The University Press, Cambridge, England, p. 59; 1935.

Theory of the Stroboscopic Oscilloscope*

In high-frequency work it is desirable to have a means of detecting the power, frequency and wave shape of high-frequency signals in the form of signals at a much lower frequency.

It is now possible to obtain an essentially detailed representation of the wave shape of a repeated microwave pulse using presentation equipment operating at very low frequencies.[1,2] In one of these cases, this is done by convolving the signal spectrum with a reference carrier pulse spectrum having a repetition rate which is slightly different from the signal repetition rate. In the other case, it will be shown that the reference pulse must have a flat frequency spectrum which covers the bandwidth of the signal.

Represent the signal repetition rate as p cps and the "sampling" repetition rate as $p+\Delta p$. The signal can be represented by its Fourier series.

$$f_1(t) = \sum_{n=-\infty}^{\infty} a_n e^{jnp2\pi t}. \tag{1}$$

Only a finite number of terms of the series are necessary to obtain a sufficiently accurate reproduction of the time function. Now redefine the signal as

$$f_1(t) = \sum_{n=m}^{l} a_n e^{jnp2\pi t}. \tag{2}$$

The most desirable reference spectrum would be a flat spectrum, for example, that denoted by

$$f_2(t) = \sum_{n=m}^{l} e^{jn(p+\Delta p)2\pi t}. \tag{3}$$

* Received by the IRE, December 5, 1961; revised manuscript received, January 8, 1962.

[1] W. M. Goodall and A. F. Dietrich, "Fractional millimicrosecond electrical stroboscope," Proc. IRE, vol. 48, pp. 1591–1594; September, 1960.

[2] A. F. Dietrich, "8- and 11-Gc nanosecond pulses produced by harmonic generation," Proc. IRE, vol. 49, pp. 972–973; May, 1961.

Convolving the spectra of (3) and (2) (multiplying the time functions), and passing them through a low-pass filter

$$\left(0 \text{ to } \frac{(l-m)}{2}\Delta p\right),$$

the output signal $f_3(t)$ becomes

$$f_3(t) = \sum_{n=m}^{l} a_n e^{jn\Delta p2\pi t}. \tag{4}$$

The output [(4)] is identical to the input [(2)], with the exception that the frequency components are scaled down by a factor of $p/\Delta p$. This implies that the bandwidth is also scaled down by a factor of $p/\Delta p$. This process is represented in Fig. 1 for a frequency ratio $p/\Delta p$ of 8.

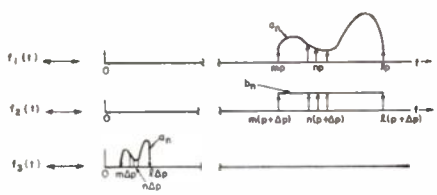


Fig. 1—$b_n=1$. Frequency distribution for input, reference and output signals.

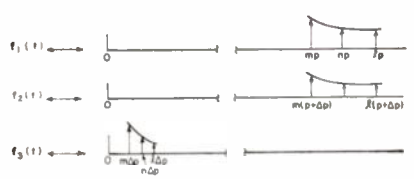


Fig. 2—$b_n=a_n$. (Spectra before amplification.) Frequency distribution for input, reference and output signals.

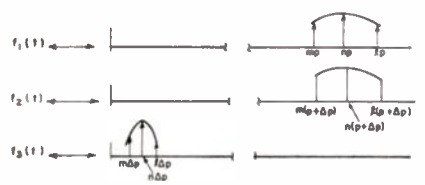


Fig. 3—$b_n=a_n$. (Spectra after amplification.) Frequency distribution for input, reference and output signals.

Now consider the case where both signals have the same arbitrary amplitude distribution,

$$f_1(t) = \sum_{n=m}^{l} a_n e^{jnp2\pi t} \tag{5}$$

$$f_2(t) = \sum_{n=m}^{l} a_n e^{jn(p+\Delta p)2\pi t}. \tag{6}$$

This was the case approximately realized by Goodall and Dietrich.[1] It is represented in Fig. 2.

Fig. 2 represents the probable frequency distribution for the output of diodes operating in the "snap-off" mode. Traveling-wave amplifiers were used in the measurement technique. They were adjusted to modify the spectrum to the form shown in Fig. 3.

If the output signal is passed through a narrow-band filter as before, the output will be

$$f_3(t) = \sum_{n=m}^{l} a_n^2 e^{jn\Delta p 2\pi t}. \quad (7)$$

The amplitude distribution, in the frequency domain, of the pulse which is reduced in frequency [(7)], is now the square of the original amplitude distribution.

In the most general case, the reference function becomes

$$f_2(t) = \sum_{n=m}^{l} b_n e^{jn(p+\Delta p)2\pi t}. \quad (8)$$

Then the output spectrum becomes

$$f_3(t) = \sum_{n=m}^{l} a_n b_n e^{jn\Delta p 2\pi t}. \quad (9)$$

Tabulating these cases,

Frequency Domain	Case I	Case II	Case III
Signal Distribution	a_n	a_n	a_n
"Sampling" Distribution	1	a_n	b_n
Output Distribution	a_n	a_n^2	$a_n b_n$

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A Transistor Preamplifier for Fast Transients*

During the development of the pulsed ferrite generator[1] the need arose for a fast pulse preamplifier with low sensitivity to strong electromagnetic fields. In the chosen design, low-drain mesa transistors are used so that battery operation may be employed. The resulting unit is physically small, very well shielded, because both the amplifier and battery are contained in the same metal box, and may be operated in strong steady magnetic fields.

Motorola 2N700 transistors were chosen in the interests of cost, battery consumption, and gain bandwidth. The transistors operate at $V_c = 6$ v, $I_c = 2$ ma, an economical operating point which 1) gives adequate bias stability without recourse to bias feedback, and 2) yields a minimum noise figure and a high value of f_t, the short-circuit gain-bandwidth factor for a grounded emitter stage.

The basic amplifier configuration of cascaded, grounded-emitter stages with individual shunt feedback has been described by several authors[2-5] for wide-band applications. However, the design equations given in these references only apply to a single stage.

A detailed analysis for the general iterative case [*i.e.*, input impedance $Z_1(p)$ of each stage becomes the load impedance R_L of the previous stage] was undertaken. The analysis shows that, for a 2N700 stage with R_L in the range 50 to 80 ohms, $Z_1(p)$ is sensibly constant with frequency. (This result was checked experimentally. A 2N700 transistor, with β, the short-circuit current gain equal to 8, $r_b' = 60$ ohms, feedback resistance $R_f = 500$ ohms, and $R_L = 65$ ohms has $Z_1(0) = 75$ ohms, a value which varies less than ± 5 per cent over the range 10 Mc to 500 Mc.) Hence, the cascaded stages are, in effect, isolated, *i.e.*, almost no frequency dependent loading occurs from one stage to the next. An iterative amplifier of n stages without inductive peaking has a predominant nth order pole which determines the leading edge response to a step function and leads to the over-all rise-time relation:

$$t_r \cong \frac{0.385 n^{1/2}(r_b' + R_f + R_L)[1 + 2\pi f_t r_e' C_c(1 + R_L/r_e')]}{f_t\left[R_L + r_e' + \dfrac{r_b' + R_f}{1+\beta}\right]}.$$

Other design equations involve the over-all current gain and input impedance,

$$A_n = \left[\frac{\beta B_f - R}{R + R_f + R_L(1+\beta)}\right]^n$$

$$Z_1(0) = R_L = \frac{R(R_f + R_L)}{R + R_f + R_L(1+\beta)},$$

where

$$R = r_b' + r_e'(1+\beta),$$

and r_e' is the Shockley emitter resistance kT/qI_E.

For a given A_n, there is an optimum value of n which gives a minimum value of t_r. This value may be found by manipulating the above expressions, or more quickly, by substituting directly for a series of values of n. A typical plot of t_r vs n for 2N700 stages with $A_n = 30$, is given in Fig. 1. Clearly, the choice of n is not critical near the optimum value.

Inductance inserted in the feedback loop splits the nth order pole of $A_n(p)$ into complex poles, thereby reducing the rise time of the system. Typically, a reduction of 40 per cent in t_r may be obtained by this means. Individual L adjustment is required.

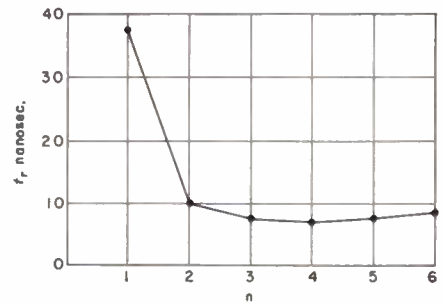


Fig. 1—Rise time vs number of stages for $A_n = 30$.

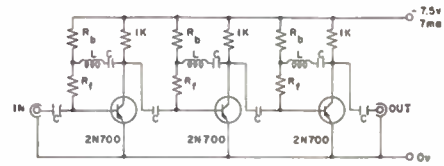


Fig. 2—Circuit diagram. Capacitance C is 0.02 μf ceramic paralleled with 0.25 μf. $R_f = 470$ Ω IRC type HF.

The circuit for a three-stage amplifier is shown in Fig. 2. Resistor R_b is adjusted for each transistor so that $I_c = 2$ ma.

Measured Amplifier Characteristics

Voltage gain = 27 db (for $R_g = 0$).
Rise time (no peaking) = 6 nsec (no overshoot).
Rise time (with peaking) = 4.5 nsec (5 per cent overshoot).
Noise figure = 8 db.
Input impedance $Z_1(0) = R_L = 75$ ohms.
Peak output voltage = 0.25 volt.
Range of $R_b = 10$ to 20 kilohms.
Range of $L = 0.2$ to 0.4 μh.
Droop rate = 4 per cent μsec.

The preamplifier is useful for feeding directly into a Tektronix 517A oscilloscope. Because the last stage has a higher load impedance (170 ohms) in this arrangement, the voltage gain is increased by 4 db while the over-all rise time is not measurably increased. For nonzero source resistance R_g, the low-frequency voltage gain is reduced by

$$20 \log_{10} \frac{R_g + Z_1(0)}{Z_1(0)} \text{ db}.$$

If the preamplifier is to be used for long pulses, the capacitiors should be increased so that the droop rate is reduced.

The author wishes to gratefully acknowledge the assistance of Professor R. M. Scarlett who supervised this work.

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[1] B. J. Elliott, *et al.*, "Pulsed ferrimagnetic microwave generator," *J. Appl. Phys.*, vol. 31, pp. 400S-401S; May, 1960.

[2] F. H. Blecher, "Design principles for single loop transistor feedback amplifiers," IRE Trans. on Circuit Theory, vol. CT-4, pp. 145-156; September, 1957.

[3] J. C. de Broekert and R. M. Scarlett, "A Transistor Amplifier with 100-Mc Bandwidth," Stanford Electronics Lab., Rept. No. 514-1; January, 1959.

[4] W. E. Ballentine and F. H. Blecher, "Broadband Transistor Video Amplifiers," *Digest of Technical Papers*, 1959 Solid-State Circuits Conf., pp. 42-43.

[5] W. A. Rheinfelder, "Wideband video amplifier design using mesa transistors," *Electronic Design*, pp. 46-49; August, 1960.

A Note on the Radiation Resistance and Field Strength of Large Loop Antennas*

When deriving expressions for the radiation resistance and the field strength of large circular loop antennas, it is customary to expand the vector potential due to the current in the loop into a series of Bessel functions.[1,2] It may be thought that this is a necessary procedure in view of the existing circular symmetry. The purpose of this note is to point out that the radiation resistance as well as the field strength, not only of a circular loop but also of a square or polygonal loop, may be equally easily derived by a power series expansion. Moreover, this procedure gives a clearer insight into the relations between the different types of loop.

Referring to Fig. 1 it may be shown that the vector potential at any point Q is in the y direction and that at a large distance from the loop its magnitude is given in rationalized MKS units by

$$A = (\mu_0 I_0 k\lambda/2\pi^2 r)\cos(\omega t - \omega r c^{-1}) f(k,\phi) \quad (1)$$

where

$$f(t,\phi) = \int_0^{\frac{1}{2}\pi} \cos\theta \sin(k\cos\phi\cos\theta)\,d\theta \quad (2)$$

$$k = \omega a/c = 2\pi a/\lambda.$$

$$\mu_0 = 4\pi \cdot 10^{-7} \text{ henries/meter}$$

$$c = 3.10^8 \text{ meters/sec.} \quad (3)$$

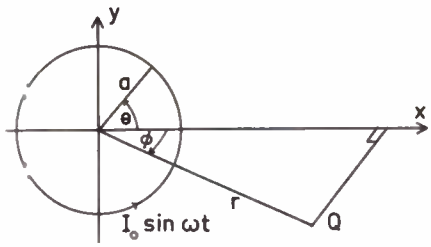


Fig. 1—Geometry of circular loop.

Instead of replacing $\sin(k\cos\phi\cos\theta)$ in (2) by the Fourier series

$$\sin(k\cos\phi\cos\theta) = J_1(k\cos\phi)\cos\theta - J_3(k\cos\phi)\cos 3\theta + \cdots \quad (4)$$

(where $J_1, J_2, \cdots$, are the Bessel functions of the first kind and first, second, $\cdots$ order) and integrating term by term, we shall simply replace it by its power series in the argument and integrate term by term to obtain the power series for the vector potential

$$A = A_0\left\{1 - \frac{(k\cos\phi)^2}{8} + \cdots + (-)^{n-1}\frac{(\tfrac{1}{2}k\cos\phi)^{2n-2}}{(n-1)!\,n!} - \cdots\right\} \quad (5)$$

where

$$A_0 = (\mu_0 I_0 k^2\lambda/8\pi r)\cos\phi\cos(\omega t - \omega r c^{-1}).$$

On examining the power series, we see that

$$A = (\mu_0 I_0 k\lambda/4\pi r)\cos(\omega t - \omega r c^{-1}) J_1(k\cos\phi) \quad (6)$$

but the Bessel function J_1 does not occur explicitly in our calculation.

The electric field is

$$E = (\tfrac{1}{2}\mu_0 c I_0 k r^{-1}) J_1(k\cos\phi)\sin(\omega t - \omega r c^{-1}). \quad (7)$$

The radiated power is the time rate of work on the current of the electric field at the loop.[2] The radiation resistance is then given by

$$R = \tfrac{1}{2}\mu_0 c k \int_0^{\pi} d\theta \sin(2k\sin\tfrac{1}{2}\theta)\cos\theta/\sin\tfrac{1}{2}\theta \quad (8)$$

We again choose to replace $\sin(2k\sin\frac{1}{2}\theta)$ by its power series instead of by a Fourier series. Integrating term by term we then obtain

$$R = \frac{\pi}{6}\mu_0 c k^4\left\{1 - \frac{k^2}{5} + \cdots + (-)^{n-1}\frac{6\,k^{2n-2}}{(n-1)!(n+1)!(2n+1)} - \cdots\right\}$$
$$= 20\pi^2 k^4(1 - k^2/5 + k^4/56 - k^6/1080 + \cdots). \quad (9)$$

On examination of this series it is seen that

$$R = \tfrac{1}{2}\pi\mu_0 c k \int_0^{2k} J_2(x)\,dx. \quad (10)$$

The radiation field of a square loop carrying a uniform current $I_0\sin\omega t$ may be expressed entirely in terms of the trigonometric functions.

The radiation resistance may be written

$$R = (2\mu_0 c k'/\pi)\int_{-\frac{1}{4}}^{\frac{1}{4}} d\alpha \int_{-\frac{1}{4}}^{\frac{1}{4}} d\beta F(\alpha,\beta) \quad (11)$$

where

$$F(\alpha,\beta) = \frac{\sin[2k'(\alpha-\beta)]}{\alpha-\beta} - \frac{\sin[2k'\{1+(\alpha-\beta)^2\}^{\frac{1}{2}}]}{\{1+(\alpha-\beta)^2\}^{\frac{1}{2}}},$$

$$k' = (\omega/2c) \times (\textit{length of side of square}).$$

Using the result

$$\int_{-\frac{1}{4}}^{\frac{1}{4}} d\alpha \int_{-\frac{1}{4}}^{\frac{1}{4}} d\beta(\alpha-\beta)^{2m} = 1/(m+1)(2m+1)$$

we obtain the power series for the radiation resistance

$$R \approx 20\pi^2 k^4(1 - k^2/5\cdot09 + k^4/50\cdot0 - k^6/1135 + \cdots) \quad (12)$$

where k applies to the circle or square if it is defined by

$$k^2 = (\omega/c)^2\pi^{-1} \times (\textit{area of loop}).$$

This reasoning may be extended to polygonal loops of any number of sides. The similarity of (9) and (12) for small k indicates the relation of both loops to the magnetic dipole of magnetic moment

$$(\textit{current}) \times (\textit{area of loop}).$$

Sherman[3] has derived the properties of a loop antenna fed at a single point. His equations (14) and (19) may be obtained in power series form in an exactly analogous manner.

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* Received by the IRE, November 28, 1961. This work was supported by a grant from the Radio Research Board of Australia.

[1] D. Foster, "Loop antennas with uniform current," Proc. IRE, vol. 32, pp. 603–607; October, 1944.

[2] E. B. Moullin, "Radiation from large circular loops," *J. IEE (London)*, pt. 3, vol. 93, pp. 345–351; September, 1946.

[3] J. B. Sherman, "Circular loop antennas at ultra-high frequencies," Proc. IRE, vol. 32, pp. 534–537; September, 1944.

Noise Figure Calculation Based on the Admittance Matrix of the Network*

The method described gives a solution for noise voltages and noise figure by means of the admittance matrix of the noisy network under consideration. The network is assumed to be linear, passive and time-invariant and is shown in a general form in Fig. 1(a). For convenience of the calculation the floating noise current generator I_{ij} is replaced as shown in Fig. 1(b). V_k is the desired response.

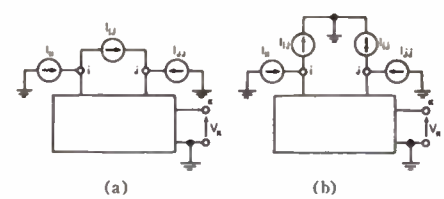


Fig. 1.

If the current noise generators were replaced by current signal generators, due to the linearity, one would receive for the response

$$V_k = \sum_{i=1}^{k} V_{ki} = \sum_{i=1}^{k} I_{ii}\frac{\Delta_{ik}}{\Delta} + \frac{1}{2}\sum_{i,j=1}^{k} I_{ij}\frac{\Delta_{jk}-\Delta_{ik}}{\Delta} = \frac{1}{\Delta}\sum_{i,j=1}^{k} I_{ij}[\Delta_{ik}\delta_{ij} + \tfrac{1}{2}(\Delta_{jk}-\Delta_{ik})].$$

V_{ki} is the contribution to the total response V_k resulting from the current signal generators connected to node i. In the case where incoherent current noise generators are connected,

$$V_k^2 = \sum_{i=1}^{k} V_{ki}^2 = \frac{1}{\Delta^2}\sum_{i,j=1}^{k} I_{ij}^2[\Delta_{ik}^2\delta_{ij} + \tfrac{1}{2}(\Delta_{jk}-\Delta_{ik})^2] = \frac{1}{\Delta^2} I_{ij}^2 M_{ij}, \quad (1)$$

* Received by the IRE, November 21, 1961.

where summation over repeated indexes is in mind, and M_{ij} is a symmetrical tensor of second rank.

The noise voltage resulting from the antenna[1] alone (assumed to be connected between node 1 and the reference node) is

$$V_k' = \frac{1}{\Delta^2} I_A^2 \Delta_{1k}^2. \quad (2)$$

Defining the noise figure as $V_k^2/V_k'^2$,

$$N = \frac{I_{ij}^2 \cdot M_{ij}}{I_A^2 \cdot \Delta_{1k}^2} \qquad i,j = 1, 2, \cdots k. \quad (3)$$

The grounded grid amplifier of Fig. 2. serves as an example. Y_A is the antenna admittance and Y_1 is the vacuum tube input admittance, a current noise generator being connected across each of them.

$$I^2 = (4kTB)K_T g, \quad (4)$$

where $Y = g - jb$; T is the room temperature and K_T is the temperature coefficient. $K_T = 1$ for an usual admittance. K_T is a function of the orientation and the frequency in the case of an antenna. For the input admittance of a vacuum tube $K_T = (1 + 4\, g_e/g)$, where g is the total input conductance, g_e being the part due to electron transient time. The current noise generator I_s, connected between cathode and anode, accounts for the shot noise.

$$I_s^2 = (4kTB) g_m R_N, \quad (5)$$

where R_N is the noise resistance of the tube.

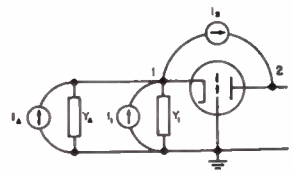


Fig. 2.

The Y matrix of the circuit diagram of Fig. 2 is

$$\begin{matrix} & 1 & 2 \\ 1 & g_m + g_p + Y_1 + Y_A & -g_p \\ 2 & -g_m - g_p & g_p \end{matrix},$$

and the corresponding M tensor is

$$M = \begin{bmatrix} \Delta_{12}^2 & \tfrac{1}{2}(\Delta_{12} - \Delta_{22})^2 \\ \tfrac{1}{2}(\Delta_{22} - \Delta_{12})^2 & \Delta_{22}^2 \end{bmatrix} = \begin{bmatrix} (g_m + g_p)^2 & \tfrac{1}{2}(Y_1 + Y_A)^2 \\ \tfrac{1}{2}(Y_1 + Y_A)^2 & (g_m + g_p + Y_1 + Y_A)^2 \end{bmatrix}.$$

Since

$$I_{11}^2 = I_1^2 + I_A^2, \quad I_{12}^2 = I_{21}^2 = I_s^2, \quad I_{22}^2 = 0.$$

$$N = \frac{(I_A^2 + I_1^2)(g_m + g_p)^2 + I_s^2(Y_1 + Y_A)^2}{I_A^2(g_m + g_p)^2} = 1 + \frac{I_1^2 + \left(\dfrac{Y_1 + Y_A}{g_m + g_p}\right)^2 I_s^2}{I_A^2}. \quad (6)$$

Since all current noise generators are proportional to the factor $(4kTB)$ the factor cancels out from the expression for N.

[1] "Antenna" refers to the signal generator connected to the input terminals of the network.

In view of the fact that the current noise generators are proportional to the conductance, one should not conclude that the susceptance does not contribute to N. Indeed, from (6): $(Y_1 + Y_A)^2 = (g_1 + g_A)^2 + (b_1 + b_A)^2$, N being minimum for $b_A = -b_1$.

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Millimeter Wavelength Atmospheric Absorption*

As the search for spectrum space proceeds, the millimeter wavelength range becomes an increasingly important study area. Sylvania's Amherst Laboratories recently undertook a program with a twofold object: 1) to prove the feasibility of a two-way voice communication system in the 64–74 kMc frequency range, and 2) to investigate absorption characteristics of oxygen and water vapor in the same range.

A two-way communication link was set up with one terminal at Sylvania's Amherst Laboratories and the other, 6.1 km away, at the University of Buffalo. At this reporting, the test frequency being used is 69.9 kMc.

The transmitter and receiver are mounted on the same rack permitting the use of a single QKK865 for both transmitter and local oscillator. The transmitter employs a two-channel pulse position modulator to convey information. The receiver is of a conventional superheterodyne type, with the QKK865 as local oscillator, a 60-Mc intermediate-frequency amplifier and IN2792 mixer crystals, in a balanced mixer configuration. It features an automatic frequency control.

On a sunny day when the temperature was 67°F and the relative humidity 68 per cent, an attenuation of 1.35 db/km was recorded. With these weather conditions and the uncondensed water vapor absorption used in the calculation (0.75 db/km at 70 kMc), the theoretical oxygen and water vapor absorption is 1.27 db/km.[1,2] The slight discrepancy is likely due to inaccuracies in the measured noise figure used in determining the 1.35 db/km attenuation.

Measurements are continuing to establish absorptions due to oxygen, uncondensed water vapor, and light rain and fog.

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* Received by the IRE, November 24, 1961.

[1] W. T. Hunt, "Survey of Attenuation by the Earth's Atmosphere at Millimeter Radio Wavelengths Reconnaissance Lab., WADD Project 4062, Task 62706. WADD Tech. Note 60-232; November, 1960.

[2] C. W. Tolbert, A. W. Straiton and J. R. Gerhardt, "A Study and Analysis of Anomalous Atmospheric Water Vapor Absorption of Millimeter Wavelength Radiation," Elec. Engrg. Res. Lab., University of Texas, Austin, Tex., Rept. No. 117, Contract Nonr-375(01); October 31, 1960.

Transistors as Function Generators*

It has been pointed out by Deb and Sen[1] that in a grounded base-junction transistor with the circuit arrangement shown in Fig. 1, the output current can be made proportional to the product of input voltage and current over a wide range of variation of the input current for a certain value of the resistance R. A transistor can be used to work as a squarer by suitably selecting

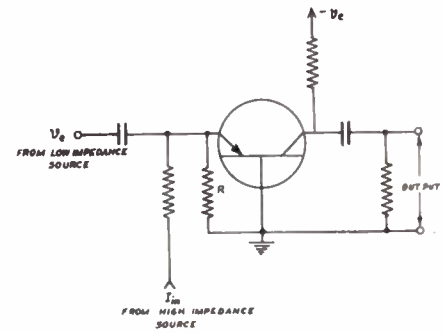


Fig. 1.

the value of the resistance R and making it operate in that region of its characteristics where $r_b(1-\alpha)$ decreases with the emitter current. This conclusion can also be reached by a semigraphical approach. The relationship between the output and input current can be expressed as

$$i_0 = B v_s I_{in}^2, \quad (1)$$

where

$$B = \frac{\alpha}{K}\left[-\frac{K}{R I_{in}^2} + \left(1 + \frac{r_b(1-\alpha)}{R}\right)\frac{1}{I_{in}} - \frac{r_b(1-\alpha)}{K}\left(1 + \frac{r_b(1-\alpha)}{R}\right) + I_{in}\left(\frac{r_b(1-\alpha)}{K}\right)^2\left(1 + \frac{r_b(1-\alpha)}{R}\right)\right] \quad (2)$$

neglecting higher powers;

and

$$K = \frac{kT}{q}.$$

As the first approximation, in the region of interest, we may make $r_b(1-\alpha)$ equal to $a_0 - a_1 I_{in}$; a particular value of R may then be found graphically for a particular transistor which will keep the value of B nearly constant over a considerable range of the input current I_{in}. For a 2N215 transistor with the value of $R = 100$ ohms the square law relationship between the output and input currents is found to be valid over the range 0.3 ma to 1.0 ma at 25°C.

The circuit can be modified as shown in Fig. 2 for establishing a relationship between the output and input current of the form

$$i_0 = c v_s I_{in}^{1/2} \quad (3)$$

* Received by the IRE, November 17, 1961.

[1] S. Deb and J. K. Sen, "Variation of input conductance of a grounded base-junction transistor," *Electronic Engrg.*, vol. 31, p. 753; December, 1959.

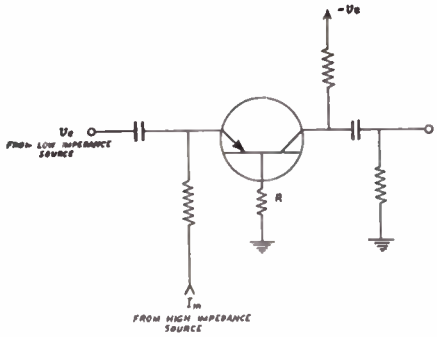


Fig. 2.

where C is a constant. This square-root extracting circuit works on the principle that the gain of the amplifier is mainly controlled by I_{in} so long as $r_e > (R+r_b)(1-\alpha)$, but will tend to stabilize when $r_e < (R-r_b)(1-\alpha)$. Variation of α with I_{in} also aids this process. Experiments carried out with 2N215 and OC 71 transistors show that in both cases a response proportional to the square root of the input current is obtained for $R = 1000$ ohms at 25°C over the range 0.1 to 1.2 ma. It is not difficult to see that suitable adjustment of R will result in a logarithmic response.

The advantages of such circuits are firstly, their compactness and secondly, the possibility of eliminating the use of dc amplifiers for subsequent amplifications since the product appears as a modulated sinusoidal current. Moreover, these types of function generators have a substantially large bandwidth compared with those using break diode characteristics.

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Some Characteristics of Tunnel-Diode UHF Mixers*

Tunnel-diode frequency converters operating in the UHF frequency band are described in the literature.[1,2] These are reported to have low noise figures and operation with gain when externally biased for the optimum operating point. Further data on tunnel-diode mixers are reported here. In particular, a tunnel-diode downconverter is described that requires no external bias and offers equal performance characteristics in terms of low noise, stability and gain. Laboratory tests indicate good stability and a dynamic range that is comparable to that of conventional diode mixers.

A controlled-source representation of

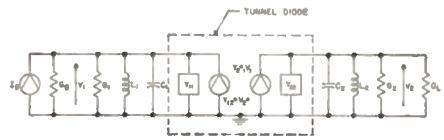


Fig. 1—Tunnel-diode mixer equivalent circuit.

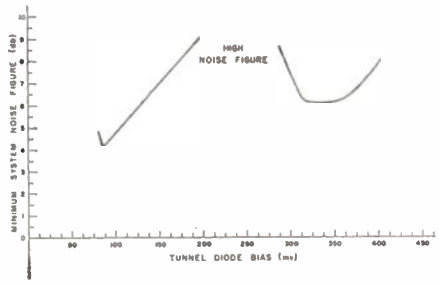


Fig. 2—Minimum noise figure vs bias.

the tunnel-diode mixer was employed for the purpose of calculating analytically the power gain and the noise figure. The tunnel-diode capacitance effects were included but the series inductance and resistance were neglected. The tunnel-diode current-voltage relationships are given by the matrix

$$\begin{bmatrix} G_D + j\omega_1 C_D & -(\Delta G) + j\omega_1(\Delta C) \\ -(\Delta G) + j\omega_2(\Delta C) & G_D - j\omega_2 C_D \end{bmatrix} \quad (1)$$

and the equivalent circuit is shown in Fig. 1; G_D and C_D are the tunnel-diode average conductance and capacitance, ω_1 and ω_2 are the input and output frequencies, ΔG and ΔC are one half the peak conductance and capacitance swings introduced by the local oscillator, respectively.

The expressions for power gain A_p and the apparent noise figure F' at resonance, obtained from the equivalent circuit are

$$A_p = \frac{4G_g G_L[(\Delta G)^2 + \omega_2^2(\Delta C)^2]}{(G_D + G_2 + G_L)^2\left[G_D + G_1 + G_g - \dfrac{(\Delta G)^2 + \omega_1\omega_2(\Delta C)^2}{(G_D + G_2 + G_L)}\right]^2} \quad (2)$$

and

$$F' = \frac{G_g + G_1 + G_e}{G_g} + \frac{G_L + G_2 + G_e}{G_g}\left[\frac{(G_g + G_1 + G_D)^2 + X_{02}^2}{(\Delta G)^2 + \omega_2(\Delta C)^2}\right] \quad (3)$$

where

$$X_{02} = \frac{(\omega_2 - \omega_1)(\Delta G)(\Delta C)}{(G_1 + G_L + G_D)}$$

and G_e is the shot-noise equivalent conductance.

A tunnel-diode mixer downconverting from 1 kMc to 30 Mc was constructed using a 1 ma germanium tunnel diode. The source and load impedances are 30 ohms each and the local oscillator power is 1 mw. A 1 db gain and a double sideband system noise figure of 4.3 db (for an IF noise figure of 5 db) were measured. The converter is stable with large variations in parameters.

Fig. 2 gives the system noise figure and Fig. 3 the conversion power gain as a function of the tunnel-diode bias. These measurements were made with the circuit ad-

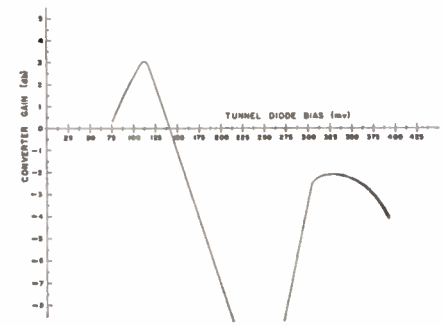


Fig. 3—Gain vs bias.

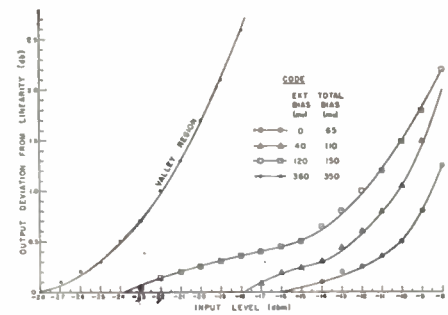


Fig. 4—Linearity characteristics.

justed for a minimum noise figure. Considerably higher levels of gain are attainable with higher noise figures. As seen in Fig. 2, there are two promising regions: 1) just beyond the peak and 2) just beyond the valley. Best operation is obtained in region 1) as seen in Figs. 2–4. Fig. 4 gives the input-output characteristic as a function of the bias point. It is interesting to note that the largest signal handling capability is obtained at the minimum noise figure point. The dynamic range is considerably better than that of a tunnel-diode amplifier.

It is possible to operate the tunnel-diode converter at the minimum noise figure point in region 1) without the use of an external bias. This is done by properly choosing the dc resistance in parallel with the tunnel diode. For the mixer described here, a 10-ohm resistance was found to be the correct value. It should be pointed out that forward self-bias is not possible with conventional diodes since their even order derivatives are always positive, while the second derivative of the tunnel diode is negative in the tunneling region.

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* Received by the IRE, November 17, 1961.

[1] K. K. N. Chang, G. H. Heilmeier and H. J. Prager, "Low noise tunnel diode down-converter having conversion gain," Proc. IRE, vol. 48, pp. 854–858; May, 1960.

[2] F. Sterzer and A. Presser, "Stable low-noise tunnel-diode frequency converters," Proc. IRE (Correspondence), vol. 49, p. 1318; August, 1961.

Coincidence Techniques for Radar Receivers*

A recent paper by Endresen and Hedemark[1] analyzes the anti-interference properties and detectability losses for two sweep coincidence techniques applied to a double threshold automatic detector. The conclusion stresses the advantage of using coincidence techniques for suppression of random pulse interference.

A different conclusion, however, can be arrived at based upon the analysis given in the above paper.

It can be seen that coincidence schemes used in connection with a digital detector of the type postulated will not give any interference protection that could not have been obtained in a simpler manner by a suitable adjustment of the two thresholds. This is proved by the equivalence of the lowest curves in Figs. 4, 7 and 8.[1] No coincidence technique can, of course, go further than demanding all hits to exceed the first threshold. A few specific examples also indicate that no advantage in basic detectability is gained by coincidence schemes as compared with an adjustment of the two thresholds.

From Figs. 4 and 9[1] it is seen that a second threshold of $m=8$ roughly corresponds to double coincidence and $m=9$ to triple coincidence in relating "relative effective disturbance time" with "average duty cycle." The detectability loss for $m=8$ and $m=9$ has been determined from the graphs given in the above paper and is presented in Table I below. Comparison with Table I of Endresen and Hedemark shows only a small difference in noise performance between the two methods of interference suppression.

Based on this comparison the use of coincidence schemes in a double threshold detector seems unjustified as essentially the same over-all performance can be obtained by a simple adjustment of the two detector thresholds.

It should also be noted that the comparison given in Example 1 of Endresen and Hedemark is not realistic as the effect of the false alarm rate p_0 after the first threshold is not taken into account when calculating the "relative effective disturbance time." The effective average duty cycle of interference should in fact be

$$p_0' = p_0 + p_i - p_0 p_i.$$

Using this expression Table II has been obtained respectively for the coincidence case and the threshold adjustment case. The improvement brought forth is seen to be considerably less than argued in Example 1 and indicates that triple coincidence or second threshold $m=9$ only gives a marginal improvement for the detectability loss caused.

TABLE I

DETERMINATION OF REQUIRED SIGNAL-TO-NOISE RATIO
$n=10$, $p_{FA}=10^{-6}$*

Second threshold m		5†		8		9	
Probability p_D of detection		90%	50%	90%	50%	90%	50%
Probability p_0		0.033		0.145		0.210	
Probability p		0.65	0.45	0.89	0.75	0.945	0.84
Required SNR	Steady signal	6.0 db	4.0 db	6.6 db	4.7 db	7.1 db	5.1 db
	Noise-like signal	8.4 db	5.0 db	11.9 db	7.5 db	14.2 db	9.0 db

* The notation is as used in Endresen and Hedemark.[1]
† This column is reproduced from Endresen and Hedemark.[1]

TABLE II

DETERMINATION OF "RELATIVE EFFECTIVE DISTURBANCE TIME"

$p_0'=p_0 \quad p_i-p_0p_i \quad p_i=0.2$

	No coincidence $m=5$	Double coincidence $m=5$	Triple coincidence $m=5$
Probability p_0'	0.226	0.290	0.328
Relative effective disturbance time	5.5%	0.5%	0.2%
No Coincidence	$m=5$	$m=8$	$m=9$
Probability p_0'	0.226	0.316	0.368
Relative effective disturbance time	5.5%	0.3%	0.1%

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Authors' Comment[2]

Our paper was written with the object of deriving expressions useful for a quantitative evaluation of a digital detection method employing coincidence circuits, and not to advocate that this is the optimum method for data processing. Other methods may be equally or more efficient. Hansen thus demonstrates by an example that similar results can be obtained by increasing the second threshold, and a reviewer informs us that interesting results are found if the zeros and the ones are given different weights in the integration process. The underlying idea behind all such schemes is that the returned ensemble of pulses has a certain pattern, the characteristics of which may not be possessed by signals due to, *e.g.*, jamming or other interference, and the general problem is to develop the most efficient way of pattern recognition. We hope, as do certainly all radar designers and users, that the various methods of interference suppression can be evaluated in quantitative terms, such that the best circuit can be selected for a given environment.

Hansen's examples are correct and his comments are very interesting. A couple of points may, however, be questioned. He states that ". . . coincidence schemes . . . will not give any interference protection that could not have been obtained . . . by a suitable adjustment of the two thresholds." Hansen has proved that this is so in one particular case. The fact that the lowest curves in our Figs. 4, 7 and 8 are identical merely implies that an ensemble of n 1's contains $n-1$ pairs and $n-2$ triples, and has no direct relevance in this connection. His statement may well represent a general truth, but a general proof has not been given.

He also states that ". . . the use of coincidence schemes in a double threshold detector seems unjustified as essentially the same over-all performance can be obtained by a simple adjustment of the two detector thresholds." One might here get the impression that one method is much more complex than the other. This might be so if our Fig. 3 represented complete block diagrams of coincidence receivers. That is, however, not the case. The diagrams are drawn in that particular way only to give a visual picture of the mathematical problem, and must not be confused with a circuit design. In order to employ the double threshold method of detection at all, the technical complexity must also be above a certain threshold. The difficult task is to isolate an ensemble from all other ensembles, and this can be done by gating and storage, by $n-1$ delay lines, or by a combination of delay lines, gates and stores. When such an isolation has been performed, the combination of the individual pulses in a desired manner is rather easy. One may in some cases find that the circuit difference between a straightforward double threshold system and a coincidence system mainly lies in the way in which various diodes are connected.

Our Example 1 is valid when the impulsive interference only is taken into account, and the example, which was given before the first threshold setting was discussed, was quoted mainly in order to show how the curves can be used. Hansen is, however, correct in demonstrating that the combined action of interference and noise reduces the efficiency of the coincidence—and other—methods. This is due to the great steepness of the curves, and can be accounted for in the way Hansen shows when the first threshold has been set.

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* Received by the IRE, December 1, 1961.
[1] K. Endresen and R. Hedemark, "Coincidence techniques for radar receivers employing a double threshold method of detection," PROC. IRE, vol. 49, pp. 1561–1567; October, 1961.

[2] Received by the IRE, December 18, 1961.

A Microwave Phase Discriminator*

A circuit is described below with which changes in the relative phase between two microwave signals can be measured. It is a microwave analog of the Foster-Seely[1] type of ratio detector normally used at RF frequencies. It has the advantage that it can be used with fairly low-power microwave signals.

Fig. 1 shows the circuit diagram. The two signals to be compared are introduced at the ports A and B. The signal at A is split into two in-phase components (a_1 and a_2) in a series tee. The signal B is split into two out-of-phase components (b_1 and b_2) in a magic tee. b_1 and b_2 are added to a_1 and a_2 respectively through 10-db directional couplers. The magic tee is used here instead of a shunt tee to give a convenient port for the local oscillator signal.

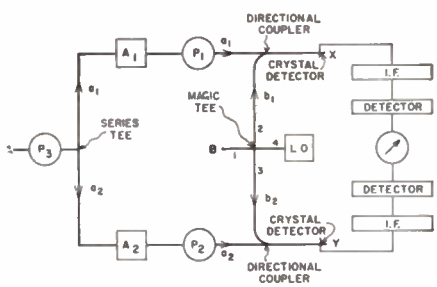


Fig. 1—Circuit diagram of phase discriminator. A_1, A_2 are attenuators and P_1, P_2, P_3 are phase shifters.

The outputs of crystal detectors at X and Y are fed into IF amplifiers. The rectified outputs of these amplifiers are then added in a meter. The requirements for the system to operate are then

1) $|a_1| = |b_1|$ and $|a_2| = |b_2|$.
2) $\bar{a}_1$ and $\bar{b}_1$, $\bar{a}_2$ and $\bar{b}_2$ are 90° out of phase.

The first condition merely ensures that the system has maximum sensitivity, so that only the phase conditions are at all critical. Condition 1) can be ensured by setting the two attenuators in the a_1, a_2 arms and condition 2) by setting the phase changers P_1 and P_2. The phase shifter P_3 is used to compensate for, and to measure, changes in phase between the signals A and B.

The system is set up in four stages:

a) With P_3 at some arbitrary position the attenuator A_1 and phase shifter P_1 are adjusted to give zero output from the IF amplifier connected to X.
b) With P_3 rotated 180° from its position in a), A_2 and P_2 are adjusted to give zero output at the IF amplifier at Y.
c) The phase shifter P_3 is rotated through 90°.
d) The outputs of the two amplifiers are connected to the meter and their gains are adjusted so that the meter reads zero.

* Received by the IRE, December 7, 1961.

[1] See, for example F. E. Terman, "Radio Engineering," McGraw-Hill Book Co., Inc., New York, N. Y.; 1947.

The system has the advantage that one can compensate for any nonideal phase and amplitude changes occurring in the separate arms of the microwave circuit. Under such conditions the zero position of the discriminator is ideally independent of the amplitude of either signal A or B. The meter reading can be used to indicate the phase difference between A and B when their amplitudes are constant, otherwise one has to use changes in P_3 (*i.e.*, bring the output to zero with P_3).

Such a circuit operating at X-band frequencies has been set up in the authors' laboratory using commercial components. To test the system, power of about 10^{-8} watts was fed into a 3-db directional coupler. One half was fed into the discriminator at A while the other half was fed into a microwave cavity through a circulator. The output of the circulator was fed into port B.

When it was set up reasonably carefully, the discriminator was observed to be relatively independent of amplitude changes (typically a change of 10 db in amplitude at B gave a variation in meter reading equivalent to a phase change ~2°), and sensitivities ~10 mv per degree were easy to realize with IF amplifiers of gain $\sim 2\times 10^5$, operating at 60 Mc.

The double superheterodyne system was found to give the discriminator a very narrow bandwidth. Two identical IF amplifiers would be required to overcome this. Alternatively, one could use a single IF amplifier and switch its input, at some convenient rate, between the two crystals in the microwave circuit. For applications where larger powers can be tolerated a simple dc detection system could be used.

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Optimal Message for Zero Memory Systems with Additive Gaussian Noise*

The unconventional approach to the problem of least-square filtering by finding the characteristics of a class of input processes for which the optimal operator is in the form of a polynomial was treated recently by Balakrishnan.[1] This note is concerned particularly with the case in which the noise is additive Gaussian and the prescribed filter belongs to the class of all zero memory systems. Let the message $m(t)$ and the noise $n(t)$ be two statistically independent random processes, and let their sum be denoted by $x(t)$. Let $m(t)$ be the desired output. The given zero memory system $K(\cdot)$ is therefore least square optimum among the class of all zero memory devices if it satisfies[2]

$$K(x) = \int_{-\infty}^{+\infty} m p(m/x)dm \qquad (1)$$

where $p(m/x)$ is the conditional probability density function of m given x.

Eq. (1) can also be written as

$$K(x)p(x) = 1/2\pi \int_{-\infty}^{+\infty} F_n(u)\left[\frac{d}{dju}F_m(u)\right]e^{-jux}du, \qquad (2)$$

where $F_m(u)$ and $F_n(u)$ are the characteristic functions of the message and noise, respectively, and $p(x)$ is the probability density function of the input process. To see this, we multiply both sides of (1) by $p(x)$ to obtain

$$K(x)p(x) = \int_{-\infty}^{+\infty} m p(m/x)p(x)dm. \qquad (3)$$

Consider

$$E(\exp(jsm)\exp(jux)) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \exp(jsm) \cdot \exp(jux)p(m/x)p(x)dmdx. \qquad (4)$$

Since the message and noise are statistically independent, we see

$$E(\exp(jsm)\exp(jux)) = F_n(u)F_m(u+s). \qquad (5)$$

Differentiating both sides of (4) with respect to js, setting $s=0$ and using (5), we find that $F_n(u)d/djuF_m(u)$ is the Fourier transform of the right-hand side of (3). Hence, (2) follows.

Let us now specialize (2) to the case of Gaussian noise. Let

$$F_n(u) = \exp(-\tfrac{1}{2}\sigma^2u^2), \qquad (6)$$

where σ^2 is the variance of the noise process. Integrating the right-hand side of (2) with respect to u by parts once and using (6), we find that $p(x)$ satisfies the differential equation

$$\sigma^2\frac{dp(x)}{dx} = p(x)(K(x) - x). \qquad (7)$$

Hence, the probability density function of the input process and the optimum zero memory filter are related by

$$p(x) = B\exp\left(-\frac{x^2}{2\sigma^2} + (1/\sigma^2)\int K(x)dx\right), \qquad (8)$$

where B is a constant used to satisfy the constraint that

$$\int_{-\infty}^{+\infty} p(x)dx = 1.$$

It is clear from (8) that $K(x)$ is far from being arbitrary. We shall now consider the optimal messages associated with two specific filters of practical interest.

1) *A Linear Filter:*

$$K(x) = ax. \qquad (9)$$

* Received by the IRE, December 7, 1961; revised manuscript received, January 5, 1962.

[1] A. V. Balakrishnan, "On a characterization of processes for which the optimal mean-square systems are of specified form," IRE Trans. on Information Theory, vol. IT-6, pp. 490–500; September, 1960.

[2] For simplicity, we have omitted the argument t.

Substituting (9) into (8) and using (6) yield

$$F_m(u) = \exp\left(-\frac{a}{2(1-a)}\sigma^2 u^2\right). \quad (10)$$

In order for (10) to be the characteristic function of a physical process, it is necessary and sufficient that $0<a<1$. As expected, the optimal message is a Gaussian process with variance $\sigma^2(a/1-a)$.

2) *A Limiter:*

Let us assume that the prescribed filter is a limiter and can be approximated by

$$K(x) = Na\tanh\frac{ax}{\sigma^2}, \quad (11)$$

where N is a positive integer. Substituting (11) into (8) and letting

$$A_i = \binom{N}{i}\exp\left(\frac{(N-2i)^2a^2}{2\sigma^2}\right), \quad (i=0, 1, \cdots, N), \quad (12)$$

where $\binom{N}{i}$ is the binomial coefficient, we find

$$p(x) = B(\tfrac{1}{2})^N\sum_{i=0}^{N} A_i \cdot\exp\left(-\frac{1}{2\sigma^2}(x-(N-2i)a)^2\right). \quad (13)$$

Hence,

$$F_m(u) = \frac{1}{\sum_{e=0}^{N} A_e}\sum_{i=0}^{N} A_i\exp\left(ju(N-2i)a\right), \quad (14)$$

which shows a somewhat unexpected result that the optimal message is a discrete amplitude process. The amplitude of the message process can assume values $(N-2i)a$, $(i=0, 1, \cdots, N)$ at any time with probabilities $A_i/\Sigma A_e$. It is interesting to note that, if the prescribed filter is enlarged to include the class of all filters that makes use of the present as well as the past $k-1$ samples of the input process,[3] and if the noise is multidimensional Gaussian, then (7) becomes

$$K(x_1, \cdots, x_k)p(x_1, \cdots, x_k) = x_k p(x_1 \cdots x_k) + \sum_{e=1}^{k}\sigma_{ek}\frac{\partial p(x_1, \cdots, x_k)}{\partial x_e}, \quad (15)$$

where x_i $(i=1, 2, \cdots, k)$ are samples of the input processes at times $t_i(t_k\geq t_{k-1}, \cdots, \geq t_i)$, $K(x_1, \cdots, x_k)$ is the prescribed filter, $p(x_1, \cdots, x_k)$ is the joint probability density function of the input process and $\sigma_{ek} = E(n_e n_k)$. We note that (15) is a partial differential equation of the first order with constant coefficients; hence, a general solution may be obtained by standard methods.[4] However, it is not clear just what conditions must be imposed on $K(x_1, \cdots, x_k)$ so that the solution coincides with a probability density function.

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[3] Discrete parameter processes are assumed.
[4] I. N. Sneddon, "Elements of Partial Differential Equations," McGraw-Hill Book Co., Inc., New York, N. Y., ch. 2; 1957.

Man-Machine Communication*

For some while in reading accounts of efforts to bring the brain and the computer into closer commune (both in concept and in communication) it has struck me that one tack has been neglected. Praiseworthy efforts in speech analysis and programming have led to the ability of particular machines to recognize the spoken decimal digits. From biophysics we have learned enough to encourage us to assemble complex arrays of neuron-like elements which have adaptive properties and are capable of recognition processes. Printing devices have come a long way in relieving the computer of the handicap of being tongue-tied. Extensions of these successes will no doubt lead to remarkable accomplishments in the future.

The first and latter efforts are directed at improving communications in both directions between man and computer. Work with synthetic neurons appears to be aimed at giving the machine special capabilities heretofore found only in living organisms. Imitation here can surely be construed as flattery of the success of a billion years of natural selection, or of the Master.

Acknowledging the merits of the central nervous system of man and the beasts falls short of giving it its due in the context of the efforts referred to above. Rather than attempt to teach a dim-witted machine to recognize speech, why don't we let the machine help the marvelously adaptive brain adjust to communication means more suitable to electronic hardware? Not only do we little understand the mechanism of the human brain, we little comprehend its potentialities. Would not the ancient Greeks, resurrected, be surprised at what accomplishments are standard in a 17-year-old American, IQ 100?

What is needed is a major effort to determine what may be accomplished by coupling a living organism in a feedback loop with a computer in a manner devised to condition the organism to communication with the machine. The opportunities for sensory connection are various; learning might be encouraged by reward or punishment, subtle or severe.

Success might be expected first for situations where vocabulary requirements are not severe: air traffic control, computer programming, reservations systems, certain information retrieval systems. A language achieved by mutual human and machine adaption might be expected to be much more efficient, or less redundant, than human speech, which has not been subjected to very powerful or prolonged forces of natural selection.

One might shudder that this is the last straw in the subjection of man to the machine: when he has to give up his native language, even in partial measure, in order to earn his living, to survive. The philosopher may well worry more about this than the clerk who takes two semesters of computer pseudo-speech in the twelfth grade. Perhaps there is consolation to be found in the potentiality for coupling a mind with exceptional imaginative or synthetic powers to a machine of lightning speed and powerful memory. Given an artist and a machine with sound output or a special display unit one might anticipate something new in the field of creative arts.

Man-machine symbiosis of a sort exists today. Should all our electronic calculators suddenly stop there would be many a panic. With the passage of time the association will become more intimate. The versatility of the living nervous system may contribute in new and untried ways to this association.

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* Received by the IRE, November 27, 1961.

Discussion of "Tapered Distributed RC Lines for Phase-Shift Oscillators"*

In the above paper,[1] Edson comments that by an odd coincidence, the magnitude of V_t/V_1 is closely equal to $1+\alpha_1/(km)$. The following calculations will show that the coincidence is not odd, but is to be expected, at least for small values of m and for $m>1$.

Referring to Fig. 2 of the paper, it can be seen that except for a small kink near the origin, β/k is approximately equal to m. Combining this fact with (11) of the paper gives

$$\alpha \mp k = \frac{k^2m^2}{\beta} \simeq km.$$

Since α_1 is the lower of the two values of α,

$$\alpha_1 \simeq k(m-1).$$

A look at Fig. 2 will show that this approximation is valid for $m>1$. Substituting this value of α_1 in (16) and simplifying, one obtains

$$\left|\frac{V_t}{V_1}\right| = 2\left\{\frac{1}{\left(1+\frac{1}{2m}\right)^2+\left(\frac{1}{2m}\right)^2}\right\}^{\frac{1}{2}}.$$

For $m>1$, $[1/(2m)]^2$ may be neglected in comparison with $[1+1/(2m)]^2$. Thus,

$$\left|\frac{V_t}{V_1}\right| \simeq 2\left(1+\frac{1}{2m}\right)^{-1} \simeq 2-\frac{1}{m}$$

neglecting square and higher powers of $1/(2m)$. To the same extent of approximation as used above,

$$1+\frac{\alpha_1}{km} \simeq 2-\frac{1}{m}.$$

* Received by the IRE, December 5, 1961; revised manuscript received January 8, 1962.
[1] W. A. Edson, Proc. IRE, vol. 49, pp. 1021–1024; June, 1961.

Thus,

$$\left|\frac{V_t}{V_1}\right| \simeq 1 + \frac{\alpha_1}{km}$$

for $m>1$. For small values of m, $\alpha_1/km \simeq 0$ from Fig. 3; also from Fig. 2, as $m \to 0$, $\alpha_1 \to 0$ and $\beta \to 0$. Therefore,

$$|V_t/V_1| \simeq 1 + \frac{\alpha_1}{km} \qquad \text{for } m \to 0.$$

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Synthesis of Distributed-Parameter RC Networks*

Recent work[1,2] in designing network-response functions by shaping and distributed-parameter circuits have established the feasibility of a new and useful technique for "synthesis" of network functions. However, the full potential of these synthesis techniques appears to have been overlooked by these investigators. The purpose of this communication is to draw attention to three broad areas of investigation where thin-film distributed-parameter techniques lead to improvements in design flexibility and in operational characteristics, namely:

Network Shaping

Network response can be controlled by shaping the morphology of the network in several ways, *e.g.*, multilayer deposition[3,4] leads to film-type sandwich structures such as the C-R-NC and R-C-NR four-terminal networks in Fig. 1. Thickness and geometry of the film can be varied such as the linear or exponential taper[5] illustrated in Fig. 2. Topologies not realizable by pig-tailed lumped-parameter components can be achieved. For example, Fig. 1 shows a radial transmission line for which the matrix elements can be evaluated in closed form.[6]

Multiterminal Networks

Functional flexibility in network realization results from the large number of possible alternatives in connecting the terminals of a basic film-type structure. The interaction between adjacent films is described mathematically by laws governing multiterminal systems.[7,8] External constraints are imposed upon the network by connecting or by floating, specified terminals: a new network results, which is referred to as a subnetwork. For example, the radial transmission line, Fig. 1, can be connected to give 31 different two-terminal subnetworks. An estimate of the total number of subnetworks available from a given multiterminal network is presented in Fig. 3. Present techniques of network analysis are, with a few exceptions,[7,9] limited to three-terminal two-port systems. Thus, improved flexibility of design in response of film-type circuits appears predicated upon more effective utilization of subnetwork generation or similar techniques of realizing functions inherent in a multiterminal system.

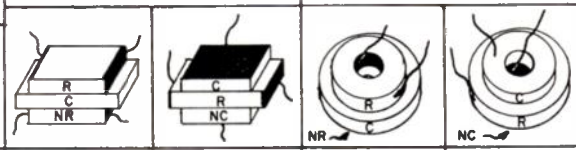
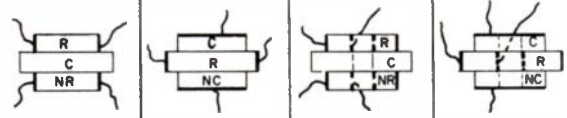
DISTRIBUTED PARAMETER NETWORK	R C NR	R C NC	R C NR	R C NC
SYMBOL	R - C - NR	C - R - NC	R - C - NR	C - R - NC
TRANSMISSION LINE	RECTANGULAR		RADIAL	
GEOMETRY				
STRUCTURE				
ONE-PORTS	13	13	31	31
THREE-TERMINAL TWO-PORTS	16	17	30	30
FOUR-TERMINAL TWO-PORTS	3	2	3	3

Fig. 1—Network shaping by multilayer structures.

Normalized Parameter	Rectangular	Linear Taper Approximate	Exponential Taper Approximate	Resistive Disk
Resistance $\frac{s}{\rho}R$	$\frac{\ell}{w}$	$\frac{(\ell)}{w}\frac{n \log}{(n-1)}$	$\frac{n-1}{aw}$	$\frac{\log n}{2\pi}$
Capacitance $\frac{t}{\epsilon}C$	ℓw	$(\ell w)\frac{n+1}{2n}$	$w\frac{(n-1)}{an}$	$\pi\frac{w^2}{n^2}(n^2-1)$
Time Constant $\frac{st}{\rho\epsilon}RC$	ℓ^2	$(\ell^2)\frac{(n+1)\log n}{2(n-1)}$	$\frac{(n-1)^2}{na^2}$	$\frac{w^2}{2n^2}(n^2-1)\log n$
Impedance Level $\frac{\epsilon}{\rho}\frac{R}{C}$	$\frac{1}{w^2}$	$(\frac{1}{w^2})\frac{2n^2 \log n}{n^2-1}$	$\frac{n}{w^2}$	$\frac{1}{2\pi^2}\frac{n^2 \log n}{w^2(n^2-1)}$

Fig. 2—Network shaping by tapering.

* Received by the IRE, November 15, 1961.

[1] L. B. H. Wilson and R. B. Wilson, "Shaping of distributed RC networks," Proc. IRE, vol. 49, pp. 1330–1331; August, 1961.

[2] W. A. Edson, "Tapered distributed RC lines for phase-shift oscillators," Proc. IRE, vol. 49, pp. 1021–1024; June, 1961.

[3] W. W. Happ and G. C. Riddle, "Limitations of film-type circuits consisting of resistive and capacitive layers," 1961 IRE International Convention Record, pt. 6, pp. 141–165.

[4] W. D. Fuller, "Titanium thin-film circuits," *Proc. Nat'l Electronics Conf.*, Nat'l Electronics Conf., Inc., Chicago, Ill., pp. 32–43; 1961.

[5] W. D. Fuller and W. W. Happ, "Design procedures for film-type distributed parameter circuits," *Proc. Nat'l Electronics Conf.*, Nat'l Electronics Conf., Inc., Chicago, Ill., pp. 597–610; 1961.

[6] W. W. Happ and P. S. Castro, "Distributed parameter circuit design techniques," *Proc. Nat'l Electronics Conf.*, Nat'l Electronics Conf., Inc., Chicago, Ill., pp. 44–70; 1961.

[7] P. S. Castro, "Microsystem circuit analysis," *Elec. Engrg.*, vol. 80, pp. 535–542; July, 1961.

[8] P. S. Castro and W. W. Happ, "Subnetworks," to be presented at the 1962 IRE International Convention.

[9] T. R. Nisbet and W. W. Happ, "The calculus of deviations applied to transistor circuit and network analysis," *J. Brit. IRE*, vol. 25, pp. 437–450; May, 1961.

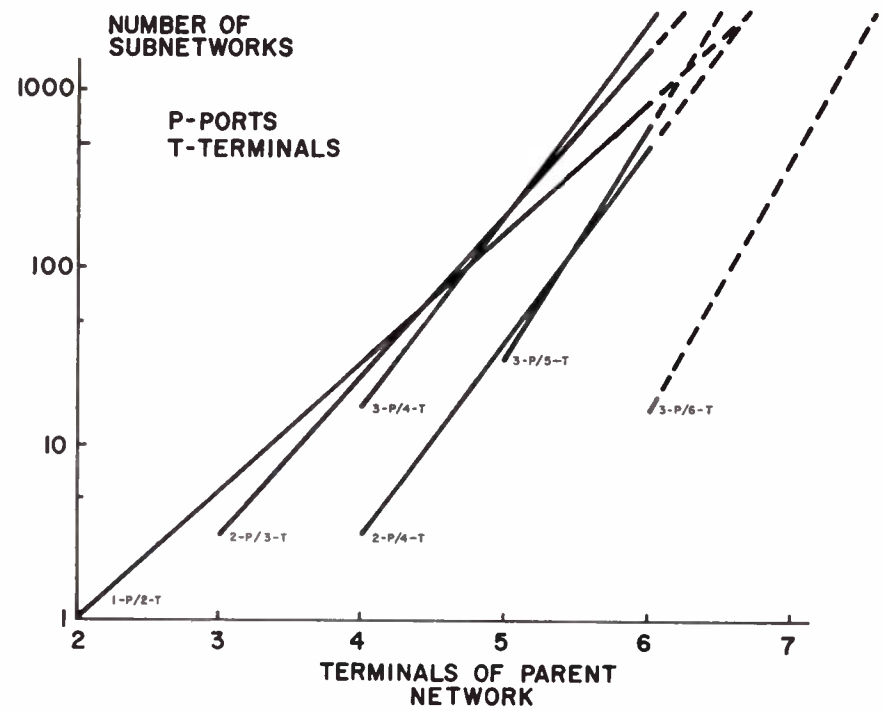


Fig. 3—Estimate of number of nonredundant subnetworks.

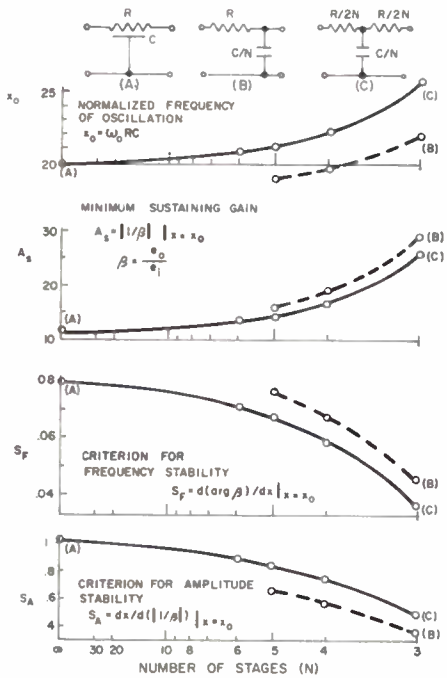


Fig. 4—Figures-of-merit for phase-shift networks.

Figures-of-Merit

A distinct advantage of thin-film circuits results from the possibility of optimising figures-of-merit more effectively than is generally possible with ready-made, pigtailed components. For example, figures-of-merit for phase-shift oscillators[1,2] are shown in Fig. 4, with the corresponding N-stage lumped-parameter networks to illustrate the asymptotic character of distributed-parameter networks. Similarly, appropriate figures-of-merit for other film-type circuits[10–12] can be established.

Acknowledgment

This work is part of a continuing program in the synthesis of thin-film integrated circuits performed in the Microsystems Electronics Department at Lockheed.

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[10] W. D. Fuller and P. S. Castro, "A microsystem bandpass amplifier," *Proc. Natl. Electronics Conf.*, Nat'l Electronics Conf., Inc., Chicago, Ill., pp. 139–151; 1960.
[11] W. W. Happ and P. S. Castro, "Distributed parameter circuits and microsystems electronics," *Proc. Nat'l. Electronics Conf.*, Nat'l Electronics Conf., Inc., Chicago, Ill., pp. 448–460; 1960.
[12] W. W. Happ, W. D. Fuller and P. S. Castro, "Synthesis of solid-state distributed parameter functions," to be presented at the 1962 IRE International Convention.

Diagonalizing Quadratic Filters*

Let a signal $x(t)$ be analyzed by N linear filters that produce the corresponding component signals $y_n(t)$,

$$y_n(t) = \int_{-\infty}^{\infty} h_n(\tau)x(t-\tau)d\tau \qquad (1)$$

where $h_n(t)$ is the impulse response of the nth analyzing filter. A quadratic filter[1] with output $w(t)$ is defined as a quadratic form in the component signals (1), *i.e.*,

$$w(t) = \sum_{m=1}^{N}\sum_{n=m}^{N} a_{mn}y_m(t)y_n(t). \qquad (2)$$

It is a well-known fact that there exists a (nonunique) linear change of variables[2]

$$z_m(t) = \sum_{n=1}^{N} b_{mn}y_n(t) \qquad (3)$$

such that (2) is diagonalized by the elimination of cross products

$$w(t) = \sum_{n=1}^{N} c_n z_n^2(t) \qquad (4)$$

where the c_n are determined by the a_{mn} and b_{mn} coefficients. This diagonalizing transformation is clearly equivalent to a change in analyzing filters to a new set with impulse responses $k_m(t)$,

$$k_m(t) = \sum_{n=1}^{N} b_{mn}h_n(t). \qquad (5)$$

It would appear to be helpful to employ this new set of analyzing filters for at least two reasons.

First, the quadratic filter represented by (4) has N multipliers, whereas the quadratic filter corresponding to (2) may require as many as $N(N+1)/2$ multipliers.

Second, intuitive interpretation of filter operation may be simplified by the elimination of cross products. For one example, suppose it turned out that the power density (or energy) spectra of the new $k_n(t)$ filters were nonoverlapping. If, in addition, one were mainly interested in a smoothed version of $w(t)$, this smoothed $w(t)$ is simply a weighted sum of energies (instantaneous energies which have been smoothed but not averaged over all time) contained in nonoverlapping regions of the spectrum of $x(t)$. For another illustration, suppose that the $k_n(t)$ filters are the same except for pure delays (same power density spectra, phase responses differ by a linear function). Then the filter (4) can be reduced to a single linear filter followed by a single squaring device followed by a transversal (tapped-delay-line) filter.

It is worth noting the simple fact that if the original filters are orthonormal, *i.e.*, if

$$\int_{-\infty}^{\infty} h_m(t)h_n(t)dt = \begin{cases} 1 & \text{for } m = n \\ 0 & \text{for } m \neq n, \end{cases} \qquad (6)$$

then an orthonormal diagnonalizing transformation[2] in (5) preserves orthonormality in the new analyzing filter set. The same comment of course applies to the component signals (although orthonormality of the analyzing filters does not imply orthonormality of the component signals, and vice-versa).

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* Received by the IRE, January 26, 1962.

[1] This might be called a Wiener polynomial filter, although the polynomial is not orthogonal. See N. Wiener, "Nonlinear Problems in Random Theory," The Technology Press, JohnWiley and Sons, Inc., New York, N. Y.; 1958.
[2] See, for example, F. B. Hildebrand, "Methods of Applied Mathematics," Prentice-Hall, Inc., Englewood Cliffs, N. J., pp. 35–39; 1952.

Use of the Earth's Magnetic Field for Navigation and Attitude Control*

Use of the earth's magnetic field for navigation and attitude control of orbiting earth satellites is an attractive possibility. This note briefly summarizes preliminary study in this area undertaken at The Bissett-Berman Corporation.[1]

Navigation

A self-contained navigation system sufficiently accurate for many applications may be feasible by taking advantage of the existence of the earth's magnetic equator. Future satellite experimental measurements may confirm the contention that the shape of the magnetic equator is relatively constant at satellite altitudes, even in the presence of magnetic storms which primarily influence the horizontal component of the field. If the contention is true, it should be possible to represent the longitude of intersection ρ_m between the satellite orbit path and the magnetic equator as a single-valued continuous function of the inclination angle i and the longitude of the ascending node, Ω. That is

$$\rho_m = f(i, \Omega). \tag{1}$$

Using the above relationship which may be stored in analog form within a satellite, a procedure is indicated for dead reckoning navigation in circular orbits based simply on accumulated clock time from magnetic equator crossings. Passage of the magnetic equator may be sensed by a vertically oriented magnetometer which reads zero output. Different possibilities for mechanizing navigation equations are available. For example, one possibility investigated is a straightforward analog approach using resolvers and a servomotor to generate latitude and longitude coordinates.

A striking advantage of the concept given above is the fact that dead reckoning errors cannot accumulate beyond magnetic equator crossings which essentially amount to positional fixes. Further, since satellite latitude at the equator should be much better known than magnetic equator longitude, it is possible to consider simple ways to correct clock rate drifts, the primary source of equipment errors over long satellite lifetimes.

Attitude Control

The principle employed for attitude control utilizes the interaction between an external magnetic field, β, in this case the earth's, and an internally generated magnetic moment, M. This relationship is provided by the vector torque equation,

$$\bar{T} = \bar{M} \times \bar{\beta}. \tag{2}$$

If suitably generated, such torques may be used as primary means for axis misalignment correction or as a technique for desaturating inertia wheels used for fine control. In fact, preliminary work has already been performed in such directions.[2]

One configuration has been investigated which uses this principle in a particularly simple and potentially attractive manner. In this configuration a spinning earth satellite with spin axis aligned to the axis of the orbit plane may scan the earth's surface by using sensors spaced along a parallel to the spin axis. This configuration presents inherent gyroscopic stability. Further, the major source of misalignment is due to orbit plane precession, in the order of a few degrees per day. If current is applied with the proper sense to a coil wound about the spin axis, the satellite may be caused to precess in a direction to correct spin axis misalignment. In using this technique, axis misalignments may be sensed as bank angles determined on the basis of outputs of two infrared cells that detect right and left, front and rear horizon crossings. It is well to note that corrective torques cannot increase or decrease the spin rate since from (2),

$$\bar{T} \cdot \bar{\beta} = \bar{M} \times \bar{\beta} \cdot \bar{\beta} = 0. \tag{3}$$

For many impulse-corrective schemes, wobble represents a problem since when torques are applied, the net angular momentum vector will displace from the body axis along which it was concentrated prior to correction. For a spinning disk-like vehicle, the wobble angle δ has been derived as

$$\delta = \arctan\left[\frac{\omega_H}{\omega_z} \left| \sin \omega_z t \right|\right], \tag{4}$$

where

ω_H = precession rate,
ω_z = spin rate,
t = time duration of corrective torquing.

Since misalignments occur very slowly for this configuration, corrective precession may be applied over long time durations; therefore, precession rates are low. A typical rate of 3×10^{-5} radians/sec results from energizing a 3-ft diameter coil with a current of 0.80 amperes in a 0.25 gauss field (to produce a torque of about 1.2×10^{-3} lb-ft). This rate is much less than the typical spin rate of, say, 0.5 rps and wobble is virtually nonexistent.

The magnetic torquer described above may be implemented without adding to the satellite battery load. Correction may be applied only when the satellite is in sunlight at which times corrective current is passed directly from solar cells through a reversing switch to the spin axis coil. A controller is necessary to determine the desired direction of current and on this basis actuate the reversing switch. The direction depends, in turn, upon the earth's relative magnetic field vector in satellite coordinates. Rather than use devices such as magnetometers to perform this determination, it is possible to expose the torquer coil to sample activations and sense the direction of satellite precession. If the sample activation causes increasing bank angle error, the controller reverses the direction of current flow through the torquer coil, thereby reducing the bank angle error.

Acknowledgment

Dr. G. F. Floyd of The Bissett-Berman Corporation was originator of the approaches discussed above. Other staff members who aided in this effort include L. C. Murdock and W. R. Martin.

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The Effective Earth Radius Obtained Through Conformal Mapping*

Let us assume the law of refraction is valid for radio waves in the earth's atmosphere. Let this atmosphere be determined by the height variation of its refractive index μ only. Let it also be acceptable to idealize the refracting properties so that all ray paths are circles. It follows in accordance with Fig. 1

$$1/\rho = -\frac{1}{\mu}\frac{d\mu}{dh}\cos\xi, \tag{1}$$

$$\rho \cos\xi = \rho' \cos\xi', \tag{2}$$

$$\cos\xi_0 = \cos\xi'/\cos\xi, \tag{3}$$

$$\mu = \mu_0 \exp\left[-\log_e(1 + h/\rho + h^2/2R\rho)\right], \tag{4}$$

where (4) is a solution of (1) with ρ constant along the ray path.

Let us now map K_{z_2} of radius ρ (Fig. 2) into $K\lambda_2$ of infinite radius (Fig. 3) and K_{z_1} of radius R into K_{λ_1} whose radius R_{eff} is to be determined. For conceptual reasons it is convenient to introduce a ω plane. The circles K_{z_1}, K_{z_2} and K_{λ_1}, K_{λ_2} are mapped into concentric circles in the ω plane by means of fractional linear functions

$$\omega = s_a \frac{z - \alpha_1}{z - \alpha_2} \tag{5}$$

and

$$\omega = s_b \frac{\lambda - \beta_1}{\lambda - \beta_2}, \tag{6}$$

where s_a, s_b are arbitrary complex constants; α_1, α_2 are the source and sink points in the z plane; and β_1, β_2 are the source and sink points in the λ plane. Let us choose s_a, s_b such that K_{z_1}, K_{λ_1} are both mapped into the unit circle K_{ω_1}, and K_{z_2}, K_{λ_2} are both mapped into K_{ω_2} ($|\omega| = R_\omega > 1$). During transformations (5) and (6) the double ratios remain invariant.[1] It follows that

$$\Delta(K_{z_1}, K_{z_2}) = \frac{z_1 - z_2}{z_1' - z^2} : \frac{z_1 - z_2'}{z_1' - z_2'}, \tag{7}$$

$$\Delta(K_{\lambda_1}, K_{\lambda_2}) = \frac{\lambda_1 - \lambda_2}{\lambda_1' - \lambda_2}, \tag{8}$$

$$\Delta(K_{\omega_1}, K_{\omega_2}) = \left(\frac{R_\omega - 1}{R_\omega + 1}\right)^2, \tag{9}$$

$$\Delta(K_{z_1}, K_{z_2}) = \Delta(K_{\lambda_1}, K_{\lambda_2}) = \Delta(K_{\omega_1}, K_{\omega_2}). \tag{10}$$

* Received by the IRE, December 22, 1961.
[1] Some of the work reviewed here was conducted under contract with The Boeing Co.

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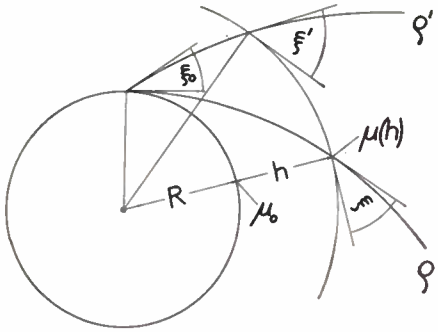


Fig. 1.

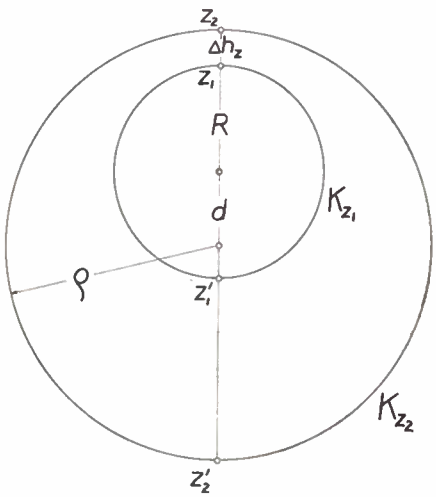


Fig. 2.

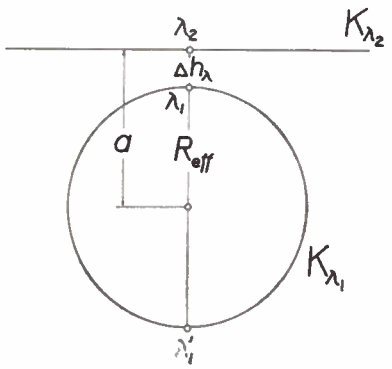


Fig. 3.

Eqs. (7) and (8) can also be written as

$$\Delta(K_{z_1}, K_{z_2}) = \frac{(\rho - R)^2 - d^2}{(\rho + R)^2 - d^2} \qquad (11)$$

and

$$\Delta(K_{\lambda_1}, K_{\lambda_2}) = \frac{a - R_{\text{eff}}}{a + R_{\text{eff}}}. \qquad (12)$$

Eqs. (10)–(12) yield

$$\frac{1}{R_{\text{eff}}} = \left(\frac{1}{R} - \frac{1}{\rho}\right)\frac{(\Delta h_z)}{(\Delta h_\lambda)} - \frac{(\Delta h_z)^2}{2R\rho(\Delta h_\lambda)}, \qquad (13)$$

which relates R in the z plane to R_{eff} in the λ plane, if ρ in the z plane corresponds to an infinite radius in the λ plane. Eq. (13) can readily be simplified to agree with an approximate expression obtained elsewhere.[2,3]

If a circle of radius $\rho' = \rho/\cos\xi_0$ (Fig. 1) is made to originate at z_2 in the z plane, it becomes a straight line through λ_2 in the λ plane with ξ_0 preserved. Because of the constraint $\rho' = \rho/\cos\xi_0$, which is a consequence of (1)–(4), it can easily be shown that R_{eff} of (13) remains invariant for all values of ρ' and thus for all departure angles ξ_0.

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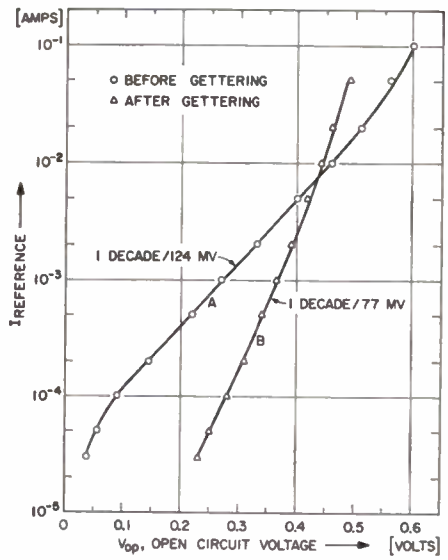


Fig. 1—Forward current-voltage characteristics of silicon solar cell before and after "gettering" treatment. Slopes are indicated by increase of voltage for one decade current increase.

Gettering Effects on the Forward Characteristics of Silicon Solar Cells*

Glassy oxide layers can act as "getters" for metal impurities in Si p-n junctions. It has been shown[1] that diffusions employing such layers yield diodes with "hard" breakdown and improved reverse characteristics. In this note, we report effects upon the forward current-voltage characteriscis of p-n junctions in silicon solar cells after such "gettering" treatment.

Silicon solar cells have unexplained[2] low slopes (d ln I/dV) of the forward current I vs voltage V. There is still some question whether this is a basic feature[3] or not. However, it is our opinion that both the low slopes and the reported "soft" breakdown[4] indicate unnecessary and avoidable current paths.[2,5] It is shown here that "gettering" can increase the slopes to values that are to be expected from p-n junction theory.

Fig. 1, curve A, shown a forward current voltage relation of a medium efficiency Si p-*on*-n solar cell (Type 110C, Hoffman Electronics Corporation). The open circuit voltage V_{op} was measured for different illumination levels. Illumination was monitored via the short circuit current I_{ref} of a simultaneously illuminated reference cell. (Active area: 1.8 cm².) With this method characteristics can be measured for cells without ohmic contacts.[5,6] Cell contacts had to be removed because of the subsequent "gettering" treatment.

The "gettering" was done by "paint-on" using B_2O_3 solution together with a boron predeposit using a B_2O_3 source.[1] The B_2O_3 solution was applied to the bottom of the cell, and the cell placed in a platinum box[7] with a B_2O_3 source. Diffusion was done at 1200°C for ½ hour. The "paint-on" -layer was etched off the bottom side, and the current-voltage characteristic measured as before. Curve B of Fig. 1 shows the distinct increase in slope. This curve can be explained by theory.[8]

It is thus possible to increase the low slope of the forward characteristic of solar cells by "gettering." A junction motion of the order of 1 micron is caused by the additional diffusion time, but this does not seem a likely explanation of this change of slope. With the previous evidence[1] it seems more plausible that the "gettering" removed or at least redistributed metal impurities within the junction. This would mean that impurities are at least partly responsible for the observed anomalous slopes.

The "gettering" effect is further evidence for the need of cleaner material for higher efficiency solar cells.

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* Received by the IRE, December 18, 1961. This work was sponsored by the Wright Air Development Center, U. S. Air Force, Dayton, Ohio.
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Contributors



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Dr. Wolfe is a member of the American Physical Society, Phi Beta Kappa, and Sigma Xi.

IRE Awards, 1962

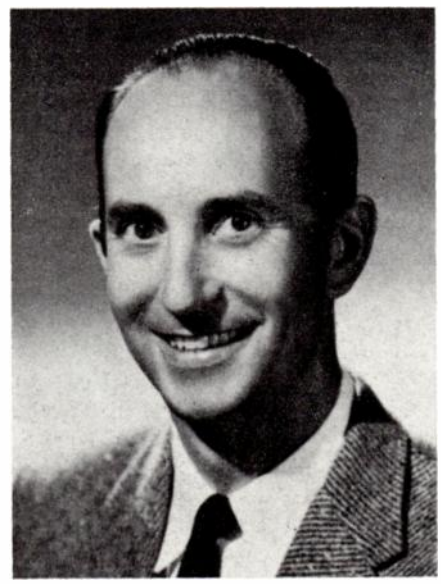
Medal of Honor Award



EDWARD V. APPLETON

For distinguished pioneer work in investigating the ionosphere by means of radio waves.

Memorial Prize Award in Memory of Morris N. Liebmann



VICTOR H. RUMSEY

For basic contributions to the development of frequency independent antennas.

Memorial Prize Award in Memory of Browder J. Thompson



HENRI B. SMETS

For his paper entitled "Analysis and Synthesis of Nonlinear Systems," which appeared in the December, 1960 issue of the IRE TRANSACTIONS ON CIRCUIT THEORY.

Memorial Prize Award in Memory of Harry Diamond



WILLIAM CULSHAW

For outstanding accomplishments in the field of microwave optics and interferometry.

Prize Award by Vladimir K. Zworykin



GEORGE A. MORTON

For his contribution to electronic television through the development of camera and imaging tubes.

Prize Award by W. R. G. Baker



MARVIN CHODOROW

For his paper (with Tore Wessel-Berg) entitled "A High-Efficiency Klystron with Distributed Interaction," which appeared in the January, 1961 issue of the IRE TRANSACTIONS ON ELECTRON DEVICES.

Prize Award by W. R. G. Baker



TORE WESSEL-BERG

For his paper (with Marvin Chodorow) entitled "A High-Efficiency Klystron with Distributed Interaction," which appeared in the January, 1961 issue of the IRE TRANSACTIONS ON ELECTRON DEVICES.

New Fellows



BENJAMIN ADLER

For contributions toward the effective utilization of the UHF spectrum.



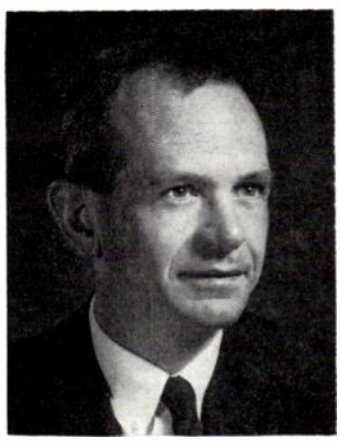
G. J. ANDREWS

For leadership in electronic engineering in Argentina and service to The Institute of Radio Engineers.



H. G. BAERWALD

For contributions to network theory and to the theory of piezoelectric devices.



C. K. BIRDSALL

For contributions to research on traveling wave tubes.



F. E. BORGNIS

For leadership in engineering education and research and contribution in the fields of electronics and acoustics.



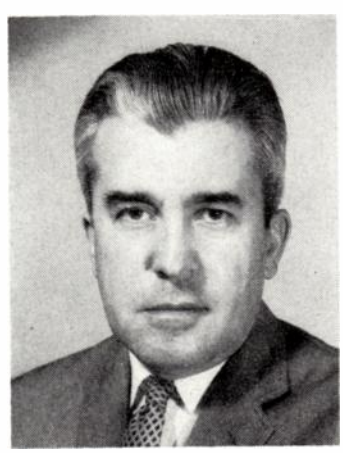
G. A. BOUTRY

For contributions to electro-optical science, color television, and European television standards.



F. W. BROWN

For direction and administration of research in the field of radio wave propagation.



T. J. CARROLL

For contributions to the understanding of tropospheric propagation.



R. S. CARUTHERS

For contributions in the fields of multiplexing and long-distance telephony.

New Fellows



S. S. L. CHANG

For contributions to information theory and to control systems theory.



E. W. CHAPIN

For contributions to the measurement and reduction of radio frequency interference and to the formulation of standards, rules and regulations in this field.



A. R. D'HEEDENE

For contributions to the development of networks for communication systems.



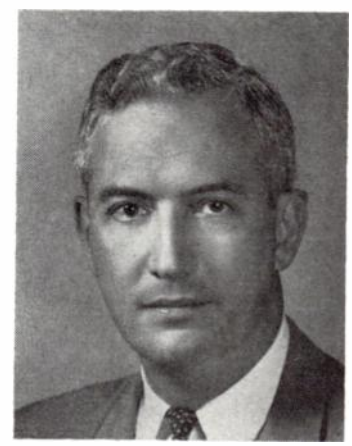
ARTHUR DORNE

For contributions to the design of antennas, particularly for aircraft.



L. W. ERATH

For contributions to seismic and geophysical instruments and to naval ordnance.



R. G. FELLERS

For research at millimeter wavelengths.



L. B. FELSEN

For contributions to electromagnetic theory and measurement.



P. J. FRANKLIN

For pioneering contributions to printed circuit technology.



P. E. GREEN, JR.

For contributions to radar astronomy and communication through multipath channels.

New Fellows



F. T. Haddock, Jr.

For contributions to radio astronomy.



R. C. Hansen

For contributions to the theory of antenna systems.



H. F. Hastings, Sr.

For contributions to radio instrumentation in the field of precision time and frequency measurement.



H. A. Haus

For contributions to noise theory in electron-beam devices and electric networks.



Hubert Heffner

For contributions to the theory of backward wave oscillators and parametric amplifiers.



M. W. Horrell

For contributions to military electronics and computer engineering.



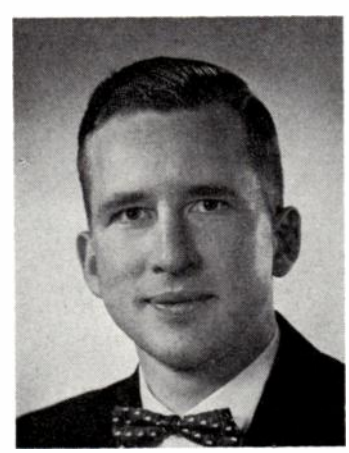
W. L. Hughes

For contributions to color television.



J. F. Hull

For contributions to the advancement of the art of crossed-field microwave devices.



H. R. Johnson

For contributions to voltage-tuned microwave oscillators.

New Fellows



W. C. JOHNSON

For contributions to electrical engineering education.



T. F. JONES, Jr.

For contributions to electrical engineering education.



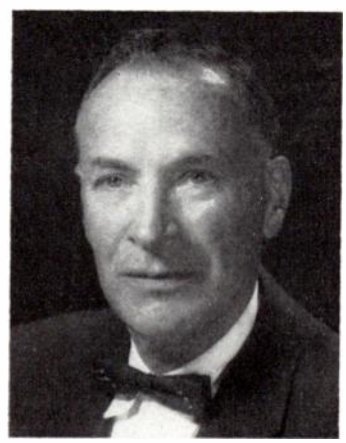
J. F. KEITHLEY

For contributions to electronic instrumentation.



HARRY KIHN

For contributions to color television circuitry.



A. P. KING

For contributions to waveguide theory and applications.



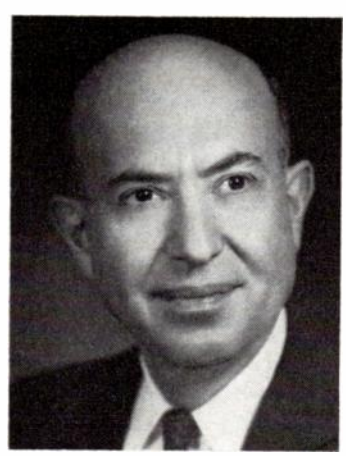
MAX KNOLL

For work on cathode ray tubes, in particular the electron microscope and image storage tubes



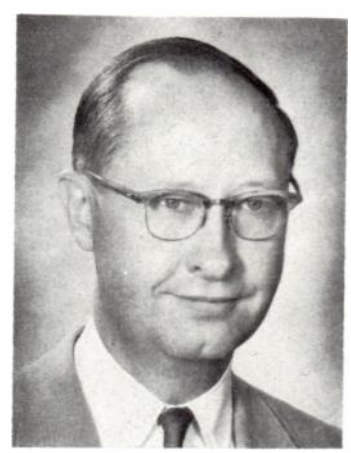
H. N. KOZANOWSKI

For early contributions to electronic circuits.



SIDNEY KRASIK

For contributions toward the development of microwave devices and nuclear power plants.



H. L. KRAUSS

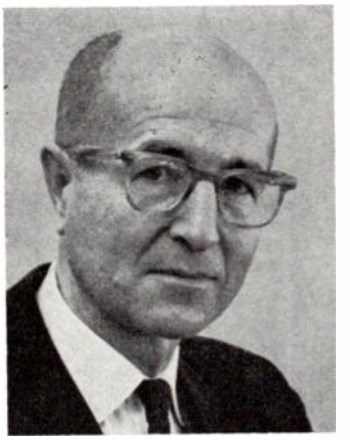
For contributions to electrical engineering education.

New Fellows



J. G. KREER

For contributions to standardization.



D. B. LANGMUIR

For contributions of the field of electrostatic propulsion.



F. W. LEHAN

For contributions to space electronics and telemetry.



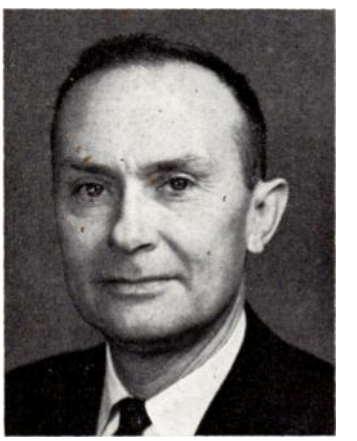
ANDREW LONGACRE

For originality and resourcefulness in developing military electronic equipment.



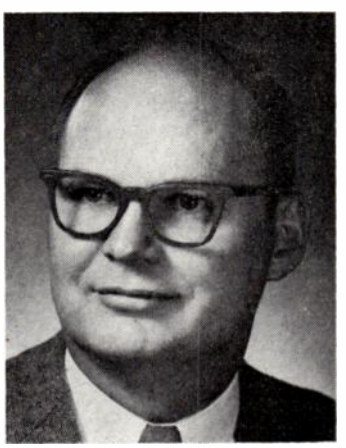
S. G. LUTZ

For improvements in long distance communications techniques and methods of miniaturizing electronic circuitry.



R. W. MASTERS

For contributions in the field of antennas and RF transmission systems.



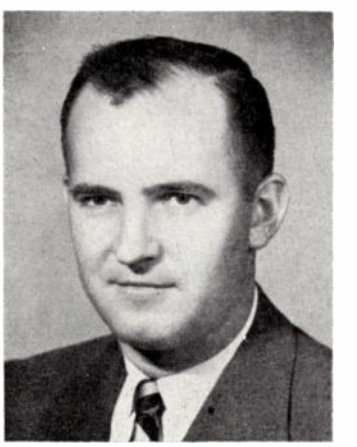
J. L. MCLUCAS

For contributions to the transmission and recording of radar presentations.



BROCKWAY MCMILLAN

For contributions to information theory, circuit theory, and systems analysis.



R. F. METTLER

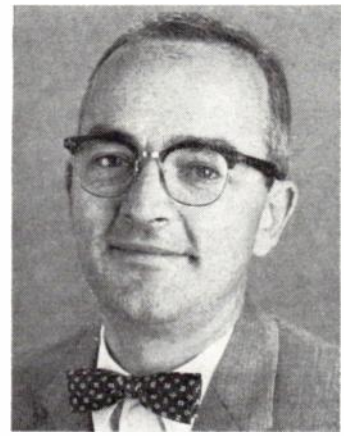
For contributions to radar and ballistic missiles.

New Fellows



G. F. Montgomery

For contributions to electronic instrumentation.



R. K. Moore

For contributions to electromagnetic propagation and engineering education.



R. B. Muchmore

For accomplishments in the field of microwaves.



G. E. Mueller

For accomplishments in the field of microwave antennas and tubes.



E. L. Norton

For fundamental contributions to circuit theory.



E. W. Pappenfus

For contributions to single sideband communications and to multi-channel frequency control systems.



A. M. Peterson

For contributions to propagation aspects of communications.



W. J. Pietenpol

For contributions to transistor technology.



Robert Price

For contributions to communication system theory and its use in radar contact with Venus.

New Fellows



F. H. Raymond

For contributions to the analysis and development of electronic computers and automation systems.



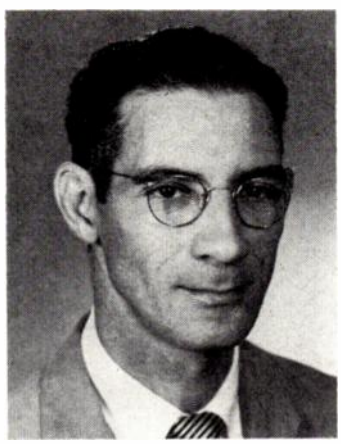
P. A. Redhead

For contributions to the field of electron devices and to ultra-high vacuum technology.



John Ruze

For contributions to the theory of antenna design.



Vincent Salmon

For contributions to acoustics.



J. M. Salzer

For contributions to the technology of the electronic digital computer.



Wolja Saraga

For contributions to network theory and its application in communications.



R. J. Schwarz

For contributions to engineering education and to system theory.



David Slepian

For contributions to information theory and noise analysis.



S. T. Smith

For contributions to electron tube technology.

New Fellows



R. L. SNYDER

For contributions to the development of electron tubes and of digital computers.



R. W. SONNENFELDT

For contributions to color television and to digital techniques.



A. P. STERN

For contributions and leadership in the field of solid-state circuits.



D. M. STUART

For contributions to electronic aids to air navigation.



F. L. H. M. STUMPERS

For contributions to communication theory.



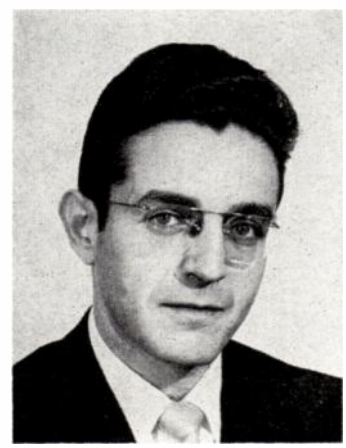
C. T. TAI

For contributions to electromagnetic and antenna theory.



C. H. TOWNES

For fundamental contributions to the MASER.



VICTOR TWERSKY

For contributions to electromagnetic scattering theory.

J. L. VAN SOEST

For contributions to defense research in the Netherlands.

New Fellows



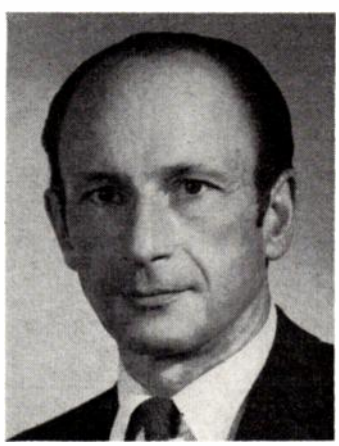
M. E. Van Valkenburg
For contributions to circuit theory.



J. R. Wait
For contributions in electromagnetic theory and radio propagation.



W. H. Ware
For contributions in the early development of digital computers.



F. M. Wiener
For research in electroacoustics.



E. G. Witting
For services and contributions to military electronics.



H. J. Woll
For contributions to tube and transistor circuitry.

Books

Elihu Thomson: Beloved Scientist, by David O. Woodbury

Published (1960) by Harvard University Press, Cambridge, Mass. 350 pages+6 index pages+xv pages. Illus. 6×9¼.

MIT's J. R. Killian, Jr., calls it a new edition in the preface, but this biography of Elihu Thomson (1853–1936) actually reproduces the original 1944 version with photographic exactitude; Killian's "appreciation" and a few irrelevant pictures are the only new material. Thomson was the co-founder of the Thomson-Houston Co. (one of the predecessors of the General Electric Co.) who made important contributions to the development of electric machines and transformers, originated electric welding and the integrating watt-hour meter, and invented many other devices. He was one of the first AIEE presidents (in 1889), served as MIT's acting president in 1920–1922, and received many distinctions. His closest brush with scientific fame came in 1876: in disproving Edison's contention that the sparks observed at some distance from sparking equipment were of nonelectric origin (Edison's "etheric force"), Thomson came close to anticipating Hertz in the discovery of electromagnetic-wave propagation.

The historian of technology might regret that the book remains almost wholly devoid of bibliographical references and consequently a bit shaky as to historical detail. The exigencies of the publishing business (or the author's disinclination) evidently made it impracticable to bring out a truly new edition in which the faults of the old could have been corrected and recent relevant literature (*e.g.*, M. Josephson's "Edison," published by McGraw-Hill in 1959) could have been taken into account. Moreover, time marches on: the present book reasserts, for instance, that the building in which Thomson experimented with sparks "still stands and is still in use," whereas it was in fact demolished in 1950. But these professional misgivings aside, Woodbury's popular account makes interesting reading and might indeed appeal, as Killian hopes, "to new generations of youth;" heaven knows there are few enough books around with an engineer for the hero.

CHARLES SÜSSKIND
University of California
Berkeley, Calif.

Automatic Control Engineering, by F. H. Ravan

Published (1961) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 402 pages+8 index pages+xi pages+17 appendix pages+problems. Illus. 6¼×9¼. $11.50.

Probably every professor who has taught courses in feedback control has developed his own set of teaching notes which seem to him to be a more logical and lucid presentation of automatic control than any other text available. Consequently, a large number of professors decide to incorporate these notes, which have been successfully used and improved for several semesters, into a textbook. The book under discussion falls into this category as explained in its preface. Whether or not it will be used by other instructors will probably depend considerably on how well the text agrees with their individual course outlines. It should be noted, however, that this book does have an organization which is somewhat different from the usual automatic control textbook in that it emphasizes the mechanical aspects of control. In fact, control system components are introduced with a spring, mass, and damper, and throughout the text, mechanical, electric, pneumatic, and hydraulic components are continually being described and referenced.

The book is published as one of the McGraw-Hill mechanical engineering series, and in this respect it is probably unique. The first chapter is a conventional and a very brief introduction to automatic control, and the succeeding chapters consider the representation of control components, the representation of control systems, steady state operation, the Laplace transform, the characteristic function, the root locus method, analog computers, frequency response methods, and improving system performance. The final chapters consider hydraulic, pneumatic, electrical, inertial, and nonlinear systems. Four appendices are included to discuss the relationship between the Laplace transforms, the Fourier series, and the Fourier integral; the response of a system to an arbitrary input by convolution; a method of obtaining the frequency response from the transient response, and, conversely, the transient response from the frequency response. Finally, there are 40 pages of problems which should be of interest to many professors seeking new material.

The first chapters are treated in a rather conventional manner except for the aforementioned references to mechanical components. The asymptotic frequency plots are shown, quite refreshingly, on log magnitude scales. The unnecessary and wasteful convention of converting to db is not used. However, the cut and try methods used in improving system performance do seem to be inefficient, because simple synthesis methods have been presented in the literature which give direct solutions. Unfortunately, there is very little emphasis on the meaning of performance and the corresponding and eternal conflicts between errors, response time, noise, and stability. The chapters on hydraulic, pneumatic, and electrical systems are essentially clear and detailed discussions of some system components.

The chaper on nonlinear systems includes an introduction to sampled data systems. This misplaced section of nine pages lies between a ten page introduction to describing functions which introduces the chapter and a four page description of phase plane techniques which ends the chapter.

Unfortunately, there is no mention of state variables or matrix notation which is used in nearly all recent theoretical work on automatic control. Perhaps this is excusable in a text intended for college juniors and seniors interested in practical control applications, but some foundation in these basic fundamentals must be given if a student is to communicate with control theoreticians and thus " . . . help to bridge the gap between theory and practice," as the author suggests in his preface.

It is evident that there is still a great need for an engineering textbook which will help to bridge the gap between the old and new theoretical techniques of describing automatic control phenomenon.

GEORGE S. AXELBY
Air Arm Division
Westinghouse Electric Corp.
Baltimore, Md.

Instruments and Measurements: Chemical Analysis, Electric Quantities, Nucleonics and Process Control, Vol. II, H. von Koch and G. Ljungberg, Eds.

Published (1961) by Academic Press Publishers, 111 Fifth Ave., New York 3, N. Y. 720 pages. Illus. 6¼×10. $22.00.

This book, together with its companion Volume I, form the proceedings of the Fifth International Instruments and Measurements Conference held in Stockholm in 1960. The book is divided into three sections of roughly equal length: 1) nuclear instrumentation, 2) measurement of electric and magnetic quantities, and 3) reactor control. Of the 68 papers in Volume II, 14 are written in German, the remainder being written in English.

A list of the topics considered in each section (the number of papers dealing with each topic follows in parentheses) gives a clearer picture of the contents. Nuclear instrumentation: semiconductors and their uses in nuclear instrumentation (3), health physics instrumentation and measurements (5), scintillation counting techniques (3), applications of optical spectroscopy to quantitative analysis and isotopic abundance determination (4), measurements used in nuclear energy industry (3), applications of nuclear methods to industrial measurements (5), miscellaneous (4). Electric and magnetic quantities: precision electrical measurements (3), microwave apparatus and techniques (5), magnetic measurements (3), digital representation of experimental data (4), miscellaneous electrical instruments, circuitry, and measurements (10). Reactor control: general reactor control and stability (2), control problems associated with specific reactors (3), neutron detectors (3), use of transistors and magnetic amplifiers in reactor instrumentation (2), specific instrumentation problems (3), general reactor instrumentation (3).

The articles, for the most part, are clearly written and illustrated, technically accurate, and strike a reasonable balance between comprehensiveness and inclusion of specific details. However, in a book covering such a wide range of topics, it probably is best to examine it with a "What's in it for me?" attitude. It is likely that the average reader of this review will find five to ten articles which are of immediate interest and usefulness. Another consideration is the book's usefulness during the next five to ten years. New methods and new instruments already are being developed, others will come, and the Sixth International Instruments and Measurements Conference probably will meet no later than 1965. It is therefore likely that, for most readers, the usefulness of the book over a ten-year period will not exceed twice its immediate usefulness.

Although this book is not one that the average reader of this review will want for his personal library, it is a reference book of considerable merit which can be used with profit by persons working in the areas with which it deals. It is, therefore, highly recommended that it be added to the libraries of research laboratories, private research organizations, and universities.

W. T. Achor
RCA Laboratories
Princeton, N. J.

Adaptive Control Systems, Eli Mishkin and Ludwig Braun, Jr., Eds.

Published (1961) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 527 pages+5 index pages+xiv pages. Illus. 6¼×9¼. $16.50.

Adaptive control systems may be viewed as a class of control systems in which provisions are made to compensate automatically for the effect of parameter variations in plant, input signal, or even disturbances of the system. As a relatively new field of investigation, it enjoys unprecedented popularity due to its potential for revolutionary development. A natural consequence of so much attention has been a flood of literature on the topic. The present volume, the first one devoted to this burgeoning field, is intended partly to serve as a guide to research in the field.

That this book should not be viewed as one which gives even a tentative summary of works in the area of adaptive control systems is carefully pointed out by the editors at the outset. Rather, it provides a viewpoint, that of the Polytechnic Institute of Brooklyn, the individual sections of the book having been contributed by professors and graduate students of the Institute.

In a sense the title of the volume is not particularly apt, since even as is stated by its editors in the preface: "The material presented in this book concerns most of the major parts that comprise the theory and design of feedback control systems. The four parts of the book deal, respectively, with linear systems, nonlinear systems, adaptive control systems and some selected topics in systems engineering."

A discussion of each of the seventeen chapters would be too lengthy; it will be worthwhile however, to consider some of the more significant features: Truxal contributed an introductory chapter as well as two chapters in Part I. As usual, it is a pleasure to read his lucid style. In the introduction, the important point is eloquently made that the difference between the adaptive control systems and ordinary feedback control systems is mainly one of viewpoint. The relations between adaptive systems and the so-called optimalizing systems are pointed out.

Chapter 4 is recommended to anyone with a pedagogical bent. Here Truxal draws from his experience instances of unusual design problems which amply demonstrate their challenging aspects. These illustrations can instantly condition the student to appreciate the control problem as no amount of theorizing can. Chapter 3 also by Truxal, deals with the important problem of process identification.

Mishkin contributed a chapter on analysis and design of nonlinear systems in the phase plane which include nonlinear compensation techniques, notably those by Kalman, which have not appeared hitherto in book form. In another chapter on "Analytical Theory of Nonlinear Systems," Mishkin presented some of the nonlinear theories of Norbert Wiener. In particular, the method of representing a functional in orthogonal function series is well discussed.

Professor W. A. Lynch made a concise exposition on elementary signal-flow theory.

Kenneth Kaplan presented a well-written review of techniques in the design of intentionally nonlinear systems. Included in the discussions are sections on inaccuracies in the model elements in the "model feedback" systems, simple optimum response systems, and final-value systems.

Part 3, titled Adaptive Control Systems, is the key section of the book. Here, a review of the state of the art is undertaken by Haddad and Braun (automatic methods of process identification), J. J. Bongiorno, Jr. (adaptive control systems), Braun (computer-controlled adaptive control systems), and R. A. Haddad (some unusual but nonadaptive systems). Those who have done work in the field will appreciate the care with which the representative schemes and methods are chosen.

Even so, the keen reader may at this point suffer a slight disappointment on the methods themselves. While there is no dearth of interesting approaches, it is significant that most of the papers are concerned only with the demonstration of feasibility, without considering the more practical questions of stability, convergence, sensitivity to signal and plant parameter variations, and even realizability. All this leads one to wonder whether the field, as covered by this volume, has really progressed beyond the "sound and fury" stage. The section by J. J. Bongiorno is informative in this regard, in that some of the difficulties involved in practical applications of the methods discussed are considered.

Part 4 of the book features a 50-page review of the digital techniques by M. M. Drossman and an interesting chapter on game theory and linear programming by L. P. Grayson. The last three chapters are not altogether successful. In the chapter on decision theory, an illustrative example erroneously indicates that the theory can somehow be applied to the output of a quantized filter seemingly without realizing that a major part of the decision has already been made in the choosing of the threshold of the digital filter. The chapter on queuing systems is well written, but it neglects to point out in what way the method may be used in control application. The chapter on multistage decision processes is much too brief.

In general, other than the reservations already indicated, (some of them through no fault of the contributors) the writers did well what they set out to do. The book is intended for practicing engineers, and, as such, the inclusion of the diverse topics seems justifiable. The editing is well done, and a consistent style as well as viewpoint is achieved.

J. C. Hsu
Bell Telephone Laboratories
Whippany, N. J.

Crossed-Field Microwave Devices, Vols. 1 and 2, E. Okress, Ed. in Chief

Published (1961) by Academic Press Inc., 111 Fifth Ave., New York 3, N. Y. Vol. 1: 637 pages+8 index pages+xxii pages+ 3 appendix pages+references by chapter. Vol. 2: 514 pages+6 index pages +xxii pages+references by chapter. Illus. 6¼×9¼. Vol. 1, $22.00 vol. 2, $18.00.

Since "Microwave Magnetrons" was published in 1948, there has appeared no book on crossed-field devices in the English language. This vacuum has now been filled by a compilation in two volumes of contributions from fifty-seven workers in the field. As the contributors cover only their special areas of interest, the book has the character of a collection of freestanding articles. Limited time has prevented the Editors from a more thoroughgoing editing job. The disjointed form of the book is, however, also a reflection of the historical development and the present state of the crossed-field art. Much theoretical and experimental work needs yet to be done to bring the understanding of crossedfield devices on a level with that of other microwave tubes.

A consequence of the form of the book is that a particular theoretical problem may be discussed repeatedly, often in a contradictory form, by several writers. For the worker in the field, these contributions provide a good review of where the various theoretical problems stand and he may well be stimulated to do some thinking on his own. However, for the ever-innocent student, who is dutifully courted in the preface, the theoretical part of the book must sometimes be very hard to read. The technical part of the book is, on the other hand, of a high quality and many of the old timers in the field have presented clear and extremely valuable accounts of the various devices. Most of this material has not been published previously, or it has appeared in internal reports.

The first volume is devoted largely to the theoretical analysis of the crossed-field interaction. It starts out with an introductory review by the Editors in which

most of the crossed-field problems are briefly discussed. To mention a few of the most interesting sections of the first volume, J. Arnaud treats, in a long article, the theory of bar-type structures. He thus makes available in English a review of Leblond and Mourier's simple but efficient method of analyzing such structures. Arnaud's section suffers somewhat by not having been sufficiently edited, and some French idioms and notations could have been translated into a more commonly accepted language.

A valuable chapter is edited by G. R. Feaster with a thorough discussion of the magnetron oscillator-type cathodes. O. Doehler reviews the injection problem in beam-type devices and gives a few practical points on the sole current. G. S. Kino gives a condensed and clear discussion of his two guns.

The two last chapters or two-thirds of the first volume deal with the noise problem, the steady state and the RF analytical solutions for both the magnetron oscillator and the beam-type devices. The cutoff magnetron is discussed and the reader is given as many points of view as there are contributors. Buneman's theory of the transient formation of the single stream Brillouin state is finally in print. His article is very enjoyable reading. It is followed by G. Hok's statistical theory of the magnetron space-charge cloud, an enlarged version of his previously published article. T. Van Duzer and J. R. Whinnery give the first comprehensive discussion of the noise problem in beam-type devices. They analyze what appear to be all existing theories at present, and they present part of their own contribution to the field, because their beam models differ.

The small signal theory is treated by O. Buneman and G. Mourier from their respective points of view. According to Buneman's theory, thick beams are unstable and according to Mourier's, they are not.

The large signal theory is taken care of by Mourier, Gandhi, Rowe, Feinstein, Kino, Hull and others. The computers have a field day. It is strange that the large signal work of J. R. Anderson is not included. His work also contained some very important experimental results.

The second volume has two parts devoted to crossed-field devices and to magnetron oscillator systems. Among the contributors we find O. Doehler on the M-type carcinotron, D. A. Wilbur and P. H. Peters on the voltage tunable magnetron—an excellent article, C. L. Cuccia on the grid controlled magnetron, B. Agdur on the strophotron, W. C. Brown on the amplitron—a long and thorough analysis, R. G. Robertshaw and W. E. Willshaw on the low-field magnetron. In the second part, phasing by RF signals is discussed by E. E. David, frequency pushing and spectrum shape by C. R. Schumacher, loading effects by W. L. Pritchard, frequency and amplitude modulation by J. S. Donal and starting phenomena and jitter by G. C. Turrell. Apart from a few beauty spots, the second volume can be well recommended.

In the preface the Editors complain that "the availability of qualified physicists and engineers active in the field was not satisfied to the extent desired, primarily due to the time element." "Crossed-Field Microwave Devices" reads like a *Who's Who* in the magnetron field. I can only discover Slater, Allis and Gould missing, but they have all made their marks clearly elsewhere. Meanwhile, we are waiting for a strong man to write a treatise on crossed-field phenomena.

J. W. KLUVER
Bell Telephone Laboratories
Murray Hill, N. J.

Microwave Tubes: Proceedings of the International Congress on Microwave Tubes, Munich, June 7–11, 1960, J. Wosnick, Ed.

Published (1961) by Academic Press, Inc., 111 Fifth Ave., New York 3, N. Y. 608 pages+xi pages +references by chapter. Illus. 8½×12. $50.00.

Every two years, people engaged in research and development on microwave tubes gather together for an international conference. This volume contains the proceedings of the 1960 meeting. The contributions originated in Austria, England, France, Germany, Hungary, Japan, The Netherlands, Norway, Sweden, and the United States. The volume contains a total of 138 papers of which 91 are in English, 30 in German, and 17 in French. The principal subjects covered are klystrons, traveling-wave tubes, backward-wave tubes, magnetrons, space-charge waves, slow-wave structures, parametric devices, masers, noise, electron guns, beam focusing, gas discharges, plasmas, and vacuum-tube technology.

The papers are all complete, with illustrations, and the general level of excellence is high. The papers were written primarily for the microwave specialist, and provide an excellent world-wide survey of the state of research and development in microwave tubes in 1960.

CASPER W. BARNES, JR.
Stanford Research Institute
Menlo Park, Calif.

Temperature Measurements in Engineering, Vol. 2, by H. D. Baker, E. A. Ryder, and N. H. Baker

Published (1961) by John Wiley and Sons, Inc., 440 Park Ave. S., New York 16, N. Y. 473 pages+36 index pages+vii pages+references by chapter. Illus. 6×9¼. $13.00.

When a radio engineer is asked to measure temperature, his first reaction is to get a thermometer or maybe a thermocouple. Then, as his problem develops, he finds that there are many facets of temperature measurement which he has never considered. At this point he would do well to spend some hours studying "Temperature Measurement in Engineering" by Baker, Ryder and Baker.

In these volumes, he will find chapters on thermocouples, resistance thermometers and radiation pyrometry, as well as ten chapters describing applications. All but the discussion of thermocouples are in Volume II.

Part I of Volume II contains the discussion of resistance thermometers and radiation detectors. For each of these there is first a chapter of a descriptive nature and then a chapter of design calculations, with examples. Part II contains the ten chapters on applications, and covers a wide range of temperatures from those near absolute zero encountered in superconductivity studies to those in the highest ranges encountered in studies of stars and in nuclear explosions. A wide variety of techniques is described, using not only the three basic devices mentioned earlier, but also such means as temperature-sensitive coatings, microwave absorption and Doppler broadening of spectral lines. The chapter titles are: Surface Temperatures; Rapidly Changing Temperatures; Moving Bodies; Transparent Bodies; Liquids; Gases· High-Temperature Gases; Low Temperatures; Flame Temperatures; Arc, Plasma, Upper-Air, Stellar, and Nuclear-Reactor Temperatures.

One of the outstanding features of the book is the collect on of references, which contains 1576 items. The great majority of these are to scientific or engineering journals and there are few references to technical memoranda or house organs issued by manufacturers.

The authors have done a fine job in placing a large amount of information in their book. They have written a guide for the engineer or scientist not skilled in temperature measurement, who is about to underake a problem in this fascinating area.

GEORGE B. HOADLEY
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Raleigh, N. C.

Advances in Electronics and Electron Physics, Vol. 15, L. Marton, Ed.

Published (1961) by Academic Press, Inc., 111 Fifth Ave., New York 3, N. Y. 383 pages+27 index pages+x pages+references by chapter. Illus. 6½×9½. $13.00.

This new volume in the "Advances in Electronics and Electron Physics" series contains six excellent review articles. The chapter headings are: Atomic Beam Frequency Standards, Masers and Other Quantum Mechanical Amplifiers, Relaxation in Diluted Paramagnetic Salts at Very Low Temperatures, Millimeter Wave Techniques, The Distribution of Electrons in the Ionosphere, and The Autodyne as Applied to Paramagnetic Resonance.

The primary objectives of an "Advances in . . . " book are to provide instruction and guidance for the neophyte, to aid the memory of the expert, to draw together loose ends of wide ranging subjects, and to provide an up-to-date list of the most important and instructive references. These objectives are well met in all the contributions to this book, at least as far as this reviewer can tell. In this last phrase lies the weakness of this, or any other "Advances" book. Very few prospective readers are likely to be interested in or knowledgeable about *all* the articles in such a grab bag—articles whose common denominator is the involvement of electrons in relatively well (but recently!) understood phenomena.

Many potential users of this book will tend merely to look up the one article of interest to them in the nearest library. This reviewer urges such people to buy the book instead, gobble the chapter of their choice, and peruse the others at leisure. It is a pleasant way to learn.

For example, although many engineers encounter frequency standards problems, few are likely to be very familiar with the substance of the first article. This chapter, on atomic beams, begins with a discussion of the elementary quantum mechanical spectroscopy formulas, utilizing excellent vector model illustrations. The article continues with a derivation of the atom trajectories and line intensities in a beam spectrometer, a description of suitable magnetic field geometries, beam detectors, and sources. It then goes on to treat transition probabilities at some length. The whole discussion is admirably clear as far as it goes. Naturally, it has faults due to compression. For instance, expectation values and matrix elements are used, but there is no indication as to the origins of the wave functions. This should not deter the reader having some knowledge of quantum mechanics; others are not likely to benefit from the details anyway. After the section on basics, the article continues with an exposition of the uncertainties in measurement and interpretation, specific examples of apparatus, and a survey of probable future developments.

Space does not permit description of all the articles, but the balance of qualitative and quantitative information is similar in them. The maser article is good and astonishingly up to date; however, a more explicit discussion of coherence in lasers would have been desirable. The word "coherence" does not even appear in the subject index, although there is considerable discussion in the text. All in all, this volume is an excellent addition to the series.

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Aerospace Telemetry, Harry L. Stiltz, Ed.

Published (1961) by Prentice-Hall, Inc., Englewood Cliffs, N. J. 421 pages+7 index pages+xiii pages+76 appendix pages. Illus. 6½×9¼. $15.00.

This book is divided into eleven separate sections. Harry L. Stiltz acted as the editor and the author of the first and introductory section. This section is of a general nature describing telemetry techniques and equipment requirements. The remaining ten sections have been written by ten specialists in their respective fields. The subjects covered include signal conditioning, frequency division telemetry, data sampling, pulse amplitude modulation, pulse duration modulation, pulse code modulated telemetry, radio frequency link subcarrier discriminators, PAM/PDM decommutation, magnetic tape recording and, finally, telemetry system design. Detailed mathematical analyses are given in three of the appendices and the fourth gives the most recent version of the IRIG telemetry standards.

The material is well organized and well prepared, but because each section is written by a different author, there is naturally a different style of writing for each section and each author approaches his problem from a slightly different point of view. Some approaches are more satisfactory than others.

The initial introduction by Stiltz gives a broad-brush picture of the telemetry field. The section on signal conditioning is excellent, easily understood and presents a logical development of the Signal Conditioning problem.

The section on frequency division telemetry is written from the viewpoint of a circuit design engineer with emphasis on the hardware aspects of the problem and presents one manufacturer's product line as being representative of the equipment available.

The section on data sampling is particularly clear and very good. The discussion on sampling is carefully presented in a particularly clear and well organized manner. The basic fundamentals are strong and the example systems are clearly described.

The section on PDM is presented from the hardware approach which is combined with the historical basis for the IRIG standards.

The section on pulse code modulated telemetry approaches the problem from the hardware viewpoint and describes the present state of the art in some detail. Some simple logic diagrams are given and various systems are described.

The section on radio frequency links is handled in an excellent manner. It covers the requirements for selecting and designing suitable RF links as well as specific problems encountered in designing the transmitter and the receiver for these links. Diversity techniques such as space diversity, frequency diversity, and polarization diversity are included. The basic transmission formula for the space link is given along with a complete discussion of its use. The theory and application is covered in a very concise and well organized manner.

The section on subcarrier discriminators is approached from the hardware standpoint, and gives a thorough description of the present existing techniques with block diagrams showing the operation and some mathematical analysis showing the theory of the operation of the present hardware. This is followed by a discussion illustrating how specifications can be written to describe desired discriminator operation in terms of the IRIG standards.

The section on PAM/PDM decommutation describes the operation of currently available equipment.

The section on recording is a good and fundamental presentation of magnetic tape recording developed from the basic theory. It is easy to understand and quite complete including analog, pulse, predetection and pulse code recording. It presents the limitations of present equipment and describes future trends with suggestions of how equipment may improve. It is completed by a summary which successfully ties together the entire section.

The final section is on systems. Since this is a large topic, it is difficult to cover. The approach given here is the hardware approach describing existing equipment. The concept of information transfer, which is fundamental to telemetry systems, is stated but not developed or emphasized.

"The book is designed as a textbook for senior classes in electrical engineering, a reference guide for experienced telemetry engineers, a training aid for inexperienced engineers desiring to enter the telemetry field, the reading material for the junior executive who suddenly discovers that the telemetry operations for which he is responsible are beyond his comprehension. . . ." This is the statement which is set forth at the beginning of the preface. The book certainly meets all of these requirements, and at the present time is one of the best available sources of information on aerospace telemetry.

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Scientific Basis of Electrical Engineering, by J. M. Ham and G. R. Slemon

Published (1961) by John Wiley and Sons, Inc., 440 Park Ave., S., New York 16, N. Y. 816 pages+6 index pages+xv pages+3 bibliography pages+36 appendix pages. Illus. 6×9¼. $9.95.

The purpose of this book is "to provide the content for a first course in electricity and electrical engineering at the university level for engineering and science students." In terms of its stated purpose, the book competes with those used for introductory electrical physics courses in many universities. In the opinion of this reviewer, the authors have done an outstanding job of selection of basic material, and of clear and precise exposition. The coverage of material goes considerably beyond that normally provided in a first course.

In their introduction, the authors state that prior study of the calculus is not essential. However, the presentation of material makes use of the concept of limit, summation, and both differentiation and integration to the same extent that might have been expected if a knowledge of calculus had been required. Since most schools expect a calculus background in advance of a study of such importance as that represented by this book, it seems unfortunate that the authors have not recognized this in their introductory statement.

In addition to the introduction, there are eight chapters of which three are concerned primarily with electric and magnetic field theory; three treat the nature and properties of materials including the structure of matter and energy-state models of atoms and of electrons in solid state conductors, insulators, and semiconductors. Two chapters are devoted primarily to electric circuits and circuit analysis. Topics covered include: electric forces and fields; magnetic forces and fields; time-varying electric and magnetic fields; electrical conduction in conductors, in solid state insulators and in semiconductors; properties of materials in electric fields and in magnetic fields; an introduction to electric circuits and to circuit analysis, and a rather well organized

introduction to electron and atomic physics including models for atoms, ionization, carrier flow in conductors and in semiconductors, atomic binding in crystalline structures, and electron energy bands in crystalline solids.

One regrets that the authors have chosen to continue the electromotive force misnomer, although pointing out that "despite its name, the electromotive force property of a device is not a force property." On the credit side, however, the authors succeed admirably in presenting clear concepts of basic electric and magnetic field relationships including Maxwell's equations.

The text contains 150 pages devoted to 235 problems. The answers to many of these problems are given. The problems seem to be well chosen to illustrate the text material. Diagrams, drawings, three dimensional sketches and other illustrations are very carefully prepared and skillfully presented. In the opinion of this reviewer, this text is an excellent introduction to the field of electrical science.

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URSI Handbook of Ionogram Interpretation and Reduction, W. R. Piggott and K. Rawer, Eds.

Published (1961) by Elsevier Publishing Co., Amsterdam (D. Van Nostrand Co., Inc., Princeton, N. J., USA distributors). 186 pages + xi pages + 6 pages of general references. Illus. 6 × 9½. $14.00.

Routine synoptic observations of ionospheric weather are made for the same basic reasons that they are made of tropospheric weather: 1) in order to issue predictions for users; and 2) in order to provide researchers with the phenomenological description necessary to deduce a dynamical global model. The basic instrument for probing the ionosphere is the ionosonde or vertical-incidence sounder. This is a radar using pulses of 50 to 100μsec duration at a radio frequency which is swept from about 0.5 to 20 mc/s.[1] In this technique, the pulses are directed vertically upward from a rhombic antenna mounted in a vertical plane (often, a half-rhombic or "delta"). The radar range, or "virtual height," depends upon the distribution of electrons in the ionosphere and the radio frequency used. Higher frequencies require greater electron density for reflection. As the waves enter the bottom of the ionosphere at some 85 km, they encounter increasing electron density. Consequently, as the radio frequency is increased, the reflection height increases so that the height-distribution of the electrons is revealed by sweeping the frequency.

This very powerful and widely used technique was begun when Appleton and Barnett first obtained direct evidence of ionospheric reflection in 1925 using CW signals, as did Breit and Tuve in the same year using pulsed signals. These experiments contributed much to the development of radar.[2]

The ionosonde is normally arranged to produce a graph of the "virtual height" from which the echoes are received as a function of frequency. Their records, known as "ionograms," can be very complicated and highly variable and this book is devoted to the advanced and intricate problem of scaling and interpreting these records.

During the recent International Geophysical Year 1957–58 (IGY), great progress was made in obtaining international agreement on standards for the interpretation and reduction of ionograms, and it is for that reason that this book is published now. It is the work of the World Wide Soundings Committee which consists of A. H. Shapley, Chairman (USA), Y. Aono (Japan), W. R. Piggott (UK), N. V. Mednikova (USSR), K. Rawer (W. Germany), J. Turner (Australia), R. W. Knecht (USA), and fourteen consultants from seven additional countries. The committee still exists and is continuing its work so a word about its history and present position will be helpful to many readers.

The IGY was a program of the International Council of Scientific Unions (ICSU) and was operated by the Special Committee for the IGY (CSAGI) appointed by ICSU. The International Scientific Radio Union (URSI) was one of the principal ICSU unions participating in the IGY and set up its own IGY Committee, with Sir Edward Appleton as chairman, to plan its program of participation. The World Wide Soundings Committee (WWSC) was appointed by the URSI-IGY Committee as a subcommittee. Now that the IGY is over, ICSU has disbanded CSAGI, and URSI its IGY Committee. But in order to continue international cooperation and coordination in geophysics indefinitely, and especially to continue the World Data Centers actively, the ICSU has set up a new International Geophysics Committee (CIG) and the World Wide Soundings Committee has been transferred to it as a subcommittee.

For more extensive treatment of various topics, the present book makes frequent reference to the IGY Manual for Ionospheric Vertical Soundings,[3] and it is only fair to say that all but the advanced worker will find that book more useful as a point of beginning than this one. However, if he gets deeply into the restricted subject of ionogram interpretation, this book will become essential also.

The last half of the book is entitled a Supplement and is devoted to subjects especially suitable for research. This portion of the book has been produced mainly by the editors themselves rather than by the committee as a whole. They point out that although the Supplement covers topics of much current interest, its value will undoubtedly be shorter-lived than the first section of the book. The Supplement is, however, a very fine compendium of current problems in ionospheric research. Among other things, it includes an excellent summary of the methods of deducing true-height profiles from ionograms. The six pages of general references at the end of the book, organized under ten headings, also make a useful compendium.

The World Wide Soundings Committee addressed itself early in its work to the very difficult problem of interpreting and reducing ionograms from polar caps, auroral zone, and equatorial zone stations. It has essentially solved this problem with the promulgation of the "f-plot,"[4] the use of "gain runs," and the establishment of uniform scaling rules. Once these were introduced as standard procedure, it was clear that they had universal benefits for handling observations from all latitudes.

An "Atlas of Ionograms"[5] was compiled for the Committee in 1957 by J. W. Wright and R. W. Knecht. These authors are both at the National Bureau of Standards and are, respectively, a consultant to and a member of the Committee. E. E. Stevens of the Canadian Defense Research Board (DRTE) has recently compiled an atlas of high-latitude ionograms with interpretive comments entitled "The Complexity of High Latitude Ionograms."[6] An "Atlas of Oblique Incidence Ionograms" was compiled by V. Agy, K. Davies, and R. Salaman of the National Bureau of Standards in 1959.[7]

Readers interested in this subject will also enjoy reading "A History of Vertical Incidence Sounding at the National Bureau of Standards," by S. C. Gladden.[8]

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[1] Sweep-frequency sounding below 500 kc has been done on an experimental basis. See J. M. Watts and and J. N. Brown, *Jour. Geophys. Res.*, pp. 71–86, March, 1954; and J. M. Watts, *idem*, pp. 717–726, December, 1958.

[2] See E. G. Bowen, Ed., "A Textbook of Radar," by the staff of the Australian CSIRO Radiophysics Lab., Cambridge University Press, p. 1; 1954.

[3] "Annals of the IGY," vol. 3, pt. 1, Pergamon Press, New York, N. Y., 167 pages; 1957.

[4] Devised by J. H. Meek of the Canadian Defence Research Board (DRTE) and first recommended by the World Wide Soundings Committee's predecessor, the URSI High Latitude Committee, 1954–55.

[5] J. W. Wright and R. W. Knecht, "Atlas of Ionograms," Natl. Bureau Standards Rept. No. 5097; June, 1957. (Address inquiries to A. H. Shapley, Natl. Bureau Standards, Boulder, Colo.)

[6] Available from The Queen's Printer, Ottawa, Ont., Canada, $0.35. Cat. no. DR51-61.

[7] V. Agy, K. Davies, and R. Salaman, "Atlas of Oblique Incidence Ionograms," Natl. Bureau Standards Tech. Note 31; 1959. (Available from U. S. Dept. of Commerce, Office of Tech. Services, Washington, D. C.; $2.25.)

[8] S. C. Gladden, "A History of Vertical Incidence Sounding at the National Bureau of Standards," Natl. Bureau Standards Tech. Note 28; September, 1959; *idem*. $2.00.

Scanning the Transactions

Bionics or Electrology? This is the eye-catching question which greeted readers on the introductory page of the February issue of PGIT TRANSACTIONS, a special issue containing papers on human perception, neural mechanisms, coding and detection, and automatic recognition systems. The question was posed by the editor because the issue brings together noteworthy papers which deal respectively with the fields of psychology, anatomy and physiology, and engineering—and which at the same time all concern the transfer, processing, and coding of information. The answer given by the editor, however, has a pertinence which carries well beyond the subject of this particular issue. Commenting on the current hoopla concerning the cross-fertilization of engineering and the life sciences, the editor was moved to note: "Not to say that such interactions should be scorned. But there must be more to these attempts than merely concocting a name, generating well-intentioned enthusiasm, speculating with the aid of brain-computer analogies, and holding symposia packed with 'preliminary' results from inconclusive experiments. A bona fide 'interdiscipline' draws its vitality from people of demonstrated achievement in the contributing disciplines, not from those who merely apply terminology of one field to another." Returning to the opening question above, one might ask whether, with this special issue, the PGIT is venturing into Bionics. The editor's answer: an emphatic "No!" The issue, he points out, is concerned with achievements at the *discipline* level. If one insists on a name, one might call the subject "Electrology." This is the leftover after Bionics has been removed from electronics and biology. Its one great virtue is that the term lacks the euphony to become a fixture in the language. (E. E. David, Jr., "Bionics or Electrology," IRE TRANS. ON INFORMATION THEORY, February 1962.)

Phenomenal phenomena. The invention of the transistor 14 years ago did much to bring into focus the importance of solid-state phenomena and effects. Today, the number of such phenomena is indeed impressive. Among those that are electric or magnetic in nature we can count the Hall effect and magnetoresistance. When the photic properties of materials are considered, the list is lengthened considerably by the addition of the photovoltaic effect, photoconductivity, photoelectric emission, the photodielectric effect, the photomagnetoelectric effect and, finally, the Dember effect (*i.e.*, the production of a potential difference between two regions of a semiconductor when one region is illuminated). The list doesn't stop there, however. Thermal effects also play important roles: thermionic emission, thermoelectric (Seebeck, Peltier, and Thomson) effects, and thermomagnetoelectric phenomena such as the Ettinghausen, Nernst, Righi-Leduc, and Ettinghausen-Nernst effects. Secondary emission should also be added to the inventory. The foregoing list of 17 solid-state phenomena is only a partial listing of one category of effects, namely, those which primarily depend on the transport of electrons and holes or are intimately associated with band structure. At least two other categories could also be added: resonance effects, and effects related to dielectric properties and to transport phenomena for particles other than electrons and holes. The inventory of solid-state phenomena in nature's storehouse is indeed phenomenal. (E. J. Scheibner, "Solid-State phenomena and effects—Part I," IRE TRANS. ON COMPONENT PARTS, December 1961.)

Can machines think? Volumes have been written on this subject during the past decade. Indeed, the question was discussed more than 300 years ago by Descartes, and other ramifications (*e.g.*, human vs non-human, or animal, mentality) have engrossed human experts in the art of thinking throughout the ages. At one time or another, the matter has been discussed from virtually every conceivable viewpoint, including philosophy, religion, psychology, physiology, physics, engineering and, last but not least, semantics. The question is raised again here only because it is symbolic of a growing disagreement regarding the basic philosophy of intelligent machines. The exact nature of this disagreement has been hard to specify. However, it has become increasingly clear that the question "Can machines think?" is no longer regarded as a basic issue. In order to clarify just what the issues are in the current controversy, two authorities, representing opposite poles of opinion, have made a unique joint effort to determine the areas where they agree and disagree. As to areas of agreement, for example, they find that they both believe that it is certainly *logically* and *physically* possible for a digital computer to do any sort of information processing that a man can, including thinking or invention. As to whether it is *practically* possible, they both feel that it is reasonable to suppose that by small increments in understanding and abilities we shall eventually be able to reproduce thinking, and that the machines that do it will bear very little resemblance to the computing machines of today. Question: What, then, is the basic disagreement between the current schools of thought? Answer: The value to science and technology of the work that has been done to date on the theory of intelligent machines. One school believes that a great amount of generality is possible in the approaches to pattern recognition and similar problems, and that present work contributes at least a little to the eventual development of a general scientific theory of intelligent machines. The other school is undecided on even the possibility of ever developing a general theory, and for the present is convinced that each problem must be attacked separately, that there is no strong connection among them, and that certainly nothing of value in developing a general theory has been reported yet. As a parting shot, the latter group urges that until people get some good ideas they should refrain from cluttering the literature. (J. L. Kelly, Jr. and O. G. Selfridge, "Sophistication in computers: A disagreement," IRE TRANS. ON INFORMATION THEORY, February 1962.)

The contributions which circuit theorists have made to the progress of the electronics field is not always as fully appreciated as it should be. What brings this to mind is the recent publication of an issue of TRANSACTIONS devoted entirely to solid-state circuit papers. The exploitation of solid-state materials and the development of new devices has had a revolutionary impact on electronics during the past decade. Not to be overlooked, however, is the important role which the circuit theorist has played. His skill in evolving new analysis techniques for linear and nonlinear passive and active networks, in determining the fundamental limitations on the properties of networks containing solid-state devices, and in developing design procedures for these networks has been instrumental in enabling circuit designers to exploit the special properties of solid-state components in a optimum manner. As the issue clearly demonstrates, the widespread introduction of new solid-state devices, both in the past and at present, has been due in substantial measure to the important work of the circuit theorist. (F. H. Blecher and J. M. Sipress, "Forward to solid-state circuits papers," IRE TRANS. ON CIRCUIT THEORY, December 1961.)

Abstracts of IRE Transactions

The following issues of TRANSACTIONS have recently been published, and are now available from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

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Microwave Theory and Techniques	MTT-10, No. 1	2.25	3.25	4.50

Antennas and Propagation

VOL. AP-10, NO. 1, JANUARY, 1962

Status of Plasma Physics—K. M. Siegel (p. 2)

Transconductance Properties of Plasmas—J. E. Drummond (p. 4)

Radio-frequency effects arising from motions of the electrons and ions in plasmas are reviewed. Starting with cases of simple straight line orbits, the relationship between theory and experiment is cited in regard to wave dispersion, damping, amplification, and radiation. Circular and spiral orbits as well as linear and drifting-linear vibration orbits are considered. These examples show the common properties that linear drifting can produce damping or amplification while periodicities or near periodicities produce radiative coupling. The insight thus gained leads to some concluding remarks concerning more general orbits.

Particle and Photon Transport in Plasmas—R. K. Osborn (p. 8)

This paper presents a unified development of kinetic equations describing particle and photon transport in plasmas. The development proceeds deductively from a conventional quantum field theoretic formulation of electrodynamics, albeit via many approximations—many of which are largely untested. It is found that the equations for the particle distributions are a generalization to the plasma of the equations postulated by Uehling and Uhlenbeck for neutral quantum gases. These equations reduce to the usual Boltzmann equation with self-consistent fields in the classical limit.

Similarly it is found that the kinetic equation for the photons is a slightly generalized version of a low-energy limit of the equation deduced by Foldy for the description of the propagation of γ-rays in matter. The generalization consists in showing that the photons propagate between events in the plasma with a group velocity which is in general different from c and in the retention of the influence of the density of photons and particles in final states upon emission and scattering processes so that the appropriate thermodynamic solutions are readily demonstrable.

The Relation Between the Transport and the Orbit Models for a Plasma—S. Frankenthal and W. P. Allis (p. 15)

Starting with the Boltzmann equation and the dynamic equation of a charged particle, we develop a transport (particle) model for the plasma as well as an orbit (guiding-center) model which is valid for arbitrarily large orbits. The development facilitates the interpretation of the difference between the two models and sets the stage for the derivation of the conditions under which the two become interchangeable. These conditions include restrictions on the particle distribution and on the field gradients. The role of each model in the formulation of the self-consistent-field problem in the plasma is discussed.

A Coaxial Low-Density Plasma Experiment—A. Olte, J. S. King, and E. K. Miller (p. 24)

The design of an inverted coaxial plasma diode is discussed in considerable detail. The RF transmission and reflection measurements of a 15-cm-long diode are presented and compared with a preliminary theory. An attempt is made to account for the electron collision with the walls.

Interaction of a High-Intensity EM Field with a Low-Density Plasma—K.-M. Chen (p. 31)

The interaction of a high-intensity EM field with a low-density plasma, including a collisionless plasma and a weakly ionized gas, is considered. The electron velocity distribution function is obtained exactly from a Boltzmann equation in each case without making any small perturbation approximation. The electron velocity distribution function obtained gives rise to significant results for some plasma parameters as functions of the intensity of EM field. It is also shown that conventional results for the small field case can be obtained from the results presented in this paper.

Nonlinear Electrical Conductivity of a Fully Ionized Gas—K.-M. Chen (p. 43)

The electrical conductivity of a fully ionized gas is analyzed based on the Fokker-Planck equation. It is found to have nonlinear characteristics if the impressed electric field is not restricted to be very small. The electrical conductivity of both dc and ac cases is investigated and the critical conditions are discussed. A convenient way of obtaining an approximate conductivity is also presented.

Scattering and Guided Waves at an Interface Between Air and a Compressible Plasma—A. Hessel, N. Marcuvitz, and J. Shmoys (p. 48)

Propagation of waves in a compressible, isotropic, collisionless electron plasma is studied. Optical and acoustics modes of propagation are examined in detail. Scattering and guiding properties of a plane interface between free space and plasma are investigated. It is found that electromagnetic energy in theory can be completely converted into plasma waves. A surface wave is found whose properties are affected slightly by the compressibility for $(\omega_p/\omega) > \sqrt{2}$. In contrast to the case of purely dielectric plasma, this surface wave has no high-frequency cutoff. Formal expressions for electromagnetic and acoustic fields excited by a magnetic line source in free space, parallel to the interface, are obtained.

The Influence of Complex Waves on the Radiation Field of a Slot-Excited Plasma Layer—T. Tamir and A. A. Oliner (p. 55)

A study of the near field of a magnetic line source located inside an isotropic plasma layer reveals, in addition to a weakly-excited space wave, strong E mode complex waves corresponding to poles in the integral representation of the field solution. Under these conditions, the radiation field may be calculated by means of a Kirchhoff-Huygens integration over the pole contributions in the near field. This result is in excellent agreement with the accurate steepest-descent evaluation whenever the complex waves are dominant. Depending on its location in the steepest-descent plane, each pole contributes either a broad peak at broadside or a sharp peak at an oblique angle.

In the frequency range in which the plasma is opaque, the complex waves are spectral and yield a single radiation peak at broadside, and with small power. Also, surface waves may be present and contribute to the far field located near the plasma-air interface. When the plasma is transparent only leaky waves exist, the strongest of which accounts for a sharp major peak that closely corresponds to the critical angle obtained by geometrical optics. The weaker leaky waves may yield additional but minor peaks, or contribute at broadside only.

The more practical case of a distributed source is also treated. Its solution is shown to be obtainable directly from that for the line source; the expression for the radiation pattern is then given by the product of the line source solution and that for the source distribution in the absence of the plasma layer.

The Radiation Pattern of a Microwave Horn and a Plasma Layer—W. L. Flock and R. S. Elliott (p. 65)

Theoretical and experimental studies have been made of the performance of a microwave horn terminated in a ground plane overlain by a plasma layer. The purpose was the determination of the effect of the plasma layer on the radiation pattern of the horn.

Electron currents in the plasma were calculated on the basis of the assumption that a plane wavefront emanated from the mouth of the horn. The radiation from the horn was considered to be due to a magnetic current sheet that covered the horn aperture. The electron currents and the magnetic currents together were considered to constitute the source currents of an antenna. The experimental program

consisted of measuring the influence of a transient gaseous discharge and afterglow on the radiation pattern of a horn. The operating frequency was 9745 Mc.

The results indicate a diversion of energy to the off-axis region, as compared to the pattern of the horn in free space. The effect is significant for electron densities of the order of one-tenth of the critical electron density, for the geometry employed. The study is of value in considering the problem of communicating with a hypersonic vehicle during the re-entry phase.

Radiation from Linear Electric or Magnetic Antennas Surrounded by a Spherical Plasma Shell—H. R. Raemer (p. 69)

The radiation from a linear electric or a linear magnetic antenna surrounded by a spherical shell of plasma is analyzed in detail.

The antenna is assumed to be small compared to a free-space wavelength, but large enough to radiate a few multipole modes beyond the lowest order or dipole mode. The antenna fields are represented in terms of spherical vector wave functions, leading to a somewhat tedious but tractable calculation of modal coefficients and hence of the fields in and external to the plasma.

In addition to reflection and absorption losses in the plasma itself, the effect of plasma reflections on antenna current or magnetization are approximated by a perturbation technique applied to the classical Hallen integral equation, with the infinite free-space case taken as the zero order solution.

Anisotropic Plasma-Covered Magnetic Line Source—R. Shore and G. Meltz (p. 78)

Radiation from a magnetic line source in a ground plane covered by an anisotropic lossy plasma layer is considered. A magnetostatic field is impressed parallel to the slab and normal to the source. Expressions are obtained by Fourier analysis and the stationary phase procedure for the far-field components of both radiating modes. Numerical results are given for the uniaxial plasma without losses. It is shown that in this case pattern maxima and minima are directly related to ordinary transmission-line reflection conditions expressed in terms of a "transverse-wavelength."

Plasma Simulation by Artificial Dielectrics and Parallel-Plate Media—W. Rotman (p. 82)

A plasma in the absence of dc magnetic fields is representable, from the electromagnetic viewpoint, as a lossy dielectric with a complex index of refraction whose real part is less than one. Its electrical properties, such as propagation constant and intrinsic impedance, can be simulated by microwave structures, such as artificial dielectrics of lossy metallic rods, and by H-plane parallel-plated guides.

Design techniques are presented for application to the modeling of plasma media. Examples include problems of radiation from antennas on a plasma-coated ground plane, with magnetic line sources and electric aperture radiators simulated by parallel-plate guides and rodded media, respectively. Radiation patterns of these models show good agreement with established theory. Waveguide measurements on the rodded media also confirm the expected propagation and impedance characteristics.

Communications (p. 96)
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Papers to be Published in Future Issues (Inside Back Cover)

Audio

Vol. AU-9, No. 6, November-December, 1961

The Editor's Corner (p. 183)
PGA News (p. 184)

Power Requirements for Speech Communications Systems—R. L. Craiglow, N. R. Getzin, and R. A. Swanson (p. 186)

This paper presents a simple method for predicting the power required for audio, AM, DSBSC, and SSB speech communication systems which are peak-power limited and are operating in the presence of "white" Gaussian noise. The effects of simple speech processing such as pre-emphasis, filtering, volume compression, symmetrical peak clipping, and frequency translation are considered both singly and in combination. The method is based on empirical data and is directly applicable to many practical speech communication problems encountered by the radio engineer.

Automation of Speech, Speech Synthesis and Synthetic Speech, A Bibliographical Survey from 1950–1960—P. L. Simmons (p. 191)

This paper presents an enumerative bibliography of the literature on the automation of speech from 1950–1960. The key developments in this area are presented in the introduction. The eventual goal is the fully automated speaking machine. Selections for the bibliography include significant corporate documents, periodical literature and abstracts of research.

A Dual Channel Transistor Power Amplifier—A. B. Bereskin (p. 197)

This paper describes the theory and performance of a dual channel transistor power amplifier capable of developing 30 watts in each channel with less than 1% intermodulation distortion. Full power is developed at frequencies below 20 cycles per second. Detailed transformer construction and amplifier assembly information is presented along with a list of parts and purchasing information.

Eight Cardinal Points in Loudspeakers for Sound Reproduction—P. W. Klipsch (p. 204)

Good audio sound quality in stereophonic reproduction may be summarized in the "eight cardinal points of loudspeakers," which are: 1) minimal distortion, 2) optimum size, 3) avoidance of rattles, 4) avoidance of shadows, 5) avoidance of cavities, 6) wide spacing, 7) proper number and 8) toe-in.

"Colorless" Artificial Reverberation—M. R. Schroeder and B. F. Logan (p. 209)

Electronic devices are widely used to introduce in sound signals an artificial reverberation subjectively similar to that caused by multiple reflections in a room. Attention is focused on those devices employing delay loops. Usually, these devices have a comb-like frequency response which adds an undesired "color" to the sound quality. Also, for a given reverberation, time the density of echoes is far below that encountered in a room, giving rise to a noticeable flutter effect in transient sounds. A class of all-pass filters is described which may be employed in cascade to obtain "colorless" reverberation with high echo density.

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Automatic Control

Vol. AC-7, No. 1, January, 1962

Knowledge in the Large—Editorial (p. 1)
The Issue in Brief (p. 2)

Stability Analysis of Nonlinear Control Systems by the Second Method of Liapunov—Z. V. Rekasius and J. E. Gibson (p. 3)

The second method of Liapunov is used to study asymptotic stability of feedback control systems with single nonlinear elements. The paper aims at a systematic development of Liapunov functions in terms of canonic transformations of state variables. This approach yields various simplified stability criteria; a rather complete table of such criteria is included.

Several insights believed novel concerning the failure of the method in certain practical cases are presented. The root locus of the linear portion of the system is used to predict the applicability of the method. The proposed pole- and zero-shifting techniques extend the applicability of the method to many practical systems in which the method would fail without these techniques.

Stability of Nonlinear Sampled-Data Control Systems—S. Kodama (p. 15)

With regard to the asymptotic stability in the large of nonlinear, autonomous sampled-data systems, the following conjecture has been quoted frequently in the literature. Namely, "if the linearized system is stable for all points of the state space, the original nonlinear system is asymptotically stable in the large" (henceforth abbreviated a.s.i.l.).

This paper shows by counter examples that the statement is not true in general. Both total and incremental linearizations are considered and in both cases the conjecture is false. Finally, a sufficient condition for a a.s.i.l. is given.

Decision-Making in Adaptive Control Systems—J. C. Hsu and W. E. Meserve (p. 24)

An approach to the analysis and synthesis of adaptive control systems taking into account the effect of inexact measurements is presented here. The approach is based on the method of generalized quantized compensation. The mathematical tools needed for the analysis are adapted from the discipline of statistical inference. In particular, decision theory is used.

An important consequence of inexact measurement is that the problems of identification and of control cannot be considered separately. Decision theory is used as the link that logically relates the two. Current application of decision functions has mostly been limited to cases where the unknown parameters to be determined can take on only discrete values. In view of the continuous variation of the parameters, assumptions that they take on discrete values lead to results whose optimality is not justifiable. Several possible extensions are presented. In addition, a sequential decision scheme that can be applied to reduce expected measurement time is presented.

An attempt is made to make the statistical analysis largely self-contained and lucid to those not familiar with statistical inference procedures.

A Self-Adjusting Control System with Large Initial Error—R. N. Clark and P. C. Wheeler (p. 33)

A performance measuring, plant-adaptive control system is described. A linear plant having two variable parameters induces a large system error which is reduced by adjustments made in two controller parameters. An adaptive computer, the logical design of which is based on a Newton's method of descent, generates the controller-parameter changes from measurements of the integral-of-error squared (ISE).

This method is evaluated with regard to the time interval required to reduce ISE from a large initial value to a small prescribed limit. The average adaptation time for this system is shown to be approximately sixty times the response time of the system when the system error is zero.

Adaptive Sampling Frequency for Sampled-Data Control Systems—R. C. Dorf, M. C. Farren, and C. A. Phillips (p. 38)

Sampled-data control systems generally have fixed sampling frequencies which must be set high enough to give satisfactory performance for all anticipated conditions. A study is made here of an adaptive system which varies the sampling frequency by measuring a system

parameter. It is shown that a sampler followed by a zero-order hold whose sampling period is controlled by the absolute value of the first derivative of the error signal will be a more "efficient" sampler than a fixed-frequency sampler. That is, over a given time interval, fewer samples are needed with the variable-frequency system than with a fixed-frequency system while maintaining essentially the same response characteristics.

Analog computer studies of simple Type I and Type II sampled-data servo systems with error sampling and unity feedback verified the method. Standard analog computer components were used to set up a simulated servo system, a rate detector, absolute-value detector, a voltage-controlled oscillator, and a sampler and zero-order hold.

The system described reduced the number of samples required for response to a step input to about three-quarters that required in a fixed-sampling-frequency system. Over a long period of time savings in the number of samples required can be expected to be between 25 and 50 per cent. In many applications the savings produced by reducing the over-all number of samples required may outweigh the added complexity of the adaptive-sampling frequency system.

Plant Adaptive Systems Versus Ordinary Feedback Systems—I. M. Horowitz (p. 48)

The limitations in classical feedback that might jusify the more complex plant or process adaptive systems are studied. Some of the limitations cited in the adaptive literature apply only to the classical single-degree-of-freedom configuration and not to the classical two-degree-of-freedom structures. Model and conditional feedback configurations are not superior to ordinary two-degree-of-freedom configurations. Time invariant (classical) compensation is adequate for coping with the sensitivity and disturbance problem in lightly damped and drifting plant poles. Two significant limitations in ordinary linear feedback systems that may justify the adaptive approach are:

a) Their susceptibility to feedback transducer noise when the plant by itself does not have the loop gain area required for the desired sensitivity properties of the system;
b) The limited sensitivity reduction achievable in nonminimum phase and unstable plants.

The first of these may be eased by a multiple-loop design and the second by a parallel plant design. However, it has not been shown how the adaptive systems overcome the limitations of ordinary feedback systems.

Convolution *Z*-Transform Method Applied to Certain Nonlinear Discrete Systems—E. I. Jury and M. A. Pai (p. 57)

This paper extends to discrete systems the method of complex convolution developed by Weber for continuous systems. In this paper the convolution z-transform method is applied to obtain an explicit solution of certain nonlinear difference equations. The explicit solution is often desired for system design as well as for obtaining the response for large intervals of time. In these difference equations which describe the physical discrete systems, it is assumed that the nonlinearities are "small." This is necessitated by the form of solution applicable to the use of the convolution method. The advantage of the method is to systematize the procedure for the solution as well as to obtain results in a closed form. The convergence of the solution is discussed as well as applications to certain examples.

Two numerical examples are worked out to illustrate the method. Explicit approximate solution is obtained and the results compare favorably with the numerical solution of the nonlinear difference equation as a recurrence relationship.

Asymmetric Non-Mean-Square Error Criteria—J. L. Brown (p. 64)

In the theory of linear prediction and/or filtering, it is well known that the optimum linear device obtained using the minimum mean-square error criterion is also optimum for a much wider class of symmetric error criteria if the input process is Gaussian. This result is extended here to include nonsymmetric error criteria as well as the case of nonstationary Gaussian inputs. A simple direct proof is given which exploits the fact that the probability density function of the error is known explicitly. The method consists of showing that the expected value of the generalized error weighting function $\phi(\epsilon)$ is a monotonic (nondecreasing) function of the mean-squared error.

Compatibility of a Two-Degree-of-Freedom System with a Set of Independent Specifications—S. J. Merchav (p. 67)

In feedback control systems in which more than one transfer function must be specified, a multi-degree-of-freedom configuration is required. In many practical situations a two-degree-of-freedom configuration is of interest. This paper deals with the conditions that must be fulfilled in the choise of transfer functions so that two sets of specifications can be fulfilled by a given configuration. The possibility of implementing two sets of specifications independently is determined by the degree of complexity allowed in the individual transfer functions of the system. A method is described by which the compatibility of a given structure with a set of specifications can be insured. With the aid of a procedure which is illustrated in two examples, the minimum degree of complexity in the individual blocks is determined in relation with the high-frequency behavior of the system.

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Bio-Medical Electronics

Vol. BME-9, No. 1, January, 1962

Quantification in the Life Sciences—L. B. Lusted (p. 1)

Computer Techniques for the Study of Patterns in the Electroencephalogram—B. G. Farley, L. S. Frishkopf, W. A. Clark, Jr., and J. T. Gilmore, Jr. (p. 4)

A process has been explored using the Lincoln TX-O computer for detecting patterns in the electroencephalogram and for recognizing the characteristics of the EEG corresponding to individual subjects. Preliminary results indicate that a number of different subjects and states of the same subject can be distinguished with excellent probability.

Analog Computer Simulation of a Neural Element—F. F. Hiltz (p. 12)

As a prelude to the study of the adaptive-behavior and data-handling characteristics of natural and artificial neural networks, an analog model of a single neuron was developed.

An analog computer was employed to reproduce the known electrical characteristics of a neuron in a qualitative simulation study of neuronal behavior. A self-imposed criterion of a minimum number of analog-computer components was adopted for the single-neuron simulation in anticipation of network studies. This criterion led to the development of a simple analog circuit which has qualitatively reproduced some of the known electrical characteristics of a neuron, such as: initiation of an action potential in the presence of suprathreshold depolarizing (or excitatory) inputs; strength-duration relationship; accommodation; refractoriness; rate of pulse repetition as a function of the input depolarization level; and prolonged action potentials.

The simulation method adopted consisted of four major analog-computer components, three operational amplifiers and a single-shot multivibrator. The circuit developed has a linear forward path with a nonlinear form of feedback. A discussion is given of the properties exhibited by the simulated neuron with and without the nonlinear feedback.

A mathematical method for linearly approximating nonlinear behavior is presented. This method is known as the "describing function technique," and its application to the analysis of neuronal behavior is described, as well as the technique's application to the synthesis of simulation networks.

How Can the Waveforms of a Clinical Electrocardiogram be Measured Automatically by a Computer?—C. A. Caceres (p. 21)

A clinical electrocardiographic interpretation depends on use of classifications tailored by the physician to suit his own clinical practice. These classifications are built up from the correlations of multiple combinations of electrocardiographic parameters and their measurements to clinical entities.

If the clinical electrocardiogram or any other clinically used "electro-medical" signal is to be examined by a computer it is the specialist of the subject matter who must develop a step by step organization and detailed logic of the material so that the "computer specialist" can follow it. With this available, the "computer specialist" is able to properly detail the procedures that the computer will follow to perform the desired service for the practicing physician.

Pattern Recognition in the Clinical Electrocardiogram—C. A. Steinberg, S. Abraham, and C. A. Caceres (p. 23)

This study was undertaken to demonstrate the feasibility of use of computers in extracting clinically useful parameters from electrophysiologic waveforms. The ECG leads were recorded on magnetic tape. The analog signal was sampled 625 times per second and that data was converted to a form suitable for a general-purpose digital computer. Criteria for clinically significant voltage fluctuations of the signal from the baseline within specified time intervals were determined. The computer was programmed to identify those fluctuations automatically. For an output the computer produces a set of measurements of ECG waveforms from one cardiac cycle in any random 5-sec. portion of a lead. The program can be expanded to include any measurement, but for present purposes it permits determination of amplitude of *P*, *Q*, *R*, *S* and *T* waves, *ST* and *PQ* segments, and *QT* and *RR* intervals. Variables are measured to an accuracy of 1 part in 1000. Measurements conform to those obtainable by careful hand measurement of magnified tracings of the original records. Automatically derived data can be simultaneously used in computer-programmed statistical analysis to permit classification of the tracings into categories of normality or abnormality. The entire automated system can thus become a diagnostic aid to the physician.

This paper deals with one phase of a project directed at the development of an automated system to aid in the diagnosis of heart disease. In work previously reported, it was demonstrated that the general-purpose digital computer using statistical techniques can be used to characterize and classify normal and pathological subjects. The technique used was based on multi-dimensional-probability density functions utilizing the clinically used measurements manually derived from the ECG,

ballistocardiogram, phonocardiogram, and the arterial pressure pulse. Because manual efforts required to measure clinically useful parameters from these physiological waveforms are unduly tedious, studies of this type are impractical except for a small number of cases.

This paper is concerned with a computer program for automatically recognizing and measuring the clinically useful parameters from an ECG waveform. The techniques and the methodology developed for pattern recognition in the ECG can serve as a basis for pattern recognition programs for other physiological waveforms.

Interpretation and Application of Statistical Analysis for Random Physical Phenomena—I. S. Bendat (p. 31)

This paper is an expository presentation on 1) mathematical and statistical concepts deemed to be important in analyzing the nature of random physical phenomena, 2) development of over-all procedures for evaluating single records and a collection of records, and 3) particular details on interpreting and applying probability density functions, correlation functions, and power spectral density functions. The discussion is directed towards a general audience to help bring about a wider understanding of these ideas for application to many problems such as: vibration in space vehicles, meteorological or oceanographic prediction, electrical noise properties, biomedical research, etc.

Pulsed Ultrasonic Transit Time Flowmeter—D. L. Franklin, D. W. Baker, and R. F. Rauchmer (p. 44)

The difference in effective velocity of sound pulses propagated alternately upstream and downstream through moving blood is a measure of the blood velocity. A blood flowmeter based on this principle has been developed and employed in routine experiments over a period of four years. The travel time of sound pulses passing diagonally through the blood vessel is measured by gating a ramp voltage generator during the transit of each sound pulse from the transmitter crystal to the receiver crystal. The peak voltage attained by the ramp is stored and compared with the peak voltage attained by the subsequent ramp when the direction of propagation is reversed. The cycle is repeated 400 times each second so that a 400-cps carrier is formed. The amplitude of the carrier is proportional to the magnitude of the flow, and the phase of the carrier indicates direction of flow. The total P-P noise and long-term drift is less than $7\cdot10)^{-11}$ sec difference in transit time over a four-hour measurement period, under optimal conditions. Here a demodulator limited the rise time of the instrument to 20 msec. Each upstream-downstream measurement requires only 240 μsec of the total available 2500 μsec, so that a time sharing technique may be used to operate many flowmeters simultaneously without mutual interference. The transducers are light (about 5 grams) and economical to construct. The instrument has been used to measure flow through the main pulmonary artery, the root of the aorta, the superior mesenteric artery, the left renal artery and the terminal abdominal aorta simultaneously in ambulatory dogs. Details of the circuitry and its operation are included.

A Method of Iodine Determination by Characteristic X-Ray Absorption—O. Z. Roy, R. A. Beique, and G. L. D'Ombrain (p. 50)

This paper describes a technique for the quantitative analysis of nonradioactive iodine. The method uses the X-ray absorption discontinuities for the detection of iodine in the presence of any other absorbing substance.

A stationary lanthanum radiator converts an X-ray beam having a continous spectrum into two monochromatic beams which straddle the iodine absorption edge. The energy spread is such as to make the technique relatively independent of other foreign elements. A rotating filter alternately absorbs one of the two beams while leaving the other on continuously. The information in the beams is detected and synchronously switched into two counting circuits.

The intensity of the beams is measured by two counting-rate meters and the ratio of these intensities is obtained by a conventional self-balancing potentiometer. Since this ratio is determined every 1/60 of a second the iodine determination is insensitive to X-ray output, amplifier and detector drift.

Electronics for Whole-Body Liquid Scintillation Counters—R. D. Hiebert and J. D. Gallagher (p. 54)

Large liquid scintillation counters offer a unique combination of high sensitivity and moderate energy resolution and hence are particularly useful for the rapid measurement of the radioactivity of the human body and other large samples. This counter permits measurements of internal gamma contamination of the human body at concentrations 1000 times less than maximum permissible levels. Such an instrument can, therefore, have many practical applications to diagnosis in clinical and experimental medicine.

The instrumentation to be described is used with the new Los Alamos human counter but the techniques are applicable to large liquid scintillation counters in general. Objectives in this system are: 1) optimizing pulse-height (energy) resolution from the detector, 2) optimizing SNR, 3) long-term stability and freedom from rate and overload deficiences and 4) accuracy, speed and versatility of data handling and processing.

A Coding System for Patients with Convulsive Disorders and Children with Behavior Disturbances—E. Rodin, P. Beckett, and S. Sokolov (p. 61)

In order to take advantage of computer technology in clinical neurological research a coding system was devised for patients with convulsive disorders and behavior disordered children. The code sheets are filled in at the time of examination of the patient and this ensures that uniform data are obtained. For the most part, the system consists of graded scales. These cover most of the information which is routinely obtained in a clinical interview and examination. An effort has been made to assign qualitatively different phenomena to separate IBM columns so that direct correlations can be carried out between most of the columns without the need of prior sorting on specific items. The system deals specifically with information related to seizure patients and behavior disordered children but the basic outline is such that it can easily be adapted to any other neurological condition one may wish to study.

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Circuit Theory

Vol. CT-8, No. 4, December, 1961

Forward—F. H. Blecher and J. M. Sipress (p. 388)

Solid-State Circuit Papers

The Esaki Diode as a Network Element—B. K. Kinariwala (p. 389)

The following basic theorem is proved:

Theorem: Necessary and sufficient conditions for the physical realizability of a short-circuit admittance matrix Y of an n port obtained by imbedding an Esaki (tunnel) diode in a reciprocal lossless network are:

1) $-Y(-p)$ is a positive-real matrix with either a pole or a zero at infinity.
2) $[Ev\ Y]$ is of rank one or less.
3) $(A_1^{kk}A_2 - p^2B_1^{kk}B_2)^{1/2}$ is a polynomial which is even or odd as the degree of D is even or odd.
4) The sum of the poles (P) does not exceed the reciprocal time constant ($1/T$) of the diode.
5) The ratio of P and $1/T$ does not exceed the ratio of the determinants of Y^q and Y_{sc}^q at $p = \infty$ for all q, or

$$PT \leq \frac{\det.\ Y^q}{\det.\ Y_{sc}^q}\bigg|_{p=\infty}, \qquad q = 1, 2, \cdots, n;$$

where Ev implies the "even part of," each element of matrix Y is defined as

$$Y_{ik} = \frac{N_{ik}}{D} = \frac{pB_1^{ik} - A_1^{ik}}{A_2 - pB_2}$$

with polynomials A_2, B_2, A_1^{ik}, B_1^{ik} being even or odd as the degree of D is even or odd. The matrix Y_{sc} is the admittance matrix obtained by short circuiting the diode. The superscript q represents all possible combinations of q accessible ports (the rest are short circuited).

Noise Properties of Four-Pole Networks with Application to Parametric Devices—H. Seidel (p. 398)

The ability to employ a new concept profitably is a matter of representation. If it can be shown to be of a kind with older and more familiar building blocks, and if a common formalism may be demonstrated, then the process of understanding is a good deal simpler.

The parametric amplifier is, for all practical purposes, a product of recent technology, although its history can be traced for at least 100 years. Its mechanisms seem different from conventional structures, although it bears a dubious resemblance to mixers. Further, the noise processes come from signal and image sources, and some sort of new bookkeeping seems necessary for accounting purposes.

It is the purpose of this paper to integrate the parametric amplifier into more conventional network theory. It is a linear network amply covered by general theorems, applicable to all linear networks. However, because the noise theory of the parametric device is so relevant, these theorems will be expanded to permit general noise analysis.

Optimum Synthesis of Wide-Band Parametric Amplifiers and Converters—E. S. Kuh and M. Fukada (p. 410)

This paper derives the theoretical limitation on gain and bandwidth for parametric amplifiers and inverting-type up-converters. It shows that the transducer power gain of an amplifier or a converter can be related to the reflection coefficient of a simple matching network as

$$G \approx \frac{\omega_0}{\omega_0'} G_c \approx \frac{1}{4\,|\rho|^2},$$

where G_a and G_c are the power gain of the amplifier and the converter, respectively, ω_0 and ω_0' are the center frequencies of the signal and the idler bands, respectively, and ρ is the reflection coefficient which is limited in bandwidth by the following formula:

$$\frac{B}{\omega_0} \ln \left| \frac{1}{\rho} \right| \leq \frac{\pi}{2} \frac{C_1}{C_0} \sqrt{\frac{\omega_0'}{\omega_0}}.$$

B is the bandwidth, and $C_0 + 2C_1 \cos \tilde{\omega}\, t$ represents the variable capacitance.

Optimum Butterworth filters are used as the coupling networks. Condition for optimum matching is determined together with element values of the circuit. The theoretical limitation on bandwidth can be approached if the number

of elements in the coupling network is increased. The design of optimum wide-band amplifiers and converters become straightforward, thus eliminating any cut and try process.

High-Frequency High-Power Operation of Tunnel Diodes—C. S. Kim and A. Brändli (p. 416)

The operation of oscillators using high-current tunnel diodes above their self-resonant frequency is presented. General stability conditions of the tunnel diode, including external circuits (lumped and distributed), are discussed.

Based on a nonlinear analysis of a tunnel-diode oscillator, the power generated by the diode, the power dissipated within the diode and the power delivered to an external load are calculated as a function of frequency and loading conditions.

For operation above the self-resonant frequency, the suppression of unwanted LF oscillations is necessary. Experimental results of an oscillator circuit operating at 2–3 Gc with the suppression of LF oscillation are described. Data on the high-current tunnel diodes (50∼100 ma) used are given.

Microwave Operation of Drift Transistors in Transit-Time Mode—R. Zuleeg and V. W. Vodicka (p. 426)

The transit-time transistor and its operation was first proposed by Weinreich in relation to a diffusion transistor. The similarity to the diffusion-delay diode and the existence of a negative resistance has been pointed out in accord with the original theoretical work by Shockley. In this paper the drift transistor is analyzed in respect to transit-time effects of minority carriers across the base region, which appear at frequencies above the normal cutoff frequency and are more favorable than in a diffusion transistor due to larger excess phase shifts in the base transport factor. Amplification and power-generation properties at frequencies properly related to the base transit time are theoretically predicted and lie within frequency bands above the cutoff frequency. Experimental verification of gain and power have been obtained with some commercial and developmental high-frequency mesa-type drift transistors. The results are reported, together with the special microwave circuitry utilized in the experiments.

Although realization of gain and power in the micowave region with present transistor encapsulations encounters difficulties in the form of parasitic circuit elements, *e.g.*, lead inductances, and interelectrode capacities, a promising application of suitably designed and packaged drift transistors in the microwave-frequency region will be demonstrated.

The operation of the drift transit-time transistor is similar to its vacuum-tube counterpart. Microwave performance to date is very encouraging, and certain advantages over its vacuum-tube equivalent are indicated.

A New DC Transistor Differential Amplifier—D. F. Hilbiber (p. 434)

The stable amplification of low-level signals of less than 1 mv magnitude has usually been done with a carrier-type feedback amplifier employing a complex modulation-demodulation system incorporating a short-lived and bulky mechanical chopper. The much simpler all-transistor dc differential amplifier, however, has not been suitable due to drifts in gain and operating point during aging and temperature variations. The purpose of this paper is to relate improvements in both of these respects as a result of using planar silicon transistors described by Hoerni and a compound transistor circuit. Equivalent input drifts of $3\,\mu v/°C$ to $5\,\mu v/°C$ have been attained over the temperature range of $-70°C$ to $+125°C$, with negligible gain variations. This circuit also offers single-ended as well as differential output capabilities.

Tuned Transistor Amplifier—M. A. H. El-Said (p. 440)

The paper analyzes the input-impedance components of a grounded emitter transistor amplifier having a tuned circuit load which presents a mismatch to the transistor output impedance. This loading of the transistor permits operation of synchronously tuned amplifiers without necessity for neutralization, thus enabling easier mass production with little sacrifice in circuit amplification. A simple design procedure is given, and while the analysis is particularly applicable to IF amplifiers employing either single or double tuned circuits, the same principles can be applied in general to tuned RF amplifiers. Variation of the input-impedance components with the AGC action is also given.

Optimum Design of the Shunt-Series Feedback Pair with a Maximally Flat Magnitude Respose—M. S. Ghausi (p. 448)

In this paper, analysis and design of the shunt-series pair feedback amplifier are given. The design achieves optimum gain-bandwidth product with a maximally flat magnitude transmission for a specified gain or desensitivity. Phantom zero is used to avoid degradiation of feedback bandwidth and to obtain a filter type transient response. Experimental verification of the theory is given with medium frequency alloyed-junction transistors and HF mesa transistors. The agreement between the theoretical and experimental work is shown to be good in all cases, both in time and in frequency domains.

Rapid-Transfer Principles for Transistor Switching Circuits—A. K. Rapp and J. L. Robinson (p. 454)

Requirements on circuit performance in high data-rate systems depend on the type of system in which the circuits are to be used. The requirements must be derived accordingly. For the type of system in which processing delay is not a limiting factor, a theoretical analysis has disclosed two basic circuit requirements:

1) minimum time dispersion in binary elements,
2) minimum time to set a flip-flop.

This paper presents the salient points of the theoretical analysis and describes circuits which uniquely meet the two basic circuit requirements. Time dispersion is minimized by applying a rapid-transfer principle to current-switching requantizing circuits. These circuits completely requantize the binary elements in both time and amplitude. The time required to store a binary element in a current-switching flip-flop is reduced by operating the transistors in the active region exclusively.

Serial data rates up to 250 megabits per second have been obtained using the rapid-transfer circuit in a small test system.

Static Design of Transistor Diode Logic—P. W. Becker (p. 461)

Two techniques for static design of drift-tolerant transistor diode logic are described. As the approaches are applicable to other design problems, the descriptions have been given a rather general form.

First, three kinds of drift-tolerant design criteria are discussed: worst-case, statistical design, the multiple worst-case. The criteria illustrate different ways in which the information from the specification sheets may be applied to the design inequalities.

Second, the form of the design inequalities is discussed. Substantial simplicity is obtained by giving the inequalities a determinant form.

Finally, two ways of solving the design inequalities are demonstrated. Both methods will give the results in terms of available resistor values. The λ_s-method will give the set of highest resistor values which satisfies the design inequalities. The useful region method will determine a family of curves, each curve corresponding to a possible load on the circuit. The region which is limited by a curve illustrates all solutions (or all interesting solutions) to the design problem. The method will enable the designer to take into account the unavoidable correlations between the component parameters due to age, temperature, etc. Due to its nature, one such diagram will, in general, suffice for a project.

A diagram which illustrates all possible resistor combinations with which a NAND circuit can drive a given load, is derived in Appendix I. The AND or OR load in question determines which member of the family of curves is applicable.

The design of an iterative NOR circuit with minimum power dissipation is described in Appendix II.

High-Speed Switching Circuitry Using Tunnel Diodes—R. S. Foote and W. V. Harrison (p. 468)

A discussion of various techniques usable in obtaining high-speed digital circuit operation is presented. To gain these advanced digital speeds, tunnel diodes have been incorporated into transistor circuitry. The fast rate of change of voltage and the bistable capabilities of the tunnel diode are the characteristics which provide for higher speeds. Development has been mainly applied to the application of the GaAs tunnel diode in circuitry because of the higher output voltage available. Some of the ultimate speeds attainable in circuits providing impedance transformation and amplifications will be discussed, followed by circuit applications in more detail.

Transistor Blocking Oscillator Analysis—S. M. Korzekwa (p. 473)

Two commonly used basic transistor blocking oscillator circuits are considered: 1) a common-emitter with collector-to-base transformer coupling, and 2) a common-base circuit with collector-to-emitter transformer coupling. The pulse widths of the blocking oscillators are assumed to be dependent on the transistor and circuit parameters rather than external timing devices, *i.e.*, delay lines. Also the transformers used in the circuits are assumed to operate linearly and exhibit no saturation effects.

A review of the basic principles of operation is given and simplified equivalent circuits are included. A rise time equation is given in terms of the circuit parameters for the common-base blocking oscillator. The deterioration of the rise time with loading is shown in the equations. Pulse width equations, suitable for design purposes, are given for each type of circuit. A linear worst-case analysis shows the response of the common-base circuit to a step voltage trigger. This linear trigger analysis is an approximation due to the inherent nonlinearities associated with the transistor during the turn-on interval. However these worst-case results compare favorably with experimental rise time results. A trigger pulse of sufficient amplitude and a pulse duration of 0.05 μsec simulates the voltage step function adequately since the circuit attains a regenerative mode during that period of time. The pulse width stability of the circuits is emphasized, and the common-base circuit is shown to have a better pulse width stability than the common-emitter circuit. A pulse width stability equation is obtained by considering partial derivatives of the pulse width equation.

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Solid-State Physical Phenomena and Effects, Part I—E. J. Scheibner (p. 133)

This first part of a four part paper describes fifteen solid-state phenomena and physical effects. These phenomena are part of a group whose effects depend upon either the transport of electrons and holes or upon the band structure of the material.

Glass Migration in Ceramic-to-Metal Seals—S. S. Cole and G. C. Sommer (p. 151)

Certain metals adhere to ceramics when sintered. This adherence is important in incorporating ceramic components in electronic devices. But understanding of the adherence mechanism is limited. A study of adherence is described in this paper, and an explanation of the adherence of metal coatings to glassy high-alumina ceramics is presented.

Effect of Change of Shape on Resistance of Wire and Ribbon—C. D. Brown (p. 157)

The change in resistance of wire and ribbon when wound respectively in a toroid or cylindrical shell has been calculated. Experimental data for wires confirming the theoretical calculations are presented.

The Effect of Surface Morphology of Substrates Upon Electrical Stability of Nichrome Thin Film Resistors—W. R. Lasko and H. A. Roth (p. 160)

The effect of substrate surface roughness on the thermal stability of nichrome thin film resistors is presented. This investigation was confined primarily to glass- and alumina-type substrates. Electron microscope surface morphology examinations made of alumina substrates, obtained from different sources, revealed some differences in microstructure. No particular microdefect or combination of defects could be rigorously related to the thermal aging data for alumina. Comparative results between glass and alumina, where differences in roughness were quite pronounced, gave corresponding large differences in stability during thermal aging.

Oxidation based on surface roughness is suggested as the mechanism to account for the increase in resistance obtained on the nichrome films supported on alumina during thermal aging.

Fuel Cells—H. W. Fox and R. Roberts (p. 162)

A comparison is drawn between the theoretical efficiencies of heat-engines and fuel-cells in the conversion of chemical to electrical energy. The electrochemical principles governing the operation of fuel-cells are discussed. Short descriptions, including performance curves, are given of a few selected fuel-cell types including low, intermediate, and high temperature cells, and redox and regenerative cells. An example is given of a rough calculation of battery and fuel weight and volume for a given power level and total energy demand.

Annual Index (Follows page 174)

Information Theory

VOL. IT-8, NO. 2, FEBRUARY, 1962

Bionics or Electrology—Guest Editor—E. E. David, Jr. (p. 74)

Sophistication in Computers: A Disagreement—J. L. Kelly, Jr., and O. G. Selfridge (p. 78)

There is frequently more or less acrimonious discussion about artificial intelligence and intelligent machines and their place in science. Usually the discussion settles down to the reiteration of two points of view. This paper is concerned with the difference between them. Do they merely reflect two emotional or ethical biases, or is there an underlying technical judgment on which they disagree? The authors claim the latter and purport to show what that judgment is.

Decision Units in the Perception of Speech—G. A. Miller (p. 81)

It has been shown experimentally that speech intelligibility is a function of grammatical content. This fact implies that automatic speech recognizers may well need to include information about linguistic structure.

Visual Pattern Discrimination—B. Julesz (p. 84)

Visual discrimination experiments were conducted using unfamiliar displays generated by a digital computer. The displays contained two side-by-side fields with different statistical, topological or heuristic properties. Discrimination was defined as that spontaneous visual process which gives the immediate impression of two distinct fields. The condition for such discrimination was found to be based primarily on clusters or lines formed by proximate points of uniform brightness. A similar rule of connectivity with hue replacing brightness was obtained by using varicolored dots of equal subjective brightness. The limitations in discriminating complex line structures were also investigated.

Kinesthetic-Tactile Communications—J. C. Bliss (p. 92)

Machine aids to kinesthetic-tactile communication aim at maximizing the information-transfer rate from an external source to the human user. The display is the central problem. Source messages might be recoded into equal information units presented one at a time to the user, or a temporal or spatial display of the message may permit the user to recode the message perceptually into manageable units. The performance of these alternatives has been examined using a kinesthetic-tactile display for English text. This device consists of eight finger rests, each of which can move in 26 directions in three-dimensional space. Two methods of programming this device to present information were investigated. In the "traveling-wave" presentation, a three-dimensional traveling wave of finger movements moves across the display representing a sequence of symbols. This presentation is an example of the case in which the *user* recodes the source messages perceptually. In the "typewriter" presentation, the subject's fingers are moved corresponding to the way he would actively move them if he were typing. The latter proved to be the more effective, yielding a transmission rate of 4.5 bits/sec.

Estimation of the Subjective Effects of Noise in Low-Resolution Television Systems—R. C. Brainard, F. W. Kammerer, and E. G. Kimme (p. 99)

A model for the subjective effects of noise on television picture quality is described. Experimental and data-processing procedures are developed from this model which yield a subjective noise sensitivity function of noise frequency for monochrome low resolution video pictures. The results obtained apply to high levels of noise power. Two noise sensitivity functions are obtained using these experimental methods, one for still pictures and one for live pictures.

Analog Models of Neural Mechanisms—L. D. Harmon, J. Levinson, and W. A. Van Bergeijk (p. 107)

This paper outlines in condensed form the use that can be made of accurate neural analogs in analyzing the complexities of nervous systems. After a short review of the most pertinent information available in neurophysiology, various ways of modeling neural behavior are discussed.

A brief description is given to the "neuromime" we have used. We then describe two applications of this analog. The first is a model of the flicker-fusion mechanism of the eye, and the second is a model of the spiral innervation of the ear.

Temporal Coding of Neural Responses to Acoustic Stimuli—N. Y.-S. Kiang, M. H. Goldstein, and W. T. Peake (p. 113)

Electric responses to acoustic stimuli have been recorded from the auditory nervous system of cats. Responses of single nerve cells in the cochlear nucleus recorded with microelectrodes, and auditory nerve responses recorded with gross electrodes (which record activity of many cells) are presented as examples of the kinds of data which can be obtained. The behavior of these responses for various changes in stimulus parameters is illustrated together with several methods of data analysis. The data presented are from studies in auditory physiology in which one aim is a description of the neural coding of the temporal pattern of acoustic stimuli.

Neural Mechanisms Which Discriminate Events on the Skin—P. D. Wall and R. Melzack (p. 120)

This review examines the historical development of concepts of nervous system organization with special reference to the skin sensory system. The commonly held view that the modalities of sensation are produced solely by the initial filtering action of the receptor organs is shown not to fit the observed physiology of the first and second cells in the sensory pathway. Instead it is proposed that every discriminably different cutaneous perception is produced by a unique space-time pattern of nerve impulses. The mechanisms employed by the nervous system for generating and analyzing space-time patterns of impulses are discussed.

A Note on Learning Signal Detection—M. Kac (p. 126)

This paper considers a threshold detector operating on noisy binary pulses. It is shown that an adaptive error-correction procedure can bring the threshold to the point of equal false alarm and missed detection probabilities.

Snow Removal—A Noise-Stripping Process for Picture Signals—R. E. Graham (p. 129)

It is quite often possible to separate "picture" from "noise" in a television image. We do this when we view television under unfavorable conditions. This ability of the human observer suggests that completely automatic operation might at least partially separate noise and picture.

A nonstationary, nonlinear operation has been found which selectively removes moderate amounts of additive Gaussian noise from a received picture signal. Running tests are performed upon the signal to detect the presence of perceptually significant picture detail in a number of different categories. Depending upon the test results, a selection is made from a number of available smoothing filter modes to maximize the suppression of noise without picture blurring. No preparatory operation is required at the transmitter, so that the technique is compatible with existing picture transmission systems. The process is applicable to conventional boradcast television, and could in principle be incorporated in home receivers to improve reception in fringe areas.

Picture Coding Using Pseudo-Random Noise—L. G. Roberts (p. 145)

In order to transmit television pictures over a digital channel, it is necessary to send a binary code which represents the intensity level at each point in the picture. For good picture quality using standard PCM transmission, at least six bits are required at each sample point, since the eye is very sensitive to the small intensity steps introduced by quantization. However, by simply adding some noise to the signal before it is quantized and subtracting the same noise at the receiver, the quantization steps can be broken up and the source rate reduced to three bits per sample. Pseudo-ran-

dom number generators can be synchronized at the transmitter and receiver to provide the identical "noise" which makes the process possible. Thus, with the addition of only a small amount of equipment, the efficiency of a PCM channel can be doubled.

Speech Recognition: A Model and a Program for Research—M. Halle and K. Stevens (p. 155)

A speech recognition model is proposed in which the transformation from an input speech signal into a sequence of phonemes is carried out largely through an active or feedback process. In this process, patterns are generated internally in the analyzer according to an adaptable sequence of instructions until a best match with the input signal is obtained. Details of the process are given, and the areas where further research is needed are indicated.

Handwriting and Pattern Recognition—M. Eden (p. 160)

Handwriting can be characterized as a sequence of basic strokes connected according to rule. Handwriting so generated approximates that of humans very closely. Such a matching process can be used as the fundamental principle in a handwriting recognizer.

Design Factors in the Development of an Optical Character Recognition Machine—J. J. Leimer (p. 167)

Interest in optical character recognition has grown tremendously during the past several years. When one considers the volume of printed information that must be accessible both to human readers and to data processing machines, the increasing interest is not at all surprising.

Many optical character recognition principles that appear to be quite powerful are impractical or too costly to implement with available technology. Other principles that appear relatively economical require an input quality that is impractical to generate. The field for commercial development falls somewhere between these two extremes.

Many factors determine the character recognition principles to be utilized in the development of a machine system. Of primary importance are:

1) The shapes of the symbols to be sensed,
2) The number of different symbols to be discriminated,
3) The print quality range that must be accommodated, and
4) The required performance of the system.

Unfortunately, in the present state of the art, the relationship of these factors to each other and to a given principle can be only qualitatively defined. So, the engineer must rely on inductive reasoning, ingenuity, and experience.

This paper describes and discusses the development of a practical optical character recognition system, the character recognition portion of the IBM 1418 Optical Character Reader. The considerations involved are applicable to the development of any character recognition system.

The Characteristic Selection Problem in Recognition Systems—P. M. Lewis II (p. 171)

Design of pattern recognition systems usually involves a number of uncertainties which can be resolved only by experiment. In statistical recognition systems, pattern information is stored in the machine in the form of pattern characteristics with statistics relating the characteristics to the patterns. If the number of characteristics a system can process is limited, and if the system designer, while able to conceive of a large number of relevant characteristics, does not know which are the most important, then an experimental selection of these characteristics is required. As tools, the designer may have at his disposal a large computer, a large sample of the patterns to be recognized, and a set of programs to measure the characteristics. Thus, he can compare certain statistics relating the patterns to the characteristics. The problem is: what statistics should he calculate in order to select the best characteristics?

Assuming the characteristics to be independent in their effect on the decision, this paper examines the notion of a single number statistic for each characteristic which would have certain desirable properties related to the "goodness" of the characteristic. It is shown that, in general, no such statistic exists. However, a statistic is proposed which, while not having these properties in general, at least has them in a wide range of situations.

An experimental study of the validity of this choice is reported together with the design of a letter recognition system. Using a sample of 15 complete 62 symbol alphabets, 13 characteristics were selected. The resulting system recognized correctly 81.9% of the letters presented to it.

Visual Pattern Recognition by Moment Invariants—M.-K. Hu (p. 179)

In this paper a theory of two-dimensional moment invariants for planar geometric figures is presented. A fundamental theorem is established to relate such moment invariants to the well known algebraic invariants. Complete systems of moment invariants under translation, similitude and orthogonal transformations are derived. Some moment invariants under general two-dimensional linear transformations are also included.

Both theoretical formulation and practical models of visual pattern recognition based upon these moment invariants are discussed. A simple simulation program together with its performance are also presented. It is shown that recognition of geometrical patterns and alphabetical characters independently of position, size and orientation can be accomplished. It is also indicated that generalization is possible to include invariance with parallel projection.

Contributors (p. 188)

Affiliates of the IRE Professional Group on Information Theory (p. 191)

Microwave Theory and Techniques

VOL. MTT-10, NO. 1, JANUARY, 1962

Editorial—D. D. King (p. 2)

***X*-Band Ladder-Line Traveling-Wave Maser**—G. I. Haddad and J. E. Rowe (p. 3)

An *X*-band ruby traveling-wave maser (TWM) has been constructed and tested in which the RF structure is a double-ridge ladder line and the signal is coupled into and out of the structure with coaxial lines. The pump power is propagated in a waveguide mode and the device is operated at and below liquid helium temperatures. A four-inch electromagnet was used. The TWM was operated at the push-pull point with a pump frequency of 24 Gc and a signal frequency of approximately 9.65 Gc; the magnetic field was 4.1 kilogauss.

Electronic gains of 15 db have been obtained and bandwidths as high as 130 Mc were observed. Reduced structure losses and longer sections of ruby promise a $G^{1/2}B$ of 1100 Mc (30 db over 35 Mc).

Field Expansions in Cavities Containing Gyrotropic Media—J. Van Bladel (p. 9)

The electric and magnetic eigenvectors for cavities containing media with tensor characteristics are examined, and explicit formulas for the electric and magnetic fields are obtained in terms of volume and boundary sources.

An Impedance Transformation Method for Finding the Load Impedance of a Two-Port Network—R. Mittra and R. J. King (p. 13)

An unknown load impedance terminating a lossy two-port junction can be calculated if the input impedance and junction parameters are known. It is to be shown that there exists a linear relationship, dependent upon two calibration constants, between the input reflection coefficient and a modified reflection coefficient of the load. Applying the linear transformation to the junction input impedance permits evaluation of the unknown load impedance. Calibration is accomplished by terminating the transmission line in at least three different reactances and measuring the corresponding input reflection coefficients. These data plot into the usual circular configuration on a Smith chart from which the necessary calibration data is obtained. When several load reactances are used, the calibration accuracy can be considerably increased, since the averaging advantage of plotting a mean straight line is utilized. Furthermore, once the junction has been calibrated, its equivalent T-network impedances and scattering coefficients may be found.

Criteria for Designing High-Power Coupled Wave Duplexers and Isolators—L. R. Whicker, G. J. Neumann, and F. E. Munyak (p. 20)

This paper presents criteria for designing nonreciprocal coupled-wave devices which may be used as isolators, circulators and duplexers. An experimental model of such a device was designed and tested over a 6 per cent frequency band centered at 35 kMc, and the obtained data are in good agreement with the theory. Such devices should have numerous applications as they offer the capability of operating under extremely high power levels, and are not restricted to dominant mode operation.

Scattering Coefficients for Wall Impedance Changes in Waveguides—E. L. Johansen (p. 26)

The Wiener-Hopf technique is used to obtain an exact solution to a two-dimensional scattering problem. In the problem solved, an incident TE_{10} mode, traveling from $z = -\infty$ in the positive z direction, is confined by infinite bounding planes; these planes have infinite conductivity for $z<0$ and an impedance Z_1, for $z>0$. The scattering from the junction at $z=0$ gives rise to reflection and transmission coefficients that are exactly determined. An approximate solution for the reflection coefficients is also given when the TE_{10} mode is incident from the opposite direction. Finally, a table is presented which lists some transmission and reflection coefficients for rectangular and circular waveguides with discontinuities in the wall impedances.

An Apparent Anomaly in the Group and Energy Velocity in a Dielectrically Loaded Slow-Wave Structure—G. B. Walker and C. G. Englefield (p. 30)

This paper is concerned with group and energy velocity in a cylindrical guide periodically loaded with dielectric disks. For a TM wave a confluence may be obtained between the first and second pass band of such a structure by arranging that the characteristic impedances of the air and dielectric regions are equal when the phase change per section is π.

It was at first thought that, since the impedances are equal, there would be no reflections from the interfaces. Assuming only forward waves, however, the equivalence of group and energy velocity is violated.

The detailed analysis presented here shows that, mathematically, infinitely many solutions for the field pattern at the matched π mode are possible but the only one of these has physical significance. For this one pattern the group and energy velocities are equal.

Parallel Push-Pull Hybrid Circuit—M. Miyagi (p. 34)

This paper deals with a new hybrid circuit for signal branching or combining in parallel push-pull amplifiers. The purpose of the new hybrid circuit is to perform the branching or

combining of two pairs of signals for parallel push-pull operation, each consisting of two oppositely phased, balanced signals. The advantage of combining two pairs of parallel push-pull signals by a single component of new hybrid circuit is clear; one would require a multiplicity of conventional rat-race circuits to do the same job, inasmuch as the basic rat-race circuit is limited to only one pair of push-pull signals.

The new hybrid circuit is further elaborated to improve the performance for combining unbalanced push-pull signals by: (1) showing that the combination of unbalanced push-pull signals is equivalent to the super-position of cophase components on the balanced antiphase components; (2) analyzing the effect of the cophase components in the hybrid circuit; and (3) devising means of improving the adverse effects of the cophase components.

Finally, an evaluation is made of a parallel push-pull amplifier using the new hybrid circuit in comparison with the conventional rat-race circuits required for the same parallel push-pull operation.

Ridge Waveguide Field Description and Application to Directional Couplers—W. J. Getsinger (p. 41)

An approximate determination of the dominant-mode fields in ridge waveguides at all frequencies has been made. Evaluations of the fields along the walls of a commercially standard single-ridge guide having a usable frequency range from 3.75 to 15.0 Gc, and a commercially standard double-ridge guide having a usable frequency range from 4.7 to 11.0 Gc were carried out, and graphs drawn so that the results could be applied to practical situations. The graphs were used to design some ridge-waveguide directional couplers. Both cross-guide and broad-wall couplers were made in single-ridge waveguides and in double-ridge waveguides, using cross sections approximating those of the above commercially available ridge guides. The validity of the field graphs was demonstrated by the close correspondence between measured and predicted coupling for the cross-guide couplers, and by achieving predicted equality of coupling at the band ends for the broad-wall couplers.

A New Technique for the Measurement of Spinwave Linewidths from the Saturation of Ferrimagnetic Resonance Line—P. E. Seiden (p. 51)

A new measurement technique is described that records the ferrimagnetic saturation curve in a way that permits the Suhl critical field to be evaluated directly from the recording. This technique eliminates the tedious task of constructing point by point saturation curves for evaluating the critical field and shortens immensely the time required to determine spinwave linewidths from the saturation of the ferrimagnetic resonance line.

Frequency Doubling Using Ferrite Slabs, Particularly Planar Ferrites—I. Bady (p. 55)

An analysis is given of the results of frequency doubling experiments using relatively thick ferrite slabs. The primary frequency was 9100 Mc. It is shown that the dielectric properties of the ferrite cause the double-frequency wave to behave as a surface wave. This tends to concentrate the double-frequency fields in the vicinity of the ferrite, thus increasing its interaction with the oscillating magnetic-dipole moments that generate these fields and increasing the conversion efficiency. However, the surface-wave effect also causes a phase difference between the magnetic-dipole moments and the double-frequency fields, and this limits the efficiency obtainable through this effect. Experimental data give reasonable agreement with calculated results. Spinwave effects are considered, and it is shown that they can contribute to harmonic generat on if the precession orbits of their magnetization vectors are highly elliptical. The best conversion efficiency obtained in these experiments was—11.1 db at a peak input power level of 6300 w. Planar ferrites have inherent advantages over isotropic ferrites because the planar anisotropy greatly increases the ellipticity of the precession of the magnetization vectors of both the uniform mode and the spinwaves. The relatively large dielectric constant of planar ferrites is also helpful to frequency doubling.

Coupled Rectangular Bars Between Parallel Platers—W. J. Getsinger (p. 65)

Curves are presented giving the even-mode fringing capacitance, the odd-mode fringing capacitance, and the difference between odd- and even-mode fringing capacitances for wide ranges of thickness and spacing of rectangular bars centered between parallel plates. Simple formulas are given relating these capacitances to even- and odd-mode characteristic impedances of coupled rectangular bars. Possible applications to strip-line and other circuits are described.

The Appendix gives the derivation of the fringing capacitances by conformal mapping techniques. The results are exact for bars extending in width infinitely far from the coupling region, and have only small error (less than 1.24 per cent) for bars whose width is greater than about 35 per cent of the difference between plate spacing and bar thickness.

A Sampling Measurement of Multimode Waveguide Power—E. D. Sharp and E. M. T. Jones (p. 73)

This paper describes a simple method of measuring the total power that is propagating at various frequencies in a multimode, rectangular waveguide. It is particularly useful for determining the power that is generated at harmonic frequencies by high-power transmitters. In this method, the amplitude of the waveguide fields at a number of frequencies is sampled at evenly spaced points around the waveguide periphery. It is shown theoretically that by averaging the squares of the sampled field amplitudes, the total multimode power at the various frequencies can be determined to within ± 2 or ± 5 db, depending upon which combinations of waveguide fields are measured. The theoretical accuracy is verified by measurements at both low and high powers.

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Contributors (p. 93)

Abstracts and References

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, 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.

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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.

UDC NUMBERS

Certain changes and extensions in UDC numbers, as published in PE Notes up to and including PE 666, will be introduced in this and subsequent issues. The main changes are:

Artificial satellites:	551.507.362.2	(PE 657)
Semiconductor devices:	621.382	(PE 657)
Velocity-control tubes, klystrons, etc.:	621.385.6	(PE 634)
Quality of received signal, propagation conditions, etc.:	621.391.8	(PE 651)
Color television:	621.397.132	(PE 650)

The "Extensions and Corrections to the UDC," Ser. 3, No. 6, August, 1959, contains details of PE Notes 598–658. This and other UDC publications, including individual PE Notes, are obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands or from The British Standards Institution, 2 Park Street, London, W. 1, England.

ACOUSTICS AND AUDIO FREQUENCIES

534.2–14:534.88 710

Long-Range Shallow-Water Transmission—K. V. Mackenzie. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1505–1514; November, 1961.) Propagation losses are computed for 200–2000-cps sound in 25-fathom water for ranges up to 250 miles. Experimental data are in quantitative agreement out to 40 miles.

A list of organizations which have available English translations of Russian journals in the electronics and allied fields appears each June and December at the end of the Abstracts and References section.

The Index to the Abstracts and References published in the PROC. IRE from February, 1960 through January, 1961 is published by the PROC. IRE, May, 1961, Part II. It is also published by *Electronic Technology* and included in the March, 1961, issue of that Journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

534.2–8–14 711

Experimental Study of Diffraction and Waveguide Effects in Ultrasonic Attenuation Measurements—E. F. Carome, J. M. Witting, and P. A. Fleury. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1417–1425; October, 1961.) Measurements of attenuation in liquids of low absorption in the range 1–20 Mc are described a) for free-field conditions with circular and square sound sources, and b) for circular and rectangular waveguides.

534.231:538.566:535.42 712

Diffraction of Electromagnetic Waves by Sound Waves—Schmitt. (See 800.)

534.231–14 713

Observations of the Stability of a Normal-Mode Sound Field in an Intermediate Scale Model—J. A. Scrimger. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1329–1333; October, 1961.) Measurements of sound-pressure amplitude as a function of frequency in the range 1.1–2.4 kc were made at regular intervals in shallow water. Results are presented in the form of contour diagrams.

534.232–14 714

Vibrations of Cross-Stiffened and Sandwich Plates with Application to Underwater Sound Radiators—J. E. Greenspon. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1485–1497; November, 1961.) A simplified theory of the behavior of the plates under dynamic loading is derived, their application as transducers is discussed and design procedure suggested.

534.232:537.228.1 715

Effects of High Static Stress on the Piezoelectric Properties of Transducer Materials—H. H. A. Krueger and D. Berlincourt. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1339–1344; October, 1961.) The permanent effects of stress cycles and high compressive stresses are examined for four materials and experimental results are discussed.

534.232:537.228.1 716

Piezoelectric Generation of an Electrical Impulse—M. Redwood. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1386–1390; October, 1961.) A simplified analysis of the transient performance of a piezoelectric transducer is given in order to determine the percentage of total energy which is available as electrical energy, and to find if the rate of energy withdrawal is limited by any time constants.

534.24–14:534.88 717

Bottom Reverberation for 530- and 1030-c/s Sound in Deep Water—K. V. Mackenzie. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1498–1504; November, 1961.) Reverberation level due to nonspecular reflections is analyzed to give the scattering constant μ of the bottom. A value of 10 log $\mu = -27$ db was obtained for both frequencies.

534.26–14 718

Experimental Study of the Scattering of Acoustic Energy from Solid Metal Spheres in Water—R. R. Goodman. (*J. Acoust. Soc. Am.*, vol. 33, p. 1428; October, 1961.) Mathematical explanation of the fluctuation effect detected by Hampton and McKinney (3221 of 1961).

534.61 719

Low-Frequency Sound Propagation in Gases—F. A. Smith and W. Tempest. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1626–1627; November, 1961.) A note on results obtained using a resonance-tube method developed for measurement of sound absorption and velocity in gases.

534.61(083.74) 720

On Preferred Frequencies for Acoustical Measurement—P. Wang. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1625; November, 1961.) "A new table of frequencies is suggested to American Standards Association as amendment to S1. 6-1960."

534.75 721

Hearing Threshold for Periodic Tone Pulses—R. Plomp. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1561–1569; November, 1961.) Continuation of earlier work [3909 of 1959 (Plomp and Bouman)].

534.75:534.641 722

The Acoustic Input Impedance of the Outer Ear—E. Zwicker. (*Nachrtech. Z.*, vol. 15, pp. 397–404; August, 1961.) Theory and measurements relating to telephone handsets.

534.76 723

Phasor Analysis of some Stereophonic Phenomena—B. B. Bauer. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1536–1539; November, 1961.) Phasor analysis suggested by Sandel, *et al.* (649 of 1956) is used to predict and explain certain stereophonic effects.

534.78:681.142 724

Recognition of Speech by a Computer Program that was Written to Simulate a Model for Human Visual Pattern Perception—L. Uhr and C. Vossler. (*J. Acoust. Soc. Am.*, vol. 33, p.

1-26; October, 1961.) The program develops its own set of operators as a function of its experience with inputs presented to it. Test results are given.

534.782 725
Artificial Generation of Vowels—L. Szecsi. (*Frequenz*, vol. 15, pp. 262–265; August, 1961.) The laws underlying vowel formation are investigated, and a vowel generator is constructed which can produce nine vowels with good intelligibility.

534.79 726
Procedure for Calculation Loudness: Mark VI—S. S. Stevens. (*J. Acoust. Soc. Am.*, pp. 1577–1585; November, 1961.) Equal-loudness contours for bands of noise in a diffuse field have been approximated by straight lines in a log-log plot, and the contour spacing has been modified to allow for noise with a bandwidth greater than the critical value.

534.845 727
Problems of Field Measurement of Transmission Loss as Illustrated by Data on Lightweight Partitions used in Music Buildings—R. N. Lane and E. E. Mikeska. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1531–1535; November, 1961.)

621.395.615:534.152 728
DeForest's 'Diffraction Microphone'—Optical Detection of Sound in Air—R. C. Levine. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1625–1626; November, 1961.) Variations of the refractive index of air during transmission of a sound wave are detected by a photocell.

621.395.625.3 729
Investigation on Recent Types of Magnetic Recording Tape—E. Belger and P. Scherer. (*Rundfunktech. Mitt.*, vol. 5, pp. 193–200; August, 1961.) The possibility of improving the quality of sound recording with the types of tape available is discussed. Tape characteristics are given, and a modification of recording technique is proposed.

681.828.5 730
Sound Synthesis by Electronic Image Scanning—L. Heck. (*Elektrotech. Z.*, vol. 13, pp. 454–458; August 21, 1961.) Various methods of sound synthesis by electro-optical means are reviewed. See *e.g.*, 3617 of 1961 (Holoch).

ANTENNAS AND TRANSMISSION LINES

621.315.212.002.2 731
The Manufacture of High-Frequency Coaxial Cables—K. H. Hahne. (*Bull. Assoc. suisse élect.*, vol. 52, pp. 725–728; September 9, 1961. In German.) Review of special techniques developed for the manufacture of various types of coaxial cable.

621.372.22 732
A Generalized Hildebrand's Method for Nonuniform Transmission Lines—I. Sugai. (*Proc. IRE*, vol. 49, p. 1944; December, 1961.)

621.372.8:537.56 733
Wave Propagation in a Plasma Cable, taking account of the Effect of Translation Velocity of the Plasma and the Ratio of the Radius of the Outer to that of the Inner Conductor—P. Mieg. (*Z. angew. Phys.*, vol. 13, pp. 356–360; August, 1961.)

621.372.8:537.56 734
The Propagation of Slow Electric Waves with Superimposed Longitudinal Magnetic Field in a Plasma Cable which Approximates as Closely as Possible a Plasma Waveguide—H. Riedel. (*Z. angew. Phys.*, vol. 13, pp. 360–364; August, 1961.)

621.372.823 735
The H_{01} Mode in Circular Waveguide with Ideally Conducting Rough Wall—R. Willett. (*Arch. elekt. Übertragung*, vol. 15, pp. 386–390; August, 1961.) The effect of wall surface irregularities on the H_{01} mode is shown to be insignificant.

621.372.829:621.385.632.2 736
Wave Propagation in Ring-Sector Waveguide—K. B. Niclas. (*Arch. elekt. Übertragung*, vol. 15, pp. 347–354; August, 1961.) The type of waveguide investigated is used as a coupling element for traveling-wave tubes [see *e.g.*, 3598 of 1961 (Klein, *et al.*)]. The field distribution and cutoff wavelengths of the fundamental modes are calculated.

621.372.834 737
A Waveguide In-Line Ferrite Rotary Joint—H. Saltzman and A. Rossero. (Proc. IRE, vol. 49, pp. 1959–1960; December, 1961.)

621.372.837 738
Microwave Circulators with Faraday Rotator—E. Schuegraf. (*Frequenz*, vol. 15, pp. 266–271; August, 1961.) The reduction of the frequency and temperature dependence of the Faraday rotation, and the achievement of optimum wide-band matching at all the arms of the circulator are discussed with reference to a prototype suitable for operation at about 7 Gc.

621.372.853.2 739
Backward Waves in Longitudinally Magnetized Ferrite Rods—G. H. B. Thompson (*J. Appl. Phys.*, vol. 32, pp. 2491–2492; November, 1961.) Comment on 1729 of 1961 (Trivelpiece, *et al.*).

621.396.67:621.317.328 740
The Prediction of Aerial Radiation Patterns from Near-Field Measurements—J. Brown and E. V. Jull. (*Proc. IEE*, pt. B, vol. 108, pp. 635–644; November, 1961.) The radiated field is expanded in terms of a series of radially expanding modes. The amplitude and phase of each mode are calculated by a Fourier analysis of the measured near-field and the radiation pattern obtained as a Fourier series containing these measured amplitudes and phases.

621.396.67:621.396.933.2 741
Principle of Operation of Cage-Type Aerials for Omnidirectional Radio Beacons—H. Brunswig. (*Nachrtech. Z.*, vol. 15, pp. 381–388; August, 1961.) The design and construction of a cage-type antenna for the VOR system are described. Experimentally determined impedance locus curves are given.

621.396.676:537.56 742
Mutual Coupling of Two Thin Infinitely Long Slots Located on a Perfectly Conducting Plane in the Presence of a Uniform Plasma Layer—J. S. Yee (Proc. IRE, vol. 49, pp. 1837–1845; December, 1961.) An analytical investigation of the effects of a plasma sheath on the admittance parameters of slot antennas on re-entry vehicles.

621.396.676:537.56 743
Antenna Noise Temperature in Plasma Environment—M. P. Bachynski, I. P. French, and G. G. Cloutier. (Proc. IRE, vol. 49, pp. 1846–1857; December, 1961.) The total noise power at a receiving antenna on a hypersonic space vehicle is determined by considering the enveloping plasma sheath as a uniform slab. Noise emission from the plasma is treated as a boundary-value problem and the effect of other noise sources is included.

621.396.676:629.19 744
A Note on Antenna Breakdown—E. L. Tarca. (Proc. IRE, vol. 49, p. 1964; December, 1961.) A note on the relative importance of breakdown and recovery characteristics with reference to experiences with Titan, Atlas and Thor missiles.

621.396.676.2 745
Input Impedance and Gain Function of a Notch Antenna—T. Yoneyama and Y. Mushiake. (*Sci. Repts. Res. Insts. Tokoku Univ., Ser. B.*, vol. 13, no. 1, pp. 55–63; 1961.) The input resistance of a unipole antenna which is an analog of a notch antenna is calculated to a higher accuracy than that of previous work [1555 of 1955 (Johnson)]. Babinet's principle is applied to obtain the input impedance of the notch antenna.

621.396.677.3:621.396.965 746
Electronic Sector-Scanning Array—V. G. Welsby. (*Electronic Tech.*, vol. 39, pp. 13–18; January, 1962.) The two-element multiplicative array described earlier (2094 of 1961) can be scanned by introducing a time-varying delay in one channel. A method is detailed for producing the delay by auxiliary frequency modulation applied to the received waveform, which is then passed through a ladder network having a quadratic phase/frequency characteristic.

621.396.677.73 747
Jelly-Roll Shape shrinks Horn Antenna—L. L. Oh and C. D. Luden. (*Electronics*, vol. 34, pp. 38–39; November 3, 1961.) A compact microwave antenna derived from a horn.

621.396.677.73 748
A Theory of Receiving Aerials applied to the Re-radiation of an Electromagnetic Horn—D. Midgley. (*Proc. IEE*, pt. B, vol. 108, pp. 645–650; November, 1961.) Experimental and theoretical re-radiation polar diagrams are compared for the H plane of a rectangular pyramidal horn. A distinction is made between scattering and reradiation. Application of the theory to receiving antennas in general is discussed. See 1345 of 1947 (Pippard, *et al.*).

621.396.679.4:621.372.8 749
The Measurement of Feeder Irregularities by means of Pulses—R. Rowland. (*Marconi Rev.*, vol. 24, no. 143, pp. 182–195; 1961.) "A method of locating and measuring impedance irregularities in microwave antenna feeders is described. Some results of field use are reported. The sensitivity of the method is such that irregularities of the order of 0.03 db SWR may be measured."

AUTOMATIC COMPUTERS

681.142:537.312.62 750
Superconductive Computers—T. Maguire. (*Electronics*, vol. 34, pp. 45–51; November 24, 1961.) Factors involved in present and future use of superconductive components are assessed. New approaches to the design of superconductive storage systems are reviewed.

681.142:621.318.38 751
Forming Semi-Permanent Memories with Metal Card Storage—J. Yamato and Y. Suzuki (*Electronics*, vol. 34, pp. 136–141; November 17, 1961.) "Presence or absence of a metal shield between two closely spaced coils has a large effect on their mutual inductance. The principle is used to build a read-only memory whose content is determined by thin metal cards."

681.142:621.318.57 752
The Transfluxor as Analogue Storage Device—G. F. Haass. (*Nachrtech. Z.*, vol. 15, pp. 410–415; August, 1961.)

681.142.001.4 753
Tentative Recommendations for the Defi-

nition and Testing of the Dynamic Performance of Analogue-to-Digital Converters—W. M. Gaines and P. P. Fischer. (*Commun. and Electronics*, no. 56, pp. 387–393; September, 1961. Discussion, pp. 393–394.) Methods of classifying, specifying and testing shaft-position and analog-voltage digital converters are suggested.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.004.6:629.19 754
The Reliability of Components in Satellites—G. W. A. Dummer. (*J. Brit. IRE*, vol. 22, pp. 457–463; December, 1961.) The effects of the special hazards on component design and development for space vehicles are reviewed.

621.3.072.9:621.397.62 755
New Phase- and Frequency-Comparison Circuits—G. G. Gassmann. (*Arch. elekt. Übertragung*, vol. 15, pp. 359–376; August, 1961.) A method is described for producing a rectified voltage which is a function of the phase and frequency difference of two alternating voltages. It is particularly suitable for pulse-shaped waveforms, and its application for synchronizing systems, *e.g.*, in television receivers, is examined in detail.

621.316.84:539.23 756
Vacuum-Deposited Metal Film Resistors—G. Siddall and B. A. Probyn. (*Brit. J. Appl. Phys.*, vol. 12, pp. 668–674; December, 1961.) Detailed description of the problems and procedure involved in the production and testing of film resistors.

621.316.86.001.4 757
Noise Performance in Tin Oxide Resistors—J. G. Curtis. (*Electronics*, vol. 34, pp. 100–103 November 10, 1961.) Noise measurements show up resistor defects not found by standard tests.

621.318.4.042.1:621.318.57 758
On the Process of Flux Reversal in Multi-aperture Ferrite Cores—I. H. Rowe and G. R. Slemon. (*Commun. and Electronics*, no. 56, pp. 431–438; September, 1961.) Experimental results for two-aperture cores are presented and a model is suggested to represent the flux state within a two-aperture core for various winding-circuit combinations.

621.319.43:621.382.23 759
Silicon Junction Diodes as Variable Capacitors—J. Registrar. (*Elec. Engrg.*, vol. 33, pp. 783–787; December, 1961.) Expressions are given defining barrier width and junction capacitance, and methods of measuring the latter are suggested. Various applications of diode capacitors are described; the temperature dependence of the capacitance is a handicap.

621.372.412.001.4 760
Resistance and Frequency Variations due to Unwanted Modes in Quartz Crystals—N. Lea. (*Marconi Rev.*, vol. 24, pp. 172–181; 1961.) A numerical relation is shown to exist between the peak resistance increase and peak frequency departure caused by an unwanted mechanically coupled mode. The value provides a useful means of estimating frequency departures and determining whether a particular crystal is satisfactory.

621.372.45 761
Circuits with Nonlinear Resistance—A. Liebetegger.—(*Electronic Tech.*, vol. 39, pp. 18–22; January, 1962.) An extension of the study of series circuits with diodes (687 of 1956) to the behavior of parallel combinations of circuit elements, each circuit containing a diode as a nonlinear resistance.

621.372.54 762
The Calculation of the Numerical Values of the Elliptic Functions for Tchebycheff-Type Filters—G. Bosse. (*Frequenz*, vol. 15, pp. 249–253; August, 1961.) Formulas suitable for handling by automatic computers are derived for the solution of Jacobi's elliptic functions.

621.372.6 763
Restrictions on the Natural Frequencies of an *RC-RL* Network—D. A. Calahan. (*J. Franklin Inst.*, vol. 272, pp. 112–133; August, 1961.) Theory is developed suitable for application in the synthesis of passive and active networks.

621.373.44:621.382.23 764
Tunnel Diodes for Low-Level Triggers—Samaun. (*Electronics*, vol. 34, pp. 52–53; November 24, 1961.) A sensitive low-level circuit uses a tunnel diode to drive a Schmitt trigger.

621.374.3 765
Simulating Nerve Networks with Four-Layer Diodes—A. J. Cote, Jr. (*Electronics*, vol. 34, pp. 51–53; October 13, 1961.) A note on the operation of a neuristor model. (See 4044 of 1961.

621.374.4:621.382.2 766
Efficiency of Frequency Multipliers using Charge-Storage Effect—D. J. Roulston. (Proc. IRE, vol. 49, pp. 1961–1962; December, 1961.) In general, highest efficiency is obtained by cascading lower-order multipliers based on the depletion-layer effect, but the power rating of the charge-storage type is considerably higher.

621.374.4:621.382.23 767
A Tunnel-Diode Wide-Band Frequency-Doubling Circuit—F. D. Neu. (Proc. IRE, vol. 49, pp. 1963–1964; December, 1961.)

621.374.4:621.387 768
Generation of Microwave Harmonics in an Electrodeless Discharge at Low Pressure—C. B. Swan. (Proc. IRE, vol. 49, pp. 1941–1942; December, 1961.) Methods of producing RF harmonic power in an ionized gas are reviewed, and an experimental arrangement is described which shows improved efficiency at a fundamental wavelength of 10 cm.

621.375.9:538.569.4 769
Three-Level Maser Action in Gas: Part 1—Theory of Multiple Quantum Transition and Doppler Effect in Three-Level Gas Maser—Yajima. (See 812.)

621.375.9:538.569.4 770
Cross-Relaxation Effects in a Ruby-L-Band (1440-Mc/s) Maser at Low Magnetic Fields—G. S. Bogle and F. F. Gardner. (*Aust. J. Phys.*, vol. 14, pp. 381–402; September, 1961.) The reversals of maser behavior on cooling from 80 to 4°K are explained in terms of cross-relaxation transitions involving triple spin-flips.

621.375.9:621.372.44 771
Parametric Circuits with Nonlinear Inductances in the Lower Frequency Range—K. H. Steiner, R. Elsner and L. Pungs. (*Frequenz*, vol. 15, pp. 241–249; August, 1961.) Extension of earlier analysis [3303 of 1961 (Steiner)] to cover nonlinear inductances, and their application in amplifiers, up-converters and down-converters. Results of experiments using a ferrite core as nonlinear element at AF are discussed.

621.375.9:621.372.44 772
A Travelling-Wave Variable-Reactance-Type Parametric Amplifier—S. J. Tetenbaum, F. A. Olson, and A. Savarin. (*G. T. and E. Res. Dev. J.*, vol. 1, pp. 60–67; July, 1961.) A full description of the amplifier previously noted in 3308 of 1961.

621.375.9:621.372.44 773
A Resonant-Slot Parametric Amplifier—J. W. Amoss and G. P. Rodrigue. (Proc. IRE, vol. 49, p. 1939; December, 1961.) Brief description of a varactor-diode amplifier for operation in the range 4.3–4.9 Gc.

621.375.9:621.372.44 774
An Extremely-Wide-Band Tunable S-Band Parametric Amplifier—M. Grace. (Proc. IRE, vol. 49, p. 1940; December, 1961.) The range covered is 2.1–3.1 Gc by mechanically tuning the pump circuit and shifting the frequency of the pump source. By the latter means alone the amplifier can be tuned over a 260-Mc band.

621.375.9:621.372.44:621.385.63 775
A D.C.-Pumped Amplifier with a Two-Dimensional Field Structure—(See 1101.)

621.375.9:621.382.23 776
Stability Criteria for a Tunnel-Diode Amplifier—H. Boyet, D. Fleri, and C. A. Renton. (Proc. IRE, vol. 49, p. 1937; December, 1961.) Analysis of a type of circuit also considered by Hines (3305 of 1960).

621.375.9:621.382.23:621.372.632 777
A Tunnel-Diode Frequency Multiplier with Gain—F. S. Barnes and L. Morris. (*Proc. IEE*, vol. 49, pp. 1940–1941: December, 1961.) The multiplier described is based on the nonlinear negative-resistance characteristic of a tunnel diode, and shows a voltage gain for the second and third harmonics.

621.376.23 778
A Simple Phase Detector—G. S. P. Scantlebury. (*Elec. Engrg.*, vol. 33, pp. 803–805; December, 1961.) A phase-sensitive detector is described for use when the reference and variable signals have a common terminal.

621.376.233.029.64/.65 779
Crystal Detectors to Cover the Frequency Band 26–40 Gc/s—H. V. Shurmer. (*Proc. IEE*, pt. B, vol. 108, pp. 659–665; November, 1961.)

621.376.4.029.4 780
An Audio-Frequency Phase Modulator using Pulse Techniques—W. D. Humpage. (*Elec. Engrg.*, vol. 33, pp. 772–777; December, 1961.) The range of phase shift of the 1.592 kc carrier is 450°, and departure from linearity, as a function of the magnitude of modulation input, is less than 1 per cent.

GENERAL PHYSICS

537.291+538.691 781
The Movement of Charge Carriers in Gases with Crossed Electric and Magnetic Fields—W. O. Schumann. (*Z. angew. Phys.*, vol. 13, pp. 353–355; August, 1961.) The cases discussed are a) static magnetic field with alternating electric field at right angles, b) both fields static, and c) both fields alternating synchronously.

537.311.1 782
Theory of Impurity Resistance in Metals: Part 2—J. S. Langer. (*Phys. Rev.*, vol. 124, pp. 1003–1010; November 15, 1961.) The many-body theory developed in a previous paper (1117 of 1961) is extended to include all corrections resulting from electron-electron interactions.

537.311.3 783
Self-Trapping of an Electron by the Acoustical Mode of Lattice Vibration: Part 1—Y. Toyozawa. (*Progr. Theoret. Phys.*, vol. 26, pp. 29–44; July, 1961.) When the coupling constant between the electron and acoustic mode

vibration exceeds a critical value, the effective mass of the electron increases discontinuously and the electron takes a localized self-trapping state as an eigenstate.

537.32 784
Transient Effects in Peltier Coolers—A. D. Reich, T. Arai, and J. R. Madigen. (*J. Appl. Phys.*, vol. 32, pp. 2493–2494; November 1961.) Addendum to 1785 and 2532 of 1961.

537.525 785
New Derivation of the Vacuum Breakdown Equation relating Breakdown Voltage and Electrode Separation—A. Maitland. (*J. Appl. Phys.*, vol. 32, 2399–2407; November, 1961.)

537.533 786
Practical Calculation of the Defocusing Influence of the Space Charge: Application to Relativistic Electron Beams—A. Septier. (*J. Phys. Radium*, vol. 22, Suppl. to *Phys. Appl.*, no. 6, pp. 79A–82A; June, 1961.)

537.533:537.56 787
Interaction of a Modulated Electron Beam with a Plasma—G. D. Boyd, R. W. Gould, and L. M. Field. (PROC. IRE, vol. 49, pp. 1906–1916; December, 1961.) Report on theoretical and experimental investigations of the interaction between a microwave-modulated electron beam and a mercury-arc discharge, and of the interaction between a modulated electron beam and a slow es wave on a plasma column.

537.56 788
Transport Equations for Plasmas in Strong External Fields—E. Meeron. (*Phys. Rev.*, vol. 124, pp. 308–310; October 15, 1961.) Coupling of plasma particles to a strong electric field can greatly exceed their mutual coupling and this is shown to lead to a Vlasov-type transport equation.

537.56 789
Values of the Transport Coefficients in a Plasma for any Degree of Ionization based on a Maxwellian Distribution—I. P. Shkarofsky. (*Canad. J. Phys.*, vol. 39, pp. 1619–1703; November, 1961.) Values for electrical conductivity for any degree of ionization, steady magnetic field and various electron-neutral collision laws are presented. Other transport coefficients are tabulated. The analysis uses the Fokker-Planck and Boltzmann equations.

537.56 790
Generation and Application of Highly Ionized Quiescent Cesium Plasma in Steady State—J. Y. Wada and R. C. Knechtli. (PROC. IRE, vol. 49, pp. 1926–1931; December, 1961.) Plasma densities $>4\times10^{12}$ ions/cm^3 at greater than 90 per cent ionization have been obtained by the method described.

537.56 791
Plasma Physics—an Elementary Review—M. P. Bachynski. (PROC. IRE, vol. 49, pp. 1751–1766; December, 1961.) A summary of the role of plasma physics in current scientific research. 133 references.

537.56:537.311.37 792
The Electrical Conductivity of a Partially Ionized Gas—D. L. Sengupta. (PROC. IRE, vol. 49, pp. 1872–1876; December, 1961.) Analysis taking account of both electron-neutral particle and Coulomb-type collisions but neglecting the effects of inelastic collisions and a steady magnetic field.

537.56:537.525 793
Oscillations and Noise in Low-Pressure D.C. Discharges—F. W. Crawford and G. S. Kino. (PROC. IRE, vol. 49, pp. 1767–1788; December, 1961.) A review of experimental investigations of oscillations and fluctuations which occur spontaneously or through excitation in low-pressure hot-cathode plasmas. Methods of reducing these effects are discussed. 227 references.

538.115 794
Antiferromagnetic Susceptibility of the Plane Triangular Ising Lattice—M. F. Sykes and I. J. Zucker. (*Phys. Rev.*, vol. 124, pp. 410–414; October 15, 1961.) The antiferromagnetic susceptibility of the plane triangular Ising lattice is calculated, in terms of a power series, for all temperatures.

538.122 795
The Magnetic Field in the Vicinity of Obliquely Magnetized Cylindrical Bodies—G. Faninger and F. Trey. (*Z. angew. Phys.*, vol. 13, pp. 386–388; August, 1961.) The field distribution has been calculated and plotted for three different cases of oblique magnetization.

538.221 796
Magnetization Curve of an Infinite Cylinder—M. W. Muller and A. Wehlau. (*J. Appl. Phys.*, vol. 32, pp. 2448–2450; November, 1961.) Calculations are made for an infinite ferromagnetic cylinder with negative uniaxial anisotropy.

538.3 797
The Reciprocity Theorem of Electromagnetic Theory—P. Poincelot. (*Ann. Télécommun.*, vol. 16, pp. 154–162; July/August, 1961.) An examination of the work of several authors in order to present the theorem in the clearest way with emphasis on the physical hypotheses which are the basis of the principle.

538.3:532.59:537.56 798
Magnetohydrodynamic Waves in Cylindrical Waveguides and Toroidal Resonators—J. Szabo and I. Abonyi. (*Z. Phys.*, vol. 163, pp. 535–538; July 10, 1961.) Investigation of small-amplitude magnetohydrodynamic waves in rectangular and circular waveguides, and of standing waves in a toroidal resonator.

538.561:537.533 799
Radiation from a Modulated Electron Beam with a Plasma Background—P. Parzen. (*J. Appl. Phys.*, vol. 32, pp. 2484–2487; November, 1961.) "Expressions are derived for the electromagnetic radiation of current-modulated electron beams which emerge from a plasma. Simple expressions are derived in the case where the dielectric constant of the plasma is zero or infinity."

538.566:535.42:534.231 800
Diffraction of Electromagnetic Waves by Sound Waves—H. J. Schmitt. (*J. Acoust. Soc. Am.*, vol. 33, pp. 1288–1292; October, 1961.) The diffraction amplitude is calculated from Born's approximation. Results of measurements on microwaves affected by a standing sound wave in oil are given as a function of sound frequency and polarization of the em waves.

538.566:537.56 801
Transmission and Reflection of Electromagnetic Waves at a Plasma Boundary for Arbitrary Angles of Incidence—K. A. Graf and M. P. Bachynski. (*Canad. J. Phys.*, vol. 39, pp. 1544–1562; November, 1961.) A plane EM wave horizontally or vertically polarized incident at an arbitrary angle on a flat plasma boundary is investigated. Numerical results showing variation of attenuation and phase, power entering the plasma, and ellipticity of the reflected wave are presented.

538.566:537.56 802
Some Features of the Transverse Propagation of High-Frequency Waves in a Magnetoactive Plasma—B. N. Gershman. (*Dokl. Akad. Nauk SSSR*, vol. 137, pp. 822–825; April 1, 1961.) Mathematical analysis, based on the kinetic equations of nonrelativistic theory, for a simple case of transverse wave propagation in a uniform plasma located in a constant magnetic field. The effect of electron collisions with other particles is neglected.

538.566:537.56 803
Magneto-ionic Theory for a Fully Ionized Hydrogen Plasma—A. A. Wyller. (*Astrophys. J.*, vol. 134, pp. 718–723; November, 1961.) "The effects of electron-proton and electron-electron collisions on the real refractive index, n, and the absorptivity, $c\kappa/\omega$, are evaluated for electromagnetic wave propagation in a fully ionized hydrogen plasma under the influence of an external magnetic field. The Appleton-Hartree magneto-ionic formula, as generally applied to the solar ionosphere, is retrieved in a limiting case with the conventionally adopted expression for the "effective" electron-proton collision frequency. Electron-electron collisions are significant only in the realm of gyroresonance, where they diminish the absorptivity due to electron-proton encounters."

538.566.029.64:537.523.74 804
Frequency Conversion in a Microwave Discharge—J. R. Baird and P. D. Coleman. (PROC. IRE, vol. 49, pp. 1890–1900; December, 1961.) Analysis of the nonlinearity of a microwave discharge between two closely-spaced parallel plates of dimensions small compared to λ. Parametric amplification in a discharge is briefly considered.

538.566.029.64:537.56 805
Interaction of Microwaves in Gaseous Plasmas Immersed in Magnetic Fields—K. V. N. Rao, J. T. Verdeyen, and L. Goldstein. (PROC. IRE, vol. 49, pp. 1877–1889; December, 1961.) Experimental investigation of the interaction of two or more EM waves guided through a magnetoplasma medium, with particular consideration of EM energy transfer and its effects.

538.567.4:535.321 806
Measurement of the Refractive Index of Lucite by Recoilless Resonance Absorption—L. Grodzins and E. A. Phillips. (*Phys. Rev.*, vol. 124, pp. 774–776; November 1, 1961.) Details are given of a method of modulating the frequency of a monochromatic em wave by varying the optical path length between the source and detector. In the application described, a small frequency shift in 0.86-Å radiation is detected by recoilless resonance absorption.

538.569.4:537.311.31 807
Electron Paramagnetic Resonance for Metals with Two Conduction Bands—T. Murao. (*J. Phys. Soc. Japan*, vol. 16, pp. 1940–1947; October, 1961.)

538.569.4:538.221 808
Ferromagnetic Relaxation: Part 2—The Role of Four-Magnon Processes in Relaxing the Magnetization in Ferromagnetic Insulators—P. Pincus, M. Sparks, and R. C. LeCraw. (*Phys. Rev.*, vol. 124, pp. 1015–1020; November 15, 1961.) The effect of the exchange-induced four-magnon process should be observable in parallel pumping experiments. Four-magnon processes arising from dipole, cubic anisotropy and exchange coupling are not very effective in relaxing the uniform precession. Part 1: 3349 of 1961 (Sparks, *et al.*).

538.569.4:538.221:621.318.134 809
Contribution to the Study of Ferrimagnetic

Resonance Curves—A. J. Berteaud. (*Ann. Télécommun.*, vol. 16, pp. 163–188; July/August 1961.) Theoretical considerations, techniques for measurement of magnetic parameters and results of experiment are discussed. 31 references.

539.569.4:538.221:621.318.134 810
Relaxation Equations for Two-Magnon and Magnon-Phonon Processes in Ferrimagnetic Resonance—P. E. Seiden. (*Phys. Rev.*, vol. 124, pp. 1110–1112; November 15, 1961.) Equations giving the relaxation behavior of the magnetization in the case of ferrimagnetic resonance are derived from quantum-mechanical rate equations for spin-wave magnons.

538.569.4:621.375.9 811
Detection of Spin Magnetization Variation in a Two-Level Maser Oscillator—I. M. Firth and D. Bijl. (*Nature*, vol. 192, pp. 860–861; December 2, 1961.) A neutron-irradiated MgO sample containing about 5×10^{18} spins was mounted in a rectangular "TE_{102}" plastic cavity resonator with field-sweep excitation. Oscillations were detected which established the existence of variations of M_z.

538.569.4:621.375.9 812
Three-Level Maser Action in Gas: Part 1—Theory of Multiple Quantum Transition and Doppler Effect in Three-Level Gas Maser—T. Yajima. (*J. Phys. Soc. Japan*, vol. 16, pp. 1594–1604; August, 1961.) Discussion of the multiple quantum process for the off-resonance condition. The intensity of the emission produced is calculated using perturbation theory as well as the more general Javan's theory. The Doppler effect is analyzed from semiclassical and quantum mechanical viewpoints.

538.569.4:621.375.9:535.61-1/2 813
Lasers: Devices and Systems: Parts 2, 3 and 4—L. Dulberger and S. Vogel. (*Electronics*, vol. 34, pp. 40–44, 81–85 and 54–57; November 3, 10, and 24, 1961.) An illustrated review covering a) communications, range-finding and detection; b) military and computing applications and methods of modulation; c) scientific, medical and other devices. Part 1: 462 of February (Vogel and Dulberger).

538.569.4:621.375.9:535.61-1/2 814
Proposed Harmonic Generator or Mixer for Optical Frequencies—K. D. Froome. (*Nature*, vol. 192, pp. 859–860; December 2, 1961.) Limitations of the mixer suggested by Laine (3733 of 1961) are discussed and a simpler alternative device using liquid caesium is described.

538.569.4:621.375.9:535.61-2 815
Observation of Optical Maser Oscillation in Ruby—K. Kubota and K. Hayashi. (*J. Phys. Soc. Japan*, vol. 16, p. 2063; October, 1961.) A note on experimental results obtained using multiple dielectric layers as mirrors in the maser cavity.

538.569.4:621.375.9:535.61-2 816
Mode Characteristics and Coherence in Optical Ruby Masers—I. D. Abella and C. H. Townes. (*Nature*, vol. 192, pp. 957–959; December 9, 1961.) A discussion of a series of interference experiments in which oscillations are shown to occur at several different frequencies corresponding to various numbers of half-wavelengths between the reflecting ends of the ruby.

538.569.4:621.375.9:535.61-2 817
A Ruby Laser Exhibiting Periodic Relaxation Oscillations—R. E. Johnson, W. H. McMahan, F. J. Oharek, and A. P. Sheppard. (PROC. IRE, vol. 49, pp. 1942–1943; December, 1961.) The relaxation oscillations generated by the optical maser described may make it useful for ranging applications.

538.569.4:621.375.9:535.61-2 818
Design of a Helium-Neon Gaseous Optical Maser—C. F. Luck, R. A. Paananen, and H. Statz. (PROC. IRE, vol. 49, pp. 1954–1955; December, 1961.) Constructional details of the optical maser described in 1812 of 1961 (Javan, *et al.*).

538.569.4:621.375.9:535.61-2 819
Coherent Light Amplification in Optically Pumped Cs Vapour—S. Jacobs, G. Gould, and P. Rabinowitz. (*Phys. Rev. Lett.*, vol. 7, pp. 415–417; December 1, 1961.) Using the strong He 3888-Å line to produce a population inversion in the Cs vapor, a gain of 6 per cent is predicted for a 90-cm cell.

538.569.4:621.375.9:535.61-2 820
Signal-to-Noise Ratios in Photoelectric Mixing—B. M. Oliver. (PROC. IRE, vol. 49, pp. 1960–1961; December, 1961.) The possibility of using photoelectric mixing for the linear amplification and frequency conversion of coherent optical signals is considered.

538.614:535.854 821
A New Application of the Faraday Magneto-optical Effect for Diagnostic Measurements of Transient Magnetic Fields—R. D. Medford, W. H. W. Fletcher, J. D. Herbert, and A. L. T. Powell. (*Nature*, vol. 192, pp. 622–624; November 18, 1961.) By a combination of streak and optical interference fringe techniques with the magneto-optical method described, it is possible to determine field geometry, space time distribution of electron number density in a high-density plasma and line-integrated variations of magnetic field.

538.69:537.525 822
Radio-Frequency Discharges in Magnetic Fields—F. Bisi and B. De Michelis. (*Nuovo Cim.*, vol. 17, pp. 343–354; August 1, 1960. In English.) Report on investigations of discharges in A with the magnetic field normal to the RF electric field.

538.691 823
Drift Velocity of a Charged Particle in an Inhomogeneous Magnetic Field—J. Hurley. (*J. Appl. Phys.*, vol. 32, pp. 2368–2369; November, 1961.) A class of magnetic fields is defined for which the drift velocity may be calculated exactly.

539.2 824
Energy-Band Structure of Solids from a Perturbation on the 'Empty Lattice'—F. Bassani and V. Celli. (*J. Phys. Chem. Solids*, vol. 20, pp. 64–75; June, 1961.)

539.2:538.2 825
Instability of Antiferromagnetic Screw-type Structure of an Electron Gas—A. Yoshimori. (*Phys. Rev.*, vol. 124, pp. 326–328; October 15, 1961.) An analysis by the self-consistent field method of a screw-type structure in a free electron gas such as that proposed by Overhauser (3068 of 1960) proves that it is always unstable. The susceptibility of such a gas is also derived by the same method.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.164 826
On the Origin of Radio Emission from Cosmic Clouds—P. F. Browne. (*Astrophys. J.*, vol. 134, pp. 963–969; November, 1961.) The balance between absorption and stimulated emission for free-free transitions in a gas plasma can lead to a negative as well as a positive "effective" absorption coefficient and hence to amplification of the spontaneous emission.

523.164 827
The Australian National Radio Astronomy Observatory—(*Nature*, vol. 192, pp. 1019–1021; December 16, 1961.) A brief description of the inauguration of the observatory at Parkes, N.S.W., and of its first instrument, a 210-ft steerable paraboloid.

523.164:621.396.677 828
Report of the Advisory Panel on Radio Telescopes—G. Keller. (*Astrophys. J.*, vol. 134, pp. 927–939; November, 1961.) Special reference is made to the feasibility and cost of constructing a 1-ft beam antenna operating at 1420 Mc.

523.164:621.396.677 829
Operation at the Medicina Station of a 327-Mc/s Radio-Telescope—A. Braccesi, M. Ceccarelli, G. Mannino, G. Setti, and G. Sinigaglia. (*Nuovo Cim.*, vol. 17, pp. 614–615; August 16, 1960. In English.) A description of an interferometer-type radiotelescope which consists of a cylindrical parabolic antenna, 110-m long and 6.7-m wide, at the focus of which are 112 full-wave dipoles.

523.164.3 830
A Radio Survey of the Galactic Plane at a Frequency of 408 Mc/s: Parts 1 and 2—M. I. Large, D. S. Mathewson, and C. G. T. Haslam. (*Monthly Notices Roy. Astron. Soc.*, vol. 123, no. 2, pp. 113–132; 1961.) Of 51 discrete sources observed, most lie within $\frac{1}{4}°$ of the galactic plane, and about 70 per cent are thermal. Continuum observations show large scale features which can be interpreted in terms of a spiral model of the galaxy if independent distributions for thermal and nonthermal emission are postulated.

523.164.3 831
Recent Decametre-Wavelength Observations of Jupiter, Saturn and Venus—T. D. Carr, A. G. Smith, H. Bollhagen, N. F. Six, Jr, and N. E. Chatterton. (*Astrophys. J.*, vol. 134, pp. 105–125; July, 1961.) Observations made during 1959–1960 show that only Jupiter appears to emit extensive nonthermal radio noise.

523.164.3 832
Presence and Correlation of Fine Structure in Jovian Decametric Radiation—J. N. Douglas and H. J. Smith. (*Nature*, vol. 192, p. 741; November 25, 1961.) Results obtained from spaced-receiver observations of noise storms of Jupiter showed correlation of fine-structure components having durations of the order of hundredths of a second for receiving sites 100-km apart.

523.164.32 833
Solar Emission at Millimetre Wavelengths—C. W. Tolbert and A. W. Straiton. (*Astrophys. J.*, vol. 134, pp. 91–95; July, 1961.) Solar flux density measurements at mm λ indicate that the radiation is primarily from the photosphere and corresponds to the thermal radiation from a black body at 6000°K.

523.164.32 834
Some Solar Studies on the Occurrence of Type IV Solar Bursts of Continuum Radiation—M. R. Kundu. (*Astrophys. J.*, vol. 134, pp. 96–104; July, 1961.) Type IV solar emission in the frequency range 25–580 Mc occurs in two phases, the first usually observed at frequencies higher than 250 Mc, appears to be emitted low in the chromosphere from a source of angular size $<4'$. The second occurs high in the corona with a source size $10'$ or more.

523.164.32 835
Thermal Radio Emission from the Transition-Layer Chromosphere-Corona—C. C. Brooks and L. Oster. (*Astrophys. J.*, vol. 134, pp. 940–944; November, 1961.) Two models of the transition layer [see *Z. Astrophys.*, vol. 40, pp. 28–64; July 18, 1956. (Oster)] are computed using new values of emission and absorption coefficients. Comparison with recent observations shows that the models predict decimetre-wave emission with reasonable accuracy. See also *ibid.*, pp. 1010–1012.

523.164.32 836
The Radio Brightness Distribution on the Sun at 21 cm from Combined Eclipse and Pencil-Beam Observations—T. Krishnan and N. R. Labrum. (*Aust. J. Phys.*, vol. 14, pp. 408–419; September, 1961.) Radio bright regions appear to overlie the optical plages faculaires at a height of about 70,000 km and show similarity in size, shape and relative intensity. A higher peak temperature and gradient for the limb brightening was revealed.

523.164.32:523.75 837
The Spectral Components of 150 Major Solar Radio Events (1952–1960)—J. A. Boorman, D. J. McLean, K. V. Sheridan, and J. P. Wild. (*Monthly Notices Roy. Astron. Soc.*, vol. 124, no. 2, pp. 87–96; 1961.) Characteristics of solar radio events are listed together with the associated flare and ionospheric data; the distribution of storm-associated flares over the sun, and the variation of storm occurrence with sunspot cycle, are noted.

523.164.4 838
Observations of Radio Sources at 1.8 cm Wave-length—A. H. Barrett. (*Astrophys. J.*, vol. 134, pp. 945–958; November, 1961.) Observations of radiation from Cas A, Tau A, Orion nebula, M 17, and Cyg A are described.

523.164.4 839
Stimulated Emission of the 3.04-cm Fine-Structure Line of Hydrogen in Diffuse Nebulae—C. B. Field and R. B. Partridge. (*Astrophys. J.*, vol. 134, pp. 959–962; November, 1961.)

523.164.4 840
Radio Sources and Clusters of Galaxies—S. van den Bergh. (*Astrophys. J.*, vol. 134, pp. 970–974; November, 1961.) The result is given of a comparison of positions of radio sources in the "3C" catalog with positions of rich clusters of galaxies. See also 850 of 1961 (Mills).

523.165 841
A Note on the Unusual Variations of Cosmic-Ray Intensity during the Period 1960 November 10 to 16—T. Mathews, T. Thambyal pillai, and W. R. Webber. (*Monthly Notices Roy. Astron. Soc.*, vol. 123, pp. 97–111; 1961.) Unique features of cosmic-ray observations are described, including effects on the earth's magnetic field and effects produced by the interplanetary magnetic field. Well-defined solar-particle trapping regions appear to exist in the inner solar system. The preferential arrival of particles from directions well to the west of the sun is discussed.

523.165 842
An Analysis of the Solar Daily Variations of the Primary Cosmic Radiation Measured with the I.G.Y. Neutron Monitor Network—L. A. de Moura, G. Schwachheim, and E. R. Willner. (*Ann. Acad. Bras. Sci.*, vol. 33, pp. 141–148. June 30, 1961. In English.) The results of a harmonic analysis of monthly averaged data from world-wide monitoring stations show no asymmetry in amplitude or time of maximum for the northern and southern hemispheres.

523.165 843
Diurnal Variation and Forbush Decrease—D. Cattani, M. Galli, and P. Randi. (*Nuovo Cim.*, vol. 21, pp. 923–934; September 16, 1961. In English.) An examination of the depressions which often precede the largest Forbush-type decreases by less than 24 h.

523.165 844
The Primary Cosmic-Ray Electron Flux during a Forbush-Type Decrease—P. Meyer and R. Vogt. (*J. Geophys. Res.*, vol. 66, pp. 3950–3952; November, 1961.) Balloon observations indicate a decrease of 40 per cent in the electron flux during a Forbush decrease. It is suggested that the primary electrons are of galactic and not of solar origin.

523.165 845
Spatial Distribution of Electrons from Neutron Decay in the Outer Radiation Belt—W. N. Hess and J. Killeen. (*J. Geophys. Res.*, vol. 66, pp. 3671–3680; November, 1961.) The spatial distribution of electrons in the outer radiation belt is calculated theoretically assuming as a source the β-decay products of albedo neutrons. There is moderate agreement with satellite results.

523.165 846
Coordinates for Mapping the Distribution of Magnetically Trapped Particles—C. E. McIlwain. (*J. Geophys. Res.*, vol. 66, pp. 3681–3691; November, 1961.)

523.165:551.507.362.1 847
Measurements of Cosmic Rays on Geophysical Rockets—Yu. G. Shafer and A. V. Yarygin. (*Isk. Sput. Zemli*, no. 4, pp. 184–194; 1960. English trans. *Planet-Space Sci.*, vol. 8, pp. 165–172; December, 1961.) The rocket equipment and the results obtained during one flight are described.

523.3:621.396.96 848
Radio-Wave Scattering from the Lunar Surface—V. A. Hughes. (*Proc. Phys. Soc.*, vol. 78, pp. 988–997; November 15, 1961.) Measurements on the angular scattering properties of the lunar surface at 10 cm λ are described. For angles of incidence 3–13° at least, scattering is independent of λ over the range 10 cm–1.5 m.

523.3:621.396.96 849
The Radar Cross-Section of the Moon—T. B. A. Senior and K. M. Siegel. (PROC. IRE, vol. 49, pp. 1944–1945; December, 1961.) Reply to criticism [see 3079 of 1960 (Hughes) and 4155 of 1961 (Hayre)] of the theory of scattering from the moon's surface proposed in 3826 of 1960.

523.746 850
Magnetohydrodynamic Interpretation of Sunspot Activity—M. Steenbeck. (*Mber. Dtsch. Akad. Wiss. Berlin*, vol. 2, pp. 497–499; 1960.)

523.746.5 851
Sunspot Cycles—T. W. Bennington. (*Wireless World*, vol. 68, pp. 86–90; February, 1962.) A discussion of problems met in attempting to forecast sunspot conditions. A simple analysis is made of data from the 18 complete cycles so far recorded.

550.38:551.510.536 852
The Theory of Electric Currents in the Magnetosphere—O. Lucke and C. U. Wagner. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, pp. 463–468; 1960.) In the brief theoretical treatment given the plasma of the magnetosphere is replaced by a particle gas with diamagnetic properties.

550.38:629.19 853
Interaction of West Ford Needles with the Earth's Magnetosphere and their Lifetime—S. F. Singer. (*Nature*, vol. 192, p. 1061; December 16, 1961.) A discussion of the effects of the charge built up on the needles passing through the magnetosphere. The uncertainty of the lifetime of the needles is illustrated by calculations showing that they may reenter the atmosphere in any period from a few months to a century.

550.385.3 854
Rapid Geomagnetic Fluctuations—S. Haraldson. (*Tellus*, vol. 13, pp. 432–437; August, 1961.) An investigation of oscillations at 0.2–200 cps in the earth's magnetic field measured in the archipelago of Stockholm between July, 1957 and June, 1959.

550.385.4 855
Formation of the Geomagnetic Storm Main-Phase Ring Current—A. J. Dessler, W. B. Hanson, and E. N. Parker. (*J. Geophys. Res.*, vol. 66, pp. 3631–3637; November, 1961.) The main-phase ring current is supposed to be generated by heating the exospheric gas by hydromagnetic shock waves. The more energetic component consists of keV protons. A flux $\sim 3 \times 10^5$ hydrogen atoms/cm^2 sec^{-1} should be observed at the base of the exosphere and the decay time of the ring should be less at sunspot minimum than at sunspot maximum by a factor of three.

550.385.4 856
Spectrum of Hydromagnetic Waves in the Exosphere—G. J. F. MacDonald. (*J. Geophys. Res.*, vol. 66, pp. 3639–3670; November, 1961.) The influence of the earth's gravitational field on hydromagnetic wave propagation is discussed and the limiting conditions for the propagation of the various modes in the exosphere are considered.

550.385.4 857
Travelling Pressure Waves Associated with Geomagnetic Activity—P. Chrzanowski, G. Greene, K. T. Lemmon, and J. M. Young. (*J. Geophys. Res.*, vol. 66, pp. 3727–3733; November, 1961.) Records obtained at Washington, D.C., frequently indicate the occurrence of traveling pressure waves with periods of 20–80 sec during intervals of high geomagnetic activity.

550.385.4:551.510.536 858
Variations of the Earth's Exosphere and Geomagnetic Disturbances during the Geomagnetic Storm of 4 September 1958—T. Ondoh. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 233–254; December, 1961.) Geomagnetic data and observations on trapped particles in the outer radiation belt have been studied and a simple model of the state of the exosphere during the main phase of the storm has been proposed. 46 references.

551.507.362+629.19]:621.38 859
Missile and Space Electronics—J. F. Mason and M. F. Wolff. (*Electronics*, vol. 34, pp. 87–118; November 17, 1961.) Applications of electronics in future NASA space projects are described. A schedule of launchings for the next eight years is given. 56 references.

551.507.362.2 860
Determination of Illumination Conditions and Periods of an Artificial Satellite in Shadow and in Sunlight—I. M. Yatsunkil. (*Isk. Sput. Zemli*, no. 4, pp. 35–42; 1960. English trans., *Planet-Space Sci.*, vol. 8, pp. 159–164; December, 1961.) A method of determining the illumination conditions of a satellite is described and a brief analysis of the paths of the first three Soviet satellites is given.

551.507.362.2 861
Influence of the Earth's Oblateness on the

Rotational Motion of an Artificial Satellite—V. A. Sarychev. (*Isk. Sput. Zemli*, no. 6, pp. 3–10; 1961. English trans., *Planet-Space Sci.*, vol. 8, pp. 173–178; December, 1961.) The equations of motion are set up and the small oscillations of the satellite relative to the orbital system of coordinates are studied.

551.507.362.2 862

Variations in the Positive-Ion Concentration with Altitude from Data of Mass-Spectrometry Measurements on the Third Satellite—V. G. Istomin. (*Isk. Sput. Zemli*, no. 6, pp. 127–131; 1961. English trans., *Planet-Space Sci.*, vol. 8, pp. 179–182; December, 1961.) Mass-spectrometer measurements of the O^+ ion concentration are compared with measurements of electron concentration obtained from radio observations of the first and third Soviet satellites and with measurements of positive-ion concentration obtained with positive-ion traps installed on the third Soviet satellite.

551.507.362.2 863

Irregularities in Atmospheric Densities Deduced from Satellite Observations—L. G. Jacchia. (*Ann. Géophys.*, vol. 17, pp. 273–276; July–September, 1961. In English.) Results of observations of atmospheric drag on satellites indicate a) a pronounced diurnal bulge lagging 2 h behind the subsolar point, b) erratic fluctuations of the atmosphere above 200 km due to SW solar radiation and c) irregular perturbations of the upper atmosphere associated with magnetic storms.

551.507.362.2 864

A Theoretical Model of Temperature Variations at the Surface of an Orbiting Satellite—H. H. Lettau. (*J. Geophys. Res.*, vol. 66, pp. 3693–3698; November, 1961.)

551.510.53 865

Winds in the Upper Atmosphere—J. S. Greenhow and E. L. Neufeld. (*Quart. J. R. Met. Soc.*, vol. 87, pp. 472–489; October, 1961.) Results are given of a five-year study (1953–1958) of winds at heights of 85–100 km, obtained from radar observation of ionized meteor trails. Diurnal and seasonal variations are described in detail.

551.510.53:621.396.96 866

Radar Investigations of the Upper Atmosphere—J. S. Greenhow and C. D. Watkins. (*J. Brit. IRE*, vol. 22, pp. 477–480; December, 1961.) The parameters of the radar transmitters to be used with the two 25-m parabolic reflectors at Defford, near Malvern, are given and possible experimental investigations of ionization are discussed.

551.510.535 867

A Working Model for the Upper Atmosphere—L. G. Jacchia. (*Nature*, vol. 192, pp. 1147–1148; December 23, 1961.) The validity of a model by Nicolet is examined and some comparisons made with that of proposed earlier (182 of 1961).

551.510.535 868

Fluctuations of Electron Density in the Ionosphere—E. A. Novikov. (*Dokl. Ak. Nauk SSSR*, vol. 139, pp. 587–589; July 21, 1961.) Discussion of turbulent fluctuations in the lower ionosphere, where the frequency of ion collisions with neutral particles is large compared to the Larmor frequency.

551.510.535 869

Theory of Electrostatic Fields in the Ionosphere at Polar and Middle Geomagnetic Latitudes—D. T. Farley, Jr. (*J. Geophys. Res.*, vol. 66, pp. 3956–3957; November, 1961.) Discussion of paper by Spreiter and Briggs (3393 of 1961) and criticism of Dagg's theory of the formation of irregularities in the F region (1420 of 1958).

551.510.535 870

Two Methods of Detecting Ionospheric Disturbances—G. A. M. King and M. D. Lawden. (*J. Geophys. Res.*, vol. 66, pp. 3962–3963; November, 1961.) Describes rapid visual methods for detecting *F*-region disturbances by the distortion of $h'(f)$ traces on ionograms.

551.510.535 871

Simultaneous Study of Drifts at Different Levels in the Ionosphere by the Spaced-Receiver Method—E. B. Rao and B. R. Rao. (*J. Brit. IRE*, vol. 22, pp. 507–510; December, 1961.) By comparing drift speeds in the F2, F1 and Es regions, the effect of a lower layer on upper-layer drift measurements is deduced, and drift gradients are estimated.

551.510.535 872

The Varying Electron Density Profile of the F Region during Magnetically Quiet Nights—W. Becker. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 275–289; December, 1961.) Local height changes of about 60 km lasting for 2 h are illustrated. The general increase in height before midnight, and the presunrise decrease, are found to be independent of season. Severe vertical movements induced by a magnetic bay were not accompanied by spread echoes.

551.510.535 873

The Heat Balance of the F Region and the Saturation Effect—C. H. Cummack. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 298–302; December, 1961.) As the input of solar ultraviolet radiation to the F region increases with increasing solar activity, the volume rate of production of ionization increases to a certain point and thereafter decreases.

551.510.535:523.3 874

The Morphology of Lunar Semidiurnal Variation in f_0F2 near Solar Noon—R. G. Rastogi. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 290–297; December, 1961.) Within about 10 per cent of the magnetic equator, the phase of the lunar semidiurnal variation in f_0F2 is almost opposite to that observed elsewhere. The amplitude of the variation is greatest at the equator and near magnetic latitudes $\pm 20°$, where it is about 4 per cent of f_0F2.

551.510.535:523.746 875

Further Evidence of a Long-Term Variation in the Relationship of Solar Activity to the Ionosphere—R. Naismith and P. A. Smith. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 270–274; December, 1961.) There is evidence that, since 1938, there has been a decrease in the amount of ionization in the F2 layer for a given sunspot number. A similar conclusion was reached for the E layer [2968 of 1961 (Naismith, *et al.*)].

551.510.535:539.16:534.2 876

Round-the-World Sound Waves Produced by the Nuclear Explosion on October 30, 1961, and their Effect on the Ionosphere at Sodankylä—G. Rose, J. Oksman, and E. Kataja. (*Nature*, vol. 192, pp. 1173–1174; December 23, 1961.) Microbarograph and ionosonde recordings of the explosion are described. Disturbances due to direct traveling waves and round-the-world waves were detected on each instrument.

551.510.535:550.385.4 877

Increase of Ionization Associated with Geomagnetic Sudden Commencements—S. Matsushita. (*J. Geophys. Res.*, vol. 66, pp. 3958–3961; November, 1961.) Increases of cosmic-noise absorption in high latitudes seem to be associated with certain types of storm sudden commencement.

551.510.535:551.507.362.1 878

Measurements of Electron Concentration in the Ionosphere up to Altitudes of 420–470 km, carried out during the International Geophysical Year by means of Radio-Wave Transmissions from the Geophysical Rockets of the Academy of Sciences U.S.S.R.—K. I. Gringauz and V. A. Rudakov. (*Isk. Sput. Zemli*, no. 6, pp. 48–62; 1961. English trans., *Planet-Space Sci.*, vol. 8, pp. 183–193; December, 1961.) The determination of electron density distributions from measurements of radio-wave dispersion and the Faraday effect are examined. The results of three rocket flights to altitudes of 450–470 km in 1958 are described.

551.510.535:621.391.812.63 879

Generalized Appleton-Hartree Equation for any Degree of Ionization and Application to the Ionosphere—I. P. Shkarofsky. (PROC. IRE, vol. 49, pp. 1857–1871; December, 1961.) The equation derived is applicable to any variation of electron collision frequency with electron speed, and any degree of ionization. Results for the ionosphere are compared with experimental data. E layer results can be explained by assuming an electron temperature several times higher than the gas temperature.

551.510.535:621.391.812.63 880

The Absorption of Radio Waves in the Ionosphere with respect to Geomagnetic Current Control and Other Proposed Models—a Critical Survey—J. D. Whitehead. (*Planet-Space Sci.*, vol. 8, pp. 151–156; December, 1961.) A critical survey is given of the work of Appleton and Piggott (3220 of 1954), Shaw (2748 of 1960), Bandyopadhyay (120 of 1958), and Rumi (883 of 1961). Serious errors arise because of the neglect of deviative absorption in the E region.

551.510.536:551.594.6 881

Properties of the Outer Ionosphere Deduced from Nose Whistlers—R. L. Smith. (*J. Geophys. Res.*, vol. 66, pp. 3709–3716; November, 1961.) Analysis of nose-whistler data shows that the electron density in the outer ionosphere is proportional to the geomagnetic field strength, with a 2:1 annual variation.

551.594.5 882

Auroral Investigations during the Winter Seasons 1957/58–1959/60 and their Bearing on Solar Terrestrial Relationships—L. Vegard. (*Geofys. Publik.* (*Oslo*), vol. 22, pp. 1–50; August, 1961. In English.) The results of spectral investigations of auroras at Oslo and Tromsø.

551.594.5 883

Some Results of Investigations of Aurorae and Night Airglow during the I.G.Y. and I.G.C.—V. I. Krasovskii. (*Planet-Space Sci.*, vol. 8, pp. 125–141; December, 1961.) A review of U.S.S.R. results and a discussion of their interpretation.

551.594.5 884

Circular Symmetry in the Geomagnetic Plane for Aurora Phenomena—B. Hultqvist. (*Planet-Space Sci.*, vol. 8, pp. 142–150; December, 1961.) Projections of circles in the geomagnetic equatorial plane on to the earth's surface along the real geomagnetic field lines are compared with published observational data for the northern and southern auroral zones.

551.594.5 885

A Morning Discontinuity in the Orientation of the Quiet Auroral Arcs—B. Hultqvist, A. Egeland, and G. Gustafsson. (*Nature*, vol. 192, pp. 956–957; December 9, 1961.)

551.594.5 886

On the Association of Radio Reflections with Optical Aurora—P. A. Forsyth. (*Canad.*

J. Phys., vol. 39, pp. 1721–1724; November, 1961.) The observations provide no basis for assuming that optical and radio aurora are independent phenomena.

551.594.5:621.396.96 887
The Azimuthal Distribution of Ultra-High-Frequency Radar Echoes from Aurora—P. E. Kelly, D. R. Hansen, and P. A. Forsyth. (*Canad. J. Phys.*, vol. 39, pp. 1535–1543; November, 1961.) Partial analysis in range and azimuth of radar echoes at 448 Mc with 84-ft-diameter paraboloid antennas. Contours of constant echo occurrence are different in the two periods before and after midnight.

551.594.5:621.396.96 888
Determination of Radar Auroral Heights with the Prince Albert Radar—G. E. K. Lockwood. (*Canad. J. Phys.*, vol. 39, pp. 1725–1737; November, 1961.)

551.594.6 889
Measurement of Very-Low-Frequency Atmospherics at Bonn—H. L. König, E. Haine, and C. Antoniadis. (*Z. angew. Phys.*, vol. 13, pp. 364–367; August, 1961.) Report on measurements in the frequency range 0.5–10 cps; close agreement was found with earlier results obtained by König (3519 of 1960).

551.594.6 890
Propagation Characteristics of Whistlers Trapped in Field-Aligned Columns of Enhanced Ionization—R. L. Smith. (*J. Geophys. Res.*, vol. 66, pp. 3699–3707; November, 1961.) Whistler data are examined using ray theory to deduce properties of field-aligned ducts in the outer atmosphere.

551.594.6 891
Electromagnetic Radiation from Solar Corpuscular Streams—M. A. Gintsburg. (*Phys. Rev. Lett.*, vol. 7, pp. 399–401; December 1, 1961.) Some objections are raised to a paper by MacArthur (3311 of 1961) and theory is developed for the case of superlight motion, when the particle velocity is greater than the phase velocity of the emitted waves.

551.594.6:[550.385.4+523.165 892
Correlation between Low-Frequency Radio Noise and Magnetic and Cosmic-Ray Storms—V. Corcuff and J. P. Legrand. (*Ann. Géophys.*, vol. 17, pp. 338–340; July–September, 1961.) Measurements at Poitiers and Limeil show that VLF radio noise starts about 9 h after an SSC a maximum being reached about 18 h after the SSC. The maximum noise occurs at the maximum of cosmic-ray storms.

551.594.6:550.386 893
Geomagnetic Activity and the Reception of Whistlers in Polar Regions—G. McK. Allcock and M. F. Rodgers. (*J. Geophys. Res.*, vol. 66, pp. 3953–3955; November, 1961.) Data on whistler reception at Scott Base, Antarctica, are discussed. The frequency of occurrence of whistlers shows a diurnal variation, and decreases with increasing geomagnetic activity.

551.510.535:550.389.2 894
Some Ionospheric Results obtained during the International Geophysical Year. [Book Review]—W. J. G. Beynon. Publishers: Elsevier, Amsterdam, and Van Nostrand, London, 1960, 401 pp., 72s. (*Nature*, vol. 192, pp. 840–841; December 2, 1961.)

LOCATION AND AIDS TO NAVIGATION

534.88 895
Directional Echo-Sounding—E. A. Howson and J. R. Dunn. (*J. Inst. Nav.*, vol. 14, pp. 348–359; July, 1961.) A two-channel interferometer arrangement is compared with an eight-element hydrophone array with electronic sector scanning. Ambiguities produced in the interferometer display under certain conditions are not present in that of the more complex hydrophone system.

534.88:621.396.965.4 896
An Improved Electronic Sector-Scanning Sonar Receiver—B. S. McCartney. (*J. Brit. IRE*, vol. 22, pp. 481–488; December, 1961.) The dynamic range and channel phase stability are increased by a frequency-sweep remodulation method, and the angular resolution is improved by multiplicative scanning. See also 3615 of 1961 (Welsby).

621.396.933 897
Australian D.M.E. System—(*Proc. IRE, Aust.*, vol. 22, pp. 541–589; September, 1961.) Six papers on the system equipment, the necessity for complete coverage by DME beacons and the influence of the system on developments in air traffic control.

621.396.933.2:621.396.67 898
Principle of Operation of Cage-Type Aerials for Omnidirectional Radio Beacons—Brunswig. (See 741.)

621.396.96 899
Discussion of "Forward Scattering by Coated Objects Illuminated by Short-Wavelength Radar"—J. Fisch: K. M. Siegel and R. E. Hiatt. (PROC. IRE, vol. 49, p. 1951; December, 1961.) Comment on 4255 of 1960 (Hiatt, *et al.*) and reply by two of the authors.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 900
Photoelectric Emission: Surface Effect, Volume Effect—P. Vernier. (*J. Phys. Radium*, vol. 22, pp. 463–464; July, 1961.) Wave-theory treatment of the two effects with reference to polarized light.

535.215 901
The Fundamental Photoelectric Effect of Semiconductors and of Cs_3Sb—A. Meessen. (*J. Phys. Radium*, vol. 22, pp. 472–480; August/September, 1961.) A theory is proposed for both direct and indirect transitions from valence to conduction band. The fundamental effect is separated from secondary effects and new lines of research are suggested.

535.215:535.37 902
A Reaction-Kinetics Model with Five Transitions for Photoconductors and Luminophores—K. W. Böer and J. Voigt. (*Z. Naturforsch.*, vol. 16a, pp. 873–879; September, 1961.) Account is taken of transitions via the conduction as well as the valence band. A comparison is made with experimental results.

535.215:546.48'221 903
Contact-Potential Measurements on CdS Single Crystals—F. Eckart and H. Schulz. (*Z. Phys.*, vol. 164, pp. 83–92; July 20, 1961.) Experimental investigations of work-function changes as a result of differences in surface conditions.

535.215:546.48'221 904
The Problem of Exciton-Induced Photoemission from CdS—W. E. Spicer. (*J. Phys. Chem. Solids*, vol. 20, pp. 134–137; June, 1961.) The results of Shuba (1460 of 1957) which have been interpreted as exciton-induced photoemission, can be adequately explained by a simple exponential distribution of states from which photoelectrons are directly excited by photons.

535.215:546.48'221 905
A Magneto-Stark Effect and Exciton Motion in CdS—D. G. Thomas and J. J. Hopfield. (*Phys. Rev.*, vol. 124, pp. 657–665; November 1, 1961.) Experiments based on the Stark effect are used to determine the velocity of the wave vector and to measure the effective mass of the exciton in CdS from the relation between the velocity and momentum of the exciton.

535.215:546.48'221 906
Photoconductivity of Polycrystalline Cadmium Sulphide Layers—K. V. Shalimova, T. S. Travina, and R. R. Rezvyl. (*Dokl. Akad. Nauk SSSR*, vol. 138, pp. 334–337; May 11, 1961.) Report of an experimental vestigation in the wavelength range 225–700 investigation in the wavelength range 225–700 mμ.

535.215:546.817–31 907
Photoconductive Properties of Lead-Oxide Layers—L. Heijne. (*Philips Res. Repts.*, suppl. no. 4, pp. 1–161; 1961.) A thesis covering the characteristics, properties and applications of the material relating to the development of vidicon-type camera tubes.

535.37:546.47'221 908
The Crystal Structure of Zinc Sulphides—H. Gobrecht, H. Nelkowski, and P. Albrecht (*Z. Naturforsch.*, vol. 16a, pp. 857–860; September, 1961.) Investigation of crystal structure as a function of the conditions of crystal preparation.

535.37:546.47'221 909
The Relationship of Phosphor Properties to Preparative Methods in some ZnS:Cu,Cl Phosphors—F. H. Brown, H. Kallmann and K. Luchner. (*Z. Naturforsch.*, vol. 16a, pp. 879–884; September, 1961. In English.)

535.37:546.47'221 910
The Problem of the Saturation of Luminescence of ZnS Crystals—I. Broser and W. Klein. (*Z. Naturforsch.*, vol. 16a, pp. 894–902; September, 1961.) Investigation of emission intensity as a function of the density of the exciting electron beam, and of temperature in the range 80–450°K.

535.37:546.47'221 911
The Luminescence Properties of ZnS-Cu as a Function of the Method of Preparation—H. Ortmann and H. Hartmann. (*Z. Naturforsch.*, vol. 16a, pp. 903–909; September, 1961.)

535.37:546.47'221 912
Indium as Coactivator in ZnS-Cu Luminophores—G. Wendel. (*Z. Naturforsch.*, vol. 16a, pp. 916–920; September, 1961.) Qualitative analysis of experimental results.

535.37:546.47'221 913
Remarks on the Nature of the Luminescence Centres in Nonactivated ZnS Luminophores—W. van Gool and A. P. Cleiren. (*Z. Naturforsch.*, vol. 16a, pp. 948–950; September, 1961.) Difficulties in the interpretation of available experimental results are discussed.

535.37:546.47'273–31 914
Anhydrous Zinc Borate as a Host Crystal in Luminescence—S. Terol and M. J. Otero. (*Z. Naturforsch.*, vol. 16a, pp. 920–927; September, 1961. In English.) Various Zn borate luminophores have been prepared and their emission properties investigated, with reference to the results of other authors.

535.37:546.47'48'221 915
The Spectral Shift of the Emission Bands of Differently Activated (Zn:Cd)S Mixed-Crystal Luminophores—H. Ortmann and H. Treptow. (*Z. Naturforsch.*, vol. 16a, pp. 910–916; September, 1961.)

535.376 916
On the Theory of Electroluminescence Deterioration—P. M. Jaffe. (*J. Electrochem. Soc.*, vol. 108, pp. 711–712; July, 1961.) A maintenance curve is given which shows deterioration of emission of a ZnS-Cu, Cl powder phosphor as a function of initial output. Glow curves of the phosphor at 0, 96, 600 and 1000 h are given and discussed.

535.376 917
Growth and Decay of Luminescence Intensity under Cathode-Ray Excitation—M. Sayer. (*Proc. Phys. Soc.*, vol. 78, pp. 1017–1023; November 15, 1961.) Expressions are derived for phosphors which show exponential decay under ultraviolet excitation.

535.376:546.47'221 918
Reversible Luminescence-Centre Transformations in ZnS Phosphors—H. Blicks, N. Riehl, and R. Sizmann. (*Z. Phys.*, vol. 163, pp. 594–603; July 10, 1961.)

535.376:546.47'221 919
Electroluminescence in Zinc Sulphide as due to Minority-Carrier Injection—W. A. Thornton. (*J. Electrochem. Soc.*, vol. 108, pp. 636–645; July, 1961.) Experimental evidence is given in favor of an injection process; the acceleration-collision theory is discounted.

535.376:546.47'221 920
Thermoelectron and Induced Photoelectron Emission of Zinc Sulphide—W. Behmenburg. (*Z. Phys.*, vol. 164, pp. 222–228; August 3, 1961.) Investigations on electron-bombarded ZnS and interpretation of the various mechanisms involved.

535.376:546.47'48'221 921
Field Enhancement in ZnS·CdS-Mn Phosphors—G. Wendel. (*Mber. Dtsch. Akad. Wiss. Berlin*, vol. 2, no. 8, pp. 490–492; 1960.) Report on measurements on X-ray-excited phosphors without Au activation, which exhibit the Destriau effect.

537.227 922
Dynamic Tensile Strength of a Ferroelectric Ceramic—R. Gerson, S. R. Burlage, and D. Berlincourt. (*J. Acoust. Soc. Amer.*, vol. 33, pp. 1483–1485; November, 1961.) Specimens of good-quality $Pb(Zr,Ti)O_3$ ceramic fractured under a tension of approximately 13,000 lb/in².

537.227 923
Nature of the Ferroelectric Transition in Triglycine Sulphate—R. Blinc, S. Detoni, and M. Pinter. (*Phys. Rev.*, vol. 124, pp. 1036–1038; November 15, 1961.)

537.227 924
Dielectric Resonance in Ferroelectric Titanates in the Microwave Region—A. L. Stanford, Jr. (*Phys. Rev.*, vol. 124, pp. 408–410; October 15, 1961.) Permittivity measurements have been made in the range 250 Mc–7 Gc on $BaTiO_3$ and $(Ba, Sr)TiO_3$ in the ferroelectric and paraelectric regions, by observing the transmission of microwave energy through a sample in a coaxial line. Dispersion curves show resonance characteristics near 2 Gc as the Curie point is approached from the ferroelectric side.

537.311.31:538.63 925
de Haas-Van Alphen Effect in InBi—A. C. Thorsen and T. G. Berlincourt. (*Nature*, vol. 192, pp. 959–960; December 9, 1961.) The first observation of the oscillations in a metallic compound InBi is reported.

537.311.33 926
Distribution Functions for Hot Electrons in Many-Valley Semiconductors—H. G. Reik and H. Risken. (*Phys. Rev.*, vol. 124, pp. 777–784; November, 1961.)

537.311.33 927
Magnetic and Electric Properties of Chalcopyrite—T. Teranishi. (*J. Phys. Soc. Japan*, vol. 16, pp. 1881–1887; October, 1961.) The temperature dependence of the magnetic torque and susceptibility is investigated and the conductivity, Hall effect and thermoelectric power are given.

537.311.33 928
Strain Dependence of the Acceptor Binding Energy in Diamond-Type Semiconductors—P. J. Price. (*Phys. Rev.*, vol. 124, pp. 713–716; November, 1961.) A theoretical analysis applied to Ge with uniaxial [100] compression.

537.311.33 929
On the Coupling between Optical Lattice Vibrations and Carrier Plasma Oscillations in Polar Semiconductors—I. Yokota. (*J. Phys. Soc. Japan*, vol. 16, p. 2075; October, 1961.)

537.311.33 930
Determination of the Diffusion Coefficients, the Drift Mobility and the Lifetime of Minority Charge Carriers in Semiconductors from Delay Measurements—G. Richter and T. K. Dzong. (*Mber. Dtsch. Akad. Wiss. Berlin*, vol. 2, pp. 468–470; 1960.) Brief description of measuring apparatus and results of measurements on Sb-doped Ge crystals.

537.311.33 931
The Preparation and Properties of some II-V Semiconducting Compounds—G. A. Silvey, V. J. Lyons, and V. J. Silvestri. (*J. Electrochem. Soc.*, vol. 108, pp. 653–658; July, 1961.) Methods of purification and single-crystal growth of Cd_3As_2, $CdAs_2$, CdSb, Zn_3As_2, $ZnAs_2$ and ZnSb are discussed.

537.311.33 932
Thermal Conductivity, Thermo-e.m.f. and Electrical Conductivity of Semiconducting Mixed Crystals of the Form

$$(A_{z/2}{}^{I}B_{1-z}{}^{IV}C_{z/2}{}^{V})\ D^{VI}$$

—H. Fleischmann. (*Z. Naturforsch.*, vol. 16a, pp. 765–780; August, 1961.) Report of measurements on mixed crystals of PbTe with $AgSbTe_2$ and $AgBiTe_2$.

537.311.33:061.3 933
Proceedings of the Conference on Semiconducting Compounds—(*J. Appl. Phys.*, suppl., vol. 32, pp. 2064–2304; October, 1961.) Papers (46) presented at the conference held at Schenectady, N.Y., June 14–16, 1961.

537.311.33:537.29 934
A Contribution to the Theory of Internal Field Emission—G. Eilenberger. (*Z. Phys.*, vol. 164, pp. 59–77; July 20, 1961.) The transition probability in Zener tunneling is calculated using a) the Houston expansion, and b) free-electron functions.

537.311.33:537.32 935
Theory of Seebeck Effect in Plastically Deformed Semiconductors—T. Ohta. (*J. Phys. Soc. Japan*, vol. 16, pp. 1561–1564; August, 1961.) The effects of a reduction of free-electron density on the thermoelectric power of n-type materials is investigated theoretically for the impurity and transition ranges of temperature. Results are compared with experimental data for near-intrinsic n-type Ge in the transition range.

537.311.33:538.569.4 936
Cross-Modulation Line Profiles in Cyclotron Resonance Experiments—L. Gold. (*J. Phys. Soc. Japan*, vol. 16, p. 1643; August, 1961.) It is possible to investigate scattering and similar processes in semiconductors directly by cross-modulation measurements.

537.311.33:538.614 937
Dependence of the Free-Carrier Faraday Ellipticity in Semiconductors on Scattering Mechanisms—J. K. Furdyna and M. E. Brodwin. (*Phys. Rev.*, vol. 124, pp. 740–744; November 1, 1961.) The Faraday ellipticity is shown to depend in a rather sensitive and unique way on the scattering mechanism, the carrier distribution function and the value of the average relaxation time. See also 1562 of 1961 (Furdyna and Broersma).

537.311.33:546.26 938
On n-k Junctions in Carbon-Graphite Materials—A. S. Fialkov and Ya. G. Davidovich. (*Dokl. Akad. Nauk S.S.S.R.*, vol. 137, pp. 841–843; April 1, 1961.) Graphs are given showing the effect of heat treatment on the Hall coefficient and on the carrier concentration in the region of the junction, and the variation of thermo-EMF with temperature in the ranges 0°–1600°C and 1000°–2800°C.

537.311.33:[546.28+546.289 939
Saturation Currents at N-Type Silicon and Germanium Electrodes in Chemical Etching Solutions—D. R. Turner. (*J. Electrochem. Soc.*, vol. 108, pp. 561–563; June, 1961.) Chemical etching produces excess holes at a rate proportional to etching rate, surface recombination velocity and the anodic multiplication factor.

537.311.33:[546.28+546.289 940
The Problem of Exo-electron Emission and Induced Photoemission of Germanium and Silicon—G. Kanzler. (*Z. Phys.*, vol. 164, pp. 120–125; July 20, 1961.) Report on experimental investigations with various types of excitation.

537.311:546.28 941
The Effect of Heat Treatment on the Minority-Carrier Lifetime in Silicon—T. Asakawa. (*J. Phys. Soc. Japan*, vol. 16, pp. 1923–1933; October, 1961.)

537.311.33:546.28 942
Heavily Diffused Si p-n Junction—M. Tokunaga and K. Shono. (*J. Phys. Soc. Japan*, vol. 16, pp. 2067–2068; October, 1961.) A report of measurements of breakdown voltage on Si slices of different thicknesses prepared by simultaneous double diffusion.

537.311.33:546.28 943
Thermal Conductivity of Silicon at Low Temperatures—J. C. Thompson and B. A. Younglove. (*J. Phys. Chem. Solids*, vol. 20, pp. 146–149; June, 1961.)

537.311.33:546.28:538.569.4 944
Electron-Spin-Resonance Experiments on Donors in Silicon: Part 3—Investigation of Excited States by the Application of Uniaxial Stress and their Importance in Relaxation Processes—D. K. Wilson and G. Feher. (*Phys. Rev.*, vol. 124, pp. 1068–1083; November 15, 1961.) Excited states of Sb, P and As impurities in Si have been investigated by applying uniaxial stress and observing the electron spin resonance spectrum. Part 2: 4099 of 1959 (Feher and Gere).

537.311.33:[546.28+546.23]:539.12.04 945
The Electron Voltaic Effects in Silicon and Selenium Elements—E. W. Billington and W. Ehrenberg. (*Proc. Phys. Soc.*, vol. 78, pp. 845–853; November 15, 1961.) An experimental investigation of the effects of cathode rays on Si and Se photovoltaic cells.

537.311.33:546.28:539.23 946
Epitaxial Silicon Films by the Hydrogen Reduction of $SiCl_4$—H. C. Theuerer. (*J. Electrochem. Soc.*, vol. 108, pp. 649–653; July, 1961.)

537.311.33:546.281'26:538.569.4 947
Electron Spin Resonance Studies in SiC—H. H. Woodbury and G. W. Ludwig. (*Phys. Rev.*, vol. 124, pp. 1083–1089; November 15, 1961.) B and N impurities in 6*H* SiC replace C and occupy the three nonequivalent C sites with equal probability.

537.311.33:546.289 948
Effect of Impurity Core on Carrier Mobility in Heavily Doped Germanium—P. Csavinszky. (*J. Phys. Soc. Japan*, vol. 16, pp. 1865–1869; October, 1961.) The electron mobility in Sb-doped Ge should be larger than in As-doped Ge and the ratio should increase with electron concentration.

537.311.33:546.289 949
Interband Scattering in *n*-Type Germanium—M. I. Nathan, W. Paul, and H. Brooks. (*Phys. Rev.*, vol. 124, pp. 391–407; October 15, 1961.) Experiments on the variation of conductivity of *n*-type Ge with pressure gave results which are explained in terms of conduction-band theory.

537.311.33:546.289 950
Degenerate Germanium: Part 2—Band Gap and Carrier Recombination—H. S. Sommers, Jr. (*Phys. Rev.*, vol. 124, pp. 1101–1110; November 15, 1961.) Analysis of published data concerning the band structure of degenerate Ge shows that the optical emission, reflectivity and forward admittance of diodes are controlled primarily by the band gap and that the Fermi levels have little effect.

537.311.33:546.289 951
Improvements in the Purification of Germanium by Zone Melting—P. Gondi and G. Scacciati. (*Nuovo Cim.*, vol. 21, pp. 829–833; September 1, 1961. In English.) A new method of agitation is described. It is based on the dependence of the magnitude of repulsive forces produced in the liquid Ge on the frequency of the RF induction heating supply.

537.311.33:546.289 952
Experimental Evidence of Birefringence by Free Carriers in Semiconductors—K. J. Schmidt-Tiedemann. (*Phys. Rev. Lett.*, vol. 7, pp. 372–374; November 15, 1961.) A report of experiments with strained *n*-type Ge.

537.311.33:546.289 953
Gaseous Diffusion of Arsenic and Phosphorus into Germanium—K. Lehovec and C. Pihl. (*J. Electrochem. Soc.*, vol. 108, pp. 552–560; June, 1961.) Diffusion constants for As in Ge agree well with previous determinations; for P in Ge a value of 5.5×10^{-13} cm²/s is obtained which differs considerably from an earlier result.

537.311.33:546.289:535.215 954
Measurement of the Surface Recombination Velocity on Germanium on the Basis of the Photoelectric Voltage Spectral Response—J. Świderski.—(*Bull. Acad. Polon. Sci., Sér. Sci. Tech.*, vol. 9, No. 10, pp. 563–570; 1961. In English.) Advantages and disadvantages of the method, which can be applied to any Ge sample without treatment, are considered. It is not suitable for measuring low rates of recombination in thin samples or when the free path of minority carriers is small.

537.311.33:546.289:537.32 955
Measurement of Seebeck Effect in Plastically Bent Germanium—T. Yamashita and T. Ohta. (*J. Phys. Soc. Japan*, vol. 16, pp. 1565–1569; August, 1961.) Changes in thermoelectric power and resistivity of *n*- and *p*-type samples with plastic deformation are examined, in particular the conversion of near-intrinsic *n*-type Ge to *p*-type.

537.311.33:546.289:538.569.4 956
Line Width of Cyclotron Resonance of Pure Germanium—H. Kawamura, M. Fukai, Y. Hayashi, and T. Hashimura. (*J. Phys. Soc. Japan*, vol. 16, p. 1646; August, 1961.) The width of the resonance line increases with the increase in microwave power absorbed by the crystal.

537.311.33:546.289:538.63 957
Transverse Magnetoresistance of Germanium in the Quantum Limit—T. J. Diesel and W. F. Love. (*Phys. Rev.*, vol. 124, pp. 666–668; November 1, 1961.) Results of measurements on high-purity *n*-type Ge in the temperature range 11°–78° K are not in accordance with theoretical predictions for various scattering mechanisms.

537.311.33:546.289:538.632 958
Hall Effect in *n*- and *p*-type Germanium at 24 Gc/s—N. Watanabe. (*J. Phys. Soc. Japan*, vol. 16, pp. 1979–1988; October, 1961.) For *n*-type Ge, Hall mobility measured at 24 Gc agrees with theory. There is some discrepancy in the case of *p*-type Ge.

537.311.33:[546.681'18+546.681'19 959
Investigation of a Method of Growing Crystals of GaP and GaAs from the Vapour Phase—G. R. Antell. (*Brit. J. Appl. Phys.*, vol. 12, pp. 687–690; December, 1961.) Details are given of growth by vapor deposition on a localized cold spot and of the measured properties of the crystals.

537.311.33:546.681'19 960
Infrared Cyclotron Resonance Absorption in *n*-type GaAs—E. D. Palik, J. R. Stephenson, and R. F. Wallis. (*Phys. Rev.*, vol. 124, pp. 701–703; November 1, 1961.) "Cyclotron resonance of conduction electrons in GaAs at liquid-nitrogen temperature has been observed in the far infrared spectral region. The data yield an effective mass ratio of 0.071 ± 0.005 at the bottom of the band."

537.311.33:546.682'19 961
Electron Mobility in Indium Arsenide—R. P. Chasmar. (*J. Phys. Chem. Solids*, vol. 20, pp. 164–166; June, 1961.) Experimental results agree with theoretical estimates of electron mobility and its dependence on impurity concentration and confirm the analytical observation that few acceptor-type impurities exist in the samples examined.

537.311.33:546.682'231 962
Some Electrical and Optical Properties of InAs-In_2Se_3 and InSb-In_2Se_3 Alloys—J. C. Woolley and P. N. Keating. (*Proc. Phys. Soc.*, vol. 78, pp. 1009–1016; November 15, 1961.)

537.311.33:546.817'241 963
Interrelation of Electronic Properties and Defect Equilibria in PbTe—E. Miller, K. Komarek, and I. Cadoff. (*J. Appl. Phys.*, vol. 32, pp. 2457–2465; November, 1961.) The resistivity, Hall coefficient and Seebeck coefficients of single PbTe crystals have been measured in the range 77°–900°K.

537.311.33:546.873'231 964
Galvanomagnetic Effects in Bismuth Selenide Bi_2Se_3—K. Hashimoto. (*J. Phys. Soc. Japan*, vol. 16, pp. 1970–1979; October, 1961.)

537.311.33:546.873'241 965
Anisotropy of the Electrical Conductivity in Bismuth Telluride—R. T. Delves, A. E Bowley, D. W. Hazelden, and H. J. Goldsmid. (*Proc. Phys. Soc.*, vol. 78, pp. 838–844; November 15, 1961.)

537.311.33:621.317.3 966
A Graphical Method for Determination of Mobility Ratio in the Semiconductors from Hall-Effect Measurements Only—K. Pigoń. (*J. Appl. Phys.*, vol. 32, pp. 2369–2371; November, 1961.)

537.581:537.29 967
Temperature Dependence of Electron Emission in the Field Emission Region—R. Klein and L. B. Leder. (*Phys. Rev.*, vol. 124, pp. 1046–1049; November 15, 1961.) The field emission from a tungsten emitter is in agreement with theoretical prediction over the temperature range 4.2°–400°K. The electric intensity at the emitter surface is measured.

537.581:537.29:537.312.62 968
Field Emission from Niobium in the Normal and Superconducting States—R. Klein and L. B. Leder. (*Phys. Rev.*, vol. 124, pp. 1050–1052; November 15, 1961.) The effect of the superconducting normal transition on field emission is investigated.

538.221 969
Critical Points and Ferromagnetism—E. P. Wohlfarth and J. F. Cornwell. (*Phys. Rev. Lett.*, vol. 7, pp. 342–343; November 1, 1961.) A note on the possible significance of a peaky structure in the density-of-states curve of a ferromagnetic material.

538.221 970
Observation of the Magnetic Domain Structure during Magnetization by Alternating Fields, for Testing the Theory of Magnetization-Reversal Losses—W. Andrä, C. Greiner and W. Schwab. (*Mber. Dtsch. Akad. Wiss. Berlin*, vol. 2, no. 9, pp. 539–544; 1960.)

538.221 971
Magnetic Short-Range Order and Specific Heat in Ferromagnets and Antiferromagnets—J. S. Smart. (*J. Phys. Chem. Solids*, vol. 20, pp. 41–49; June, 1961.)

538.221 972
Several Experiments on the Memory Effect in αFe_2O_3—M. Iwata, T. Iwata, and M. Yamamoto. (*J. Phys. Soc. Japan*, vol. 16, pp. 2072–2073; October, 1961.)

538.221 973
Effect of the Substructure upon Magnetic Properties of Iron-Silicon Single Crystals—Y. Nakamura. (*J. Phys. Soc. Japan*, vol. 16, pp. 1888–1892; October, 1961.)

538.221 974
Seven Ways to Use Cobalt—F. R. Morral. (*Electronics*, vol. 34, pp. 44–47; December 1, 1961.) A survey of applications of Co in magnetic alloys, thin films, ferrites, hermetic seals, printed circuits, semiconductors and masers. 56 references.

538.221 975
New Magnetic Ternary Compound with a High Crystalline Anisotropy—J. H. Wernick, S. E. Haszko, and W. J. Romanow. (*J. Appl. Phys.*, vol. 32, p. 2495; November, 1961.) A note on the magnetic properties of MnAlGe which are comparable to those of $BaFe_{12}O_{19}$.

538.221 976
On the New Magnetic Phase in Manganese-Aluminium-Copper System—I. Tsuboya. (*J. Phys. Soc. Japan*, vol. 16, pp. 1875–1880; October, 1961.) A ferromagnetic phase exists in Cu-poor Mn-Al-Cu alloy. The crystal structure is CsCl type.

538.221:537.312.8:681.142 977
Magnetoresistive Effect as a Possible Memory Device—C. Pettus and T. Young. (PROC. IRE, vol. 49, pp. 1943–1944; December, 1961.) The use of Fe or Ni-Fe film elements as storage devices for automatic computers is discussed.

538.221:538.541 978
The Eddy Current Damping in Ferromagnetic Layers—M. C. Gutzwiller. (*Z. Angew. Math. Phys.*, vol. 12, pp. 508–516; November 25, 1961.) Calculation of the distribution and effect of eddy currents induced in two conducting plates by a ferromagnetic disk placed between them.

538.221:538.569.4 979
Bloch Wall Excitation. Application to Nuclear Resonance in a Bloch Wall—J. M. Winter. (*Phys. Rev.*, vol. 124, pp. 452–459; October 15, 1961.) A theoretical investigation of the recently observed phenomena of nuclear magnetic resonances in ferromagnetic substances gives relaxation times of the order of those observed.

538.221:539.23 980
Uniaxial Magnetic Anisotropy of Nickel and Iron Thin Films from Cathode Sputtering—H. Gärtner. (*Z. Naturforsch.*, vol. 16a, p. 841; August, 1961.)

538.221:539.23 981
The Structure of Nickel Films from Cathode Sputtering—H. Gärtner. (*Z. Naturforsch.*, vol. 16a, p. 840; August, 1961.)

538.221:539.23 982
Bloch and Néel-Walls in Thin Ferromagnetic Films—H. D. Dietze and H. Thomas. (*Z. Phys.*, vol. 163, pp. 523–534; July 10, 1961.) Exact calculation of the domain-wall stray field energy and comparison of results with those based on Néel's theory (180 of 1956).

538.221:539.23 983
Spontaneous Magnetization of Collectively Paramagnetic Domains and Thin Films—A. Knappwost and G. Rust. (*Z. Metallkde*, vol. 52, pp. 795–798; December, 1961.) Discussion of experimental results with reference to theories of spontaneous magnetization.

538.221:539.23 984
Clean Glass Substrates for Permalloy Films—A. F. Fray and S. Nielsen. (*Brit. J. Appl. Phys.*, vol. 12, pp. 603–608; November, 1961.) "Possible defects on glass surfaces and methods of detecting and reducing them are discussed. A correlation between the state of the surface and the magnetic properties of permalloy films is observed. Best results were obtained on surfaces obtained by quenching molten vacuum-melted glass."

538.221:539.23 985
Investigation of the Magnetization Reversal in Thin Cobalt Films by the Magneto-optical Kerr Effect—H. Danan, W. Schüppel, W. Andrä, and H. Gengnagel. (*Mber. Dtsch. Akad. Wiss. Berlin*, vol. 2, pp. 593–597; 1960.)

538.221:539.23 986
The Effect of Magnetic Anisotropy in Cobalt Ferromagnetic Thin Films—A. Corciovei. (*J. Phys. Chem. Solids*, vol. 20, pp. 162–164; June, 1961.) The effect of the anisotropy term in the Hamiltonian is taken into account in calculating the Curie temperature as a function of film thickness for values of thickness less than 10 monatomic layers.

538.221:539.23 987
Magnetic Anisotropy of Evaporated Films: Part 1—Iron Films formed in Magnetic Field—M. Takahashi, D. Watanabe, T. Sasagawa, T. Kōno, and S. Ogawa. (*J. Phys. Soc. Japan*, vol. 16, pp. 1913–1923; October, 1961.) Report and discussion of the results of torque measurements under various conditions of film preparation.

538.221:539.234:538.61 988
The Enhancement of the Meridional Magneto-optical Kerr Effect by Vapour-Deposited Films—W. Drechsel. (*Z. Phys.*, vol. 164, pp. 308–323; August 21, 1961.) Equations are derived for calculating the effect of dielectric films on the magnitude of the Kerr effect [see also 1281 of 1959 (Kranz and Drechsel)]. Experimental investigations are described which confirm the theoretical results.

538.221:539.234:538.61 989
An Arrangement for the Photographic Recording of Weiss Domains with Exposure Times of the Order of 1 ms—W. Drechsel. (*Z. Phys.*, vol. 164, pp. 324–329; August 21, 1961.) The optical arrangement described in 1281 of 1959 (Kranz and Drechsel) is used in conjunction with an electronic flash tube.

538.221:621.318.134 990
Magnetocrystalline Anisotropy and Coercivity in a Square-Loop Ferrite Material—J. R. Chamberlain. (*Proc. Phys. Soc.*, vol. 78, pp. 819–827; November 15, 1961.) The approach to saturation of magnetization is measured at different temperatures. See also 991 below.

538.221:621.318.134 991
A Temperature-Dependent Relaxation in a Square-Loop Ferrite—J. R. Chamberlain. (*Proc. Phys. Soc.*, vol. 78, pp. 828–830; November 15, 1961.) Measurements of the initial permeability as a function of frequency and temperature are reported.

538.221:621.318.134 992
Magnetic After-Effects in Manganese-Zinc Ferrites—T. Akashi and T. Okada. (*J. Phys. Soc. Japan*, vol. 16, p. 1641; August, 1961.) Richter-type after-effects are tabulated for five samples sintered in different oxygen pressures.

538.221:621.318.134 993
Frequency Dependence of Ferromagnetic Crystalline Anisotropy of $Ni_xFe_{3-x}O_4$—S. Usami, N. Miyata, and Z. Funatogawa. (*J. Phys. Soc. Japan*, vol. 16, p. 2064; October, 1961.)

538.221:621.318.134 994
Susceptibility of Gadolinium Iron Garnet below the Néel Point—W. P. Wolf and R. M. Bozorth. (*Phys. Rev.*, vol. 124, pp. 449–452; October 15, 1961.) Deviations from a Curie law are explained in terms of paramagnetic saturation of the rare-earth moments in the exchange field produced by the Fe sublattices.

538.221:621.318.134:538.569.4 995
Low-Lying Spectrum of Rare-Earth Iron Garnets—M. Tinkham. (*Phys. Rev.*, vol. 124, pp. 311–320; October 15, 1961.) Using simplified models for the rare-earth garnets, their spectra are computed theoretically.

538.221:621.318.134:538.569.4 996
Far-Infrared Exchange Resonance of Ytterbium Iron Garnet—A. J. Sievers, III, and M. Tinkham. (*Phys. Rev.*, vol. 124, pp. 321–325; October 15, 1961.) An experimental study of a 14.1-cm^{-1} line, including the variation of frequency and absorption strength with temperature is shown to support the theory of garnets (995 above).

538.222:538.569.4:621.375.9 997
Microwave Appraisal of Maser Crystals—J. S. Thorp, J. H. Pace, and D. F. Sampson. (*Brit. J. Appl. Phys.*, vol. 12, pp. 705–707; December, 1961.) The microwave spectrometer is demonstrated as a powerful tool for assessing crystal quality under near-normal operating conditions. A comparison of ruby samples grown from the vapor phase and from powder by flame fusion shows the former to be purer.

666.1.037.5:621.3.032.53 998
Testing of Materials for Glass-to-Metal Seals by means of Stress Birefringence—J. de Vries. (*Philips Tech. Rev.*, vol. 22, pp. 337–341; July 27, 1961.) The relative expansion of glass, metal and ceramics used in valve manufacture is tested by measuring stress birefringence in standard-shaped test seals.

MEASUREMENTS AND TEST GEAR

621.317.3:537.311.33 999
Hot Probe measures Semiconductor Thermoelectric Power—N. Bobson. (*Electronics*, vol. 34, pp. 61–63; December, 1961.) Thermoelectric power and Seebeck coefficient can be measured directly without preparing or shaping the sample.

621.317.3:537.323 1000
Measurement of the Figure of Merit of a Thermoelectric Material—A. E. Bowley, L. E. J. Cowles, G. J. Williams, and H. J. Goldsmid. (*J. Sci. Instr.*, vol. 38, pp. 433–435; November, 1961.) The apparatus uses dc and is based on Harman's technique (*J. Appl. Phys.*, vol. 29, pp. 1373–1374; September, 1958) in which a temperature gradient is established by means of the Peltier effect.

621.317.328:537.56 1001
A Method of Measurement of Flame Attenuation at 200 Mc—A. W. Biggs. (PROC. IRE, vol. 49, pp. 1917–1919; December, 1961.) VHF signal attenuation by a flame or by the exhaust trail produced by a flame is determined by measuring the voltage SWR and the shift of the minimum electric field as the ionized gases pass between two parallel plates of a short-circuited transmission line.

621.317.33:537.311.33 1002
Constant-Current Generator measures Semiconductor Resistance—P. J. Olshefski. (*Electronics*, vol. 34, p. 63; November 14, 1961.) Isolated constant-current generator reduces the time required to obtain resistivity profiles. High accuracy is obtained by reading current from dial settings instead of meters.

621.317.335.2:621.319.43 1003
Special Variable Capacitor for the Measurement of Very Small Capacitances—W. Wiessner. (*Elektrotech. Z., Edn A*, vol. 82, pp. 605–609; September 11, 1961.) A three-terminal differential capacitor for use in bridge methods of measurement is described.

621.317.374.029.6 1004
Rapid Method for Determining V.H.F. Dielectric Parameters for Liquids and Solutions using Standing-Wave Procedures—M. G. Corfield, J. Horzelski, and A. H. Price. (*Brit. J. Appl. Phys.*, vol. 12, pp. 680–682; December, 1961.) A variation of the method described by Roberts and von Hippel (178 of 1947) for the frequency range 250–900 Mc.

621.317.39:535.37 1005
The Measurement of Luminescence—G. P. Burn. (*Electronic Engrg.*, vol. 33, pp. 806–807; December, 1961.) Faint luminescence is measured by counting the output pulses from a photomultiplier. Equipment consists of a photomultiplier and preamplifier, the output of which is fed to a standard pulse height discriminator and scaler.

621.317.39.089.6:531.787.9 1006
The Dynamic Calibration of Piezoelectric Measurement Systems—W. Gohlke. (*Elektronische Rundschau*, vol. 15, pp. 354–357; August, 1961.) The calibration of rod-type piezoelectric transducers by single mechanical impulses is proposed.

621.317.7:621.391.822 1007
The Design of a Noise Generator for Measurements in the Frequency Range 30–1250 Mc/s—I. A. Harris. (*Proc. IEE*, pt. B, vol. 108, pp. 651–658; November, 1961.) The design, construction and calibration of a noise generator using a special diode mount are described. The source resistance is 50 Ω and the accuracy in noise level is within ±2 per cent for frequency up to 300 Mc; for higher frequencies where calibration against a known source is necessary, accuracy is within ±5 per cent.

621.317.7–71:621.391.822 1008
Improvement in the Performance of an Automatic Noise-Figure Meter with a Liquid-Nitrogen-Cooled Termination—C. T. Stelzried. (PROC. IRE, vol 49, p. 1963; December, 1961.) Note on a method of extending the range of a noise meter for use with low-noise amplifiers, and increasing its accuracy.

621.317.742:621.372.86 1009
A Guide to the Use of the Modified Reflectometer Technique of V.S.W.R. Measurement—W. J. Anson. (*J. Res. NBS*, vol. 65C, pp. 217–223; October–December, 1961.) The theory, operational procedure and error analysis of the technique are discussed. See also 1447 of 1960 (Engen and Beatty).

621.317.79:621.391.82 1010
Interference and the R.F.I. Meter—H. A. Favors, R. E. Bloom, and R. J. Fleischer. (*Instr. Control Sys.*, vol. 34, pp. 1443–1449; August, 1961.) Sources and types of RF noise and interference are summarized, and various test methods using a commercial-type RF interference meter are outlined.

621.317.79.029.65:621.372.86 1011
Thin Metal Films in Millimetric Wave Measurements—M. H. Cufflin (*Electronic Engrg.*, vol. 33, pp. 808–810; December, 1961.) Experimental results are given for metal films, with and without slots, on thin glass disks used as coupling and reflecting disks in circular waveguide.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

525.2:621.396.9:535.568 1012
Distance Measurement by means of a Light Ray Modulated at a Microwave Frequency—K. D. Froome and R. H. Bradsell. (*J. Sci. Instr.*, vol. 38, pp. 458–462; December, 1961.) A light beam is elliptically polarized with a modulation frequency of 9.4 Gc and returned from a distant reflector to the modulator where the ellipticity is either increased or canceled. The distance from the reflector to modulator is obained in terms of the number of modulation wavelengths. Changes in position of 0.05 mm can be detected at 50 m.

535.376.07 1013
Electroluminescent Display presents Nanosecond Pulses—R. W. Windebank. (*Electronics*, vol. 34, pp. 53–55; December, 1961.) Pulses fed into both ends of a delay line build up the voltage at the point of coincidence sufficiently to activate the phosphor strips connected at that point. Possible developments of the technique are suggested.

537.376.07 1014
Electroluminescent Devices—H. K. Henisch. (*Brit. J. Appl. Phys.*, vol. 12, pp. 660–667; December, 1961.) A survey of recent applications including alphanumeric indicators, light amplifiers and scanned picture screens.

551.508.43:621.373.421.1 1015
Experimental Microbarograph—G. W. Gardiner. (*J. Sci. Instr.*, vol. 38, pp. 510–511; December, 1961.) In the instrument described the free movement of an aneroid unit varies the capacitance of an oscillatory circuit. Measurement range is 6 mb and sensitivity of the order of 0.1 mb.

621.35 1016
Intermediate-Temperature Fuel Cells—G. V. Elmore and H. A. Tanner. (*J. Electrochem. Soc.*, vol. 108, pp. 669–671; July, 1961.) Gas fuel cells are described which develop 50–100 mA/cm² at a temperature >100°C and atmospheric pressure.

621.362 1017
The Initial Transient Behaviour of a Thermoelectric Generator—F. G. Stremler and P. E. Gray. (*Commun. and Electronics*, pp. 367–372; September, 1961.) The problem is solved using a perturbative technique, one perturbation being sufficient for the low-efficiency materials at present in use. Predictions of transient output and settling time of a generator under load can be calculated.

621.362:621.385 1018
Thermionic Conversion of Heat to Electricity—R. V. Harrowell. (*Nature*, vol. 192, pp. 611–612; November 18, 1961.) Details of a symposium on thermionic generation of electricity held in London, May 11, 1961.

621.362:621.385.3 1019
The Magnetic Triode—G. F. Harris, G. D. Sims and I. M. Stephenson. (*Electronic Tech.*, vol. 39, pp. 27–30; January, 1961.) Inefficiency of this crossed-field thermionic convertor is attributed to electron-cloud instability. Possible design improvements are suggested.

621.362:621.387 1020
A New Approach to Thermionic Energy Conversion: Space-Charge Neutralization by an Auxiliary Discharge—W. Bernstein and R. C. Knechtli. (PROC. IRE, vol. 49, pp. 1932–1936; December, 1961.)

621.385.833 1021
Electron Microscope Operating under Very High Voltage—G. Dupouy, F. Perrier, and R. Fabre. (*Rev. Gén Élec.*, vol. 70, pp. 447–452; September, 1961.) A description of the design and principal characteristics of the instrument which operates at 1.5 Mv.

621.385.833 1022
Symmetric and Asymmetric Magnetic Electron Lenses—J. Dugas, P. Durandeau, and C. Fert. (*Rev. d'Optique*, vol. 40, pp. 277–305; June, 1961.) A description of the design and properties of magnetic electron lenses is given, in particular asymmetric lenses having both polar surfaces pierced with holes of different diameter.

621.385.833 1023
Determination of Field Strength for Field Evaporation and Ionization in the Field Ion Microscope—E. W. Müller and R. D. Young. (*J. Appl. Phys.*, vol. 32, pp. 2425–2428; November, 1961.)

621.385.833:061.3 1024
Conference on Electron Microscopy—Nottingham, July 1961—P. M. Kelly and R. Reed. (*Brit. J. Appl. Phys.*, vol. 12, pp. 585–591; November, 1961.) A review of papers read at the annual conference of the Electron Microscopy Group of the Institute of Physics and the Physical Society.

621.385.833:535.41 1025
A Biprism Interferometer for Electron Waves and its Application—M. Keller. (*Z. Phys.*, vol. 164, pp. 274–291; August 21, 1961.)

621.385.833:535.41 1026
Electron Two-Beam Interference Patterns with High Path Difference—M. Keller. (*Z. Phys.*, vol. 164, pp. 292–294; August 21, 1961.)

621.398:629.19 1027
Some Telemetry Systems for Space Research—A. E. Dent, W. M. Rae, and J. H. White. (*J. Brit. IRE*, vol. 22, pp. 465–475; December, 1961.) Solid-state devices are used in recent developments of the British 24-channel system for the Skylark rocket. This system is compared with the Scout satellite system.

621.398:629.19 1028
Guidance of Space Vehicles by Radio Measurements and Command—A. R. M. Noton. (*J. Brit. Interplan. Soc.*, vol. 18, pp. 132–138; July/August, 1961.) The correction of trajectory of a vehicle after it has left the vicinity of the earth is considered and in particular the radio-command system which depends on ground tracking and computing.

629.19:537.56 1029
Ionic and Plasma Propulsion for Space Vehicles—G. R. Brewer, M. R. Currie, and R. C. Knechtli. (PROC. IRE, vol. 49, pp. 1789–1821; December, 1961.)

681.61:534.78 1030
Phonetic Typewriter III—H. F. Olson and H. Belar. (*J. Acoust. Soc. Amer.*, vol. 33, pp. 1610–1615; November, 1961.) The typewriter has a maximum capacity of only about 100 syllables but will be used in research towards a machine handling 2000 syllables.

PROPAGATION OF WAVES

621.391.812.6:537.56 1031
Transmission of Electromagnetic Waves through an Ionized Layer in the Presence of a Strong Magnetic Field—T. P. Harley and G. Tyras. (PROC. IRE, vol. 49, pp. 1822–1824; December, 1961.) Transmission through the plasma sheath which forms around a re-entry vehicle is improved by the presence of a steady magnetic field which reduces the magnitude of certain components of the permittivity tensor. See also 2339 of 1961 (Phillips *et al.*) and 1032 below.

621.391.812.6:537.56 1032
The Use of Magnetic Fields in the Elimination of the Re-entry Radio Blackout—H. Hodara. (PROC. IRE, vol. 49, pp. 1825–1830; December, 1961.) The radio blackout affecting re-entering missiles can be eliminated by the application of a static magnetic field of about 500 G to the plasma sheath.

621.391.812.6:537.56 1033
R.F. Reflectance of Plasma Sheaths—L. S. Taylor. (PROC. IRE, vol. 49, pp. 1831–1836; December, 1961.) The wave equation for the propagation of the TE mode in a plane stratified plasma sheath is solved by a method of series expansion.

621.391.812.624 1034
Tropospheric Scatter Propagation—J. B. L. Foot and W. J. Luces. (*GECJ*, vol. 28, no. 3, pp. 126–138; 1961.) During the period May, 1956–May, 1959, results were obtained initially at 3480 Mc and later also at 9640 Mc on an experimental link over 173 miles from Start Point, Devonshire, to Wembley, Middle-

sex. The feasibility of a long-distance link is demonstrated. See also 2000 *r* of 1959 (Angell *et al.*) and 3910 of 1961 (La Frenais and Lucas).

621.391.812.63 1035
Periodic Fading in Oblique-Incidence Short-Wave Transmissions—B. R. Rao, M. G. S. Rao, and D. S. Murty. (*Indian J. Phys.*, vol. 35, pp. 475–483; September, 1961.) Possible modes of propagation are determined by comparison of the theoretical and recorded occurrence of interference maxima in fading signals. A method of calculating changes in *fo* in small time intervals is also proposed.

621.391.812.63:551.507.362.2 1036
High-Frequency Fading of the 108-Mc/s Wave Radiated from an Artificial Earth Satellite as Observed at an Equatorial Station—G. S. Kent. (*J. Atmos. Terr. Phys.*, vol. 22, pp. 255–269; December, 1961.) The irregularities causing the fading were found to occur only at night and to be highly correlated with spread-F. They were concentrated in regions about 100 km in extent and were elongated along the earth's magnetic field.

621.391.812.63:551.510.535 1037
Generalized Appleton-Hartree Equation for any Degree of Ionization and Application to the Ionosphere—Shkarofsky. (See 879.)

621.391.812.63:551.510.535 1038
The Absorption of Radio Waves in the Ionosphere with respect to Geomagnetic Current Control and Other Proposed Models—a Critical Survey—Whitehead. (See 880.)

621.391.812.63.029.4 1039
The Problem of the Propagation of Long and Very Long Radio Waves around the Earth, and the Lower Ionospheric Layers (C, D and E) in the Light of Information Theory—P. E. Krasnushkin. (*Dokl. Akad. Nauk S.S.S.R.*, vol. 139, pp. 67–70; July 1, 1961.) Brief mathematical analysis assuming a) a spherical and b) a plane earth and ionosphere.

621.391.812.63.029.63 1040
Discussion of Incoherent Back-Scatter Power Measurements at 440 Mc/s—V. C. Pineo and H. W. Briscoe. (*J. Geophys. Res.*, vol. 66, pp. 3965–3966; November, 1961.) The power received by back-scatter from the F layer is several decibels below theoretical estimates. See 3641 of 1960 (Pineo *et al.*).

RECEPTION

621.376.239:537.56:621.396.96 1041
A Plasma Microwave Energy Detector—R. L. Taylor and S. B. Herskovitz. (PROC. IRE, vol. 49, pp. 1901–1906; December, 1961.) The operation of the detector described is based on the temperature sensitivity of the electron-ion recombination rate. The minimum discernible signal strength is about 1 mw peak.

621.396.669:621.372.852.1 1042
Synthesis of Interference Filters—J. S. Seeley. (*Proc. Phys. Soc.*, vol. 78, pp. 998–1008; November 15, 1961.) A method of synthesizing filters to transmit prescribed functions of frequency is applied to dielectric interference filters containing up to four $\lambda/2$ layers.

STATIONS AND COMMUNICATION SYSTEMS

621.396.41 1043
The TH Microwave Radio Relay System—(*Bell Sys. Tech. J.*, vol. 40, pp. 1459–1743; November, 1961.) Nine papers describing design aspects and engineering details of a long-haul system operating in the 5925–6425-Mc band. There are eight FM channels in each direction each with a potential bandwidth of 10 Mc.

621.396.76:681.84.087.7 1044
The American Standard for the Transmission of Stereophonic Programs over the V.H.F. F.M. Broadcasting System—K. Wilhelm. (*Nachrtech. Z.*, vol. 15, pp. 379–380; August, 1961.) Addition to earlier review (4310 of 1961) and discussion of the U. S. standard from the point of view of its applicability in Europe.

621.396.97:534.76 1045
Stereo Broadcasting in the U.S.A. and in Europe—C. Reuber. (*Elektrotech. Z., Edn B*, vol. 13, pp. 459–463; August 21, 1961.) Review of system requirements and practical possibilities. Proposed European systems are discussed, and reference is made to the recently introduced U. S. standards.

SUBSIDIARY APPARATUS

621.311.69:621.383.5:629.19 1046
Some Thermal Considerations on the Use of Solar Cells in Space Vehicles—R. P. Howson, D. H. Roberts and B. L. H. Wilson. (*J. Brit. IRE*, vol. 22, pp. 519–525; December, 1961.) The radiation balance of solar cells in space is discussed for different configurations of the cell assembly and different orbits. Surface coatings are considered.

TELEVISION AND PHOTOTELEGRAPHY

621.397.001.5 1047
Current Television Research: some Contributions by the B.B.C. Research Department—R. D. A. Maurice and G. D. Monteath. (*Brit. Commun. Electronics*, vol. 8, pp. 902–908; December, 1961.) A general review of specialized equipment.

621.397.132 1048
The Perceptibility of Nonlinear Distortion in Colour Television Pictures with the N.T.S.C. System—J. Muller and G. Wengenroth. (*Nachrtech. Z.*, vol. 15, pp. 388–395; August, 1961.) The effects of amplitude and phase distortion of the color subcarrier are considered and appropriate specifications for television links are derived.

621.397.132 1049
The SECAM Colour Television System. Comparison with the N.T.S.C. System—P. Cassagne and M. Sauvanet. (*Onde élect.*, vol. 41, pp. 689–703; September, 1961.) Analysis of the operating principles and performance data for the two systems indicates a significant advantage of SECAM in quality and cost.

621.397.2:621.395.625.3 1050
Synchronization Method for the Magnetic Storage of Video Signals—W. Zobisch. (*Tech. Mitt. BRF, Berlin*, vol. 5, pp. 66–71; June, 1961.) The permissible speed fluctuations in magnetic recording systems for television signals are evaluated and their effect on picture quality is discussed. Various recording methods are reviewed with reference to synchronization techniques.

621.397.23 1051
Signal Distortion in Television Systems with Frequency-Modulated Subcarriers—H. Schönfelder. (*Arch. Elekt. Übertragung*, vol. 15, pp. 273–284; June, 1961.) The investigation is particularly concerned with vestigial sideband transmission of the FM signal, and the transient response of a band-pass filter to an ideal frequency step function is evaluated as an approximation of the system. The effects of signal distortion on picture quality are analyzed for the case of magnetic video recording and the SECAM method of color television.

621.397.232.2:621.391.827 1052
Investigations of the Offset Operation of Television Transmitters with Wide Frequency Separation of the Vision Carriers—H. Hopf. (*Rundfunktech. Mitt.*, vol. 5, pp. 112–122 and 172–188; June and August, 1961.) Detailed results are given of extensive tests carried out to investigate the interference effects arising between transmitters using similar or different line standards, types of modulation and channel arrangement. Offset operation (see also 1032 of 1960) appears to reduce mutual interference.

621.397.331.222 1053
The Dependence of the Quality Parameters of the Vidicon on the Size of the Scanned Area of the Semiconductor Layer, for Equal Light Flux—R. Theile and F. Pilz. (*Rundfunktech. Mitt.*, vol. 5, pp. 108–111; June, 1961.) Report of investigations on 1-in and 2-in vidicons. A reduction in the size of the area scanned lessens the inertia effects at the expense of resolution and picture quality.

621.397.334:621.397.621 1054
Appraisal of the Banana-Tube Colour-Television Display System—K. G. Freeman and B. R. Overton. (*Proc. IEE*, pt. B, vol. 108, pp. 624–630; November, 1961. Discussion, pp. 639–633.) Factors determining the potentialities and limitations are considered in detail.

621.397.334:621.397.621 1055
The Banana-Tube Display System—P. Schagen. (*Proc. IEE*, pt. B, vol. 108, pp. 577–586; November, 1961. Discussion, pp. 630–633.) Color display systems with mechanical field scanning are discussed. Mirror-drum and lens-drum systems are compared and the latter system used with the banana tube is described in detail.

621.397.344:621.397.621 1056
Development of the Banana Tube—B. A. Eastwell and P. Schagen. (*Proc. IEE*, pt. B, vol. 108, pp. 587–595; November, 1961. Discussion, pp. 630–633.) The unconventional system of beam deflection and spot formation in the banana tube is considered in detail. Tube technology is discussed.

621.397.334:621.397.621 1057
Mechanical and Manufacturing Aspects of the Banana-Tube Colour-Television Display System—H. Howden. (*Proc. IEE*, pt. B, vol. 108, pp. 596–603; November, 1961. Discussion, pp. 630–633.) The major mechanical components are described together with materials and manufacturing techniques used to achieve results consistent with the requirements of the system.

621.397.334:621.397.621 1058
Circuits for the Banana-Tube Colour-Television Display System—K. G. Freeman. (*Proc. IEE*, pt. B, vol. 108, pp. 604–612; November, 1961. Discussion, pp. 630–633.) Circuits are described under the headings of tube supplies, lens drum synchronization and video-signal processing.

621.397.334:621.397.621 1059
Colorimetry of the Banana-Tube Colour-Television Display System—R. N. Jackson. (*Proc. IEE*, pt. B, vol. 108, pp. 613–623; November, 1961. Discussion, pp. 630–633.) The principal sources of errors in color reproduction are analyzed and methods of reducing color distortion are discussed.

621.397.61 1060
Video-Frequency Cable Links between

Groups of Equipment with Differing Reference Potential to Earth—E. W. Hans. (*Rundfunktech Mitt.*, vol. 5, pp. 189–192; August, 1961.) The prevention of the flow of compensating currents by means of high-impedance amplifiers inserted in the cable is discussed.

621 397.612 1061
Headsight Television System provides Remote Surveillance—C. P. Comeau and J. S. Bryan. (*Electronics*, vol. 34, pp. 86–90; November 10, 1961.) A closed-circuit television system is described in which the operator views an image on a miniature CR tube monitor fitted to his helmet. A remotely controlled camera follows the operator's head motions.

621.397.612 1062
Black Level in Television—H. V. Sims. (*Wireless World*, vol. 68, pp. 2–11; January, 1962.) Discussion of methods of controlling the black level of a tranmission by dc restoration or clamping using a line-frequency reference signal which bears a constant relation to the black level.

621.397.621 1063
Horizontal Synchronization in Television Receivers with Extended Pull-In Range—W. Bruch. (*Telefunken Ztg*, vol. 34, pp. 102–113; June, 1961. English summary, p. 189.) The design of improved control circuits for fly-wheel synchronization with extended pull-in and hold-in ranges is given.

621.397.712.3 1064
The Projected Television Studio Centre of the Österreichische Rundfunk at Wien-Königlberg [Vienna]—F. Brunner. (*Rundfunktech. Mitt.*, vol. 5, pp. 166–171; August, 1961.)

621.397.74 1065
Theoretical Plans for Television Networks: the Case where Several Programs are Radiated from Each Station—P. Blancheville and J. Couprie. (*E.B.U. Rev.*, no. 67A, pp. 103–109; June, 1961.) Various theoretical solutions of the problem of channel assignment in Bands IV/V are proposed and compared. See also 1330 of 1961 (Eden *et al.*).

621.397.74:551.507.362.2 1066
Synchronous Satellites for Intercontinental Television Systems—M. D. Hull. (*Brit. Commun. Electronics*, vol. 8, pp. 910–914; December, 1961.) Economic and political factors suggest television relays as the first practical application of satellite communication.

621.397.74:621.396.65 1067
On the Causes of Differential Gain and Phase on Frequency-Modulated Television Links—E. Castelli. (*E.B.U. Rev.*, no. 67A, pp. 90–102; June, 1961.) Gain and phase distortion and appropriate methods of equalization are considered which may also be relevant to color television systems. Experimental results obtained on a monochrome television link are given.

TUBES AND THERMIONICS

621.382.23 1068
The Physics of the Tunnel Diode—A. K. Jonscher. (*Brit. J. Appl. Phys.*, vol. 12, pp. 654–659; December, 1961.) A brief account of the physical principles governing operation, with notes on some low-temperature effects.

621.382.23 1069
The Tunnel Diode as a "Solid-State Circuit" Element—A. E. Brewster. (*J. Brit. IRE*, vol. 22, pp. 489–496; December, 1961.) The tunnel diode is proposed as the ideal active element for use in complete functional units enclosed in small capsules. Various circuits are described.

621.382.23 1070
The Design and Construction of Tunnel Diodes—J. Przybylski and G. N. Roberts. (*J. Brit. IRE*, vol. 22, pp. 497–505; December, 1961.) The characteristics, operation, manufacture and equivalent circuits of backward and tunnel diodes are described.

621.382.23 1071
Excess and Hump Current in Esaki Diodes—R. S. Claassen. (*J. Appl. Phys.*, vol. 32, pp. 2372–2378; November, 1961.) This current is explained in terms of discrete defect energy levels in the forbidden band.

621.382.23 1072
Germanium-Doped Gallium Arsenide Tunnel Diodes—R. Solomon, R. Newman, and N. R. Kyle. (*J. Electrochem. Soc.*, vol. 108, p. 716; July, 1961.) A method of producing degenerate *p*-type GaAs doped with Ge is described. Characteristics are identical to those of Zn-doped material.

621.382.23 1073
Indium Antimonide Tunnel Diodes—K. F. Hulme. (*Brit. J. Appl. Phys.*, vol. 12, pp. 651–653; December, 1961.) Performance and susceptibility to theoretical analysis make the InSb diode suitable for investigating tunneling processes.

621.382.23:061.3 1074
Proceedings of the Symposium on Tunnel Diodes—London, February 1961—I. G. Cressell. (*Brit. J. Appl. Phys.*, vol. 12, pp. 646–650; December, 1961.) A summary of the eight papers presented, which covered the theory, physical characteristics and circuit applications of tunnel diodes.

621.382.23:621.319.43 1075
Silicon Junction Diodes as Variable Capacitors—Registrar (See 759.)

621.382.23:621.391.822 1076
Excess Noise in Germanium and Gallium Arsenide Esaki Diodes in the Negative-Resistance Region—M. D. Montgomery. (*J. Appl. Phys.*, vol. 32, pp. 2408–2410; November, 1961.) Measurements of the bias dependence of excess noise in Esaki junctions at low forward biases are described.

621.382.23:621.391.822 1077
Low-Frequency Noise in Backward Diodes—W. C. Follmer. (PROC. IRE, vol. 49, pp. 1939–1940; December, 1961.) Report on noise-temperature measurements in the range 300 cps–20 kc. A 100-Mc balanced mixer incorporating this type of diode has a double-channel noise figure <7 db when used for conversion to 5 kc.

621.382.3.078 1078
Optimum Transistor Stabilization Networks—J. D. Meindl and O. Pitzalis. (*Electronic Engrg.*, vol. 33, pp. 798–802; December, 1962.) A comprehensive design theory is given in which the temperature-sensitive device parameters are recognized.

621.382.333 1079
Junction Transistor Theory—M. K. Achuthan. (*Electronic Tech.*, vol. 38, pp. 458–459; December, 1961.) Relations between terminal currents and voltages across the junctions are discussed.

621.382.333 1080
The Chargistor, a New Class of Semiconductor Devices—H. N. Yu. (*IBM J. Res. Dev.*, vol. 5, pp. 328–330; October, 1961.) A bar of semiconductor material with a number of rectifying contacts can be made to have the characteristics of triodes, tetrodes or pentodes.

621.382.333 1081
Determination from Electrical Measurement of the Impurity Concentration in the Base Material of a Low-Frequency Germanium Transistor—J. P. Biet. (*J. Phys. Radium*, vol. 22, (suppl.) *Phys. Appl.*, pp. 100A–102A; June, 1961.) The junction is maintained at a constant temperature for a series of values of collector current. A simple relation between collector current and base-emitter voltage is derived from which the impurity concentration can be deduced.

621.382.333 1082
Effect of the Accumulation of Minority Carriers in the Base on the Speed of Response of a Diffused-Base Transistor—J. Toussaint, J. Loeckx, and A. Abbondanti. (*Rev. HF, Brussels*, vol. 5, pp. 58–63; 1961.) An analysis establishing the validity of a relation from which the response time can be measured provided one parameter is known.

621.382.333 1083
Injection Efficiency in Double-Diffused Transistors—M. Klein. (PROC. IRE, vol. 49, p. 1708; November, 1961.) An approximation formula is given which allows for the intrinsic electric field and the carrier lifetime.

621.382.333 1084
Excess High-Frequency Noise in Junction Transistors—F. J. Hyde, H. J. Roberts, and B. E. Buckingham. (*Proc. Phys. Soc.*, vol. 78, pp. 1076–1077; November 15, 1961.) A model is proposed to account for the excess noise observed in *p-n-p* alloy-type asymmetrical transistors above 500 kc.

621.382.333.002.2 1085
Monte Carlo Analysis of Transistor Diffusion Techniques—D. P. Kennedy. (*IBM J. Res. Dev.*, vol. 5, pp. 331–334; October, 1961.) An analytical approach to the problem of base-width reproducibility in the construction of double-diffused transistors.

621.382.333.3.001.4 1086
Aging Tests on Germanium H.F. Transistors of Various Makes with Homogeneously Doped Base—H. König and M. J. O. Strutt. (*Arch. Elekt. Übertragung*, vol. 15, pp. 319–326; July, 1961.) Report on measurements of aging effects in five types of junction transistor. For measurements on low-frequency types see 1344 of 1961 (Vogel and Strutt).

621.382.333.4 1087
A New Semiconductor Tetrode—the Surface-Potential-Controlled Transistor—C. T. Sah. (PROC. IRE, vol. 49, pp. 1623–1634; November, 1961.) The semiconductor junction device described takes the form of a planar transistor but has an additional metal electrode placed on the oxide which covers the surface of the emitter-base junction. This "grid" controls the current gain of the transistor. Transconductances of several thousand micromhos have been achieved with the common-emitter circuit configuration.

621.383.032.217.2 1088
Photoelectric Processes in Calcium Oxide Coated Cathodes—C. H. B. Mee and F. A. Vick. (*Brit. J. Appl. Phys.*, vol. 12, pp. 698–704; December, 1961.) An experimental investigation of energy-band structures and pore photoconductivity.

621.383.4:535.215-1 1089
Far-Infrared and Microwave Detector—D. W. Goodwin and R. H. Jones. (*J. Appl.*

Phys., vol. 32, pp. 2056–2057; October, 1961.) Absorption in a semiconductor of the radiation to be detected, at the cyclotron frequency, causes a change in the static electrical conductivity: *n*-type Ge has been used successfully at 34 Gc/s.

621.383.52:621.391.822 1090
Noise in InSb Photodiodes—B. R. Pagel and R. L. Petritz. (*J. Appl. Phys.*, vol. 32, pp. 1901–1904; October, 1961.) The total measured white noise is about 1 db above the calculated photoinduced noise, which is therefore the main source observed.

621.385:621.391.822(083.72) 1091
Valve Noise: Terminology—(*Nachrtech. Z.*, vol. 14, pp. 358–361; July, 1961.) A list of 28 terms and definitions proposed by the Nachrichtentechnische Gesellschaft with corresponding English and French terms.

621.385.032.213.23 1092
Investigation of the Mechanism of Conduction in Oxide Cathodes—A. M. de Goer and N. Thibault. (*Le Vide*, vol. 16, pp. 167–175; August, 1961.) The temperature-limited current is controlled by effects at the surface where the coating is in contact with the metal support, electrons being emitted through long pores in the coating. See 2274 and 4019 of 1958 (Metson).

621.385.032.213.23 1093
Emission Fluctuations of Tungsten-Based Barium Dispenser Cathodes—I. Brodie. (*J. Appl. Phys.*, vol. 32, pp. 2039–2046; October, 1961.) Flicker effect has been measured in two L cathodes and three "impregnated" cathodes, having different porosities. The observed noise amplitudes and spectra are explained by considering the emitter surface conditions.

621.385.23 1094
Estimation of the Total Emission of a Diode under Normal Operating Conditions Without Removing the Space Charge—C. S. Bull and R. K. Fitch. (*Brit. J. Appl. Phys.*, vol. 12, pp. 566–568; October, 1961.) The total emission of a Type-EA50 diode was found by comparing two theoretical values of the space-charge smoothing factor calculated from the tube characteristics. Over the wide range of cathode temperature investigated (680–1130°K) Richardson's law did not hold. Changes in cathode work function cannot explain the discrepancy.

621.385.3:621.362 1095
The Magnetic Triode—Harris, Sims and Stephenson. (See 1019.)

621.385.5.032.265:621.318.57 1096
Noise Properties of Beam-Switching Tubes—G. F. Ross. (*Electronic Ind.*, vol. 20, pp. 96–99; July, 1961.) A report of measurements on beam-switching tubes which were specifically designed to operate as gated high-level random-noise sources of small size.

621.385.6:621.318.37 1097
Solenoids for Travelling-Wave Tubes and Klystrons—A. Zack. (*Electronics*, vol. 34, pp. 66–70; December 8, 1961.) "A survey of the principal design aspects of electromagnetic systems for microwave tubes and the mechanical techniques of cooling microwave tube solenoids."

621.385.6:621.372.8 1098
Large-Signal Interaction between a Spiralling Electron Beam and the TE_{10} Rectangular-Waveguide Mode—W. L. Dickson, C. C. Johnson, and R. W. Grow. (PROC. IRE, vol. 49, pp. 1696–1697; November, 1961.)

621.385.6:621.375.9 1099
The Splitting of the Electrokinetic Power Theorem—W. Riedler. (*Arch. Elekt. Übertragung*, vol. 15, pp. 377–385; August, 1961.) Conditions are derived under which dc and ac energy flows in three-dimensional electron beams can be separated. The ac term can be split into expressions which may be treated as generalized Manley-Rowe relations.

621.385.623.5:621.376.23 1100
Use of Reflex Klystrons for Detection and Power Measurement—V. E. Vasil'kov. (*Izv. Vyssh. Uch. Zav. Radiotekhnika*, vol. 4, pp. 262–269; May/June, 1961.) Investigation of the possible use of reflex klystrons for power measurements on pulse-modulated oscillations in the range from 1 μw to tens of milliwatts in cases where the range of UHF voltage in the interaction space is considerably lower than the accelerating potential of the resonator.

621.385.63:621.375.9:621.372.44 1101
A D.C.-Pumped Amplifier with a Two-Dimensional Field Structure—J. C. Bass. (PROC. IRE, vol. 49, pp. 1957–1958; December, 1961.) Electron-beam amplification in a periodic structure as discussed by Gould and Johnson (2047 of 1961) is considered.

621.385.632:621.372.2 1102
Additional Information on 'An Interaction Circuit for Travelling-Wave Tubes'—R. M. White, C. K. Birdsall, D. E. Chaffee, P. J. Crepeau, and I. Itzkan. (PROC. IRE, vol. 49, pp. 1686–1687; November, 1961.) Comment on 1691 of 1961 and authors' reply.

621.385.633 1103
On Backward-Wave Oscillator Stabilization—R. B. Clark and W. D. Comstock. (PROC. IRE, vol. 49, p. 1697; November, 1961.) Preliminary note on a stable and tunable microwave source operating in the *S* band.

621.385.64 1104
Coaxial Magnetron—a New Microwave Power Source—H. M. Olson and L. H. Van Ohlsen. (*Electronics*, vol. 34, pp. 78–80; November 10, 1961.) The technique discussed gives improved frequency stability, higher efficiency and simplified tuning.

621.387:621.362 1105
Open-Circuit Voltages in the Cesium Diode—F. N. Huffman. (*J. Appl. Phys.*, vol. 32, pp. 1927–1932; October, 1961.) A plasma model and a close-spaced model are used to study the variation of open-circuit voltage. Both give similar results.

621.387:621.362 1106
A New Approach to Thermionic Energy Conversion: Space-Charge Neutralization by an Auxiliary Discharge—W. Bernstein and R. C. Knechtli. (PROC. IRE, vol. 49, pp. 1932–1936; December, 1961.)

621.387.132.2 1107
Two Particular Phenomena concerning Gas Triodes—G. Giralt and Pham Huu Hiep. (*C. R. Acad. Sci., Paris*, vol. 251, pp. 1368–1370; October 3, 1961.) Two phenomena have been observed: a) the extinction of the discharge by the application of positive pulses to the grid; b) the complete transmission of an electric charge across the tube.

621.387.143 1108
The Possibility of the Smooth Control of Electron Flow in Rarefied Gas-Filled Spaces—E. Pfender and W. Bloss. (*Z. Angew. Phys.*, vol. 13, pp. 341–348; July, 1961.) Investigation of the operation of a plasmatron diode. The incorporation of a control grid provides a means of modifying some plasmatron characteristics.

621.387.3 1109
Cold-Cathode Discharge Tubes—J. F. Dix and K. B. Reed. (*Electronic Tech.*, vol. 39, pp. 31–37; January, 1961.) An equivalent circuit is derived for the impedance of a gas-discharge tube over the frequency range 20 cps–10 Mc. An examination is made of noise and impedance properties of the tube.

621.387.322.3 1110
Decade Indicator Operates off Transistors—(*Electronics*, vol. 34, pp. 60–63; November 3, 1961.) A description of a cold-cathode gas-discharge indicator tube with operating voltage <5 v.

IBM asks basic questions in computer software

How much work can computers do?



These IBM programmers are describing a machine part in AUTOPROMT, a programming language developed in cooperation with the United Aircraft Corporation.



Following orders generated by an IBM computer from an AUTOPROMT program, this numerically controlled milling machine is shaping a section of a hyperbolic paraboloid.

Men use words to symbolize ideas. Computers use a vastly different kind of language. Present computer logic requires instruction in language so rudimentary that each year millions of words of programming are devoted to basically repetitive procedures. Unless ways are found to economize on this instruction, the usefulness of computers may be limited by the shortage of trained personnel to put them to work.

IBM programmers are simplifying communication with computers. Through careful selection and ordering of references to machine structure, they have developed programming systems that transfer a large part of the repetitive work in programming to the computer itself. These systems permit programmers to express their instructions in language resembling English. They also make different machines "look alike" so that programmers can state their problems with as little difficulty as possible. In addition, IBM programmers are experimenting with systems which use the computer's own capacity to construct new programming systems, such as assemblers or compilers.

Programming systems can extend beyond the level of handling machine references automatically to include applications AUTOPROMT, IBM's system for numerical control of machine tools, is a codification of machine shop language and practice which enables a computer to determine machining instructions from a description of the part's surfaces. The computer generates the sequence of machine tool paths required to produce the part. IBM has also developed information retrieval systems which reduce the burden of indexing, abstracting or disseminating technical information. One experimental system reduces an article to an abstract by statistically determining the most significant sentences in the article.

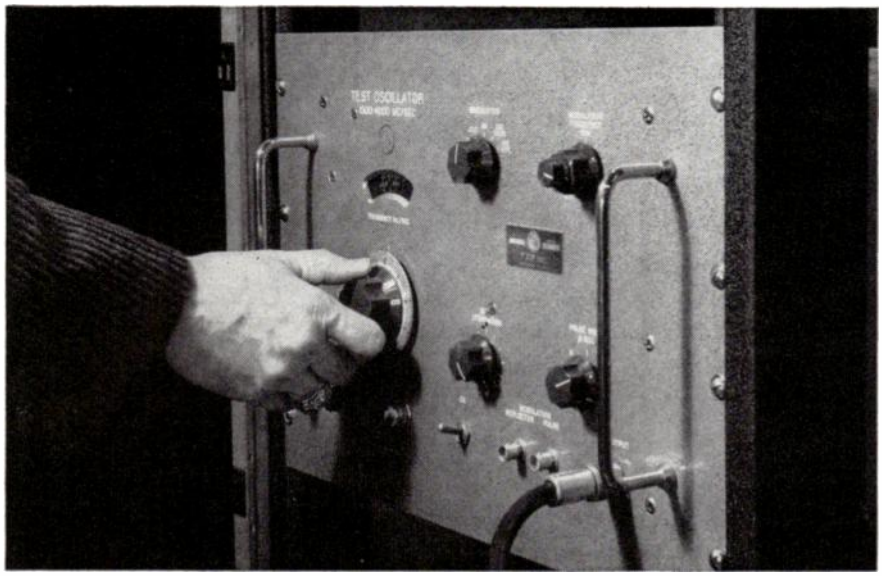
Eventually, programming systems may grow beyond boundaries of individual disciplines to include general information on the nature of the physical world. Such systems would be supported by information retrieval systems and inference systems capable of seeing logical consequences of retrieved information. They would allow men who direct computers to focus their attention on creative aspects of future problems. By making systems like these possible, IBM programmers and mathematicians are playing a leading role in applying the computer to ever-widening areas of human knowledge.

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☐ High-power coaxial cable that's really flexible

☐ New crimp-type subminiature connectors



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		Portable	Rack
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S772A	1.9 to 4.0 KMC	$1035.	$1050.
C772A	3.95 to 8.2 KMC	$1340.	$1355.
X772A	7.0 to 11.0 KMC	$1340.	$1355.
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Modulated Outputs	Internal: CW, pulse or square wave External: Pulse, square wave or FM		
External Modulation Requirements	Pulse: Positive pulse of 30 v. amplitude across 100 K ohms. Pulse width from 0.5 microsecond to square wave. Reflector: sine wave or sawtooth FM, sensitivity from 100 to 200 kc/v.		
Connectors	RF Output: Type N jack. External pulse: Type BNC jack. Reflector modulation: Type BNC jack.		
Power Requirements	115/230 v. AC, 50 or 60 cycles, 150 w.		
Dimensions & Weight	Portable: 11" high X 16" wide X 15" deep; 45 lbs. Rack: 11" high X 19" wide X 15" deep; 45 lbs.		

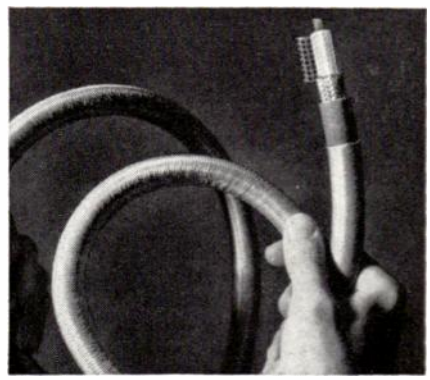
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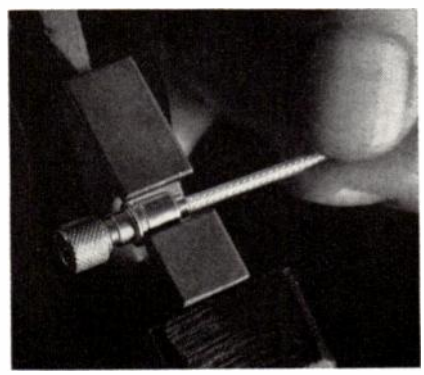
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New crimp-type subminiature connectors

FXR's new Subminax® Series 5116 quick-crimp micro-miniatures make faster, more reliable, less costly cable assemblies. And you don't have to redesign your product to use them, because Series 5116 micro-miniatures are interchangeable with competitive counterparts. In fact, the addition of this new Series to the Subminax line means that you can now specify a Subminax connector that mates with or is interchangeable with any known sub-miniature or micro-miniature coaxial connector on the market today.

The new Subminax Series 5116 has at least three major advantages over other micro-miniatures:

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☐ *Lower Price*—Series 5116 coaxial connectors are priced substantially below current prices for competitive "equivalents."

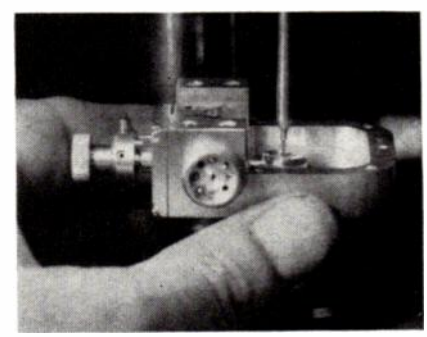
☐ *Technical Facts:* 500 VRMS; impedance: 50, 75 or 95 ohms; gold-plated captivated contacts (solder type); Teflon* insulation; silver-plated body; screw-on or push-on coupling; color coding boots—optional. For use with coaxial cables in the .075 to .115 OD range.

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Oklahoma City—December 18

"Aircraft Antennas and Instrumentations," J. Presley, Aero Commander, Inc., Bethany, Okla.

Aerospace and Navigational Electronics and Microwave Theory and Techniques

Boston—January 24

"Surveillance of Jeeps and Fuel Trucks," J. Woodward, Airborne Instruments Lab., Melville, L. I., N. Y.

Antennas and Propagation

Boston—January 31

"Backscattering from Dielectric Spheres with Applications to Weather Radar," Dr. S. S. Holt, AFCRL, Bedford, Mass.

"Antenna Power Gain and Radiation Pattern Measurement Technique," Andrew Alford, Alford Mfg. Co., Boston.

Washington, D. C.—January 16

"Two-Channel Monopulse Techniques," P. Shelton, Radiation Systems, Inc., Alexandria, Va.

Antennas and Propagation and Microwave Theory and Techniques

Baltimore—January 10

"Application of Tunnel Diode Circuits," L. Dickens (paper presented by C. Gneiting), Johns Hopkins University, Baltimore, Md.

Columbus—January 25

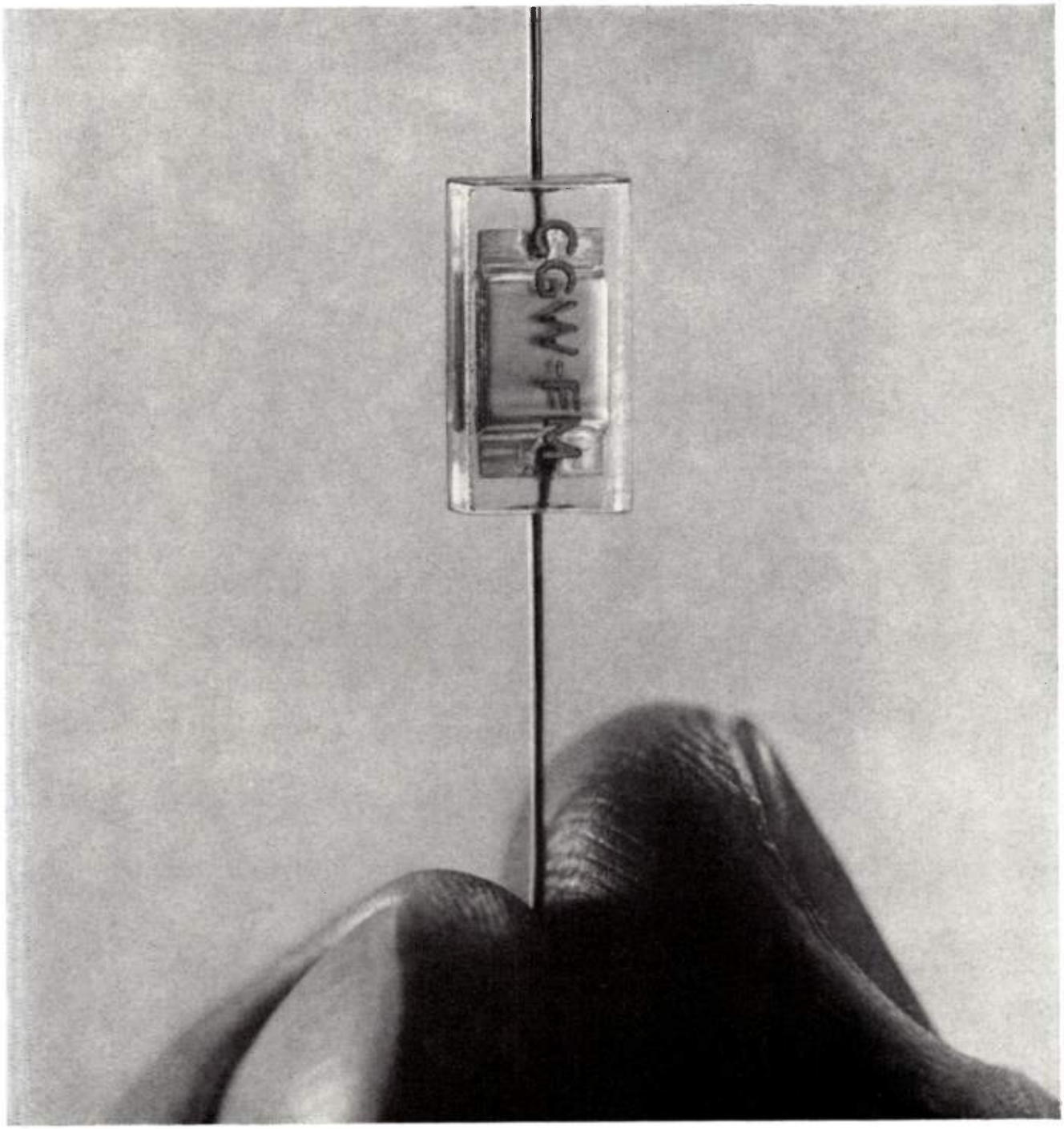
"The Role of Leaky Waves in Electromagnetic Phenomena," Professor A. A. Oliner, Microwave Research Institute, Brooklyn, N. Y.

Santa Ana—January 16

"Multi-Resonator Bandpass Filters," Dr. P. S. Carter, Jr., Stanford Research Institute.

"A Survey of Leaky Wave Antennas," Dr. R. C. Honey, Stanford Research Institute.

(Continued on page 87A)



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(Continued on page 74A)

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creating the unusual



Today there is a new Navy in the making that will need the best design, integration and evaluation talents you and your colleagues can offer.

For example, there will have to be a number of rugged new electronic/acoustical systems created for military and scientific missions operating miles down in the blackness and pressures of INNER SPACE . . . quick reaction tactical systems for hydrofoil and hydrokeel craft of all sizes and functions . . . and, of course, a variety of high capacity computing systems for nuclear-powered ships designed to launch and control advanced weapons from on, over or under the sea.

And not far in the future there will be a need for even more exotic systems devised for Naval vessels that will fly, float, submerge . . . and come up on land.

The Field Activities of the U.S. Navy's Bureau of Ships—including eleven shipyards, six laboratories and supporting industrial liaison activities—play a major role in actually creating this new Navy, including all the electronic systems and equipments required.

IF YOU	***Communication and Antenna Systems***
ARE	***Radar, Navigation and ECM***
EXPERIENCED	***Navy Tactical Data Systems***
IN	***Sonar Systems and Equipment***
	Guided Missile Weapons Systems

YOU'LL FIND UNUSUAL OPPORTUNITIES FOR INDEPENDENT AND IMPORTANT WORK WITH THE BUREAU OF SHIPS' FIELD ACTIVITIES IN ANY OF THESE CAPACITIES:



Project Supervision at a Naval Shipyard

. . . to investigate fleet requirements first hand, determining whether present electronic equipment can be adapted to an advanced requirement, or whether a new design is needed,

. . . determine the design and test specifications in accordance with the ship's operating and physical environment,

. . . evaluate and test any suggested design or improvement for operating feasibility on a particular ship or installation,

. . . integrate new systems into a ship's existing electronic environment,

. . . participate in sea trials as a final operating checkout, and as a means of suggesting still further improvements, and

. . . direct and control resulting prototype development projects.

As a Project Engineer at a Naval Shipyard, you would be expected to have an on-the-deck as well as a behind-the-desk capability for designing, integrating, testing and evaluating electronic systems . . . for seeing what is needed and how to get it done.

Applied Research at a BuShips Laboratory

. . . to do fundamental research, and experimental development—as well as subsequent reliability and stability studies—on new and novel electronic systems and equipments of all kinds,

. . . help develop Naval Tactical Data Systems for particular classes of ships, including computer integration of data received through radar, sonar, fire control and navigation devices, and the visual presentation of this data by electronic display, and

. . . conduct basic measurement programs in electronic/acoustical technology.

As a Research Engineer at a BuShips Laboratory, you would be expected to create entirely new concepts on the one hand, and perform basic measurement and evaluation work on the other . . . to come up with ideas that will work and fill an unusual need.



Systems Engineering of Shore Electronics

. . . to conduct on-site surveys for shore electronic equipments here and overseas,

. . . prepare installation designs and monitor installation of systems, and

. . . trouble-shoot for existing systems.

Operating out of a Naval Industrial Managers Office, you would help create, install and maintain a variety of shore systems wherever they might be needed . . . seeing that they work and keep on working.



Consulting Engineering with Naval Contractors

. . . to review contractor plans and procedures for installing equipment on board ship, and

. . . monitor installation, and provide consultation on installation problems.

Operating from the Supervisor of Shipbuilding's Office at a contractor facility, you would have broad responsibilities to make sure new shipboard systems and equipments were properly installed . . . and functioning.

If you are interested in any of these opportunities which now exist on both coasts and in Hawaii with the Bureau of Ships' Field Activities, we would appreciate hearing from you.

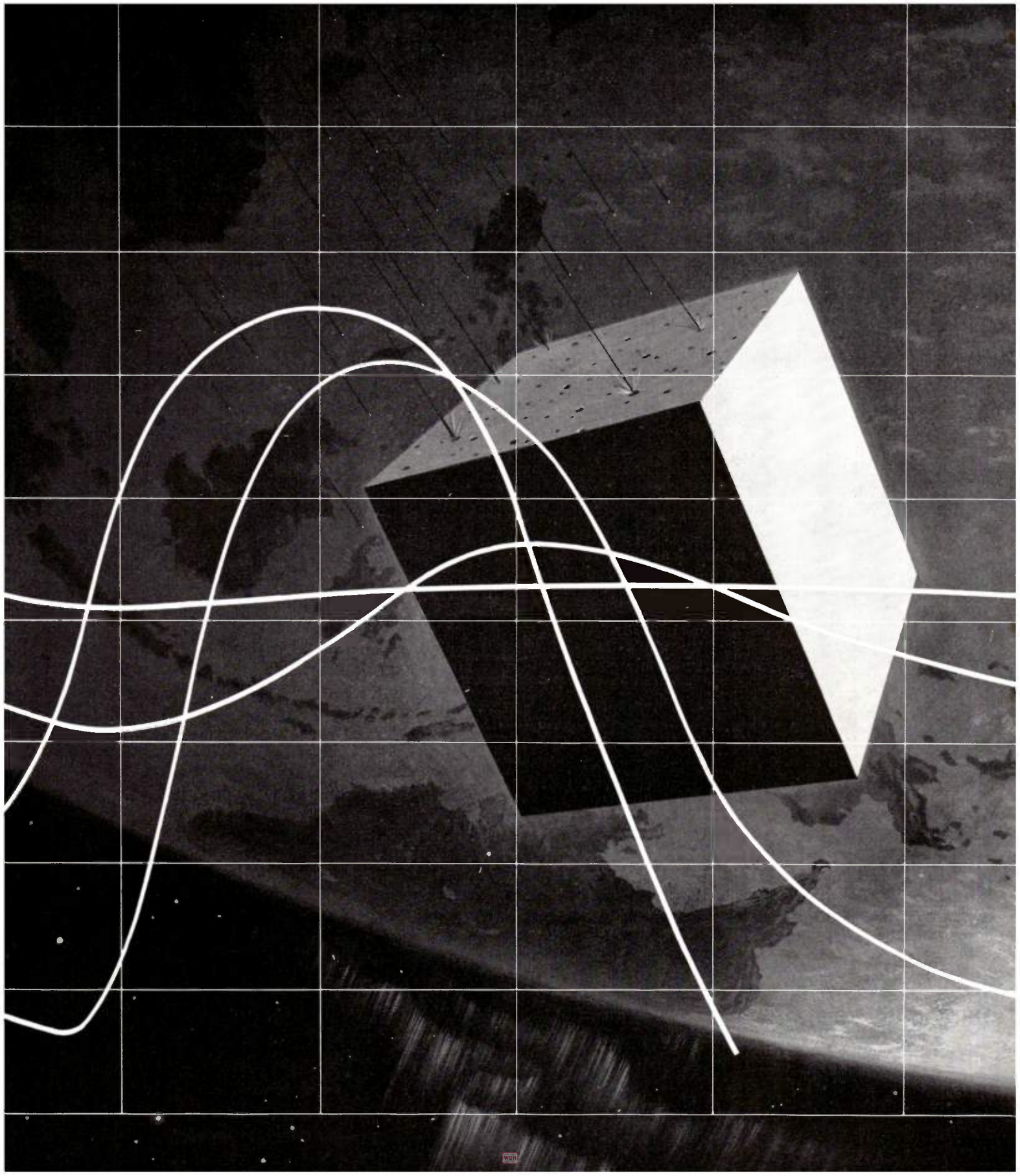
And in considering your future, don't overlook the extra benefits of Career Civil Service—liberal vacations and sick leave, wholly- or partly-supported post-graduate education, participating Health, Retirement and Life Insurance Plans.

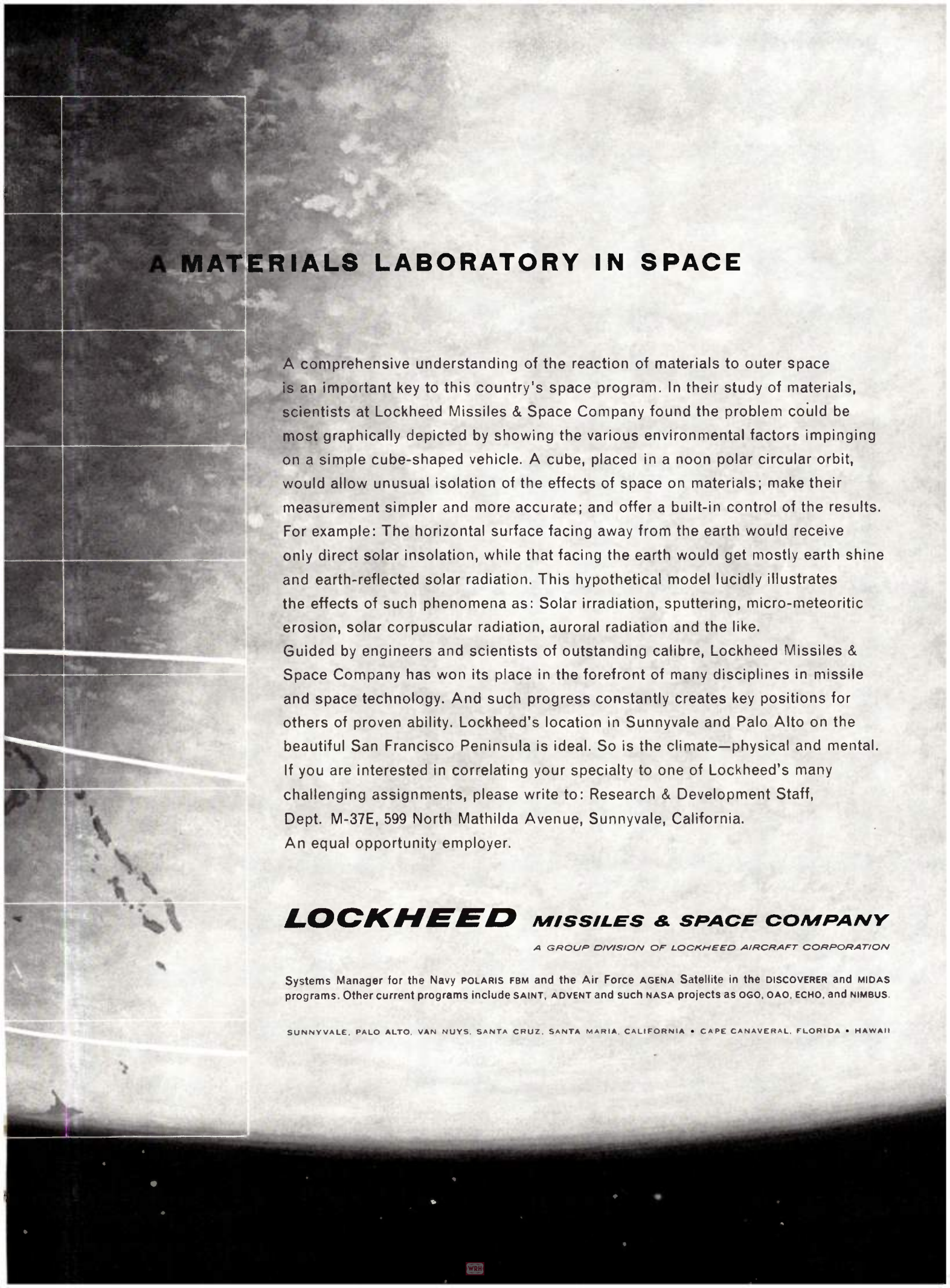
Starting Salaries $8,340 up to $12,210. Relocation expenses paid by Navy. All inquiries will be acknowledged immediately, and will be handled in complete confidence. Write: Director—Industrial Relations and Manpower.

The Bureau of SHIPS

Code 722-B, U. S. Navy Dept., Washington 25, D.C.

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A MATERIALS LABORATORY IN SPACE

A comprehensive understanding of the reaction of materials to outer space is an important key to this country's space program. In their study of materials, scientists at Lockheed Missiles & Space Company found the problem could be most graphically depicted by showing the various environmental factors impinging on a simple cube-shaped vehicle. A cube, placed in a noon polar circular orbit, would allow unusual isolation of the effects of space on materials; make their measurement simpler and more accurate; and offer a built-in control of the results. For example: The horizontal surface facing away from the earth would receive only direct solar insolation, while that facing the earth would get mostly earth shine and earth-reflected solar radiation. This hypothetical model lucidly illustrates the effects of such phenomena as: Solar irradiation, sputtering, micro-meteoritic erosion, solar corpuscular radiation, auroral radiation and the like.

Guided by engineers and scientists of outstanding calibre, Lockheed Missiles & Space Company has won its place in the forefront of many disciplines in missile and space technology. And such progress constantly creates key positions for others of proven ability. Lockheed's location in Sunnyvale and Palo Alto on the beautiful San Francisco Peninsula is ideal. So is the climate—physical and mental.

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Positions Wanted

By Armed Forces Veterans

(Continued from page 70A)

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MSEE. 3 years experience in transistorized digital systems for space probe payloads. Desires to do creative work in same or a similar field. Prefers small company or autonomous division of large company. Available in late summer. Write Box 3991 W.

ACADEMIC POSITION

B.S. and M.S. in E.E.; 3 years teaching in a university EE department prior to entering USAF for three years. Have begun work on Doctorate. Desire teaching position in Fall of 1962 with opportunity for graduate study. Write Box 3992W.

ELECTRICAL ENGINEER

USAF Officer, 44 BSEE 1940, MSEE 1957, Reg P.E. 1947. Experience: radar, communications, electronic intelligence and R&D in Special Weapons Fuzing. Prefer Southwest or possibly overseas. Available August 1962. Write Box 3993 W.



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
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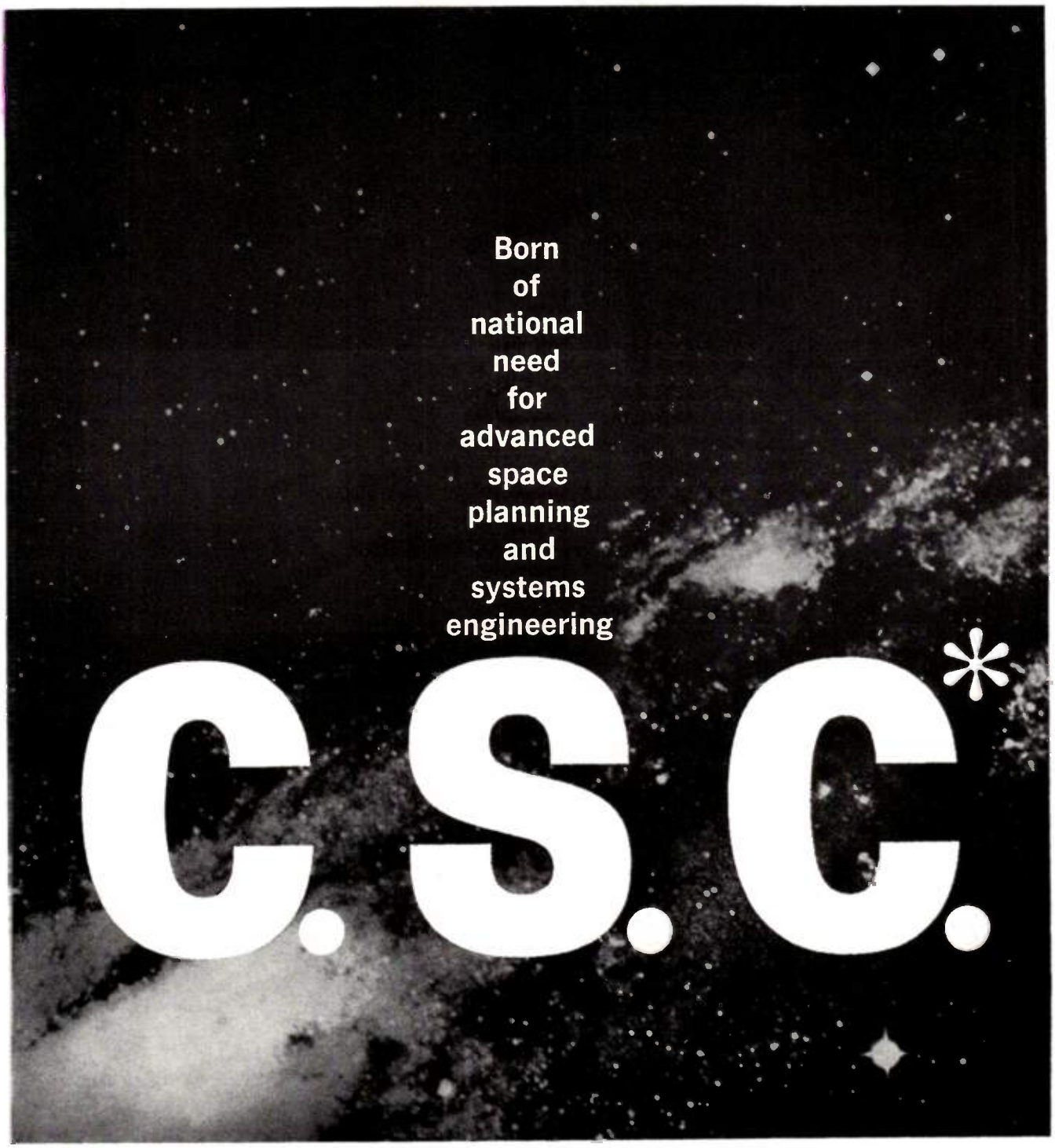
ELECTRONIC ENGINEERS

Electronic Engineers needed in the field of research, development and installation of Army Air Defense Systems. Salary to $10,635 per annum. Positions are in the Career Civil Service and are subject to Federal Civil Service benefits and requirements. Apply Civilian Personnel Office, Fort George G. Meade, Maryland.

McMASTER UNIVERSITY

Applications are invited for appointments in the Department of Electrical Engineering. Candidates should be qualified, or have interests, in one or more of the following fields: Circuits, electronics, control systems, communication systems, information theory, computers and digital systems. Applicants should hold a doctorate in Electrical Engineering, or in an appropriate branch of Mechanical Engineering or Physics, or should have equivalent qualifications and experience. Duties include teaching at undergraduate and graduate levels, conducting and supervising research. Salary according to qualifications and experience. Minimum rates: Assistant Professor, $7020.00; Associate Professor, $9,000.00; Professor, $11,700.00. Additional stipends for summer research. Applications and inquiries should be addressed to The Chairman, Department of Electrical Engineering. McMaster University, Hamilton, Ontario.

(Continued on page 76A)



*The United Aircraft Corporate Systems Center

Men of diverse technical and scientific disciplines at UAC's Corporate Systems Center are dedicated to a single purpose: to develop, manage and produce the complex systems which will shape man's future. Broad as that canvas may be, the brush strokes must be applied with infinite patience and consummate skill. While some C.S.C. scientists and engineers are active at the concept and analysis level, others are engaged in detailed feasibility studies and experimental development.

Under contract to the U. S. Air Force, C.S.C. is currently designing and developing an advanced stellar inertial guidance system. Other programs involve mobile ballistic missiles, terminal air defense, orbital rendezvous and satellite navigation and control. Simultaneously, our Weather System Center is assisting the Air Force and the F.A.A. in developing integrated and vastly accelerated methods for gathering and processing weather data.

Corporate Systems Center staff members enjoy funding stability, while being in a position to take advantage of the tremendous scientific and engineering capabilities and R&D facilities of United Aircraft Corporation.

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Positions Open

(Continued from page 74A)

TEACHERS

The Electrical Engineering Department of the City College of New York has several positions available on the teaching staff beginning September 1962. Rank and Salary commensurate with qualifications and experience. Opportunity for Graduate Study. Applicants must be present residents of the United States. Address inquiry to Prof. H. Taub, Dept. of Electrical Engineering, The City College, Convent Ave. at 139th Street, New York 31, New York.

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We hold the responsibility for special instrumentation for four large test reactors (MTR, ETR, EOCR, and ATR), the four SPERT reactors, three critical facilities (RMF, ARMF, and ETRC), and the Chemical Processing Plant (CPP).

Openings exist for Electrical Engineers, Physicists, Engineering Physicists, and others who have several years experience and interest in this field.

Write: Personnel Administration, Phillips Petroleum Company, P.O. Box 2067-CH, Idaho Falls, Idaho.

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Associate Professor and Associate Director of Research in Electrical Engineering. To have the responsibility for developing a research program including the securing of research contracts and the directing of research activity. Salary depending on experience and academic background. Write to Head, Electrical Engineering Department, South Dakota School of Mines and Technology, Rapid City, South Dakota.

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Ph.D. or equiv. exp.; background in servomechanisms, transistor circuitry, digital computers; to join medical group with aggressive experimental program in medical electronics. Long-term NIH support. N.Y. Area. Write Box 2067.

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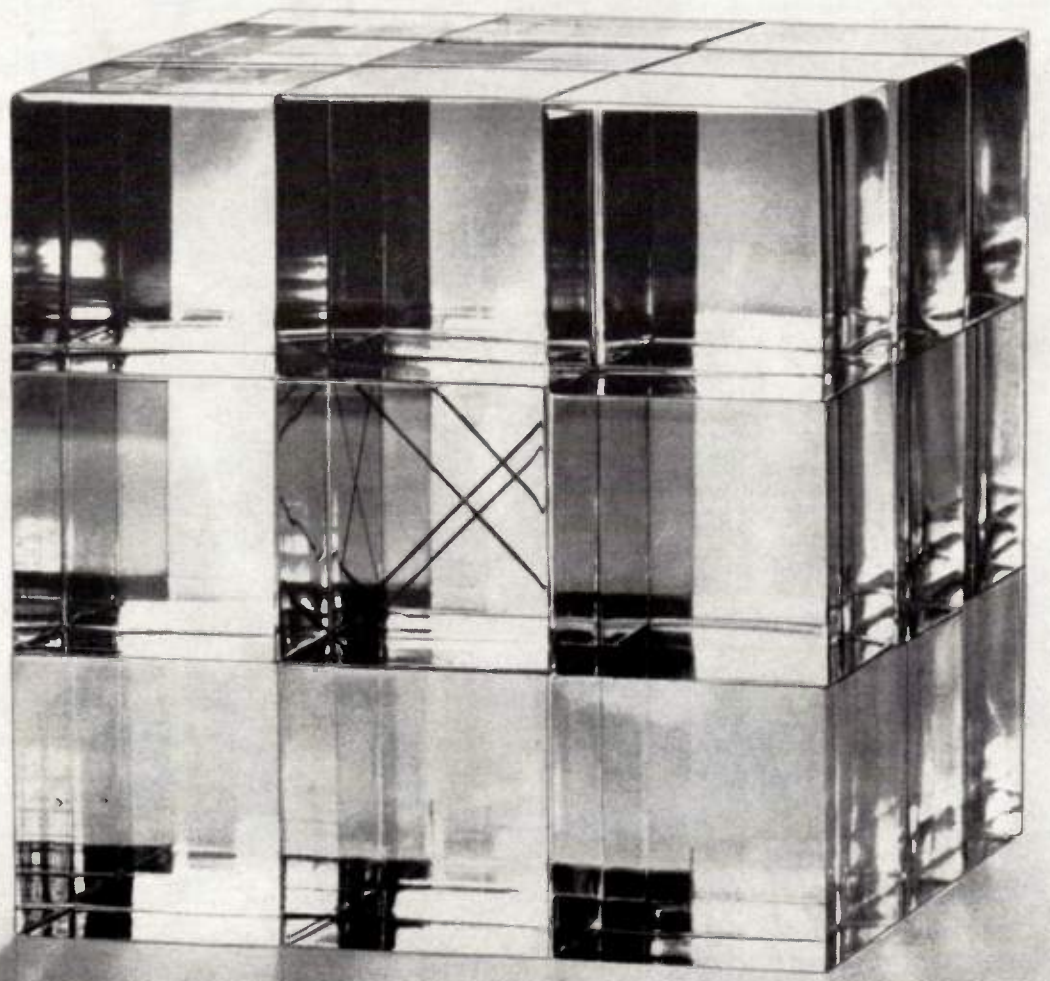
(Continued on page 78A)

ACHPHENOMENON

The mind focuses upon the center cube, each face having required a distinct cut. Until that realization, the problem of proving that a minimum of six cuts is necessary to make twenty seven cubes out of one appears insurmountable. Insight, perception, Achphenomenon at work.

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- **HOMING**

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In connection with the development of the homing guidance for the Typhon missiles, openings exist in the following three areas: (1) development, evaluation, and testing of homing antenna systems, (2) design and development of low-noise semi-conductor devices for use as microwave energy sources, and (3) a miniaturization program to reduce the physical size and weight of components to adapt to the limited packaging space available. Respondents should have a B.S. or M.S. in electronic engineering and experience in digital and microwave electronic design.

Other career positions involve work concerned primarily with the development of a two-way high-speed data link between the missile and radar in the Typhon system, employing digital and short pulse techniques. Additional duties include systems testing and analysis, as well as preparation of specs and other technical documentation. Some personal representation for the Laboratory in working relationships with subcontractors will be required.

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Positions Open

(Continued from page 76A)

CHAIRMAN OF ELECTRONIC TECHNOLOGY

The position of Chairman of the Faculty of Electronic Technology is open at Arizona State University. Electronic Technology is devoted to the preparation of Engineering Technicians in a four-year program which leads to a Bachelor of Science degree. Interested persons holding a M.A., M.S., or Ph.D., having teaching, industrial and administrative experience in electronics are invited to correspond with the Division of Industrial Education, Arizona State University, Tempe, Arizona.

GRADUATE STUDY & RESEARCH IN ELECTRICAL ENGINEERING

Scholarships of $1,940.00 and assistantships of $600.00 are available for the Session 1962-3. Inquiries should be addressed to: The Chairman, Department of Electrical Engineering, McMaster University, Hamilton, Ontario.

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ENGINEER

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Applications are invited for an Assistant or Associate Professor of Electrical Engineering. Candidates should be well qualified academically, preferably to the doctorate level, and should have some research, industrial design, or teaching experience. Specialization may be in Control Systems, Circuit Theory, or other fields of Electronics. Write to: Chairman, Department of Electrical Engineering, Sacramento State College, 6000 J Street, Sacramento 19, California.

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(Continued on page 80A)



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Positions Open

(Continued from page 78A)

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(Continued on page 82A)

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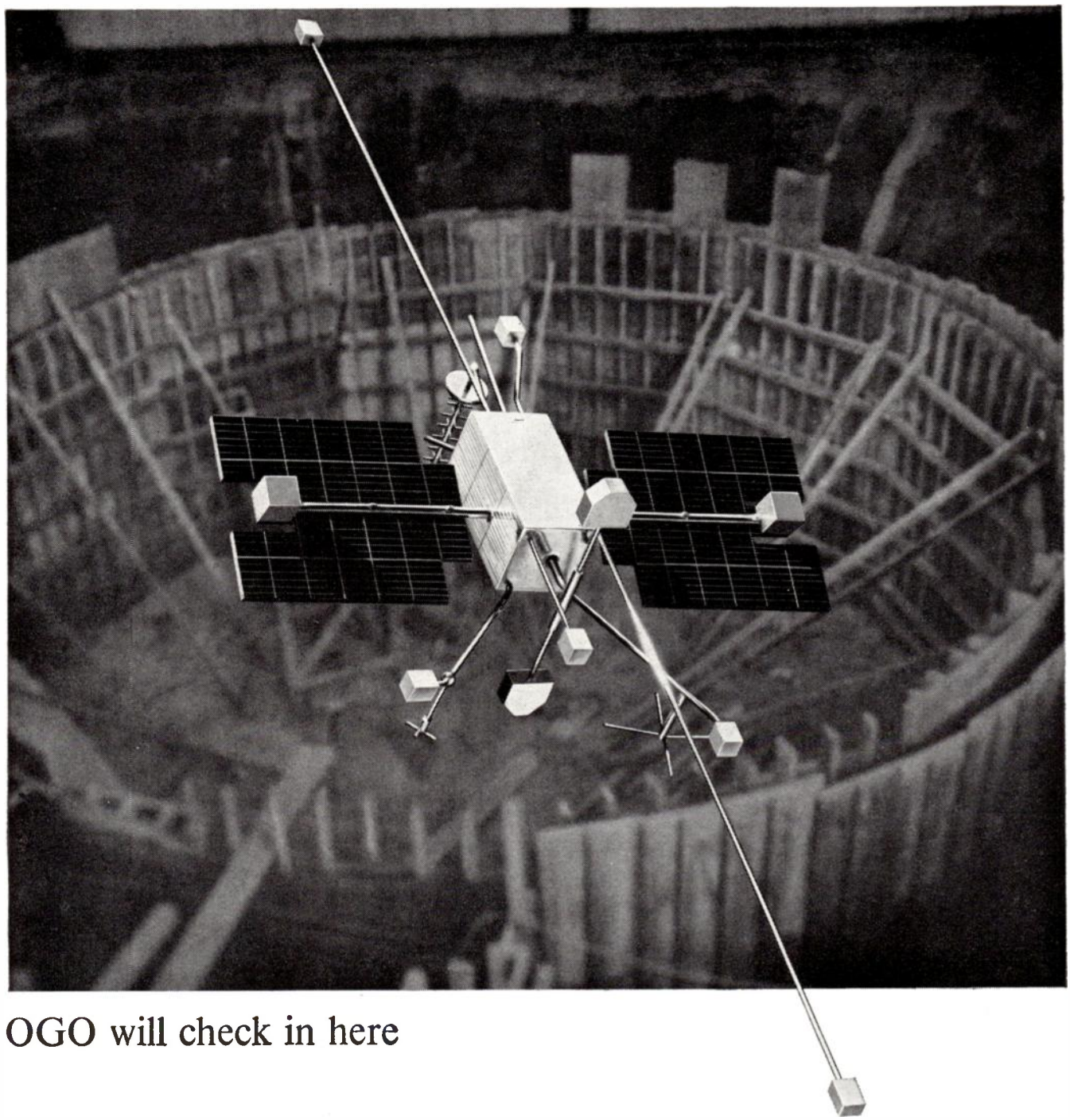
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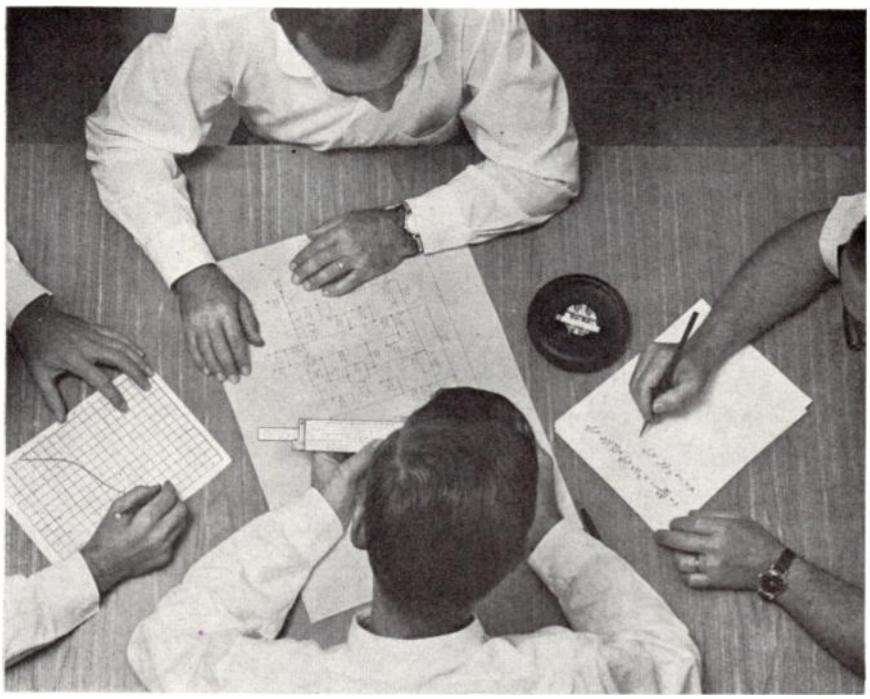
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P. O. Box 1417, Scottsdale, Arizona

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Chicago, Illinois, and at Culver City and Riverside, California

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Positions Open

(Continued from page 80A)

to $2500 per year. Send transcript and vitae to: Head, Electronics and Instrumentation, University of Arkansas, Graduate Institute of Technology, P.O. Box 3017, Little Rock, Arkansas.

ASSISTANT PROFESSOR OF E. E.

Ph.D. required and competence in Circuit Theory and/or Solid State phenomena desirable. Should have a definite interest in research and some teaching experience. Position available Sept. 1962. Write Head of E. E. Dept., State Univ. of Iowa, Iowa City, Iowa.

ENGINEER-MATHEMATICIAN

Senior position open for analytical engineer or applied mathematician. Salary, pension, and other benefits fully competitive with industry. Ph.D. essential. Course work will be at the graduate and advanced under-graduate level. Ample time and encouragement for personal research work, including participation in activities of University Computation Center with 1620 computer. Pleasant living and working conditions in attractive uncrowded city. Address inquiries to Robert A. Chipman, Chairman E. E. Dept., University of Toledo, Toledo 6, Ohio.

TEACHING POSITION

Expanding work in the Department of Electrical Engineering, Air Force Institute of Technology, requires an added staff member. Ph.D. desired, but M.S. with appropriate experience may be satisfactory. Beginning salary approximately $9000-$12,000 depending on qualifications. Employment effected according to Civil Service Regulations. Address inquiries to Head, Department of Electrical Engineering, Air Force Institute of Technology, Wright-Patterson AF Base, Ohio.

TEACHING AT ALASKA

The University of Alaska will have an opening for an instructor or assistant or associate professor. We are teaching electronics and communications and are ready to expand into power system engineering. Research might be on the ionosphere or in northern problems in communications or power. Write to J. G. Tryon, Head, Department of Electrical Engineering, University of Alaska, College, Alaska. Airmail please.

ENGINEER

E.E.—Audio Circuitry. Design of commercial high-fidelity, phonograph, and AM-FM tuner circuitry. Responsible for overall equipment performance, components, evaluation and follow-through. Transistor circuitry experience desirable. Generous salary and benefits. Write Mr. R. D. Sommer, Westinghouse Television-Radio Division, Metuchen, N.J. An equal opportunity employer.

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Teaching position in electrical engineering M.S. or Ph. D. with interest in teaching and developing courses in an electrical engineering undergraduate program. Openings are immediately available in Electronics, Energy Conversion, Electromagnetic Fields and Power Systems. Salary commensurate with background and experience. Write to Harley Anderson, Chairman, Electricity & Electronics Department, General Motors Institute, Flint 2, Michigan.

SYSTEM ENGINEERING—EARTH SCIENCES

Creative electrical/electronic engineers to conduct research and development program on auto-

(Continued on page 84A)

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For more specific information, write to Dr. Alexander Weir, Northrop Corporation, Box 1525, Beverly Hills, California. You will receive a prompt reply.

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b) **Pattern Recognition**
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e) **Cryogenic Gyro**
f) **Thin Film Cryotron**
g) **Gearless Power Drives**
h) **TIMMS**
i) **Sonar**

The special technical problems of modern "ordnance" create opportunities offering unusually high orders of specific disciplinary challenge and wide-ranging systems responsibility.

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If your degree is in EE, Physics or Math (Bachelors' to PhD) and any of the above areas interest you, write us in full confidence. We promise you a prompt reply. Address your letter or resume to Mr. D. F. Kline, Div. 53-MD.

ORDNANCE DEPARTMENT

GENERAL ELECTRIC

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Positions Open

(Continued from page 82A)

mation in data accumulation, reduction and processing in geology—geophysics, water resources investigations, geodesy, photogrammetry and allied fields including development of new techniques and equipment for sensing, transmitting, logging, processing and storing of mass data. Contact Placement Officer, U.S. Geological Survey, Washington 25, D.C.

ELECTRONICS ENGINEER—SALES

We are manufacturer's representatives selling high-quality instruments and OEM components to the electronic industry. The complexity of the product we handle requires a man having a BSEE degree and several years of experience. Fine, challenging opportunity with a fast growing organization. Compensation is by drawing against commission for field sales work. Contact Mr. George L. Boyden, Saunders & Company, 53 Prospect Street, Waltham 54, Mass.

ELECTRONIC SALES—INTERNAL

Inside technical sales. The expanded scope of our activity as an electronic manufacturer's representative has created an opportunity for a man to assist field salesmen by conducting mailing and phoning programs for our Waltham office. Ideal opportunity for a capable, disabled veteran. Secretarial skills such as shorthand and typing would be preferred but not necessary. Contact Mr. George L. Boyden, Saunders & Company, 53 Prospect Street, Waltham 54, Mass.

ELECTRONICS ENGINEER—EXPERIMENTAL SURGERY

For research program involving electronic organ and muscle control. M.S. or equiv. exp. servomechanisms; digital computers; transistor circuitry. Industrial background desirable. N.Y. area. Write Box 2069.

ELECTRONIC ENGINEER

Inductive Devices. Well established and growing company located in Culver City, Calif. has an excellent opportunity for a capable engineer to organize and manage the design and manufacture of low pass, high pass and band pass filters and electro-magnetic delay lines. Salary will be commensurate with training, experience and ability to manage. Liberal company benefits, Box 2070.

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SRI's expanding research efforts in our Electromagnetics Laboratory have created unique opportunities for MS and PhD physicists and engineers with backgrounds and interests in the following areas: Lasers; Microwave Components; Low-and High-Power Microwave Filters; Solid-State Filters; Parametric Amplifiers. Our work involves theoretical and experimental research. Located on the San Francisco Peninsula, SRI offers rich professional association, industrial-level salaries and advanced study opportunities. Please send resume or contact R. K. Ditmore, Stanford Research Institute, Menlo Park, California. An equal opportunity employer.

TEACHING POSITION

Excellent teaching opportunity will be available beginning September, 1962. Ph.D. preferred but will consider outstanding candidates with lesser qualifications. Attractive full-year contact available. Salary range is $7500-$9500. Location in the Midwest at a medium-size private university. Send complete resume to Box 2071.

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Speidel Corporation's Industrial Division offers exceptional opportunities for electronics engineers with B.S., M.S. and Ph.D. degrees to assume intermediate, senior and project engineer responsibilities in new programs for aerospace and commercial fields. Speidel desires men with experience in one or more of the following areas: Field Theory, Transistor Circuits, Magnetic Tape Recording, Electro-Mechanical Instruments, and Circuit Analysis for work on development of Recorder-Reproducers and Magnetohydrodynamic Gyros. Contact (call collect 8 a.m.-8 p.m.) Mr. Joseph Motherway, Chief Engineer, R & D, Speidel Corp., Industrial Div., Speidel Industrial Park, Warwick, Rhode Island, REgent 9-7000. An equal opportunity employer.

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Inquiries are invited from electronics engineers to join the staff of the M.I.T.-Harvard 6 Bev Electron Acclerator. Experience in one or more of the following specialties is desirable: design and development of dc to nanosecond circuits, data handling and computer techniques. Excellent qualifications and 3 to 5 years practical experience required. Resumes, including salary requirements, should be addressed to the Director, Cambridge Electron Accelerator, Harvard University, 42 Oxford Street, Cambridge 38, Mass.

DEPUTY TECHNICAL DIRECTOR—ISRAEL

A practical engineer with a minimum of 7 years working experience and at least 3 years in development or design and series production scheduling of work on electronic components, such as coilpacks, I.F. transformers, potentiometers, tuning condensers, etc. This position is available on a 3 year contractual basis. For information inquire COMOI, 515 Park Ave., New York 22, N.Y. Plaza 2-0600.

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ASSOCIATE PROFESSOR OF E. E.

Position open September 1962 to teach undergraduate and graduate courses. Must have Ph.D. degree, or MS with equivalent experience. Specialty in networks or electromagnetic theory. Submit resume to Chairman, Electrical Engineering Dept., University of North Dakota, Grand Forks, North Dakota.

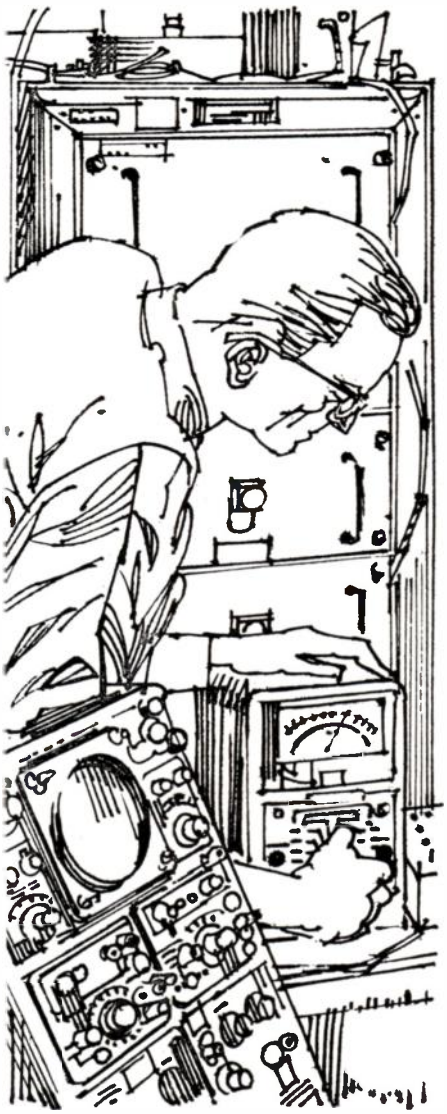
PH.D. OPENING

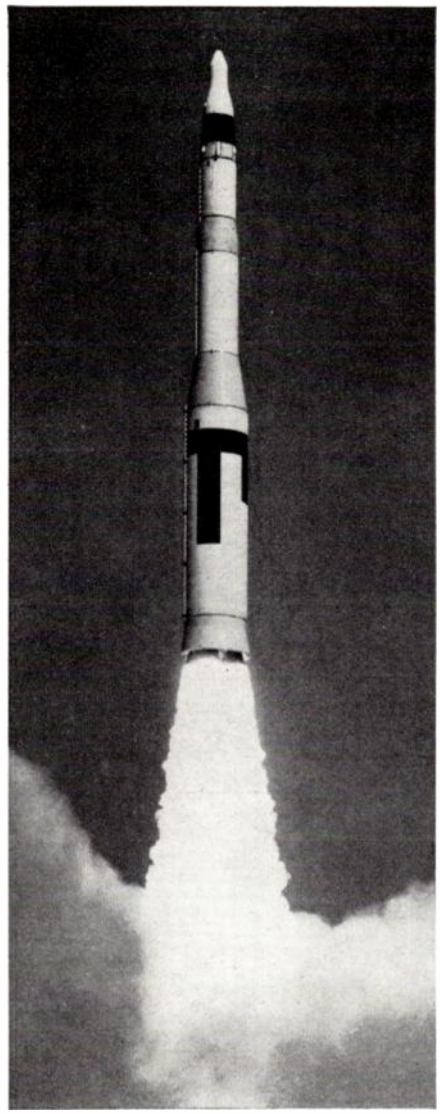
Excellent opportunity for Ph.D. with background in microwaves and/or solid state. Some teaching and some research required. Private consulting encouraged. Department has Ph.D. program. Good salary and rank arrangements will be made for exceptional man from either the industrial or academic fields. Address replies to: Dr. Fred Schumann, Chairman, Electrical Engineering Department, Vanderbilt University, Nashville, Tennessee.

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Responsible for performing systems design for proposals, improved systems, integrating inputs (technical design & program planning.) Provide preproposal and proposal & technical

(Continued on page 87A)





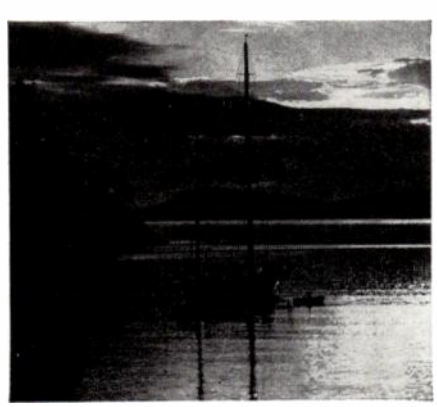


BOEING OPENINGS FOR ELECTRONIC/ELECTRICAL ENGINEERS

Boeing's Aero-Space Division, holder of major contracts on such advanced space programs as SATURN, DYNA-SOAR and MINUTEMAN, has a number of immediate, long-range openings offering professional challenge, and in many instances, unique ground-floor opportunities in newly-formed divisional organizations.

ELECTRONIC/ELECTRICAL engineering assignments are available in many areas, including the design of electronic equipment, the development of improved design techniques, electronic parts, electronic packaging techniques and the design and development of improved electronic systems.

Salaries are commensurate with all levels of education and experience. Minimum requirements are a B.S. degree in any applicable scientific discipline. Most of the assignments are in the uncongested Pacific Northwest, offering outstanding family living and recreational advantages.



Send your resume, today, to Mr. Carl Anderson, The Boeing Company, P.O. Box 3707-PRP, Seattle 24, Washington. The Boeing Company is an equal opportunity employer.

P.S. Seattle is the scene, April 21 to October 21, of the science-oriented Century 21 World's Fair. The Fair's Boeing-sponsored Spacearium in the Science Pavilion offers simulated flights through outer space. Fair visitors are invited to stop in at the Boeing Professional Employment Information Center, near the Fair's Science Pavilion entrance.

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engineers

Currently, we have select openings for above-average engineers in the following areas:

SYSTEMS ANALYSIS AND DEVELOPMENT

Application of basic analytical knowledge to calculations regarding magnetic systems relative to the development of particle accelerators.

Design, develop and evaluate amplification, stabilization and control systems and magnetic field-measuring devices. Good basic knowledge of circuit theory required.

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Employment will be at the modern, fully-equipped research and manufacturing facilities of High Voltage Engineering Corporation where our outstanding technical staff has developed the world's most advanced line of particle accelerators and associated equipment.

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You can make this exciting future your future. Each of our development laboratories has openings for microwave tube or power grid tube development engineers. If your forte is developing new higher power, higher frequency tubes, or cavities or test equipment. Or if you have a flair for solving tube production problems and advancing production techniques and equipment, there are exciting challenges to investigate at Eimac. You'll work in an area renowned for its concentration of electronics industry, sunny weather, fine schools and pleasant living conditions. If you can qualify, write: Mr. C. F. Gieseler, Department C, Eitel-McCullough, Inc., San Carlos, California. An equal opportunity employer.

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Positions Open

(Continued from page 84A)

ntegration with customer up to award of contract, provide advanced research studies. Should ıave experience in technical direction of Air- ›orne Weapon Systems. Send resumes to: Jordan-White, Inc., 420 Lexington Avenue, New York, New York.

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The Department of Electrical Engineering seeks a Ph.D. for research and teaching in an expanding graduate program with emphasis on circuit analysis and synthesis, and the applica- ion of solid state devices. Should have experi- ence in securing and directing sponsored re- search. Applications and inquiries may be sent o John E. Dean, Head, Department of Elec- rical Engineering, Colorado State University, Fort Collins, Colorado.

Professional Group Meetings

(Continued from page 68A)

Santa Ana—November 14

"Ferrite Devices—Present and Future," Dr. H. S. Scharfman, Raytheon, Waltham, Mass. Panelists: Dr. M. T. Weiss, W. A. Hughes, A. Clavin, H. N. Chait.

Santa Ana—October 10

"Concepts for Wideband Parametric Amplifier Design," Dr. G. L. Matthaei, Stanford Research Institute, Hughes, Culver City.

"Parametric Amplifier," Dr. H. Ozaki, Stanford Research Institute, Hughes, Culver City. Panelists: R. D. Wegelein, A. D. Berk, D. B. Anderson, C. L. Cuccia.

Santa Ana—September 12

"Recent Advances and Applications of Advanced Radar Systems," Dr. N. Begovich, Hughes Aircraft Co., Fullerton, Calif.

Toronto—February 5

"Propagation and Antenna Effects in Space Communication," Dr. O. C. Hogg, Bell Telephone Labs., Holmdel, N. J.

(Continued on page 88A)



Yesterday . . . a man named Revere and a dependable steed. Today . . . sophisticated secure weapons command and control systems. The communications media differ but the need is the same . . . *get the message through.*

For tomorrow's secure communications systems . . . scientists and engineers at Amherst Laboratories are developing new concepts . . . improving existing communication techniques . . . advancing the state-of-art in survivable communications.

STAFF AND MANAGEMENT OPPORTUNITIES exist for Electronics Engineers and Physicists with 5-10 years of experience in command and control systems, aerospace communications and familiarity with advanced communications techniques. Your inquiry will be held in confidence. Please forward resume to Mr. H. L. Ackerman, Professional Employment,

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Dept. 195, 14000 Georgia Avenue
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Phone: WHitehall 2-7200

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Professional Group Meetings

(Continued from page 87A)

Audio

Chicago—January 16

"Transducers for the Measurement of Sound, Vibration, and Strain," G. W. Kamperman, Bolt, Beranek and Newman, Inc.

Cleveland—November 16

"FM Stereophonic Broadcasting," C. G. Eilers, Zenith Radio Corp., Chicago, Ill.

Automatic Control

Baltimore—January 11

"Stabilization of Ocular Motion by the Semi-Circular Canals," Dr. D. Robinson, John Hopkins Univ. Medical School, Baltimore, Md.

Chicago—February 5

"Computer Control Will Work—If . . . ," J. Hunnicutt, TRW Computers Co., Chicago.

Dallas-Fort Worth—January 23

"Automatic Digital Control of Machine Tools," C. A. Fulcher, Ling-Temco-Vought, Garland, Texas.

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SR. DEV. ENG'R.
Develop wideband i-f amplifiers, i-f oscillators, i-f isolation amplifiers & related circuits.

SR. DEV. ENG'R.
Develop X-band radar circuits & equipment including wave guide assemblies & related circuits.

SR. DEV. ENG'R.
Servomechanisms, design close loop control system.

SR. DEV. ENG'R.
Develop radar transmitters & modulators including pulse forming networks, transformers, protection circuits, X-band amplifiers & related circuits.

SR. PACKAGING ENG'RS.
Layout packaging & detailing layout of electronic sub-assemblies including i-f and r-f units.

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

Request Application or Send Resume To:

B. A. Watts, Engineering Personnel
Goodyear Aircraft Corporation
Litchfield Park, Arizona

Similar Positions at Goodyear Aircraft Corporation, Akron, Ohio.

Bio-Medical Electronics

Boston—February 6

"Human Control Characteristics," Professor T. B. Sheridan, M.I.T.

Boston—December 12

"Neural Correlates of Echo Location in Bats," Dr. A. D. Grinnell, Harvard University.

Buffalo, Niagara—January 16

"Instrumentation. Monitoring of Air for Biological Pollutants," S. Nelson, U. S. Army Biological Warfare Lab., Frederick, Md.

Buffalo, Niagara—December 13

"Miniaturization and Telemetry for Physiological Monitoring in Space," N. W. Greatbatch, Greatbatch, Inc., Clarence, N. Y.

Buffalo, Niagara—November 21

"Cardiac Pacemakers and Defibrillators," A. C. Bekate, M.D., University of Buffalo, and Baruch Berkovitz, American Optical Co.

Buffalo, Niagara—October 17

"Instrumentation in Respiratory Physiology," Dr. L. Farhi, University of Buffalo School of Medicine.

Buffalo, Niagara—September 19

"Electronic Monitoring of Patient Data during Anesthesia," S. Woldring, M.D., Roswell Park Mem. Institute, Buffalo.

Columbus—January 4

"Cognitive Processes as Related to the Servo-Model," Dr. J. S. Kidd, Battelle Mem. Institute.

"Brain as a Function of Sensory Input," B. G. Austen, Battelle Mem. Institute.

"Modeling of the Central Nervous System," A. B. Clymer, Battelle Mem. Institute.

"Visual Appearance of Stationary Objects," S. J. M. England, Columbus Psychiatric Hospital.

Los Angeles—January 18

"Intracardiac Pressure and Sound Monitoring," Dr. O. Dallons, Dallons Labs., El Segundo, Calif.

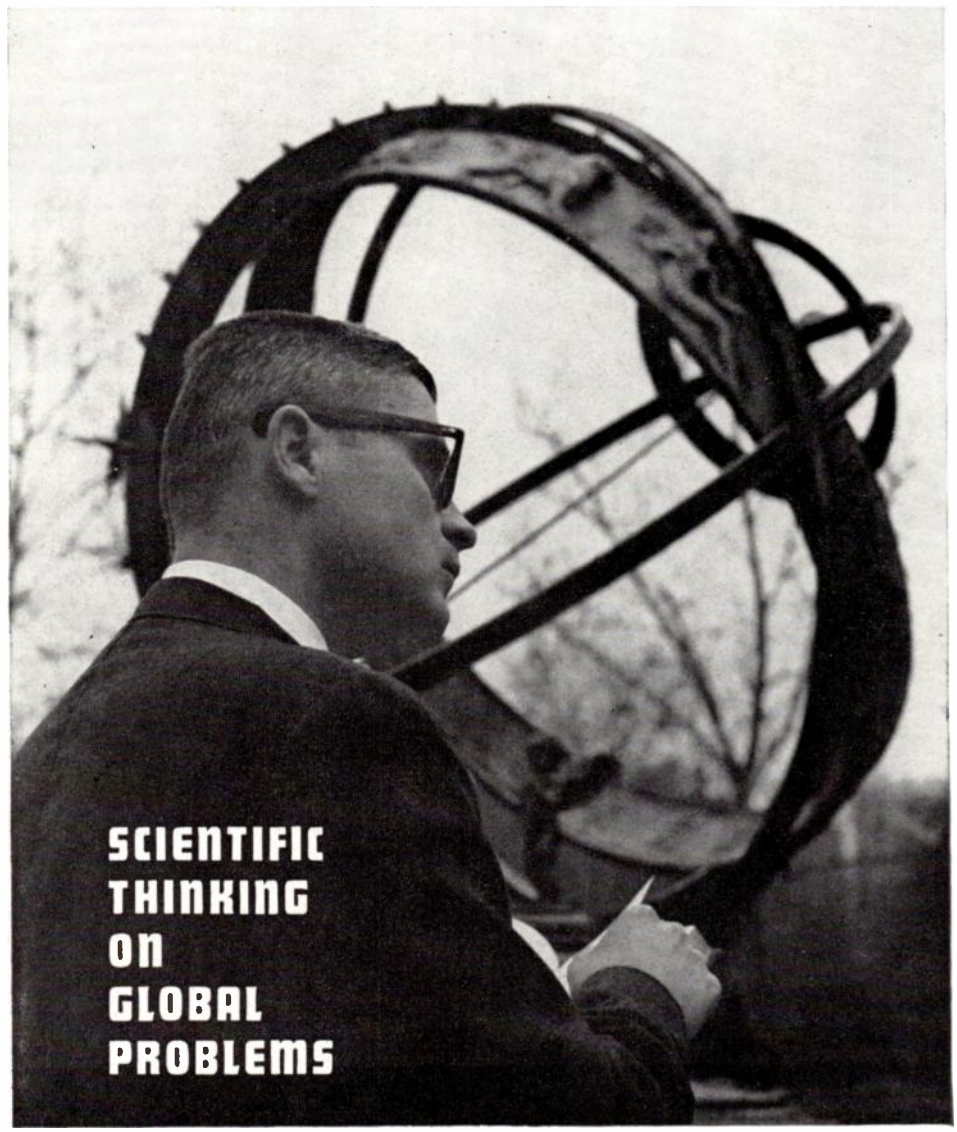
Montreal—November 30

Panel Discussion on "Electronics, A New Aid for Obstetrical Gynaecological Practice & Research. What is Needed? What are the Present Limitations?" Panel Chairman—Dr. T. Primrose; Panelists: Drs. J. S. Henry, E. H. Shabanah, F. G. Tweedy, Royal Victoria Hospital and Dr. R. M. Parsons, Montreal General Hospital and Mr. H. Kolshorn, Hako Electronics Co.

Montreal—April 19

"A Method for the Measurement of Regional Lung Function Using Xenon 133 External Counting," Dr. W. C. Ball and L. D. Pengelly, Royal Victoria Hospital.

(Continued on page 90A)



Analytical insight into world-wide problems of concern to the United States Army—this is the constant objective of the Research Analysis Corporation.

RAC scientists utilize the techniques of operations research and systems analysis. They seek answers to questions of critical importance in strategy, tactics, logistics, intelligence, air defense, management systems, and other areas of similar significance. These answers are often prerequisite to major Army decisions.

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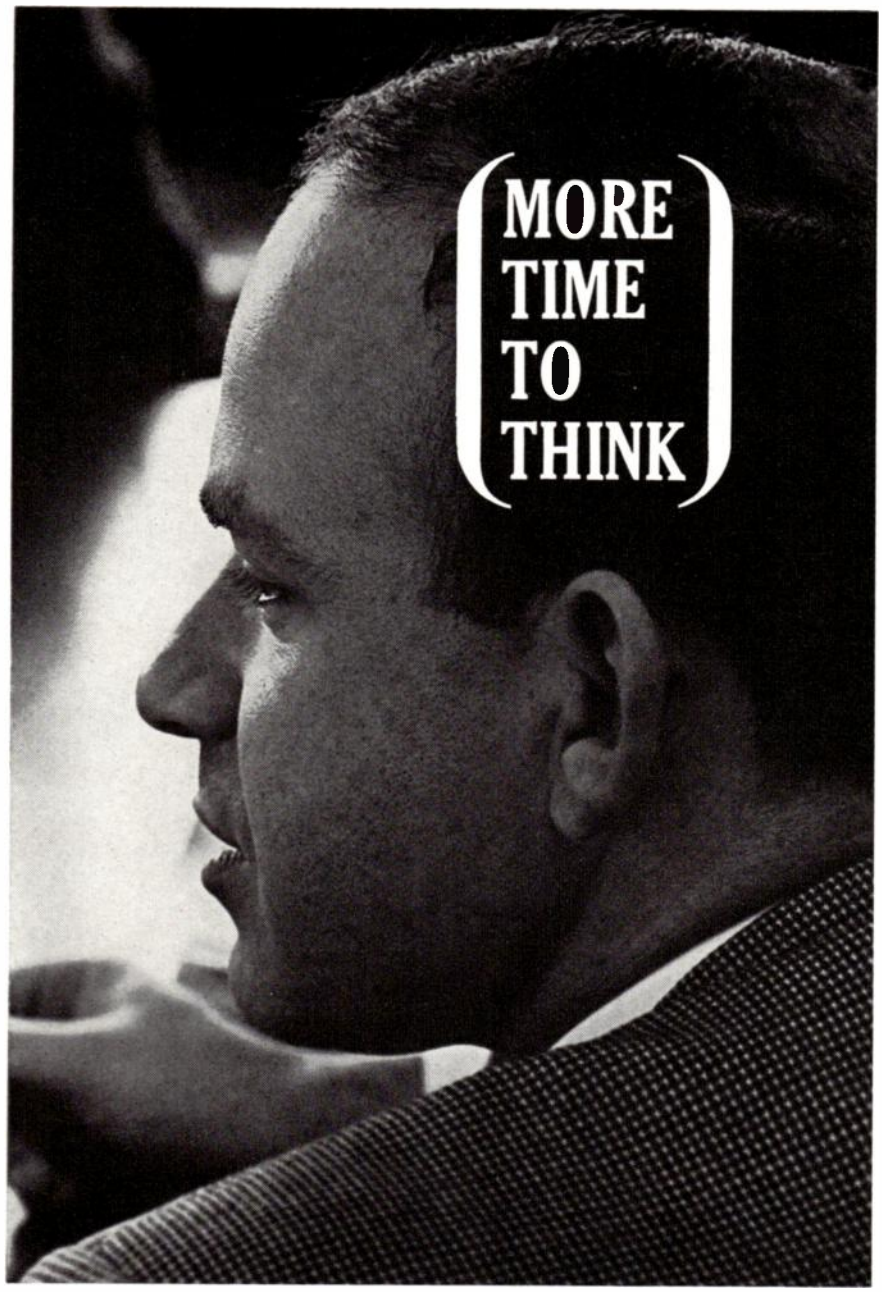
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Professional Group Meetings

(Continued from page 88A)

Montreal—February 22

"Extraction of Signals from Noise-Swamped Biological Systems—A Critical Review," Dr. J. A. Tanner, Natl. Research Council, Ottawa.

New York, Long Island, Northern New Jersey, and Princeton—January 16

"Problems and Prospects in Computer Diagnosis," R. Engle, M.D., Cornell University Medical Center.

New York, Long Island, Northern New Jersey, and Princeton—December 18

"The Clinical Application of Peripheral Nerve Conduction Velocity Studies," J. Goodgold, M.D., Institute of Rehabilitation, and S. Reiner, M.E.E., Teca Corp

New York, Long Island, Northern New Jersey and Princeton—November 28

"The Electron Microscope and its Relation to the Life Sciences," F. J. Herrmann, RCA, Camden.

Twin Cities—January 9

"A Proposal for a Medical Instrumentation Center," Dr. W. G. Kubicek, Univ. of Minnesota Medical School.

Other Activities: Tour of Medtronic, Inc., Facilities.

Broadcasting

Cleveland—December 14

"Application of Airborne Television to Public Education," F. G. Mullins, Westinghouse Elec. Corp., Baltimore, Md.

Cleveland—October 19

"New Developments in FM Stereo Techniques," A. H. Bott, Radio Corp. of America, Camden, N. J.

Florida West Coast—January 24

"Program Scheduling and Automatic Logging," S. G. Oren, IBM, Tampa, Fla.

Broadcast and TV Receivers

Chicago—February 9

"The 23-Inch 92-Degree Color Tube," R. Hanson and R. O'Fallon, Motorola, Inc.

Circuit Theory

Syracuse—January 30

"Ambiguity Functions in Signal Processing," Dr. C. A. Stutt, General Electric Co.

Communication Systems

Baltimore—January 22

"Satellite Communication Systems," G. Sanner, Bendix Radio Div., Baltimore, Md.

(Continued on page 92A)



TO ENGINEERS AND SCIENTISTS
LOOKING FOR GREATEST PERSONAL
INVOLVEMENT IN MAJOR SYSTEMS FOR SPACE:

COMMON SENSE SAYS, "LOOK TO THE HEAVENS"... OR DOES IT?

All of the glamour that surrounds hardware in orbit often obscures one very meaningful fact. As much as 80% of a complete space system is, and remains, on the ground.

Here's another fact. Within General Electric, technical competence for the ground-based portion of space programs concentrates here in Syracuse, New York.

For instance, the highly reliable radio-inertial guidance system our engineers developed for ATLAS (now operational with the USAF) is the same system that has been used for booster guidance on 75% of America's space shots.

Another system, utilizing an entirely different set of engineering concepts, is MISTRAM*. Its current function is to introduce a revolutionary magnitude of precision into ICBM trajectory measurement. Important future ramifications lie in extending the system to global ranges, satellite tracking, space guidance and hypersonic traffic control.

Still other programs such as GEESE (General Electric Electronic System Evaluator), the vast-scale Air Weapons Control System 412-L. Theoretical and Applied Space Physics, Radiation Effects Research, and many more, provide rugged exercises in technical ingenuity.

MISTRAM's basic system concept involves a geometric arrangement of 5 ground radio receiving stations. Missile position, trajectory and velocities are continuously calculated with great accuracy from phase differences in a beacon signal received from the missile. Radar is used only to orient the radio receiving antennas in the general direction of the missile.

AN ADDED THOUGHT

This much diversity in one organization generates a uniquely flexible type of career environment. You can plot and re-plot your best avenue of advancement, without having to leave the company in order to do so.

IMMEDIATE OPPORTUNITIES IN THESE AREAS:

Communication Systems / Operations Analysis / System Equipment Analysis / Weapons Integration / Applied Mathematics / Telecommunications Systems Design / Programming Analysis / Engineering Writing / Antenna & Microwave Components / Equipment Evaluation / Information Processing & Display Systems / Human Factors

For a prompt reply, mail us a copy of your resume (or an informal outline of your education and experience) in full confidence. Address to Mr. P. W. Christos, Div. 53-MD.

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DSD DEFENSE SYSTEMS DEPARTMENT
A Department of the Defense Electronics Division

GENERAL ELECTRIC

Northern Lights Office Bldg., Syracuse, New York.

RESEARCH ENGINEERS

New directions in computer-oriented research require new approaches in researchers. An expanded research program at the Data Systems Division of Litton Systems, Inc. has created high-level openings for original, creative engineers.

Applicable backgrounds include an advanced degree in Electrical Engineering (Electronics) or Physics. Experience may be in any of the following:

ELECTROMAGNETIC THEORY ■ OPTICS ■ HIGH-SPEED CIRCUITRY ■ NEW MEMORIES ■ ANALYSIS, DESIGN, OR INTERCONNECTION OF MECHANISMS ■ INFORMATION THEORY ■ SYSTEMS CONCEPTS ■ LOGIC ■ ELECTROCHEMISTRY ■ INTEGRATED CIRCUITS

Data Systems Division is located in the suburban San Fernando Valley of Los Angeles. Generous employee benefits include stock purchase and tuition-paid education plans. Relocation assistance is available.

To arrange for interview contact Mr. H. C. Laur.

DATA SYSTEMS DIVISION
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Advanced Programs Staff
In Orlando, Florida

Communications

There are staff-level vacancies requiring communications systems engineers who are experienced in circuit design and analysis. Applications include airborne and ground digital data transmission, analog and digital computer systems, pulsed RF/IF amplifiers, and command and control display systems.

Work with the team who developed Pershing, Bullpup, GAM-83, Lacrosse, Racep, Missile Master, and BIRDiE! Join them as they constantly advance the state-of-the-art in missile and electronic systems. Investigate these opportunities by sending your resume, in confidence, to Mr. P. A. Miller, Martin Company, Orlando Division, Sec. 322, Orlando, Florida. (An equal opportunity employer.)

MARTIN
ORLANDO
A Division of Martin Marietta

Professional Group Meetings

(Continued from page 90A)

Boston—January 9

Dr. A. C. Dickieson of Bell Telephone Labs. discussed in brief the general characteristics of Project Telestar.

Dr. H. T. Hokanson of the Missile and Space Dept. of the General Electric Co. discussed the subject of frequency allocations and how these may be affected by satellite uses. He then went into an interesting discussion of polar, equatorial and synchronous orbits and the effect they have upon the ground receiving stations.

Dr. R. B. Marsten of the Astro-Electronics Section of RCA presented a very interesting discussion of RCA's role in satellite communications, with particular emphasis on Project Relay sponsored by NASA.

Dr. W. E. Morrow of Lincoln Lab. gave an interesting discussion of the "Dipole" launch last October and the results that have followed their efforts to find the cause of failure of the spin-out of the dipoles.

Dr. G. E. Mueller of Space Technology Labs. discussed the Advent program.

Col. J. A. Plihal of Electronic Systems Division, Hanscom Field, discussed the armed services' interest in satellite communication systems.

Moderator: Mr. R. A. Marks of the Rome Air Development Center.

Chicago—January 16

"A Synchronously Pumped Electron Beam Parametric Amplifier for Phase-Locked FM Receivers," E. C. Adams, Zenith Radio Corp.

Northern New Jersey—October 15

The speaker's personal description of the evolution of the microwave theory, the components and applications beginning with his work with water-filled pipes, step by step, to what we know today as the state of the art. Dr. G. C. Southworth, BTL (Retired).

Northern New Jersey—September 7

Design—Problems and Techniques, "The Future of Worldwide Communications Systems," Dr. H. Busignies, ITT Corp., N. Y.

This being the first meeting of the new Chapter, Mr. G. Karger, PG Coordinator, delivered a brief address on behalf of the Section.

Communications Systems and Microwave Theory and Techniques

Northern New Jersey—November 15

"NORAD—Communications and Electronics," Brig. Gen. D. P. Gibbs, U. S. Army.

(Continued on page 94A)

The Calibre of an Aerospace Organization Is Evidenced by the Calibre of the Problems Put To It by its Customers — and by the Company to its Engineers

Engineers, Scientists

what's your opinion:

1

ON HOW TO STORE AND PRESSURIZE CRYOGENIC PROPELLANTS IN SPACE, MAINTAINING INSTANT READINESS?

At Bell Aerosystems, Design Engineers are carrying on a concentrated attack on this problem, as it relates to space propulsion rocket engines, where weight and reliability are at a premium. This is an expanding activity at Bell. *Your* professional contributions will be welcomed if your experience and background equips you to analyze steady-state and transient heat transfer effects interrelated with thermodynamics and chemical kinetics of pressurization under varying space environments.

2

ON HOW TO DESIGN A DE-CRABBING SYSTEM TO AUTOMATICALLY ALIGN AIRCRAFT LONGITUDINALLY IN CROSS-WIND LANDINGS?

Correct alignment within 3 seconds of touchdown has been obtained by Bell engineers, in developing an all-weather landing system for conventional aircraft, successfully tested in 4000 landings of USN and USAF planes. Opportunities exist to participate in advanced studies of full spectrum of problems of automatic landing of very high-speed, advanced spacecraft.

3

ON HOW TO IMPROVE THRUST-TO-WEIGHT RATIO OF ELECTRO-STATIC PROPULSION DEVICES?

Applied research and advanced development in thermoelectrics for space propulsion is an important field of interest at Bell. As a qualified member of an R & D group in this area you would be concerned with finding practical answers to applications of electro-static propulsion for such missions as: interplanetary trips to Venus; interorbital transfers; deep space probes; satellite orientation control. Investigations are also in progress to develop light-weight ionization and neutralization systems; methods of creating, controlling and accelerating plasmas.

If you would like to pit your talents against the more significant and challenging problems of the Aerospace Age, why not look into the wide variety of professional openings at Bell, some of which are listed below. Bell Aerosystems originated the AGENA rocket engine, HIPERNAS inertial systems, the revolutionary Reaction Control Concept for space vehicle steering and many other advances in missilery, avionics and propulsion... is now working on such diverse programs as the HYDROSKIMMER air cushion vehicle for the Navy, and a realistic space simulator for astronauts.

INERTIAL GUIDANCE

Various degree levels with 2 to 8 years specific experience in one of the following areas: logic design and magnetic memory development; low frequency design and development involving servos; systems and component testing, resolver chains, gyros, accelerometer integrators; inertial instrument development.

ELECTRONIC SYSTEMS

MS preferred, with minimum 5 years experience for synthesis and analysis of advanced systems such as air traffic control, target locators, visual simulators and feed-back controls. Openings also in Tucson, Arizona.

SYSTEMS ENGINEERING

BS in ME, Applied Math, AE or Physics. Experienced in the dynamics of closed-loop systems, guidance, mechanics of vehicle flight, space mechanics, analog and digital computing systems.

OPTICAL DEVELOPMENT

Advanced Engineering degree with minimum of 10 years experience in the design and construction of optical devices. For original design of optical equipment such as visual simulation apparatus, airborne sighting systems, and precision instrumentation.

DYNAMICS ENGINEERING

Degree in Math or Physics with experience in operation of analog computer equipment. To perform dynamic analysis of aircraft and missile systems, mechanization and operation of analog computer equipment in systems synthesis, design and evaluation.

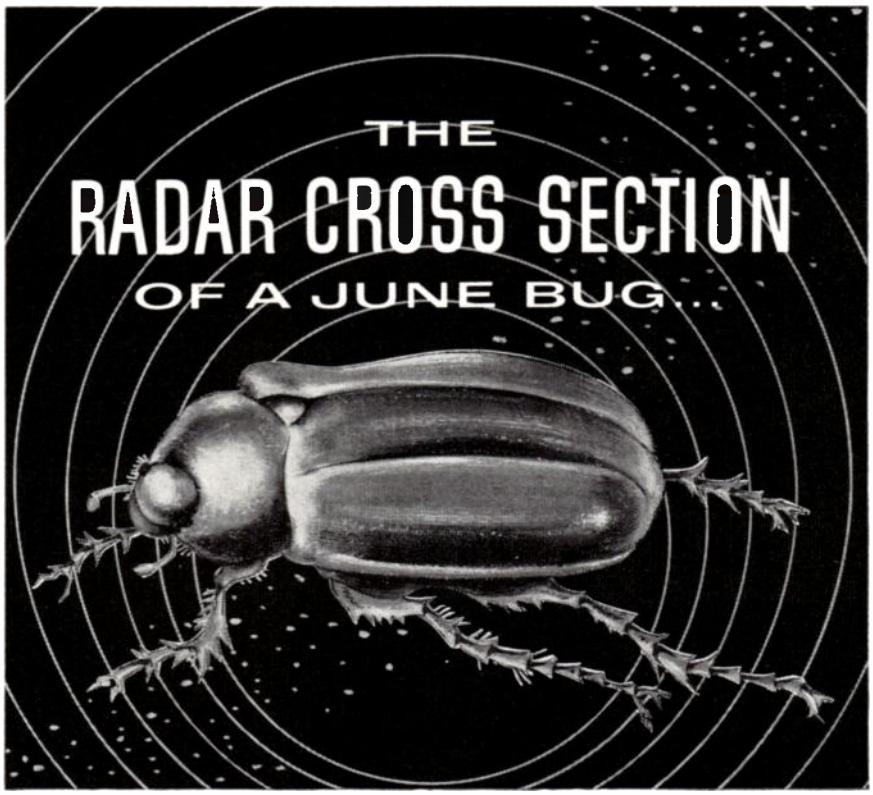
Please address resumes to Mr. George Klock

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. . . is 10^{-5} sq. meters. At least, those that sometimes interfered with our significant research in the measurement of radar cross sections were that big.

Meaningful research, however, must surmount more serious barriers than June bugs. Barriers, for example, like those of semantic differences between the tongues of electronics engineers and physicists, between aeronautical engineers and psychologists. This is particularly true in a research laboratory, where professional men of vastly different backgrounds work with and try to understand each other as they push back the frontiers in new fields.

Here, scientists and engineers with minds open to new ideas, adept at stepping over barriers between technologies, will find a broad array of problems to solve — in an environment that encourages the development of original ideas. Here, engineers conducting plasma sheath research work shoulder to shoulder with scientists doing research in ion cyclotron resonance, or in re-entry interactions with the upper atmosphere, or in gaseous electronics.

Cornell Aeronautical Laboratory welcomes atmospheric and ionospheric physicists, and engineers experienced in electronics, microwave techniques, optics, and physical chemistry as principal investigators. We invite men with *ideas* to mail the coupon today.

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Professional Group Meetings

(Continued from page 92A)

Communications Systems and Vehicular Communications

Philadelphia—January 15

Seminar on Modulation Methods for Space Communications:

"Definitions and Criteria for Evaluation," E. W. Coffey.

"Performance of Modulation Techniques Now in Use," J. R. Allen.

"Effect of Transmission Media," R. D. Lending.

"Some Aspects of Time Varying Channels," G. Lieberman.

"Multi-Parameter Modulation for the High Rate, High S/N Case," E. L. Soohoo.

Component Parts

Baltimore—January 23

"Thermoelectric Cooling and Power Generation," R. A. Bernoff, Ph.D., Melcor Electronics Corp., Farmingdale, N. Y.

Electron Devices

Boston—January 17

"Space Environment and Its Effects on Semiconductor Materials and Devices," J. F. Weller, Naval Research Lab., Washington, D. C.

"Effects of the Space Environment on Electronic Materials and Components," F. J. Campbell, Naval Research Lab., Washington, D. C.

Boston—November 20

"State-of-the-Art of Solid-State Microwave Transmitters," W. C. Maciag, Sylvania.

New York, Long Island, and Northern New Jersey—January 18

"Microwave Modulation of Light by the Electro-Optic Effects," I. P. Kaminow, Bell Telephone Labs., Holmdel, N. J.

New York, Long Island, and Northern New Jersey—December 14

"Superconducting Magnets," J. E. Kunzler, Bell Telephone Labs., Murray Hill, N. J.

New York, Long Island, and Northern New Jersey—November 9

"The Larmotron—A.D.C. Pumped Quadrupole Amplifier," G. Bernstein, S.F.D. Labs., Union, N. J.

Philadelphia—January 22

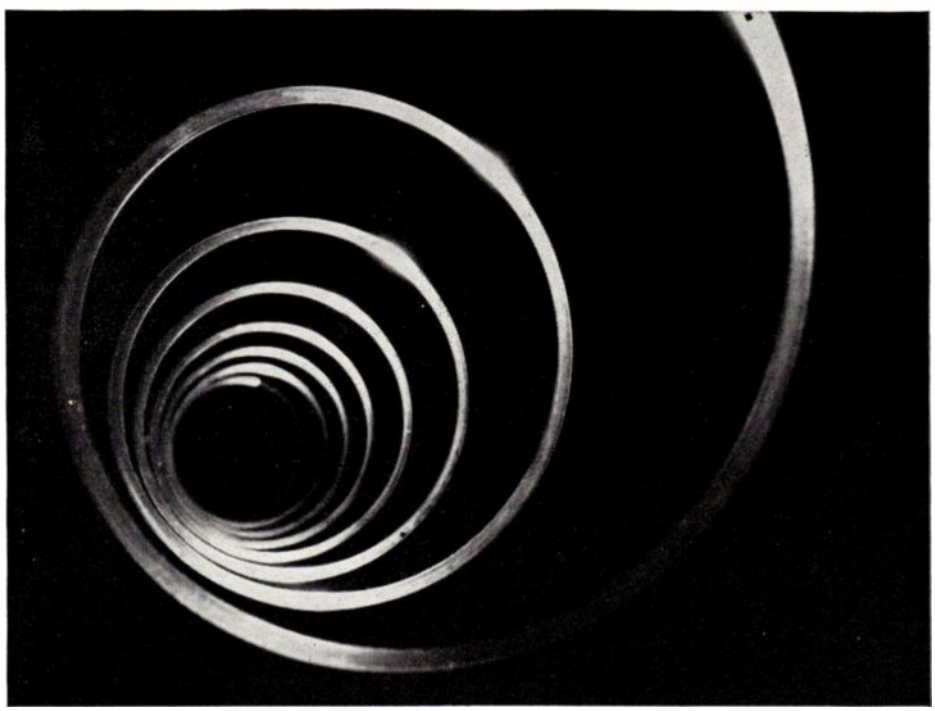
"State of the Art in Gallium Arsenide Devices," Dr. J. Hilibrand, RCA, Somerville, N. J.

Washington, D. C.—January 22

"Plasma Amplifiers and Oscillators," Dr. M. Glicksman, RCA Labs., Princeton, N. J.

(Continued on page 96A)

. . . TO THE EDGE OF SPACE AND BEYOND . .



PLANNED PROGRESS

Step by step. Stride by stride. America's space program under NASA is one of carefully planned progress. Every launch, every space probe, every orbiting vehicle contributes specific information to the mass of new knowledge and technology needed to achieve the next goal.

The historic flight of Friendship 7 was a first step. More will follow. Then an 18-orbit mission. Then Gemini, carrying two astronauts, for prolonged investigations in space. And finally Apollo, which in this decade will take men to the moon and back. This is the great leap that will free mankind from his planet.

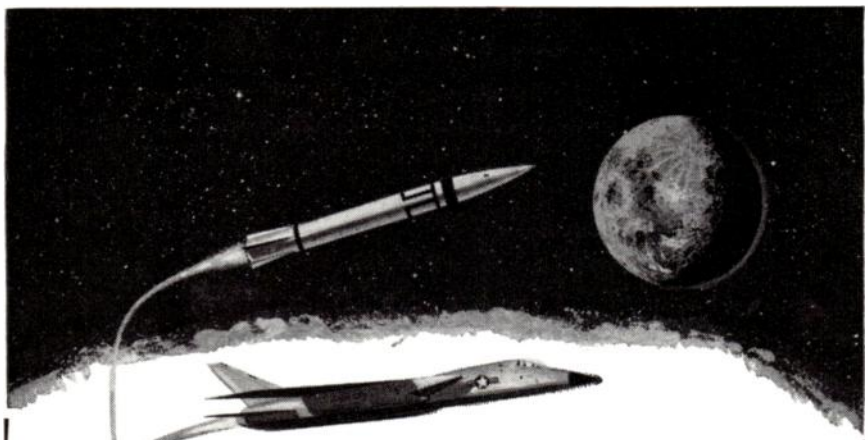
The civilian space program which NASA implements and directs is a national program with immeasurable by-products for human welfare. It is perhaps the greatest technical effort ever undertaken. Intensive scientific investigations are carried out in every field, and every modern technology. It employs weather and communications satellites, deep space and lunar probes, orbiting observatories. Thousands of problems must be solved, new technologies mastered, space oceans charted, unknown environments studied. All this must be accomplished before true space travel can be achieved by men.

To carry out its directives, NASA needs large numbers of engineers and physical scientists in all disciplines. Career opportunities for qualified men and women holding B.S., M.S., or Ph.D. degrees are virtually unlimited. In this swiftly expanding program, advancement and professional recognition can be rapid.

NASA invites your inquiry to the Personnel Director of any of the following NASA Centers: NASA Manned Spacecraft Center, Houston, Texas • NASA Goddard Space Flight Center, Greenbelt, Maryland • NASA Marshall Space Flight Center, Huntsville, Alabama • NASA Ames Research Center, Mountain View, California • NASA Flight Research Center, Edwards, California • NASA Langley Research Center, Hampton, Virginia • NASA Wallops Station, Wallops Island, Virginia • NASA Lewis Research Center, Cleveland, Ohio • NASA Headquarters, Washington 25, D. C. •

Positions filled in accordance with Aero-space Technology Announcement 252-B. All qualified applicants will receive consideration for employment without regard to race, creed or color, or national origin.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



Outstanding opportunities in:

SURFACE BASED ELECTRONIC SYSTEMS

The Columbus Division of North American Aviation is developing a major product line in surface based electronic systems. This work encompasses communications and radar systems, data processing systems, and command and control systems. Outstanding growth potential exists.

Specific openings are available for the following personnel:

Project Engineer for the development of phased array antenna systems and for advanced design of radar and communications systems.

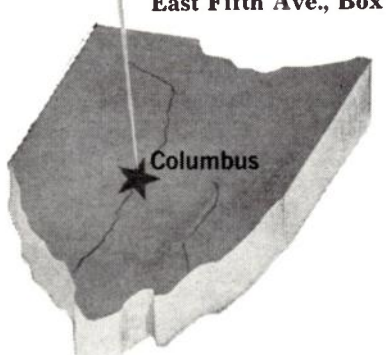
Staff Specialist to perform advanced systems analysis and operations analysis on surface based electronic systems, aircraft drones, missiles and electronic countermeasures.

Staff Specialist to analyze the design of advanced communications systems, high powered transmitters, antennas, RF transmission lines and propogation.

Senior Engineers to perform advanced systems analysis and operations analysis on surface based electronic systems, aircraft drones, missiles and electronic countermeasures.

Senior Engineer in Missile Aerodynamics to conduct stability and control, trajectory, and flight dynamics studies on advanced tactical missile systems including the effects of autopilot characteristics and system noise.

You may investigate these openings by writing to: North American Aviation, The Professional & Technical Employment Office, Attn: H. Keever, Mgr., 4300 East Fifth Ave., Box IR-459, Columbus 16, Ohio.



All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

COLUMBUS DIVISION

NORTH AMERICAN AVIATION

Professional Group Meetings

(Continued from page 94A)

Electronic Computers

Los Angeles—November 16

"Effect of Problem-Oriented Languages on Computer Design," C. Oliphant, Burroughs Corporation, Pasadena, Calif.

Los Angeles—September 21

"Deposited Composition Elements and Their Impact on Computer Technology," Dr. M. Clauser, Clauser Technology.

Los Angeles—October 19

"Riot — Real Time Input - Output Transducer," R. S. von Buelow, Systems Development Corp., Santa Monica, Calif.

New York, Northern New Jersey—November 21

"Design of Display Systems," R. L. Sisson, Auerbach Electronics.

New York, Northern New Jersey—October 25

"Airborne Digital Computers," L. F. Jones, Coral.

Omaha, Lincoln—January 29

"Computer Usage in Medicine," B. Watson, VA Hospital, Omaha.

Philadelphia—January 9

"The Use of Digital Computers in Process Control in the Steel Industry," R. W. Sonnenfeldt, RCA, Camden.

San Francisco—January 23

"The B5000 Systems Design," N. Krueder and C. Oliphant, Burroughs Corp., Electrodata Division.

Santa Ana—January 25

"Stored Logic Computers—An Overview," W. F. Bauer, Ramo-Wooldridge.

"Stored Logic Computers—Engineering Considerations," L. D. Amdahl, Ramo-Wooldridge.

"Stored Logic Computers—Programming Considerations," R. H. Hill, Ramo-Wooldridge.

Electronic Computers and Military Electronics

Philadelphia—December 14

"Army Research and Development Activities," Maj. Gen. W. J. Ely, U.S.A. Dir. of Research.

The Army Research Award was presented to Mr. A. Damask of Frankford Arsenal Institute of Research.

Engineering Management

Baltimore—January 18

"Problems of Engineering Managers," Dr. L. Ostreicher, Martin-Marietta Corp., Baltimore, Md.

(Continued on page 100A)

jpl needs

ENGINEERS & SCIENTISTS

JOIN WITH THE men and women responsible for the Nation's most challenging scientific and engineering program: the exploration of outer space.

Caltech's Jet Propulsion Laboratory has been assigned a key roll in the Nation's lunar, planetary, and interplanetary exploration programs by the National Aeronautics and Space Administration. Virtually every technical discipline is involved, and the finest minds are needed. Minds that will only take know for an answer. Minds such as yours, perhaps.

Immediate openings exist in each of JPL's eight Technical Divisions:

- SYSTEMS DIVISION
- SPACE SCIENCES DIVISION
- TELECOMMUNICATIONS DIVISION
- GUIDANCE & CONTROL DIVISION
- ENGINEERING MECHANICS DIVISION
- PHYSICAL SCIENCES DIVISION
- ENGINEERING FACILITIES DIVISION
- PROPULSION DIVISION

COMPLETE THE QUESTIONAIRE ON THE REVERSE SIDE

If you're interested in becoming a part of Jet Propulsion Laboratory's long range Space Exploration programs, simply complete the questionaire on the reverse side, fold and return postage paid card to us at once. Every completed inquiry will be acknowledged.

jpl

"Research and Development of America's lunar, planetary, and interplanetary exploration programs."

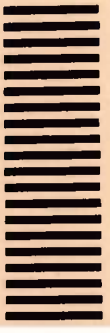
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jpl needs ENGINEERS AND SCIENTISTS

The vast amount of information to be acquired, the scientific research and testing necessary, the new concepts and techniques to be investigated and the number of areas to be explored constitute exceptional career opportunities for qualified Engineers and Scientists in the following areas:

Astronomy
- Astrophysics
- Orbital Mechanics

Electronics
- Energy Conversion Devices
- Servomechanisms
- Gyros
- Electron Optics
- Transistor Circuitry
- Semiconductor Applications
- Sensors
- Magnetic Devices
- Instrumentation
- Microwaves
- Radar
- Telemetry
- Communications—Radio
- Antennas
- Logical Design
- Digital Computers
- Analog Computers
- Data Processing

Mathematics
- Logic
- Number Theory
- Numerical Analysis
- Probability and Statistics
- Information and Communication Theory
- Computer Programming
- Celestial Mechanics

Physics
- Semiconductors
- Crystalline
- Cryogenics
- Magnetohydrodynamics
- Thermionics
- Plasma
- Optical Instruments
- Spectroscopy
- Infra-red
- Molecular-Atomic
- Atmospheric

Aeronautical Engineering
- Aerodynamics
- Stability and Controls
- Spacecraft Structures
- Propulsion Systems
- Gas Dynamics

Mechanical Engineering
- Structures
- Dynamics
- Stress Analysis
- Mechanics
- Heat Transfer
- Properties & Mechanics of Materials

Chemistry

Life Sciences

Earth Sciences

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MS			
PhD			

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how long on present job_____ salary_____

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additional interests:_____

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Mars is on the other side of this door

No. There are no Martians in there. Just humans. Just scientists and engineers poring over papers, chalking black boards, filling notebooks. And making decisions.

They're deciding what scientific instruments will go aboard the first Mariner spacecraft to fly-by the Red Planet in 1964.

They work at Caltech's Jet Propulsion Laboratory. And they like their jobs.

Behind other doors are other humans plotting more missions into space. Moon landings. Deep space communication probes. New spacecraft designs.

It's a busy world. A world peopled by people like yourself. People who want to find out what the moon is made of and if there's life on other planets.

Why do they want to find out? Because they're human. And curious. And because their training will let them only take know for an answer. Wouldn't you like to work with humans like that? Write to us. Our door is always open.

JET PROPULSION LABORATORY
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Operated by California Institute of Technology for the National Aeronautics & Space Administration

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ENGINEERS, EE:

Looking for more responsibility immediately... and a starting salary that reflects it?

General Electric's Light Military Electronics Department is seeking highly competent engineers to fill immediate technical leadership and consulting openings in the following program areas:

Space Vehicle Guidance Systems	Command Guidance & Instrumentation
Missile & Satellite Computers	A.E.W. & Control
Microelectronics	Electronic Countermeasures
Space Detection & Surveillance	Space Communications & Telemetry
Navigation & Communication Systems	Undersea Warfare Systems
Silicon Crystal Circuit Development	Thin Films
	Automated Test Equipment

LMED

LIGHT MILITARY ELECTRONICS DEPARTMENT

GENERAL ELECTRIC

THESE ARE SAMPLES OF THE IMMEDIATE OPENINGS:

TRANSISTOR CIRCUIT DESIGN
...on computers utilized in airborne early warning system.

LEAD EE
...to integrate logic and circuit design efforts on space vehicle guidance equipment.

CIRCUIT DEVELOPMENT AND APPLICATION ENGINEER
...should be capable of doing work in the following areas: a) Paper design & synthesis of complex circuitry such as is found in airborne electronics; b) Analysis of complete systems to determine and design those portions capable of being microminiaturized; c) Advise and consult with product line electronic design engineers; d) Prepare proposals.

DATA PROCESSING CONSULTING ENGINEER
...involves computer design, including logic and logic organization, basic computer circuit design, memory storage circuits and devices, overall computer systems synthesis. Also includes direct leadership of D/A projects for advance design techniques, consultation with design engineers on product line design problems, assistance in preparation of technical proposals, participation as panel member in design reviews, leadership of technical symposia in your design field.

SYSTEMS ANALYST
...includes missile flight test and analysis regarding guidance systems and computation; orbital trajectory analyses; overall system, sub-system and error analysis.

COMMUNICATION ENGINEER
...for design studies and analyses regarding command control systems for space applications.

SPACE NAVIGATION OR GUIDANCE ENGINEER
...to conduct systems studies regarding integrating hardware, e.g., developing stellar, radio or inertial navigation or guidance systems to perform specific missile function.

MICROWAVE ENGINEER
... with 3 to 5 years' antenna and microwave design experience to design radar and missile antennas, and microwave components.

For a careful review of your qualifications, and a prompt reply, forward your resume today in strictest confidence. Address: Mr. R. Zukowski, Div. 53-MD, Light Military Electronics Dept., General Electric, French Road, Utica, New York.

An Equal Opportunity Employer

Professional Group Meetings

(Continued from page 96A)

Boston—October 24

Panel Discussion on "Management by Computer."

New York, Long Island, and Northern New Jersey—January 24

"The Long Range Marketing Outlook for the Defense, Electronics and Space Industry," R. Sellers, Robert C. Sellers and Associates, Garden City, N. Y.

San Francisco—January 10

"Matrix Organization Control for Engineering," R. W. Jones, Booz, Allen and Hamilton, Los Angeles.

Engineering Writing and Speech

Boston—February 7

"Current Feeling of the Courts Towards Patents and Related Areas," R. H. Rines, patent lawyer, Rines and Rines, Boston.

Los Angeles—February 5

"Johnny Engineer Can't Write or Speak Either—and He'd Better Learn," Dr. R. Richardson, Los Angeles Board of Education.

Los Angeles—November 29

Panel discussion, "How to Improve the Technical Communication Function," R. Broman.

Twin Cities—January 29

"Communication and its Consequences," Elliott Roosevelt, Hoffman Callan Co., Minneapolis.

Human Factors in Electronics

Los Angeles—December 5

"A Model of Human Dynamic Behavior," I. Ashkenas, System Technology, Inc., Hughes, Culver City.

"Complex Displays with Vehicle Guidance and Control," A. C. Williams, System Technology, Inc., Hughes, Culver City.

Industrial Electronics

Cleveland—October 26

"Design of Digital Control Systems," W. S. Bennett, Frontier Electronics Co., Cleveland, Ohio.

Omaha, Lincoln—February 6

"Electric Home Heating Economics," R. F. Kulisek, Omaha Public Power Dist., Electric Fixture and Supply Co.

"Electric Home Heating Equipment," R. A. Fried, Omaha Public Power Dist., Electric Fixture and Supply Co.

Information Theory

Los Angeles—November 29

"Optimal Search Procedures," E. C. Posner, Caltech Jet Prop. Lab., Pasadena, Calif.

"Map-Matching Techniques," C. S. Lorens, Space-General Corp., Glendale, Calif.

Los Angeles—September 28

"Applications of Detection Theory to the Venus Radar Experiment," R. Goldstein, Caltech Jet Propulsion Lab.

"Comparison of the U. S., Russian, and British Venus Experiments," L. Malling, Caltech Jet Propulsion Lab.

San Francisco—January 25

"Project West Ford," Dr. R. W. Lerner, Lincoln Lab., M.I.T., Lexington.

Instrumentation

Chicago—January 16

"A New Approach to A-C Measurement and Calibration," P. L. Richman, Rotek Instrument Corp., Cambridge, Mass.

Long Island—January 16

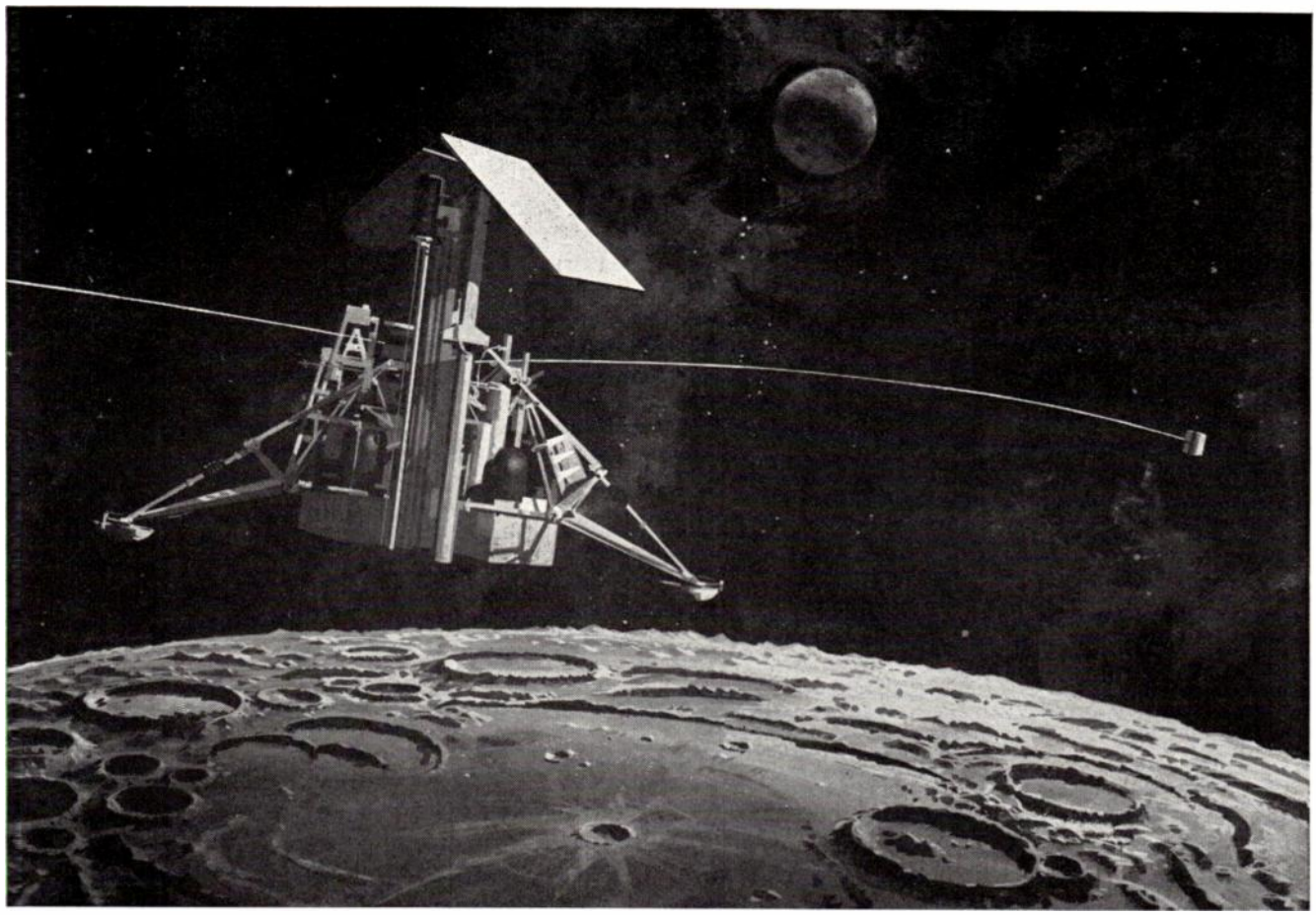
"Radar Bright Display Instrumentation," E. Gottlieb and J. Hart, General Instrument Corp., Hicksville, N. Y.

Los Angeles—January 18

"ESP Instrumentation," Rev. V. L. Cameron, Water and Mineral Locator, Elsinore, Calif.

(Continued on page 102A)

Problem for you:



Soft land this vehicle on the moon

This spacecraft is SURVEYOR, one of the many important projects now under way at Hughes. It will "soft" land on the moon sometime in 1963. Its mission: to pierce and analyze the moon's surface; to transmit back to earth high quality television pictures; and to measure the moon's magnetic and radiation characteristics. To accomplish these demanding objectives, Project Surveyor requires the talents of many imaginative junior and senior engineers and physicists to augment its outstanding staff. A degree from an accredited university and U.S. citizenship are required. Experience in Aerospace Vehicles is preferred but not necessary. A few of the openings include:

CONTROLS ENGINEERS. Concerns airborne computers and other controls related areas for: missiles and space vehicles, satellites, radar tracking, control circuitry, control systems, control techniques, transistorized equalization networks and control servomechanisms.

CIRCUIT DESIGNERS. Involves analysis and synthesis of systems for: telemetering and command circuits for space vehicles, high efficiency power supplies for airborne and space electronic systems, space command, space television, guidance and control systems, and many others.

INFRARED SPECIALISTS. To perform systems analysis and preliminary design in infrared activities for satellite detection and identification, air-to-air missiles, AICBM, infrared range measurement, air-to-air detection search sets, optical systems, detection cryogenics and others.

SYSTEMS ANALYSTS. To consider such basic problems as: requirements of manned space flight; automatic target recognition requirements for unmanned satellites or high speed strike reconnaissance systems; IR systems requirements for ballistic missile defense. Inquire today. Please airmail your resume to:

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Professional Group Meetings

(Continued from page 100A)

Philadelphia—January 8

"Electronic Standards for the Space Age," W. F. Snyder, Nat'l. Bureau of Standards, Boulder, Colo.

Washington, D. C.—February 5

"Recent Developments in F-M Radar," W. K. Saunders, Diamond Ordnance Fuze Labs., Washington, D. C.

Microwave Theory and Techniques

Albuquerque, Los Alamos—December 11

"Improved Sweep-Frequency Microwave Measurements," L. Jerons, Hewlett-Packard Co., Microwave Group.

Chicago—January 16

"An Induction Method for Electron Spin Resonance Spectroscopy," T. Burgess, Northwestern Univers'ty, Evanston, Ill.

Long Island—January 23

"Solid State Front-Ends for Radar Systems," Dr. J. Pippin, Sperry Microwave Co., Clearwater, Fla.

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Long Island—November 21

"Frequency Control by Quantum Mechanical Resonance," Dr. A. McCoubrey, Bomac Labs., Beverly, Mass.

New York—November 16

"Nonlinear Microwave Dielectric Materials," J. J. Charlton, USASRDL, Ft. Monmouth, N. J.

New York—October 19

"Summary of Amplitude Apodized Apertures," R. Malech, Dorne and Margolin, Westbury, L. I.

Northern New Jersey—January 17

"Microwave Variable Attenuators and Modulators Using Pin Diodes," N. J. Kuhn, Hewlett-Packard Co.

Northern New Jersey—November 15

"NORAD—Communications and Electronics," Brig. Gen. D. P. Gibbs, U. S. Army.

Orlando—January 24

"*X*-Band Radiometer for Noise Measurements on Low-Noise Antennas," H. N. Dawirs, Antenna Lab., The Ohio State University Research Foundation.

Washington, D. C.—January 9

"Microwaves and Communications Satellites," J. Burke, Natl. Aeronautics and Space Adm., Washington, D. C.

Washington, D. C.—December 14

"Kilomegacycle Computer Circuits and Systems," B. J. Lechner, RCA Labs., Princeton, N. J.

Military Electronics

Long Island—December 12

"Flight Test Engineering Program for the F-105D Thunderchief," J. Marvin and L. Yager, Republic Aviation Corp., Farmingdale, N. Y.

Los Angeles—January 24

"The Intelligent Use of Free Energy in Modern Industry," H. Hamilton, Gen. Precision, Inc., Glendale, Calif.

Ottawa—February 1

"Collection of Military Data," Maj. J. R. Morgan, Canadian Army, Directorate of Military Intelligence, Computing Devices of Canada, Ottawa.

"Electronic Handling of Military Information," F. Chown, Canadian Army, Directorate of Military Intelligence, Computing Devices of Canada, Ottawa.

Philadelphia—January 11

"Project SETE—Technical and Management Problems in the Military Test Equipment Effort," D. M. Goodman, New York University, N. Y., N. Y.

Rome, Utica—January 9

"Comlognet," J. Hannah, Western Union Telegraph Co.

(Continued on page 104A)

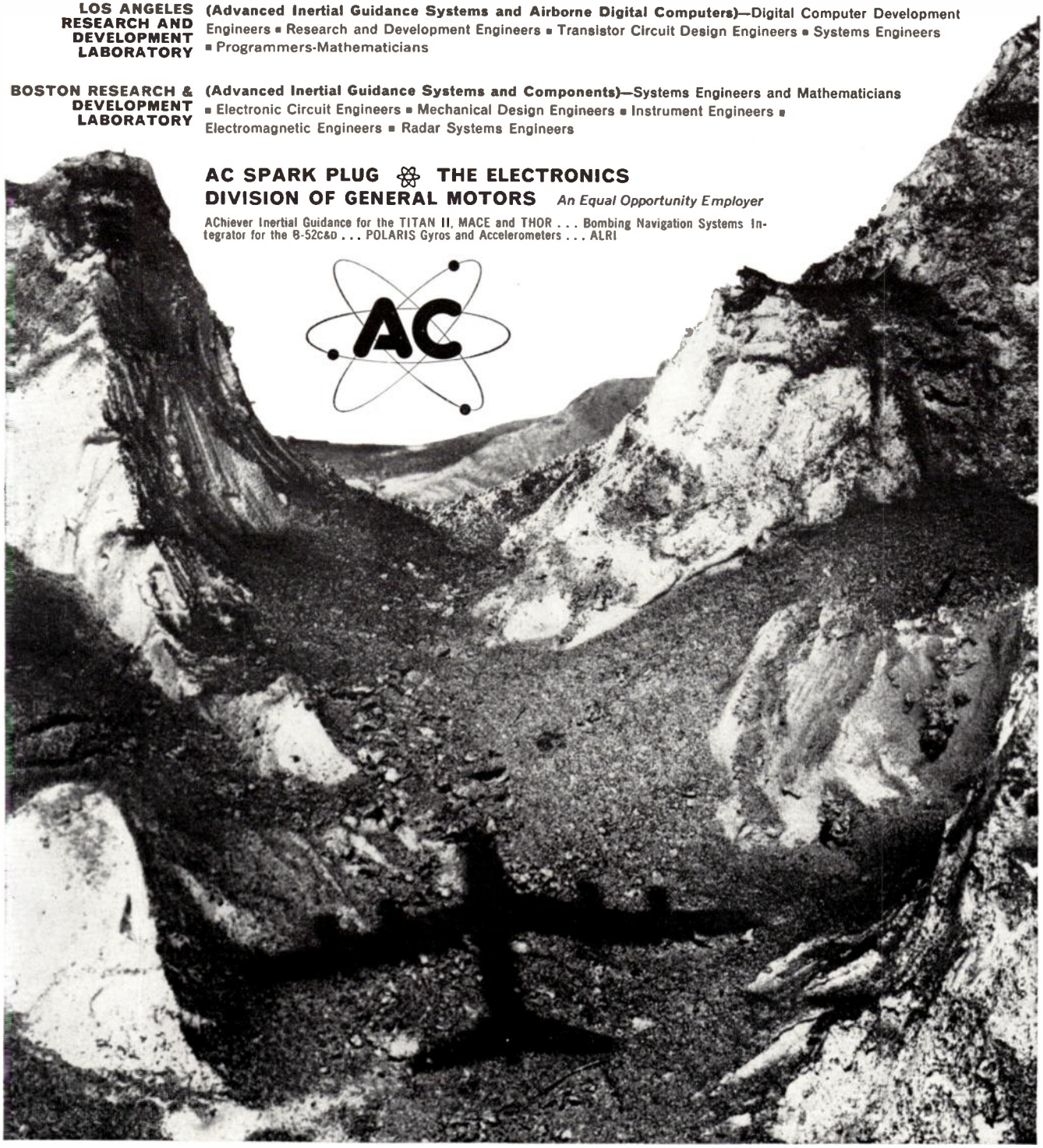
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DESIGNERS—With experience in radio receivers, frequency synthesizers, power amplifiers or radio communication systems.

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SENIOR ENGINEER—BS or MS in ME or Physics with 5 to 10 years experience in industrial sonics, thorough training in the physics of cleaning, processing and/or impact drilling, background in acoustics, general physics and chemistry.

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Professional Group Meetings

(Continued from page 102A)

Product Engineering and Production

Boston—January 23

"Heat Transfer Technique," A. D. Kraus, Sperry Gyroscope, Great Neck, N. Y.

Boston—December 7

"Review of PERT-PEP Techniques," R. Miller and J. Perlman, Raytheon Co., USAF Hanscom Field.

New York, Northern New Jersey and Long Island—January 17

"Universal Communications Transistor," I. Rudich, Amperex Electronics Corp., L. I., N. Y.

New York, Northern New Jersey and Long Island—November 29

"The Bendix Approach to High Density Soldered Modules," J. Kuller, Bendix Corp., Baltimore.

"Multilayer Printed Wiring for High Density Packaging," S. DiNuzzo, Hazeltine Electronics.

"Practical Approach to High Density Packaging Using Welding Techniques," R. Temes, General Precision, Inc.

New York, Northern New Jersey and Long Island—October 18

"Vide-Aural, A Training Technique," W. P. Perry, Bendix, Teterboro, N. J.

"Value Engineering, The Seminar Approach," A. J. Wojtowicz, Bendix, Teterboro, N. J.

Philadelphia—January 17

"Some Immortals of Science," B. Dibner, Burndy Corp.

"Coaxial Connectors Transmission Line Theory," Z. Green, Automatic Metals Corp.

Radio Quality Control

San Francisco—December 20

"ESD, LSD, and the Nature of Man," Dr. W. W. Harmon, Stanford University, Palo Alto, Calif.

Reliability and Quality Control

Chicago—January 16

"Benefits of the Titan II Parts Reliability Improvement Program," D. G. Cummings, AC Spark Plug Co., Milwaukee, Wis.

New York, Northern New Jersey and Long Island—November 13

"Effective Use of Marginal Checking in Transistorized Computers," L. W. Snell, IBM, Kingston.

(Continued on page 106A)

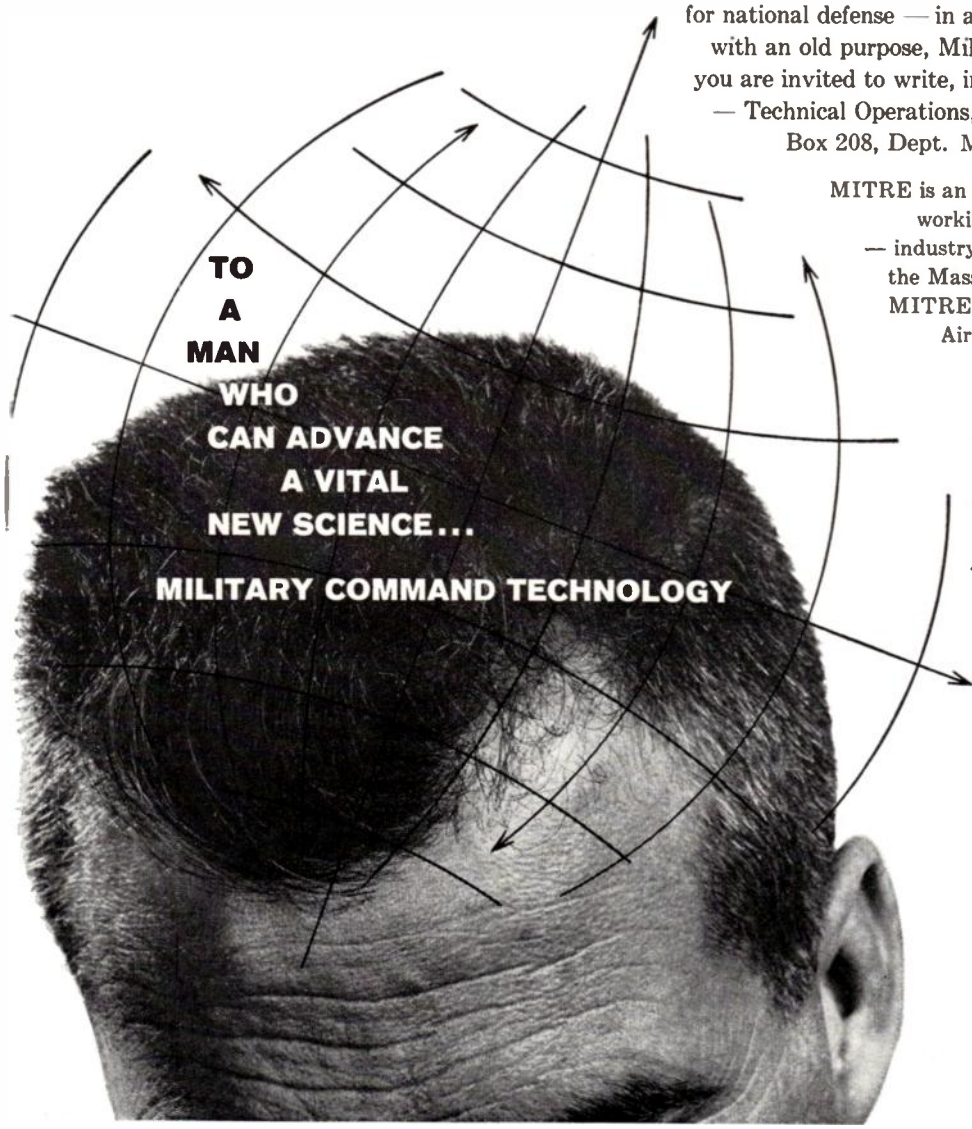
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Today this ability requires big and complex electronic systems. Their domain is the earth, the atmosphere around it, the infinite reaches of space. The concept behind them encompasses this nation's overall military strategy — present and anticipated. It includes all levels of civilian and military decision making. It provides for war plans, communications, intelligence, control of all forces, deployment of sensors, surveillance of space, logistics, support operations, and survival.

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Bay Shore, L.I., N.Y.

Professional Group Meetings

(Continued from page 104A)

New York, Northern New Jersey and Long Island—October 20

"Keynote Address," Dr. L. S. Gephart, NASA, Washington, D. C.

"Mathematical Model Analysis of the General Case System," B. Ellison and V. Selman, International Electric Corp., Paramus, N. J.

Space Electronics and Telemetry

Albuquerque, Los Alamos—November 21

"Sandia Telemetry Angle and Range Equipment," T. A. Sellers, Sandia Corp., Albuquerque, N. Mex.

Los Angeles—November 21

Panel Discussion on "PGM Telemetry Standards," P. Sehnert, B. Capps, and J. Chilton, SFTC, Aeronutronics and Douglas.

Los Angeles—October 17

"The Role of Semiconductor Strain Gage in Telemetry Applications," C. R. Shearer, Micro Systems, Inc., San Gabriel, Calif.

"Selection of Code Patterns for PCM Synchronization," J. L. Weblemoe, Naval Ordnance Lab., Corona, Calif.

Washington, D. C.—January 23

"A Critical Review of Modulation Techniques," R. W. Sanders, Space General Corp., Washington, D. C.

Vehicular Communications

New York, Northern New Jersey and Long Island—October 24

"Allocation of Frequencies for the Mobile Services—Should Changes be Made?" G. Oliv, RCA, Meadowlands, Pa.

Washington—January 29

"The Fourteen Layer Cake," J. Courtney, Lawyer, Washington, D. C.

Membership

The following transfers and admissions have been approved and are now effective:

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Becker, O. G., Paramus, N. J.
Bello, P. A., Needham, Mass.
Blakely, C. E., Atlanta, Ga.
Bushman, S. F., Des Plaines, Ill.
Crosby, H. A., Carbondale, Ill.
Gabloffsky, H., Torrance, Calif.
Geffe, P. R., Massapequa, L. I., N. Y.

(Continued on page 108A)

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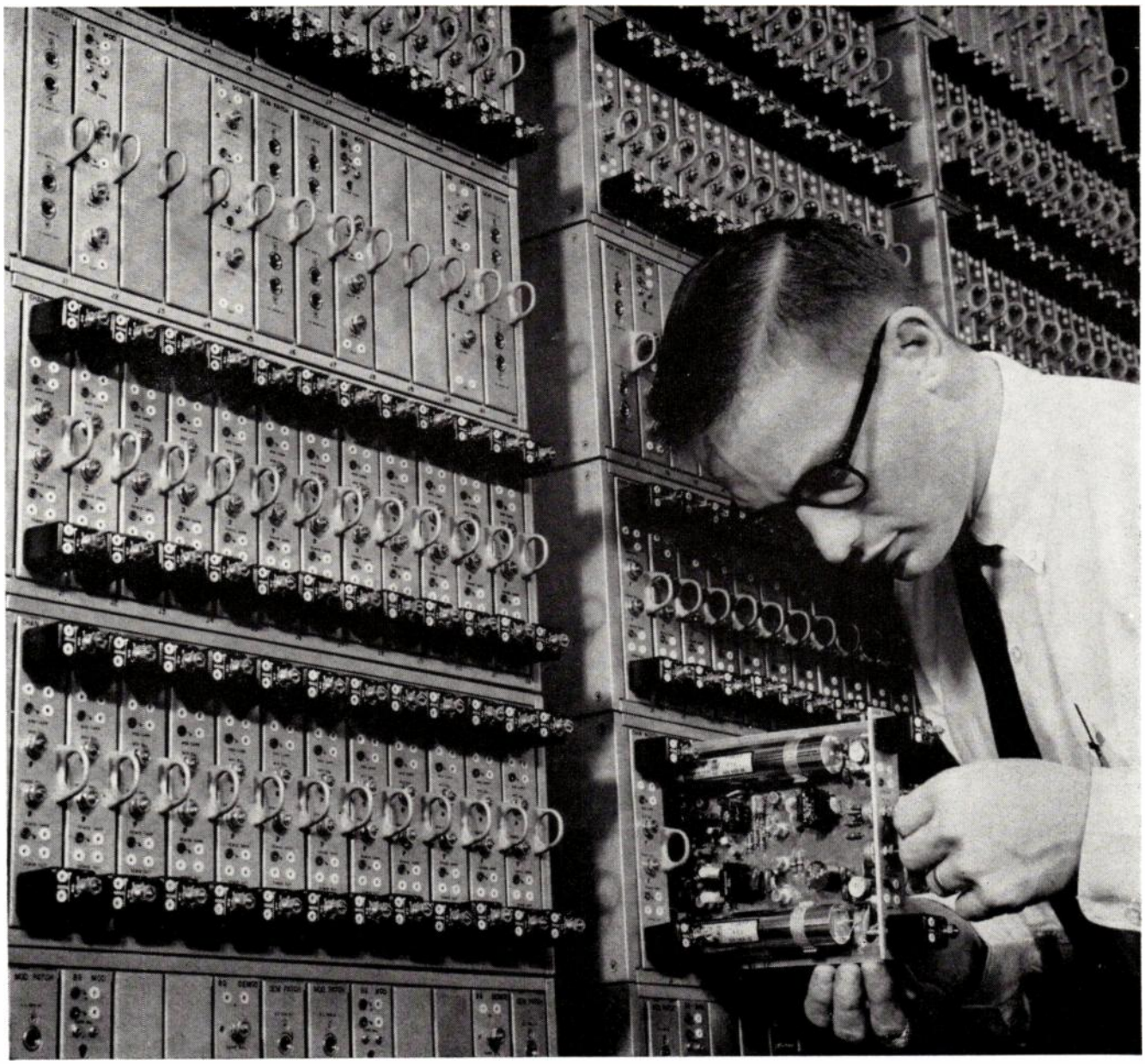
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(Continued on page 110A)

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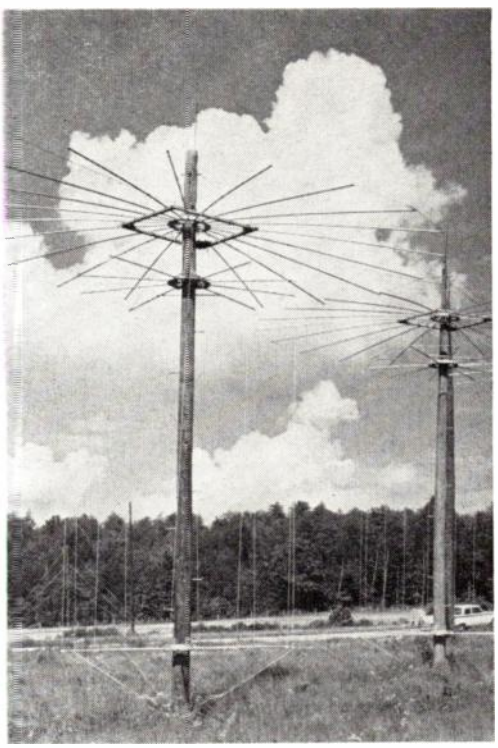
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Burkitt, F. J., Linthicum Heights, Md.
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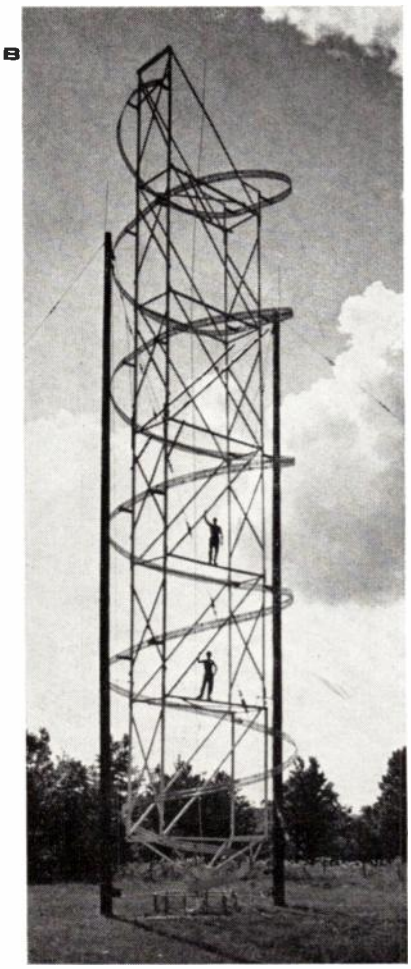
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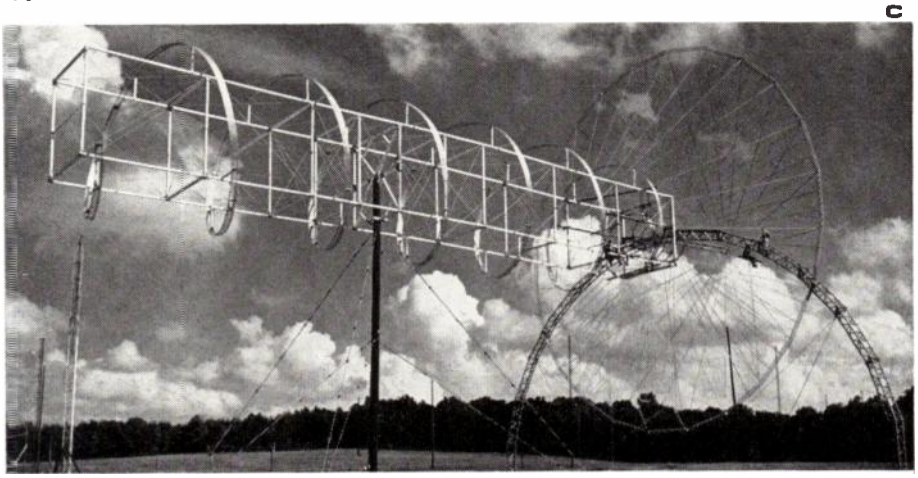


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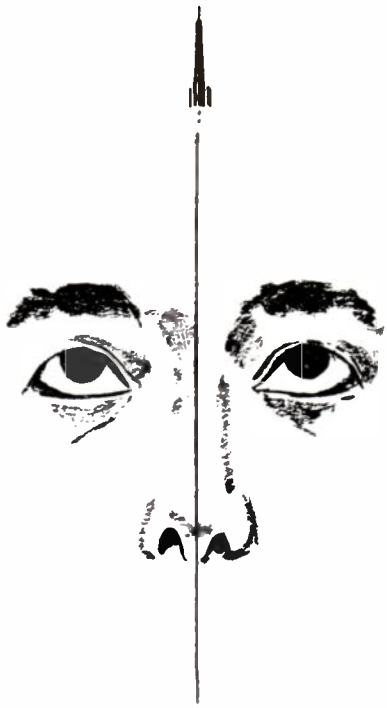
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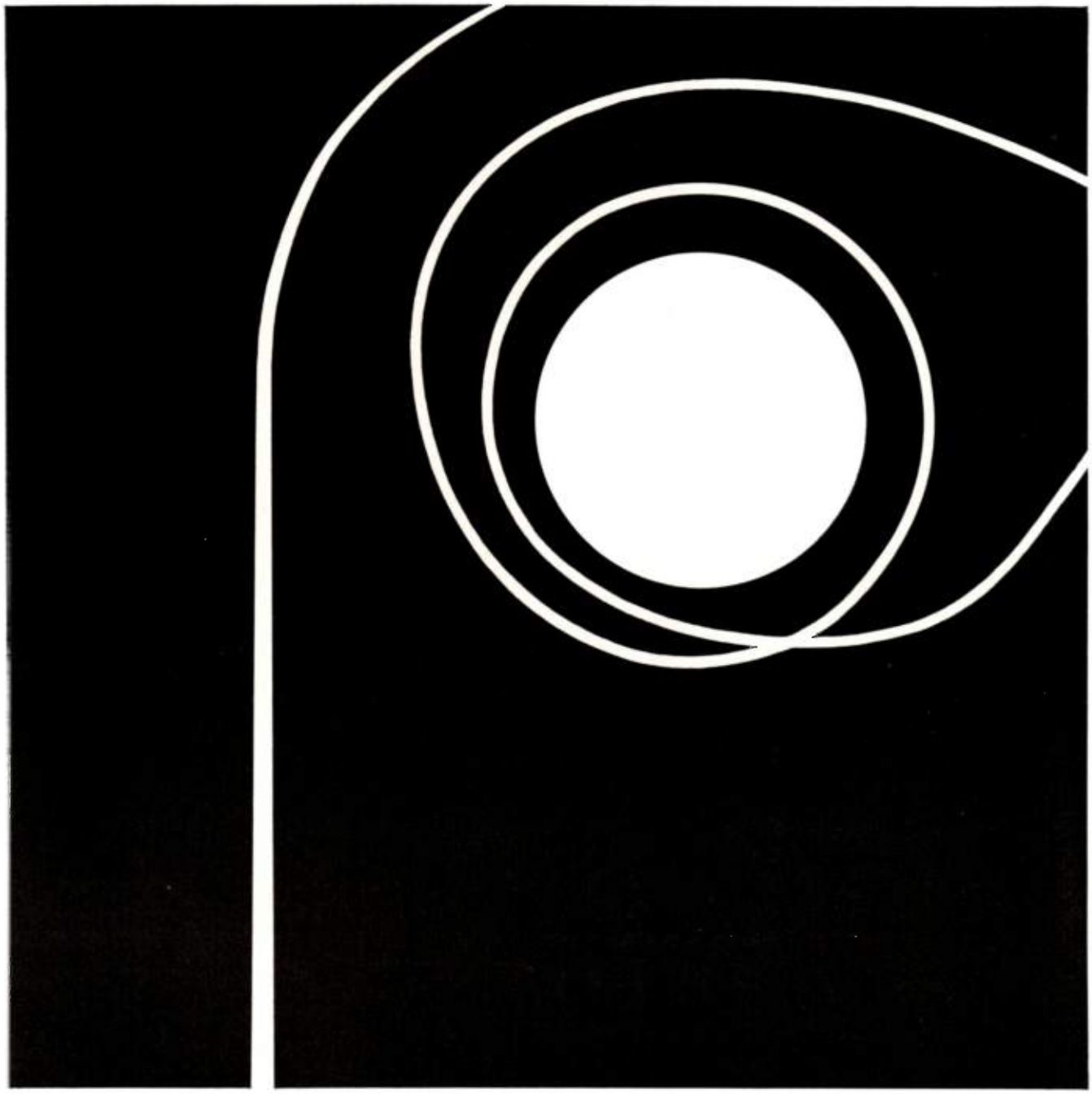
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(Continued on page 114A)



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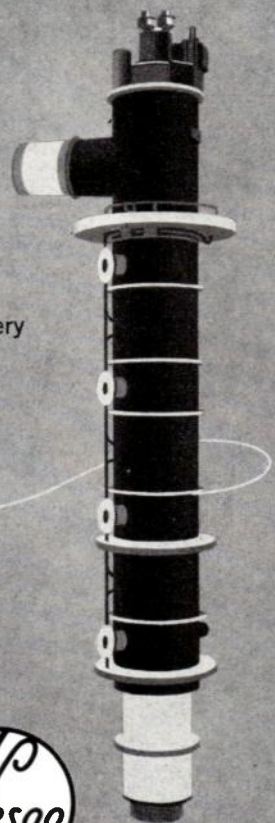
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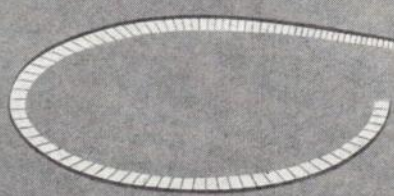
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Woerner, A., Oradell, N. J.
Wolters, G. C., Decatur, Ill.

(Continued on page 116A)



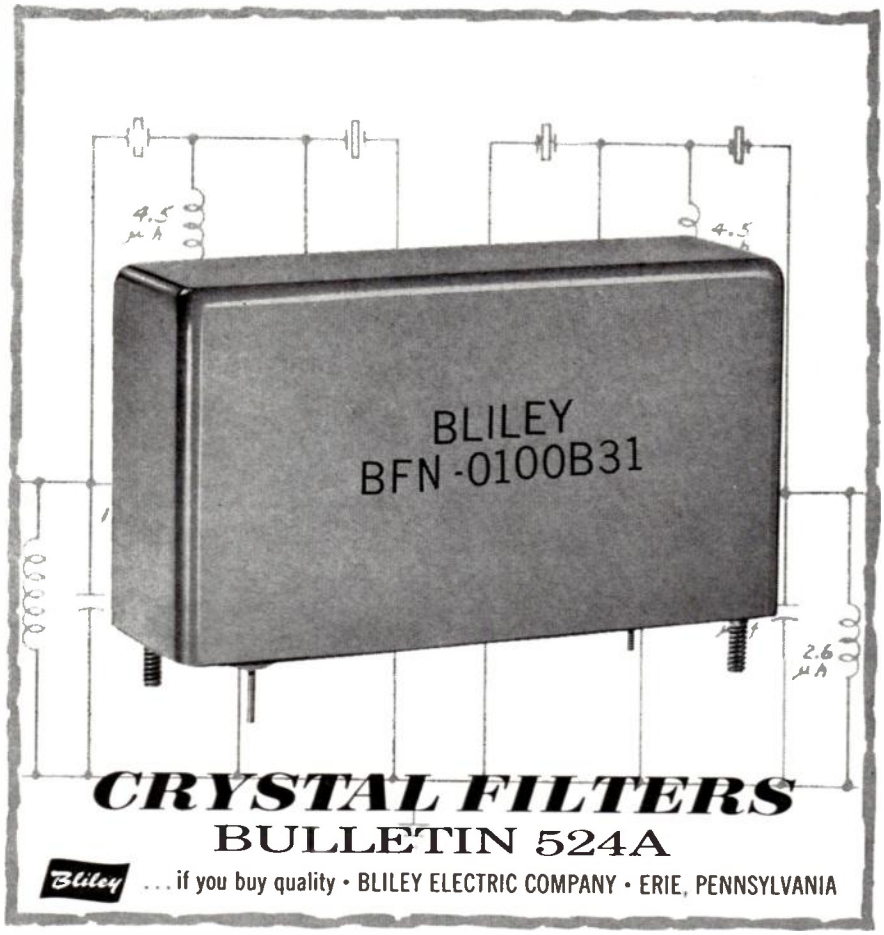
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Pertinent specifications include: **frequency range** 15 to 15,000 cps continuously tunable; **equivalent band width** 0.12 cps min. (2 sec. max. RC integrating time). 6 or 12 db per octave selectable roll-off; **gain** RMS AC in to push-pull DC out — approx. 18,000. Completely transistorized. Price: $990.

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(Continued from page 114A)

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(Continued on page 118A)

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Collector diode voltage V_{CBO}.....400 Volts
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Emitter current (continuous).....5 Amps.

Base current (continuous).....1 Amp.
Maximum junction temperature.....150°C
Minimum junction temperature.....—65°C

PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNITS
I_{CBO}	V_{CBO} = 400V, T = 125°C	—	—	10	ma
I_{CEO}	V_{CEO} = 400V	—	—	10	ma
I_{CES}	V_{CES} = 400V	—	—	10	ma
RSat	I_C = 5 amp, I_B = 1 amp	—	0.15	0.25	ohm
h_{FE}	V_{CE} = 5V, I_{CE} = 5A	10	—	—	
Rth		—	0.5	—	°C/watt

Electrical characteristics @ T_C = 25°C unless otherwise noted.

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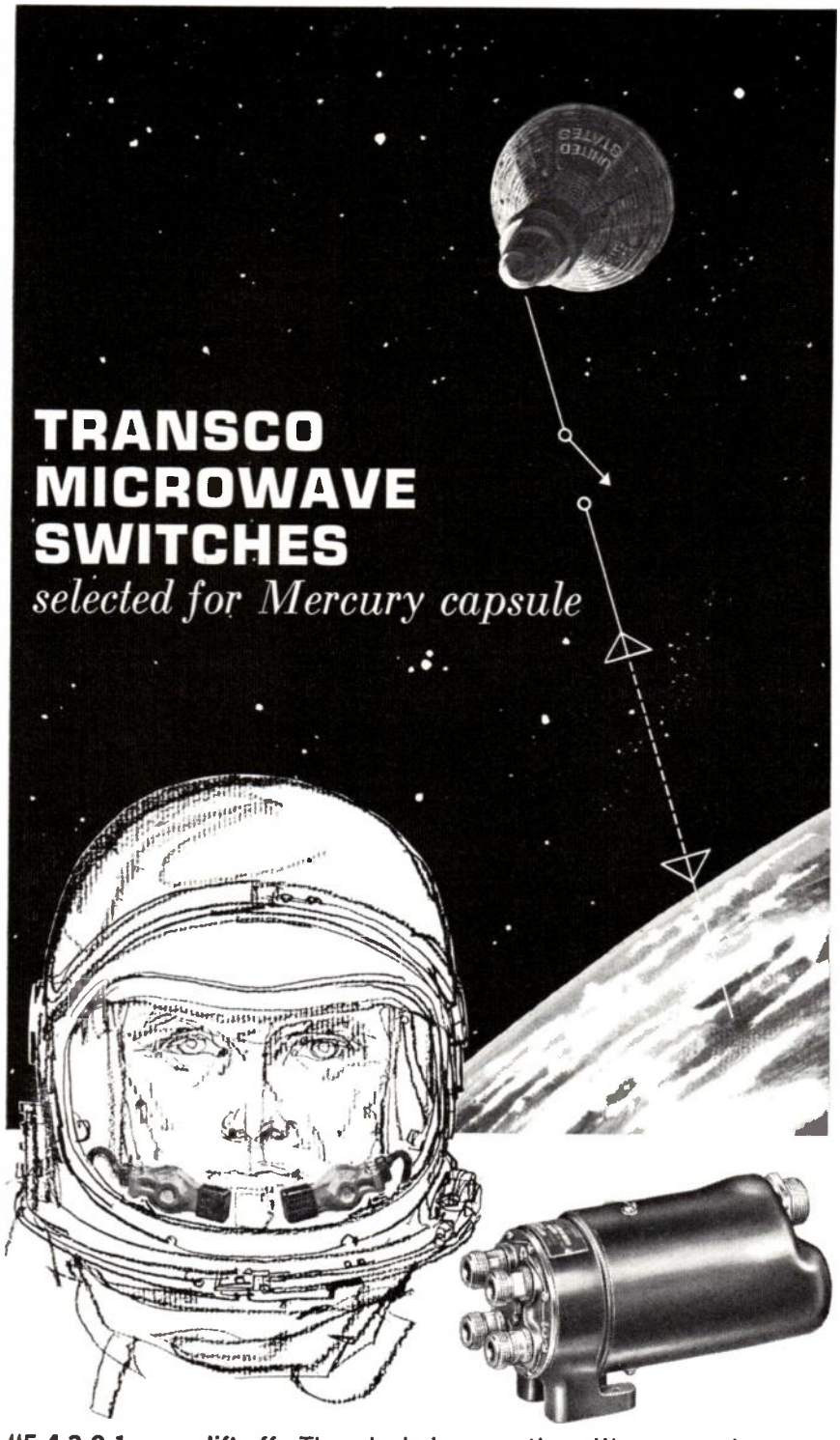
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Section Meetings

ALAMOGORDO-HOLLOMAN

"Versatile Automatic Test Equipment For Inertial Guidance Systems," C. Ames, Hughes Aircraft; 1/16/62.

ANCHORAGE

Annual election meeting; 12/4/61.

"The Present Status of the Rampart Project," H. Moats, U. S. Corps of Engineers; 1/3/62.

ATLANTA

"Time and Frequency Synchronization of Remote Standards," W. W. Wright, RMS Engineering, Inc.; 1/26/62.

BALTIMORE

"Television Astronomy and its Applications to an Orbiting Observatory," R. J. Davis, Smithsonian Astrophysical Observatory; 1/8/62.

BAY OF QUINTE

"Printed Microwave Circuits," J. H. Craven, National Research Council; 1/17/62.

BEAUMONT-PORT ARTHUR

"Directional Antennas for Broadcast Use," J. R. Rountree, Consulting Engineer; 1/23/62.

BINGHAMTON

"Digital Applications of Thermoplastic Recording," R. Reeves; General Electric Co.; 1/15/62.

BUFFALO-NIAGARA

"Molecular Electronics," H. B. Caar, Westinghouse Corp.; 1/10/62.

"New Developments in Communications," J. J. Barry, N. Y. Telephone Co.; Joint with AIEE; 2/1/62.

CANAVERAL

"Large Scale Computers in Range Instrumentation," J. R. Garrett, RCA Service Co.; 1/18/62.

CHICAGO

"Can The Midwest Become First in Electronics?" M. E. Krasnow, Hallicrafters Co.; 2/9/62.

CLEVELAND

"Voice of America," H. Ray, Rixon Corp.; "Antennas (designed for V. O. A.)," C. Smith, Smith Electronics, Inc.; 9/14/61.

(Continued on page 120A)

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ease the search for microvolt signals

The Keithley Model 103 provides the best attainable signal-to-noise ratio for input impedances of either 100 k ohms or 10 megohms. (The equivalent input noise resistance on the low noise position is only 3 k ohms.) Bandwidth of 0.1 cps to 100 kc covers a wide range of uses; eleven high and low frequency cuts permit restricted bandwidths for minimum noise.

Applications include Hall Effect studies, bridge null detection, and semiconductor investigations, as well as such biophysical applications as recording nerve action potentials.

bandwidth 0.1 cps to 100 kc using 11 high and low frequency cutoffs.

input impedance in the "Normal" mode is 10 megohms; in the "Low Noise" mode, 100 k ohms.

amplifier gain either 100 or 1000, adjustable to precise values.

input single-ended or differential.

differential rejection is at least 80 db.

power—from batteries or the Keithley Model 1031, a separate, solid state power supply with noise characteristics equivalent to batteries.

noise performance is selected with a "Normal "and "Low Noise" switch. Chart gives noise level of maximum gain from 10 cps with shorted input.

Frequency of high cutoff point	Maximum noise, microvolts RMS referred to input	
	Normal (10 meg impedance)	Low Noise (100 k impedance)
100 kc	3.0	1.9
30 kc	1.9	1.1
10 kc	1.4	0.8
3 kc	0.9	0.6
1 kc	0.7	0.4
300 cps	0.5	0.3
100 cps	0.4	0.25

prices: Model 103, $245; rack, $255
1031 Power Supply, $245; rack, $255



The Keithley Model 102B amplifier combines a 400-megohm input with high gain and low noise. It is an ideal scope preamplifier, especially for high source impedance signals. The 102B provides accurate signal amplification from piezo-electric devices; it is excellent for noise studies in solid state research, and shock and vibration analysis.

Features of the unit include a driven shield input, decade gains from 0.1 to 1000, selectable bandwidths of 2 cps to 150 kc or 2 cps to 1.7 mc, and a 5-volt, 50-ohm output for scopes and recorders.

input impedance over 400 megohms at 3 $\mu\mu$f.

low noise level, below 10 μV rms from 10 cps to 150 kc at maximum gain, input shorted.

gain accuracy of 1% at midband for all gain settings.

rise time of 0.3 μ sec at highest gain.

two accessory low capacitance probes available. **price: $335**

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Frequency Range: 50mc to 12,400 mc
Impedance: 50 ohms
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MODEL NUMBER	340	340W
FREQUENCY RANGE	50 to 12,400 mc	
MAXIMUM VSWR	1.15, 50 to 4000 mc 1.25, 4000 to 8000 mc 1.35, 8000 to 12,400 mc	
MAXIMUM INSERTION LOSS	0.15 db, 50 to 4000 mc 0.25 db, 4000 to 12,400 mc	
MAXIMUM TORQUE	1.5 in-oz	6.0 in-oz
PRICE	$175.00	$195.00

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Section Meetings

(Continued from page 118A)

"Advances in Electrical Power Production," O. G. Hanson, Con Edison Co. of N. Y., Joint meeting with AIEE, ISA and ASME; 10/12/61.

"Electronic Image Processing in Biology," C. Berkley, Journal of Medical Electronics; 11/9/61.

"The Analog Computer in Process Control," R. C. Weyrick, Goodyear Aircraft Corp.; 12/7/61.

Colombia

"Plans and Development of Communications in Colombia," E. Arboleda de Uribe, Government of Colombia; 2/2/62.

"From Abacus to Electronic Brains," J. Lopez, IBM; 2/12/62.

Connecticut

"The Bell System Automatic Central Office," J. J. Yostpille, Bell Tel. Labs.; 10/19/61.

"Pattern Recognition Theory," W. H. Highleyman, Bell Tel. Labs.; 11/16/61.

"F. M. Stereo Reception," D. R. Von Recklinghausen, H. R. Scott Co.; 1/18/62.

Dallas

"Solion Devices," R. Stewart, Texas Research and Engineering; 1/30/62.

"Fundamental Concepts of Information Theory," J. Bussgang, Consultant; 2/1/62.

"Correlation Detection," T. Cheatham, Litton Systems; 2/8/62.

Emporium

"New Products," J. R. Peltz, Sylvania Electric Products Inc.; 1/16/62.

Evansville-Owensboro

"Phase I of Shelter Survey," J. E. V. Wagner, U. S. Engineers Louisville District; 2/14/62.

Fort Huachuca

"The Relationship of Electronics to Speech Pathology," J. Lambert, U. S. Army Electronic Proving Ground; 1/22/62.

Fort Worth

Discussion of IRE-AIEE Merger, E. B. Robertson, Sr., Past President AIEE, G. K. Teal, National Director-at-Large IRE; Joint with AIEE; 2/13/62.

Hamilton

"Control of Strip Process Lines," J. G. Foulds, Steel Co. of Canada; 1/15/62.

"F.M. Stereo Adapter, design and related aspects," E. A. Thomas, General Instruments, 2/12/62.

Hawaii

"Self-Adaptive Feedback Control Systems," W. E. Meserve, Cornell University and University of Hawaii; 1/10/62.

Indianapolis

"Unipolar or Field Effect and Thin Film Devices," E. O. Johnson, RCA; 1/25/62.

Ithaca

"Coherent Light Sources and Their Applications," C. O. Alley, University of Rochester, Demonstration of ruby laser; 2/8/62.

Kitchener-Waterloo

"The Defence Research Board Topside Sounder Satellite," J. N. Barry, Defense Research, Telecommunication Establishment; 1/15/62.

London

"Radio Astronomy at the National Research Council," N. W. Broten, National Research Council; Joint meeting with AIEE, RAS and CAP; 1/22/62.

Los Angeles

"Deep Space Instrumentation Facility," N. A. Renzetti, Stanford Research Institute and JPL; "The Exploration of Space—A Progress Report," W. H. Pickering, Calif. Institute of Technology; 1/9/62.

Louisville

"Breakthroughs in Light Sources," S. C. Peek, Sylvania Electric Prod.; Joint with AIEE; 1/18/62.

Lubbock

"Automation in the City of Lubbock Waterworks," F. Kilcrease, City of Lubbock; Tour through Waterworks Dispatching Office and Microwave Facilities; 1/16/62.

Miami

"Nuclear Radiation and Civil Defense Aspects of New Weapons," M. Dauer, Director of Civil Defense for South Florida-Miami; 1/25/62.

Milwaukee

"Thermal Electricity," R. A. Otto, Westinghouse Electric Corp.; 1/15/62.

Mobile

"Radio Frequency Interference and the Engineer," D. McClain, Philco Corp.; 12/15/61.

Montreal

"The Discovery Problems in Engineering and Medicine," J. Milsum, McGill University; 1/24/62.

New York

Lecture Series—"Medical Electronics"; A. A. DeRosa, ITT Communications Systems, Inc.; H. Blum, Air Force Cambridge Research Lab.; N. S. Potter, Maxson Electronics Corp.; R. L. Schoenfield, Rockefeller Inst.; W. Welkowitz, Gulton Industries; 10/23–11/27/61.

Trip to U. S. Naval Training Device Center; 12/8/61.

"Scientific Satellites" Panel Discussion, J. V. B. Cooper, IBM Corp.; A. G. W. Cameron, Inst. of Space Studies; S. Sternberg, RCA Corp.; W. Scott, Gruman Aircraft; 2/7/62.

North Carolina

"Precise Time and Frequency in the Space and Atomic Age," W. Markovitz, U. S. Naval Observatory; 1/19/62.

Northern New Jersey

"Communications Systems Design—A Survey and a Projection," J. W. Halina, ITT Communications Systems; 1/10/62.

Omaha-Lincoln

Panel Discussion—"After Graduation, What?"; R. W. Shaw, OPPD; R. K. Ghormley, LT&T; M. B. Johnson, Western Electric; J. D. Cochran, Consumers PPD; M. Hobson, University of Nebraska; Joint with Neb. Section AIEE, and U. of Neb. IRE-AIEE Student Branch; 1/18/62.

Orlando

Panel Discussion—"PACM Telemetry"; L. Rauch, University of Michigan; P. Painter, Dynatronics, Inc.; D. D. McRae, Radiation, Inc.; L. W. Gardenhire, Radiation, Inc.; W. S. Hines, AFMTC; Joint Section and PGSET; 1/17/62.

Ottawa

Student Papers Night, "Electronic Ignition Systems," C. L. Murray, Eastern Institute of Tech.; "Semiconductor Commutators," J. R. Richardson, Queen's University; "Amplitude Density Distribution of Noise and Signals," J. G. Vaucher, University of Ottawa; "Transistorized Single Sideband Transmitter," D. Sharp, Carleton University; "A New Hyperbolic Navigation Aid," L. R. Larsen, Royal Military College; 2/7/62.

Pittsburgh

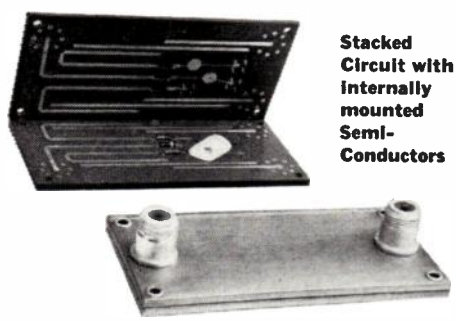
"A Wide Band Video Transportation System," F. J. Ragone, Jerrold Electronics Corp.; 1/8/62.

"FM Stereo Broadcasting," Lecture and Demonstration, R. M. Linz, G.E. Co.; 2/5/62.

(Continued on page 122A)

This means you can design microwave circuits with freedom . . . breadboard and test quickly and accurately . . . reduce package weight and volume . . . get MIL-Spec reliability . . . at lower cost. What the concept of strip transmission line promised, TRI-PLATE techniques deliver — they've made the concept a practical reality! ☐ To Breadboard and Test new circuit ideas quickly and easily — no matter how advanced or daring — a complete line of over 600 TRI-PLATE Modules is available. To help you create new directions in electronics more than 150 TRI-PLATE Mounts for standard and advanced semiconductor devices are offered. In just minutes, you can have complex working circuits ready for test and evaluation. ☐ Your Prototype circuit, custom-designed by Sanders engineering specialists, speeds the time from design to production — makes your circuit ideas pay off sooner. Microwave, semiconductor or fast switching circuits with high density packaging are effectively produced in TRI-PLATE

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Gain	25db
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Section Meetings

(Continued from page 120A)

PRINCETON

"Electronic Obstacle Detectors for the Blind," J. M. Benjamin, Jr., and Prof. T. Benham, Haverford College; 1/9/62.

REGINA

"Visual Communications," A. C. Stewart, Automatic Electric Sales; 1/24/62.

ROME-UTICA

"Comlognet," J. Hannah, Western Union Telegraph Co.; Joint with PGMIL; 1/9/62.

SACRAMENTO

Tour through KCRA-TV. Moderator—H. Hartman; 2/10/62.

SALT LAKE CITY

"Some Aspects of Dynamic Programming," J. J. Jonsson, Brigham Young University; Tour of new Brigham Young University Library; 1/12/62.

SAN ANTONIO-AUSTIN

"Plastic Balloons in the Space Age," O. C. Winzen, Winzen Research, Inc.; 12/15/61.

SOUTH BEND-MISHAWAKA

"Direct Distance Dialing System," J. Gi roy, Indiana Bell Telephone Co.; 1/4/62.

"A System for Measurement of Low Angular Rates," R. Pike, Bendix Mishawaka; "An Engineers Approach to Life's Common Denominator," E. Kent, C. G. Conn, Ltd.; "A Low Frequency Peak to Peak Signal Conditioner for Automatic Test Equipment," E. L. Denning, Bendix Mishawaka; "Trade Journal Writing, Why and How," R. Woelfle, Bendix Mishawaka; 1/25/62.

SOUTH CAROLINA

"The Place of the Student in the IRE," W. R. Crone, IRE Student Affairs Secretary; 2/7/62.

SOUTHERN ALBERTA

"Visual Communications," A. C. Stewart, Automatic Electric Sales, Ltd.; 1/25/62.

TOKYO

"The Application of Microwave Faraday Rotation to Semi-Conductors and Magnetic Materials," A.M. Portis, Osaka University; Joint with PGMTT; 11/29/61.

TORONTO

"Review of the Fundamental Principles of Maser Emission," B. P. Stoicheff, National Research Council; 1/22/62.

Tour of CFTO-TV Facilities; 2/12/62.

TUCSON

"Lunar Mapping," G. P. Kuiper, Lunar & Planetary Laboratory; 12/8/61.

TULSA

"Semiconductor Strain Gages and Instrumentation," C. Vogt, Century Electronics & Instruments; 1/18/62.

TWIN CITIES

"Guidance of Missiles and Space Vehicles," L. A. Brunker, UNIVAC; 10/25/61.

"The Customer-Genesis of Marketing," W. N. Eldred, Hewlett-Packard Co.; 11/28/61.

VANCOUVER

"Laboratory Oscilloscopes," O. Svehaug & C. Moulton, Tektronix; 12/18/61.

Field Trip to Vantel Studios, Mr. E. Rose, Vantel; 1/15/62.

VIRGINIA

"The Nike-Zeus Story," F. E. Nimmcke, Bell Tel. Labs.; Ladies Night; 1/19/62.

WESTERN MASSACHUSETTS

"The Universe," J. F. Spalding, G.E. Co.; 1/23/62.

WICHITA

"Medical Electronics In Wichita," D. Graham, Midwest Medical Research Foundation; H. B. Cordes, Lacord Instrument Co.; 1/23/62.

WILLIAMSPORT

"Susquehanna River Water Pollution Problem," Dr. Goddard, Local Civic Engineer; Mr. Harris, State Health Dept.; 11/29/61.

Social—Christmas Party and Dance; 12/15/61.

WINNIPEG

"Closed Circuit TV," A. Stewart, Automatic Electric Co.; 1/22/62.

SUBSECTIONS

BUENAVENTURA

"Microwave Systems Engineering in the Far East," W. C. Shelton, P. M. R.; 1/10/62.

BURLINGTON

"Transistors and Their Usage," R. Pruett, Texas Instruments; 12/7/61.

"94° Deflection System," K. McGlashan, Advance Ross Co.; 2/1/62.

CRESCENT BAY

Panel Discussion "Management Problems In An Engineering Organization," M. Kline, UCLA; N. Hall, Hughes Aircraft; R. Krausz, Rantec Corp.; I. Stone, Aero Physics Corp.; Joint with PGEM; 1/15/62.

EAST BAY

"The New 88" Spiral Ridge Cyclotron," B. H. Smith, University of Calif.; 10/30/61.

"Ultra Micro-Circuitry at Sandia Corporation," G. W. Rollosson, Sandia Corp.; 11/27/61.

EASTERN NORTH CAROLINA

Business Meeting; 1/12/62.

FAIRFIELD COUNTY

"Properties of Nuclear Radiation and a Survey of Radiation Detectors," M. Youdin, Eon, Inc.; Tour of Norwalk State Technical Institute, C. Greco, Supervisor of School; 2/1/62.

LANCASTER

"Superconducting Magnets: A Technological Breakthrough," J. K. Hulm, Westinghouse Research Laboratories; Joint Meeting with AIEE; 1/18/62.

LEHIGH VALLEY

"The Future of Solid State Devices," I. H. Kalish, RCA; Joint Meeting with AIEE; 10/13/61.

"The Metal Interface Amplifier," J. P. Spratt, Philco Corp.; "The Metal Interface Amplifier As A Circuit Element," S. K. Ghandi, Philco Corp; Joint Meeting with Section; 11/8/61.

"Infrared Applications," R. W. Astheimer, Barnes Engineering Co.; 1/16/62.

MERRIMACK VALLEY

"Microwatt—Microelectronics," M. J. Schuller, CBS Labs.; 1/15/62.

MID-HUDSON

"Expanding Field of Biomedical Engineering," G. N. Webb, Johns Hopkins Hospital; 1/23/62.

MONMOUTH

"Superconducting Magnets," J. E. Kunzler, Bell Tel. Labs.; 1/17/62.

NEW HAMPSHIRE

"Parametric Amplifiers," G. Wade, Raytheon Co.; 10/19/61.

"Rockets and Space Travel," D. Blitz, Sanders Associates, Inc.; Ladies Night; 11/29/61.

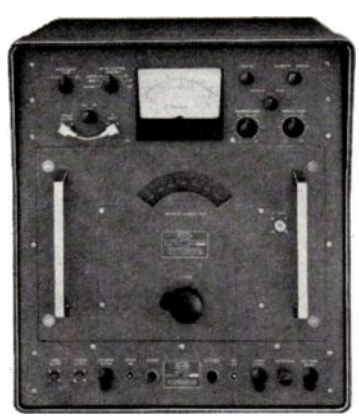
"Neurological Servomechanisms," P. Willis, Electronic Systems Lab. M.I.T.; 1/31/62.

(Continued on page 124A)

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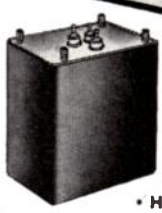
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Section Meetings

(Continued from page 122A)

NORTHERN VERMONT

"Infra Red Instrumentation of Tiros," Mr. Shwartz, Barnes Engineering Co.; 11/20/61.

"Thin Film Distillation Process"; Tour of G.E. Plant Facilities and Laboratory; Joint meeting IRE, ASME, AIEE, ASCE & VSPE; 1/19/62.

ORANGE BELT

"Military Communication Satellites," R. L. Walquist, Space Technology Labs.; 11/7/61.

Forum on "Purpose, Objectives, and Value of Professional Societies," Panelists: W. V. Bolliger, Southern Calif. Teachers Assoc.; C. C. Gill, L. A. County Medical Assoc.; J. V. Guerrera, Chairman L. A. Section; H. Schultz, Engineers & Architects Assoc.; R. Young, Past President, Pomona Valley Bar Assoc.; 9/26/61.

PASADENA

"Lasers," B. Oliver, Hewlett-Packard Co.; 11/16/61.

"The Day We Land on the Moon," Dr. Kopal, J.P.L.-N.A.S.A.; 1/17/62

READING

"Use of Man-Made Satellites for Mapping Purposes I," D. L. Birx, Franklin Institute; "Use of Man Made Satellites for Mapping Purposes II," W. M. Protheroe, Univ. of Pa.; 1/12/62.

RICHLAND

"The X-Ray Fluorescence Technique and its Application at Hanford," M. Lambert, G.E.; 1/24/62.

SANTA ANA

"Deep Space Instrumentation Facility," N. A. Renzetti, Stanford Research Inst.; "The Exploration of Space—A Progress Report," W. H. Pickering, Calif. Inst. of Tech.; 1/9/62.

SANTA BARBARA

"Whither Wescon," B. S. Angwin, G.E. Co.; W. E. Peterson, Automation Development Corp. 9/22/61.

"Professional Advancement for Engineers," W. Avery, Avery Assoc.; 10/17/61.

"Common Aviation Weather Systems," R. E. Carr, North American Weather Consultants; Joint meeting with AIEE; 11/8/61.

"Underwater Acoustic Signal Processing Techniques," C. E. Peterson, GMC; 1/16/62.

SOUTHWESTERN ONTARIO

Field Trip to Bell Telephone Co., Ltd., Windsor; Host W. Ruse; 1/16/62.

VICTORIA

"Radio Station Construction in the Arctic," J. Kiely, U. S. Navy; 11/29/61.

IRE People

(Continued from page 62A)

Donald L. Ort (S'51–A'53) has been appointed head of the W2F Engineering Project Office at the Data Systems Division of Litton Systems, Canoga Park, Calif.

Before his new assignment, Mr. Ort was head of the Advanced Development

(Continued on page 126A)

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IRE People

(Continued from page 124A)

Section of the Litton Systems Division.

He was graduated from Lehigh University in 1952 with a Bachelor's degree in electrical engineering, and from UCLA in 1961 with a Master's degree in electrical engineering.

❖

E. Ronald Reese (M'59) recently joined Electro-Optical Systems, Inc., Pasadena, Calif., as a senior engineer in the company's Advanced Electronics and Information Systems Division. He will be engaged in the design of digital systems for spacecraft.

Prior to joining EOS, Mr. Reese was a senior engineer for Space General Corp. in Glendale. Before that, he was employed at the Datalab Division of Consolidated Electrodynamics Corp. and with the Hycon Manufacturing Co. His experience in these organizations has centered around communication systems, data handling equipment, missile test equipment and radiolocator beacons.

Mr. Reese earned his Bachelor's degree in electronic engineering at Milwaukee School of Engineering; later he studied transistor electronics through a UCLA extension course. While at Milwaukee School of Engineering, he served as an instructor, teaching courses in electronic theory.

❖

The appointment of **Glenn H. Sacra** (M'56) as manager of radar marketing of the eastern operation of Sylvania Electronic Systems was recently announced.



G. H. Sacra

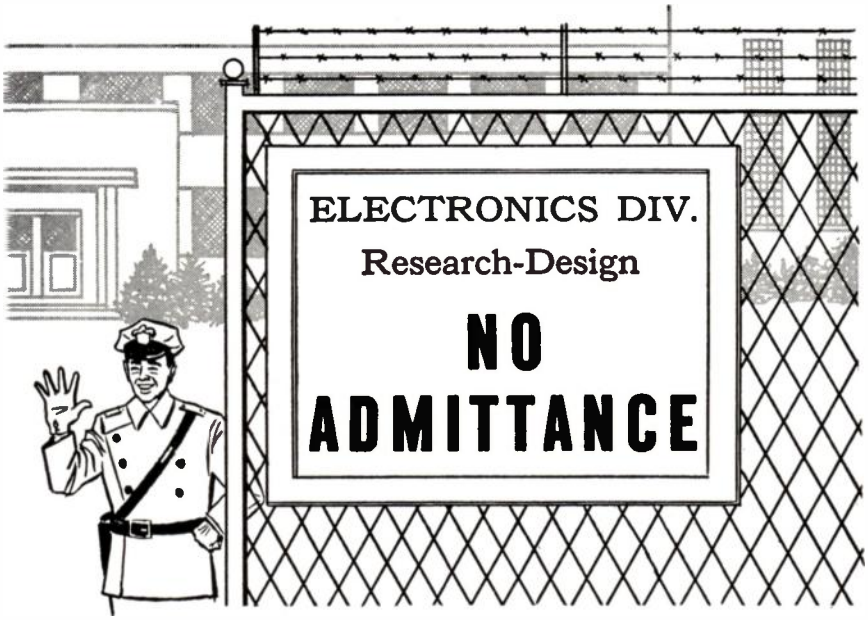
Mr. Sacra has served as manager of radar and information systems marketing at the Waltham Laboratories since July, 1961, and previously was manager of technical liaison at the same facility. He joined Sylvania as a sales engineer in 1956 in the division field office at Rome, N. Y., later serving as district manager of customer relations in that office.

A graduate of Cornell University, he received a Bachelor's degree in mechanical engineering in 1952 and a Master's degree in business administration in 1954. From 1954 to 1956, he served as an engineering procurement officer in the U. S. Air Force at the Rome Air Force Depot, Griffiss Air Force Base, Rome, N. Y.

He is a member of the Armed Forces Communications and Electronics Association and the Association of the United States Army.

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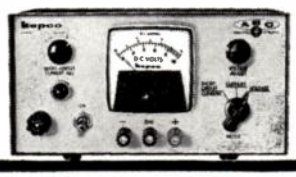
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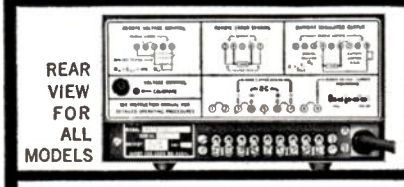
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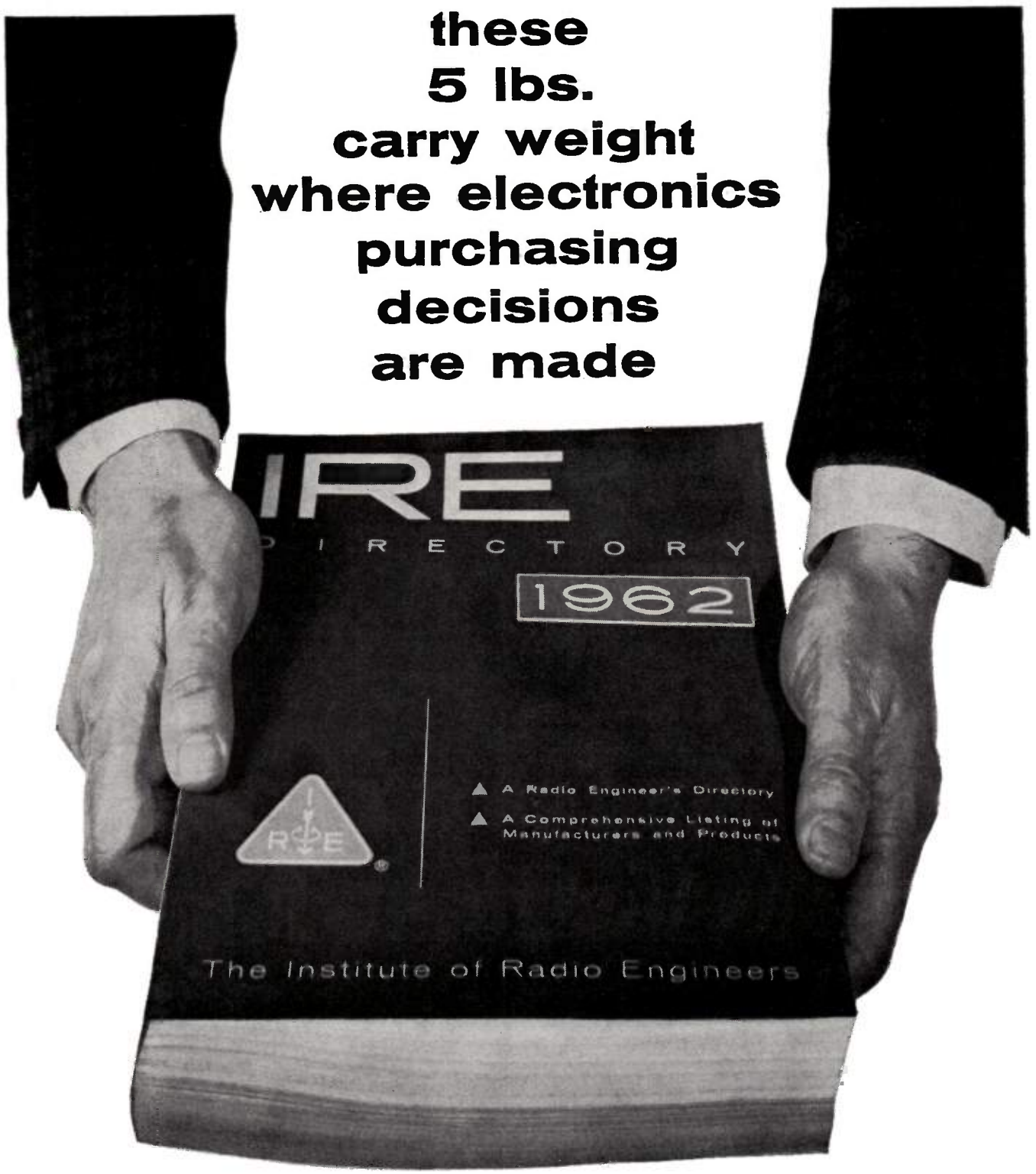
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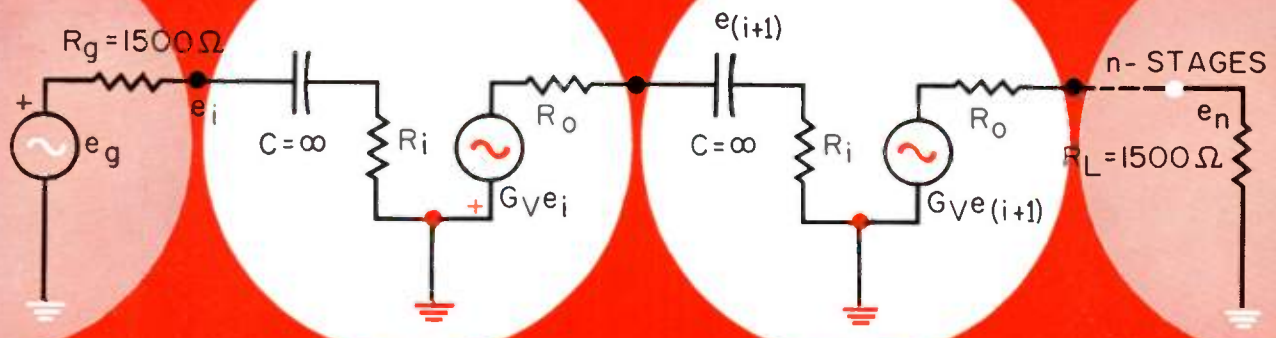
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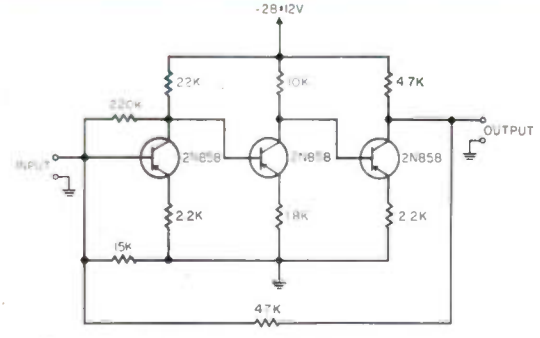
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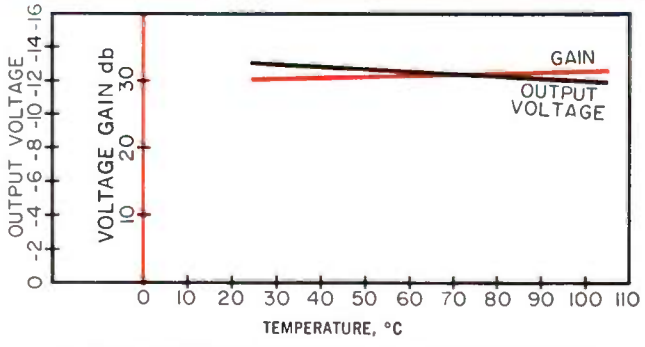


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