rfdesign

ideas for engineers

December 1985

Special Report:
Military Uses of RF

RF Technology Expo 86 Program

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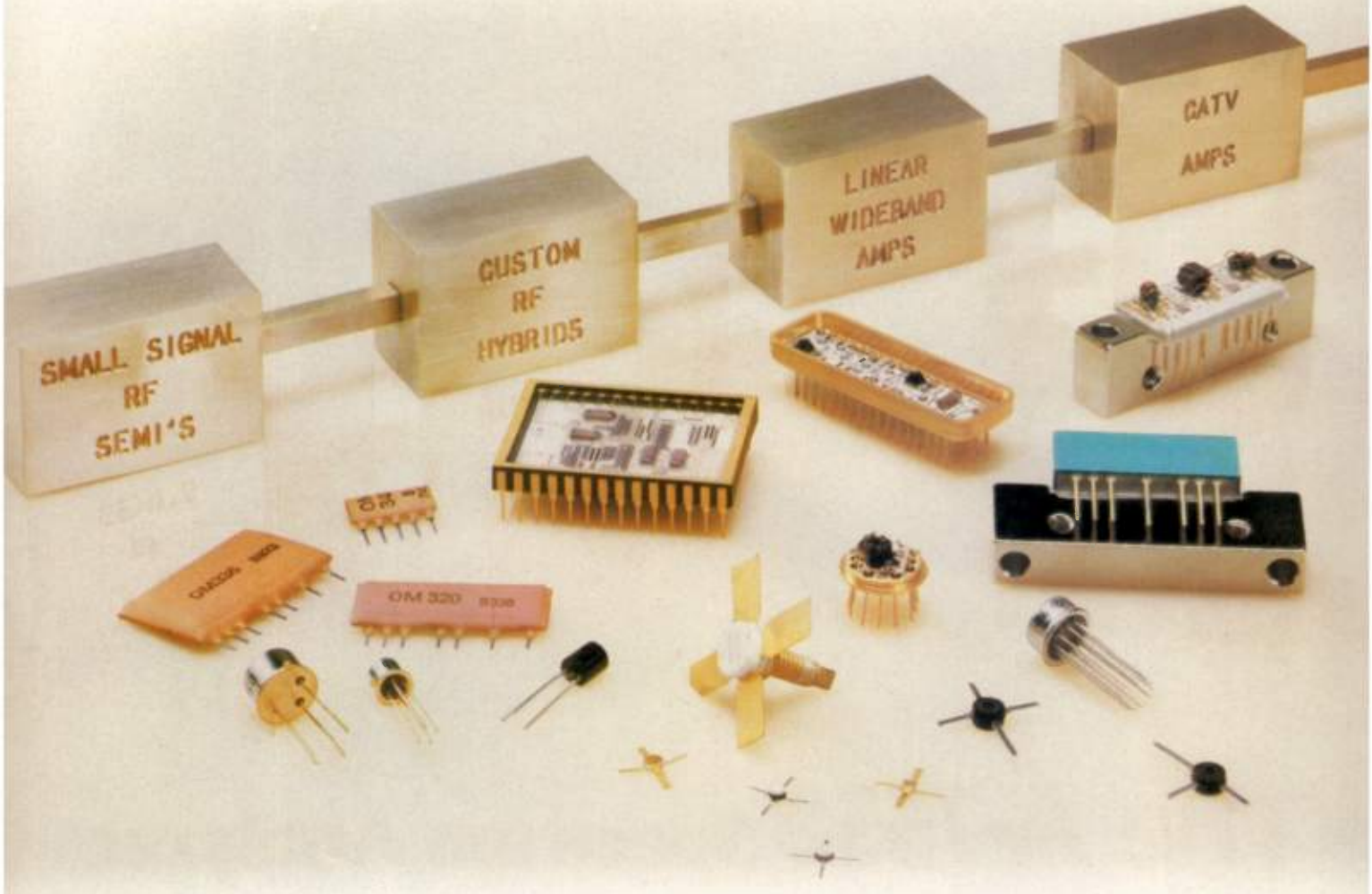

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INFO/CARD 1

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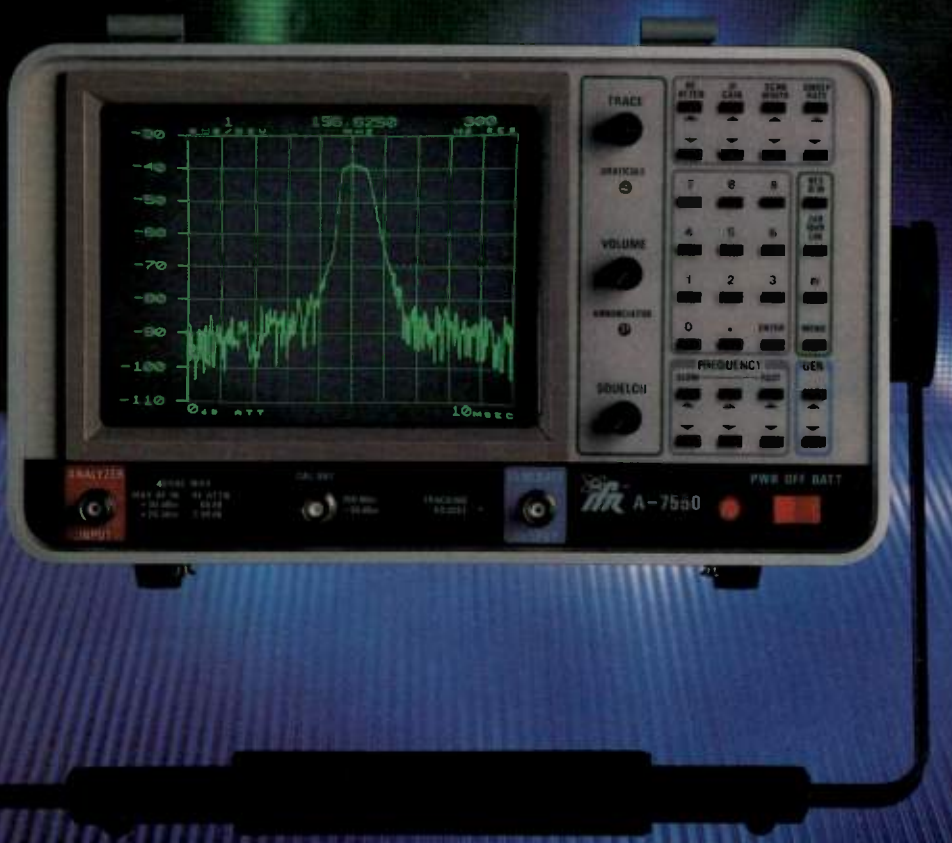

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INFO/CARD 2

GOING THE DISTANCE

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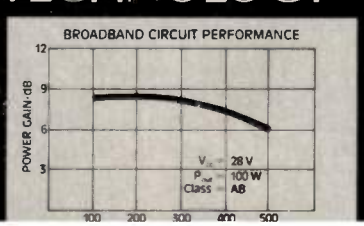

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ACRIAN

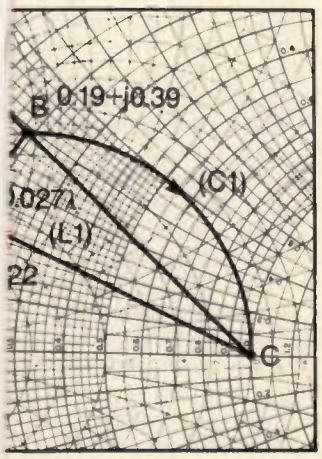
design

December 1985

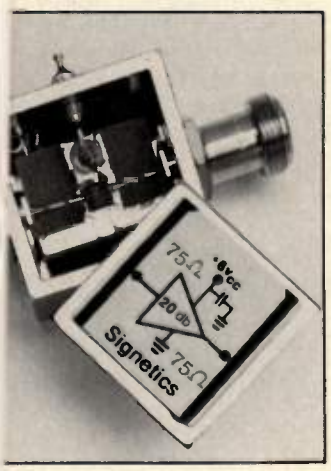
Cover

This month's cover features a new multiple receiver controller by Watkins-Johnson Company, Special Products Division, Gaithersburg, Maryland. The setting represents various military vehicles that might carry the WJ-8610A, which helps monitor and control intercept receivers in dense signal environments.

Features



Departments



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The Benefits of Military Electronics Development

By James N. MacDonald
Editor

Normally, this magazine does not cover the military electronics scene, even though many of our readers design military equipment. We concentrate on design ideas and techniques, not on systems. Sometimes, however, a subject is so interesting we cannot resist the temptation to draw our readers' attention to it, even if it does not show them how to design something better or solve a problem. The guiding philosophy in such circumstances is whether thinking about some new developments in the field might help engineers keep up with changes that could affect their career.

This kind of thought process took place as we worked on this month's Special Report. We started out to write about interesting, little-known uses of RF in industry and the military. We discovered so much going on that we finally decided to limit the subject to military uses of RF. But as we looked at the material available we began to say, "This is interesting, but how does it really help an engineer do a better job?" The result is three contributed articles describing electronic operations applicable to many military devices.

One thing our research pointed out is how much the civilian community benefits from military electronics development. The receiver controller featured in our cover is especially suitable for monitoring signals in a military environment. A Watkins-Johnson engineer pointed out that it could also be used to locate and monitor surreptitious radio signals within a large city. It could be used to track terrorist groups or drug runners. Potentially, any illegal communications network could be monitored with such a system.

Frequency-hopping techniques seem to be solely a military use of the technology, but the technique might also be used for secure business communications. We do not know to what extent commercial and government communications are being intercepted, but it would be naive to assume they are not. Most sensitive communications are encrypted, but encryption can be defeated unless it is quite sophisticated. Technology cannot stand still, even in the civilian sector.

So, we have not fulfilled the promise in last month's editorial to write about industrial uses of RF in this month's Special Report. We hope to be able to describe such uses in a future issue, because they are interesting. We also hope, however, that we will never lose the flexibility to change the focus of our Special Reports to best serve our readers' needs.

James N. MacDonald

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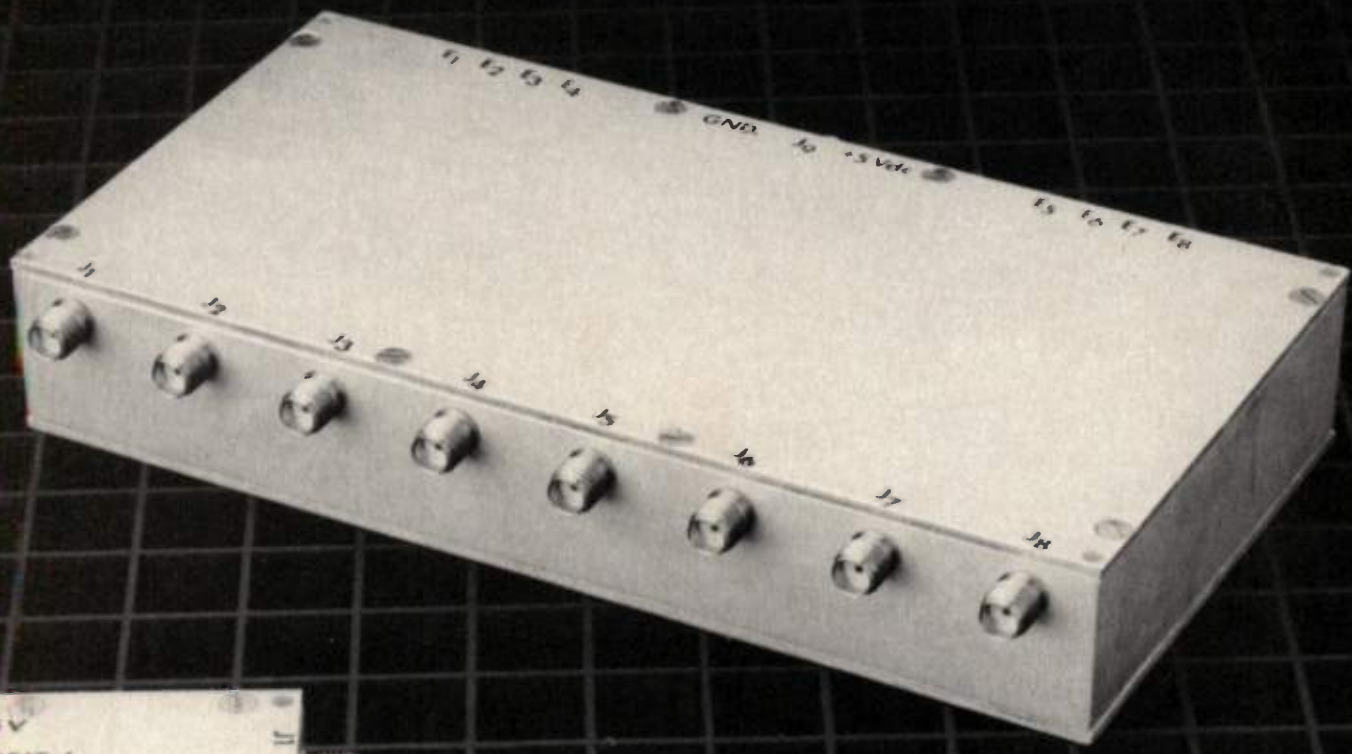

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rf viewpoint

The "Sizzle" Returns to RF

By Joseph H. Johnson
President,
Microwave Modules and Devices

What is it about a particular market area that makes it exciting? Generally, it is an attitude that becomes contagious and spreads quickly. What initiates the excitement? New and interesting programs, new discoveries, rapid growth opportunities and a chance to make a personal contribution.

The RF market had sizzle in the early 70s. What happened to it? It simply went someplace else! It went to microwaves. GaAs was new and everyone wanted to do something with it. It went to microprocessors. Suddenly everything from toys to test equipment had built in intelligence. It went to personal computers. Apple and their followers literally changed the entire electronics industry. And it went to satellite communications. Instant communications between any two points on the globe become possible for the first time.

I was not always an expert on "sizzle!" My business partner and I had wanted to go into a business of our own for several years. We wrote a business plan and discussed it with a venture capital friend of ours, one of the few venture capital people who actually understood RF. He liked the idea for the business, but said the plan lacked "sizzle." How do you add sizzle to a business plan?

We first changed the description of the market. Then we came up with a new way to approach the market. We were not going to sell modules, we were going to sell "Integrated RF Performance" and we described an industry trend away from "in-house" to the merchant market for many circuit functions. Now the plan had "sizzle" and MMD was launched!

One of the reasons the MMD plan had "sizzle" was that the whole RF market was beginning to "sizzle" again! What makes the present different from the last decade? *New visions of war:* Suddenly our servicemen have become more dependent on electronics than guns for their success and safety. Jam proof communication, long range radar, position location and the need to diversify away from the dependence on satellites have directed a new focus on the lower frequencies. *Star Wars:* This controversial program is creating a great deal of excitement. Both the neutral particle beam weapon and the free electron laser require very high power RF sources. Other linear accelerator applications from medical electronics to high energy physics research will benefit from Star Wars research. *Movement to the merchant market:* Today's sophisticated systems are more complicated, and many companies are beginning to focus their resources on systems and depend on outside companies for modular subsystems. This movement is creating many opportunities for new companies. *Cellular telephone:* This concept for mobile and portable communication is spreading world-wide and creating a new market for RF. The next generation will include a satellite link. These market shifts are requiring new products, generating new companies, and changing old companies. Dramatic market changes call for creative thinking and industry-wide movement. That means "sizzle."

There is one remaining challenge. For the new "sizzle" in RF to be complete, we must extend this excitement to university and college students. Students and professors need to become more aware of the practical aspects of RF and the new opportunities for research. Industry needs to work harder to redirect the interest of faculty and students to RF. Special awards or scholarships for new ideas and research might be the way to start. We need to interest the college student now!

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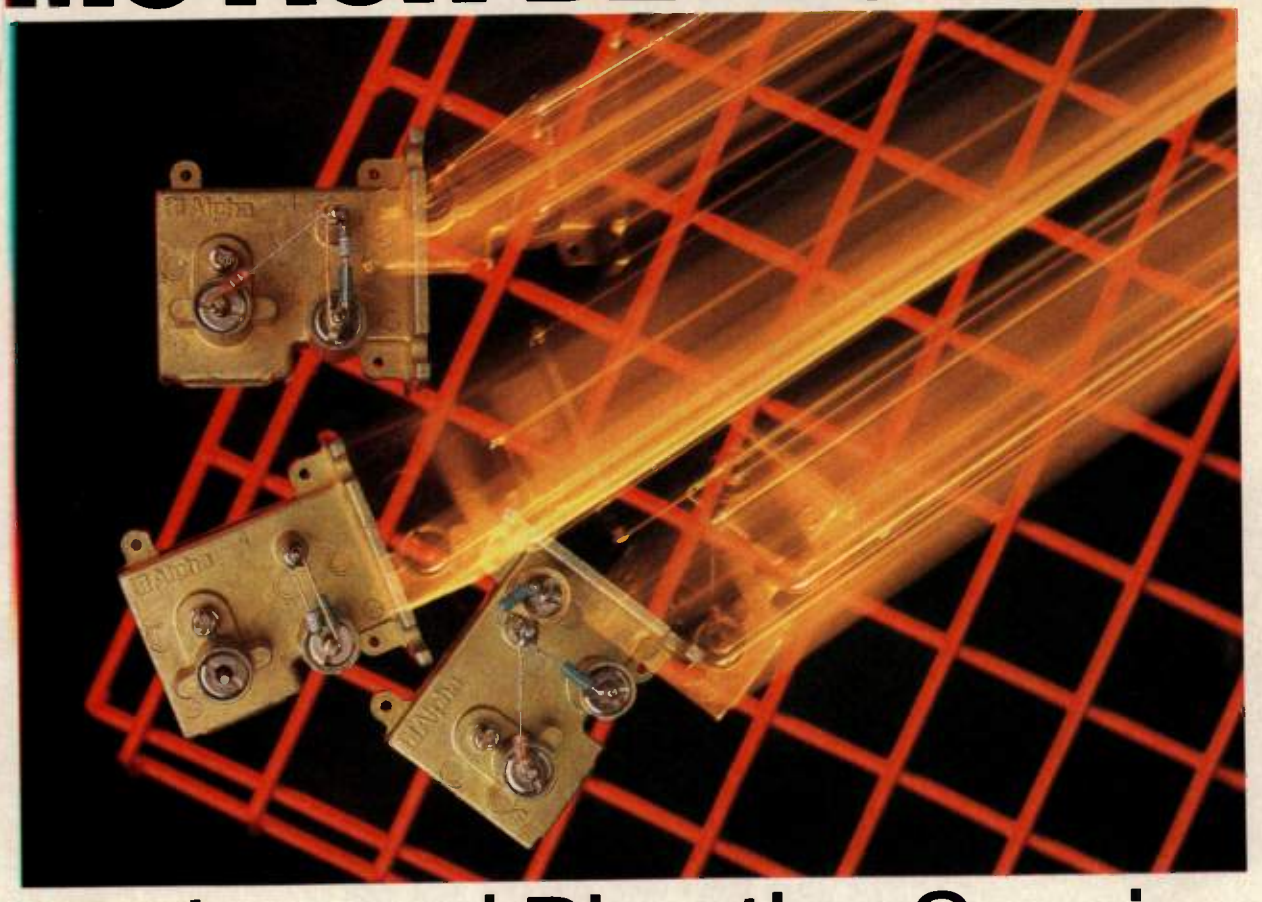
MOTION DETECTORS



Motion and Direction Sensing

When it comes to motion detectors, microwave technology offers system designers the added dimension of direction sensing to eliminate inadvertent activation from "false" signals. This advantage represents a distinct improvement over standard devices, which use light, heat or sound as a detection medium.

Microwave devices also offer the benefit of added reliability, since there is no wear from repeated mechanical contact or blinding due to extreme environmental conditions. Furthermore, they afford greater flexibility in the area of signal processing design.

As a leading manufacturer of space-qualified microwave components, Alpha offers a line of motion detector modules that is ideal for a variety of door, security and process applications. These devices are available as both motion or motion direction sensors, and they come in either CW or pulsed configurations for low power drain.

For added flexibility, units are available as oscillators only and all have a wide range of power output available. Customer engineering assistance (design, assembly, and test) is available upon request.

Applications

- Automatic Door Activation (Mounts over door. Direction sensing governs activation.)
- Intrusion Alarm Applications (Quadrature mounting available for motion comparison.)
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- Traffic Signal Activation
- Automatic Illumination

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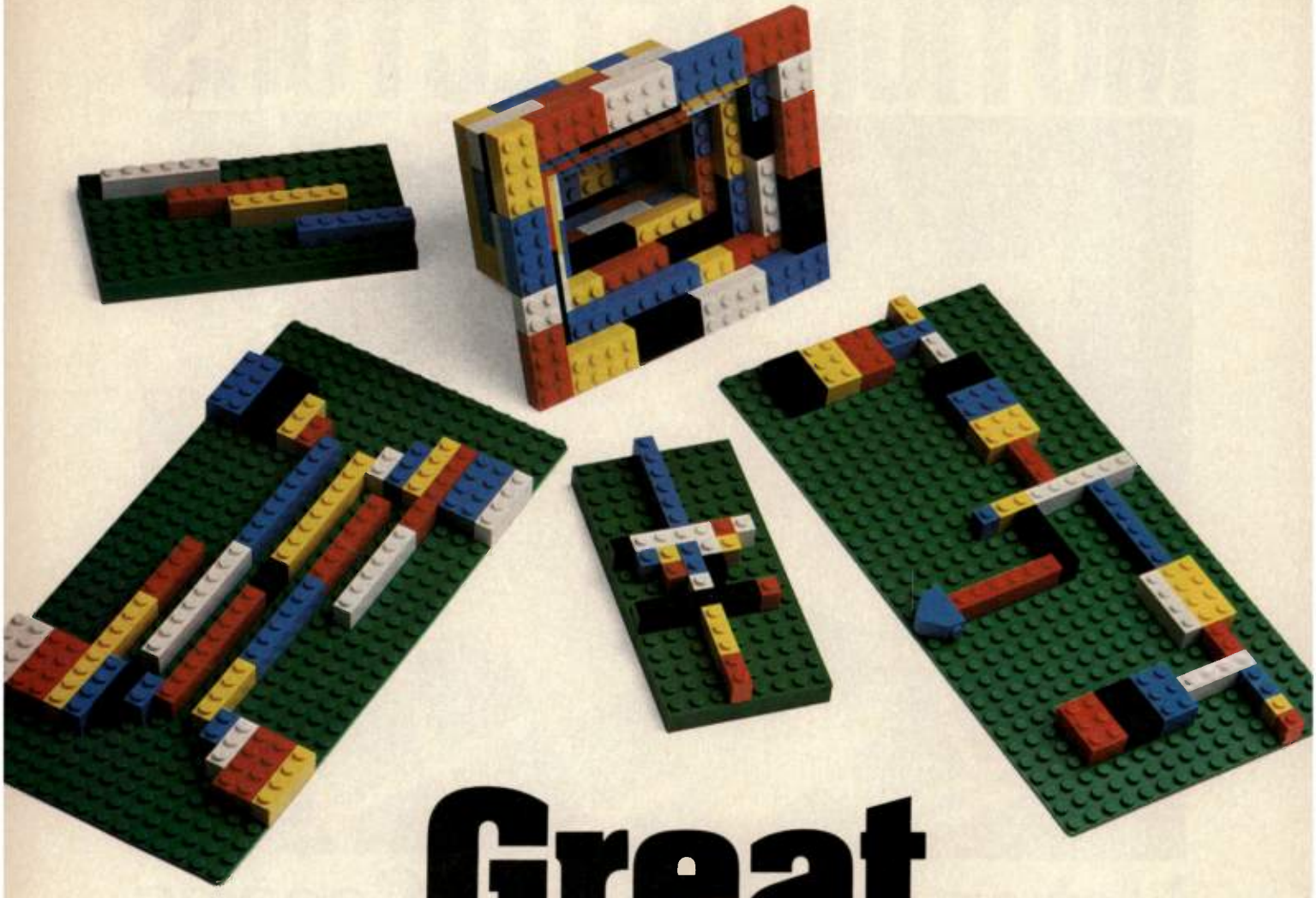

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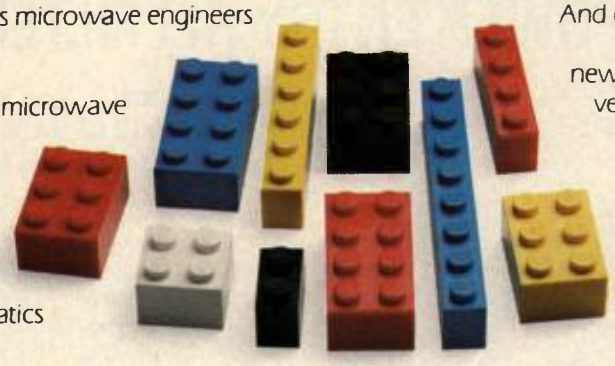

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Editor:

I read with interest the feature article in the October issue of *RF Design* on "Noise Generating Instruments." We have been involved in the field for some time, and I regret that our name was omitted from the list of companies manufacturing Noise equipment.

Our company has been designing and producing various Noise instruments for years. We are listed in numerous product directories and have had our products presented in many of the trade journals.

Enclosed herewith are product releases on some of our noise sources which should be of interest to your readers. We will appreciate your publishing these items in *RF Design* in the near future. We also request that you include our company in any listings of manufacturers of noise generating devices. Thank you.

Sheila Rabinovici
International Microwave Corp.
Stamford, Conn.

For more information about these noise instruments please circle INFO/CARD #101. — editor

Editor:

A small comment on the article "Another One-Transistor FM Transmitter" (Oct. issue). The oscillator shown is a Colpitts rather than a Clapp-Gouriet. Any radio handbook will show the difference. The Clapp-Gouriet has a third capacitor in the tuned circuit.

Some further information on these oscillators may be found in the Proceedings of the IRE for July and August 1955 in the correspondence section.

W.B. Bernard

Editor:

Finally got thumbing through the September issue of *RF Design* and ran across your editorial on the "RF" industry.

I think a good example of the increased "interest" in sub-microwave frequencies is ourselves, MSC. Historically, frequencies below a GHz, being close to DC, were looked at as being outside our bailiwick, what with circuit elements that looked like real coils of wire!

More recently, of course, MSC has become very much involved in the VHF/UHF frequency range with both CW and pulsed silicon power transistors as well as power amplifiers and subsystems. Our participation in RF Technology Expo 85 was a big success and we'll be there in 86 with more high power "RF" components.

Surprising how well "microwave" power transistor designs will perform at ½ or ⅓ the frequency (with proper modifications, of course)!

Best wishes for the continued success of *RF Design*.

Carl J. Lump
Microwave Semiconductor Corp.
Somerset, N.J.

P.S. As you wound up your editorial with a note for the "hams," I would heartily recommend promoting the professional/amateur synergy in the RF world at Expo '86 with a listing of "hams" attending (exhibitors & registrants) or at least a bulletin board for posting of individuals' QSL cards. For the record, I'm KQ2O and have been a licensed ham for over 25 years.

Good idea, Carl. We also plan to have a place for hams to write their call signs on their badges. — editor.

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RCA To Close Broadcast Division, Semiconductor Plant

RCA Corp. has announced a restructuring plan including the closing of its Broadcast Systems Division, a semiconductor plant in Florida, and merger of its Cylix data communications service with RCA Global Communications.

The closing of the Broadcast Division ends 66 years of leadership in the radio and television industry. An RCA spokesman cited financial losses and increased competition as primary reasons for the closing. The timing of the restructuring plan allows RCA to offset the gain realized by the sale of Hertz Corp.

The company had experienced losses in the Broadcast Division for the past four years and has been eliminating weak product lines. The remaining lines are television transmitters, transmitting antennas, cameras and videotape recorders. It is expected that these lines will be sold. Sales and service operations will remain in place to fulfill existing obligations and liquidate current inventory.

RCA says most engineers will be transferred to other RCA operations, but a moderate number will have their fate determined by the sale of the division's product lines. It was suggested that such personnel matters may be part of the negotiation of sale terms. Prospects for the sale of the remaining lines are good, especially for the antenna products, which have been profitable.

RF Design to Hold First Design Contest

RF Design magazine has announced it will sponsor a circuit design contest during the first quarter of 1986. Editor Jim MacDonald said the purpose of the contest is to encourage design creativity and to share design ideas among the RF community. The contest will be limited to designs of active RF circuits operating in the UHF range or below. Contest officials said an active circuit is defined as one that introduces gain or has a directional function, for example, an amplifier, oscillator, mixer, modulator or demodulator.

Entries will be accepted from now until April 15, 1986. Contest rules state the design must be original work by the entrant and not previously published. If the design develops from the designer's employment, the employer must give permission to enter it in the contest. Patent or copyright infringement will disqualify a design.

Judging criteria will include originality of concept, imaginative application of a component or device, significant cost or labor saving, elegance of design, exceptional performance, usefulness, clear description of function and reproducibility. All circuit components must be available for purchase. The designer must be able to document to the satisfaction of the judges that the circuit operates and performs as described.

Each entry must include a complete description of the circuit and its function and parts list. At least one complete circuit diagram is necessary, and additional drawings and photographs may be included for clarity.

The contest judges will be Gary Breed, *RF Design* technical editor, Andy Przedpelski, vice president for development, ARF Products, Inc., and James W. Mize, Jr., senior research engineer, Lockheed Missile and Space Co.

Entries may be sent to *RF Design*, 6530 So. Yosemite St., Englewood, CO 80111. Designs remain the property of the designer, but prize-winning designs may be published in *RF Design* magazine. Submission for the contest implies consent to such publication.

Implantable Microreceiver Relieves Chronic Pain

A neurostimulator developed by Neuromed, Ft. Lauderdale, Fla., and activated by RF signals from an external transmitter can be implanted in the body to block severe chronic pain. Electric pulses generated by the device also can alleviate symptoms of neurologic disorders, company representatives said.

A small transmitter powered by a 9 volt battery sends control signals to the receiver implanted just under the skin. A four-electrode lead conducts current from the receiver to the spinal cord or brain. The transmitting antenna is placed directly over the receiver, a single chip measuring 125 × 175 mils manufactured by Vitarel, Inc., San Diego.

The multiple-electrode lead allows the physician to position the stimulating impulses precisely in one operation. Electrodes are six millimeters apart and can be used independently to produce the desired effect. The physician can program the transmitter for frequency (20 to 1500 Hz), pulse width (50 to 500 microseconds), and amplitude. Each electrode can be programmed for positive, negative or alternating current. The patient can control frequency and amplitude within a narrower range for best effect.

Company representatives said more than 1300 Neuromed devices have been implanted since 1980 with better than 99.6 percent reliability. Multistim is the first multiprogrammable spinal cord stimulator and MIND is the only multiprogrammable brain stimulation system, they said.

Dale Electronics Products Placed on IEC-Q List

Dale Electronics, Inc., Columbus, Nebr., has become the first U.S. resistor manufacturer to have its products placed on the List of Qualified Products by the International Electrotechnical Commission Quality Assessment System for Electronic Components, according to a news release issued by the company.

The IEC-Q is designed to stimulate international trade by identifying manufacturers and specific components that meet worldwide standards of quality and performance. The program is sponsored by the International Electrotechnical Commission, Geneva, Switzerland, and includes 20 participating countries representing the major industrial nations of the world.

Dale said the products qualified include their entire metal film resistor line and their line of resistor networks, including dual-in-line and single-in-line packages. The company said approval is based on a detail inspection by UL (the International Inspectorate organization) for conformance to international requirements of product quality, inspection control and quality assurance, and on the results of extensive qualification testing on individual part types.

Dale said this qualification will allow them to compete in the international market based on complete acceptance of its product without additional testing in any

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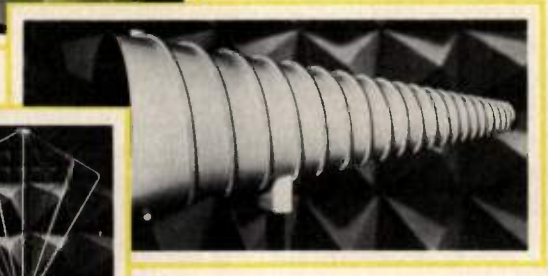

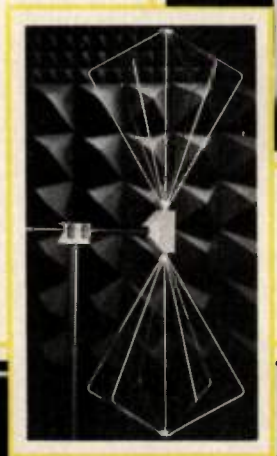

If you're involved with keeping RFI/EMI in or out, you already know about Instrument Specialties. You've probably used our beryllium copper shielding strips...received our engineering help ...even used our new line of ESD devices.

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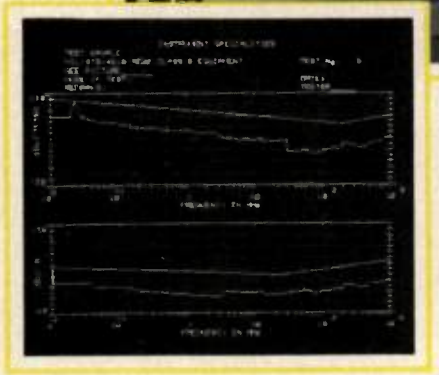

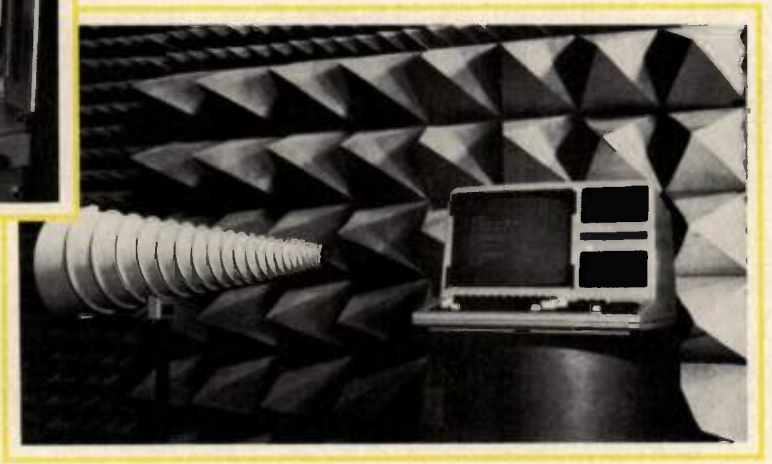

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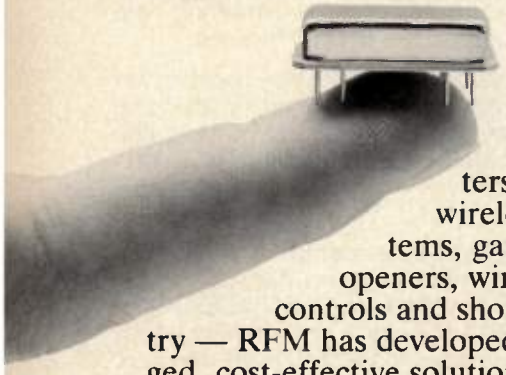

For the many applications that use low-power UHF transmitters under Part 15 — wireless security systems, garage door openers, wireless remote controls and short-range telemetry — RFM has developed an easy, rugged, cost-effective solution to transmitter design.

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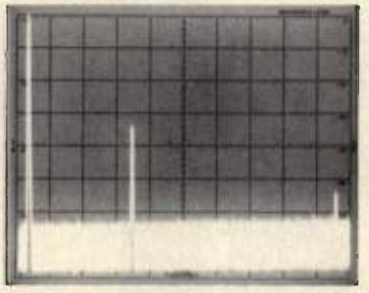
Quartz SAW resonator frequency control assures that our transmitters won't drift out of your receiver's bandpass — or into a military "forbidden band" — despite temperature or battery voltage changes, component aging or body capacitance effects.



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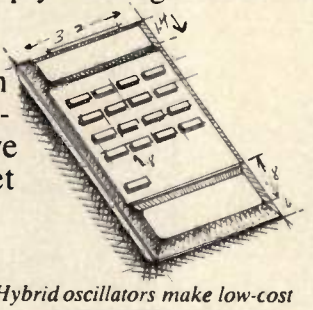

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of the participating countries. The company expects to expand its IEC-Q qualifications to its entire line of electronic components.

Besser Associates Announces Video Tape Courses

Besser Associates, Inc., Foster City, Calif., has produced three RF/Microwave engineering courses on video tape. Company president Les Besser said courses now available are: *Microwave Filters, Couplers and Matching Network Design; Transmission Lines and Physical Realizations;* and *RF and Microwave Transistor Amplifiers.* The tapes come with written study material and exercises.

Besser said the courses are a special adaptation of the *Microwave Circuit Design* continuing education seminars presented at UCLA and other institutions during the past few years. They include homework problems illustrating the latest computer aided design software tools. He said the tapes will be available in Japanese and French for the international RF/Microwave engineering community.

For details contact Ron Rose, Vice President of Marketing, Besser Associates, Inc., 187 Shooting Star, Foster City, CA 94404. The telephone number is (415) 574-5988.

Japanese Manufacturers Behind in Surface Mount Technology

Japanese semiconductor manufacturers, long believed to be leaders in the field, are slipping behind in surface mount technology, according to a new study by Product Assessment and Benn Electronics Publications (BEP).

The study, *Surface Mounted Semiconductors,* estimates that U.S. and European semiconductor manufacturers have recently invested over $20 million in tooling alone for the JEDEC plastic leaded chip carrier (PLCC) and small outline IC (SOIC) packages, options which are not currently favored by Japanese suppliers. With high levels of investment, many devices already available and many more planned for introduction this year, these outlines are now firmly set to become industry standard parts in the West.

In contrast, Japanese suppliers currently offer a variety of quad and flat packs with little standardization and low market penetration in the U.S. and Europe. Only a few products are currently offered in the PLCC and SOIC package options due to long standing reservations about market acceptance and package reliability. However, Japanese sources cannot be expected to remain behind in package technology for long, and it is significant that in the highly competitive memory market they are now offering many components in rectangular PLCC packs with a limited range of support devices.

According to *Surface Mounted Semiconductors,* the surface mounted share of world semiconductor markets is currently in the order of 5-10 percent of the total, but is set to rise to around 50 percent by 1990, with PLCC representing approximately 25 percent and SOIC some 15 percent. If realized, this prediction will represent a dramatic change in the way circuit boards are assembled and paves the way for the introduction of devices with pin counts in the 200-300 range (compared with about 100 maximum at present), which in practical terms can only be utilized commercially via SM techniques.

The activities of 31 semiconductor manufacturers and 23 suppliers of equipment and services are reviewed in *Surface Mounted Semiconductors,* including industry leaders like Texas Instruments, Motorola, Mullard, Panasonic, TDK and Dage. Detailed listings of device types or families available, future plans, price trends, packaging options and equipment capabilities are all covered on a company by company basis.

Surface Mounted Semiconductors is available from the publishers, BEP, price $12.50 (U.S.) per copy at P.O. Box 28, Luton, LU2 OED, U.K. Telephone: (0582) 417438 Telex: 827648 BENNLU G.

New Managing Innovation Report Helps Industrial Managers

To make the most of their research and development efforts, industrial managers must minimize the risks involved in R&D, keep costs low and increase productivity. To help managers accomplish these goals, Technical Insights, Inc. has published *Managing Innovation for Profit* (2nd Ed., Revised).

This new edition features 39 mini-reports on all aspects of innovation by leading R&D consultants, financial advisors and top management. All are experts at the forefront of innovation in major corporations, research groups and universities.

"All their observations come together on five basic aspects of managing innovations," emphasizes Kennth A. Kovaly, president of Technical Insights. These are: how to find, acquire and manage new technologies, how to plan for R&D success, how to measure R&D success, how to make the most of your R&D team, and how to build new R&D systems and facilities.

The experts provide information on how to use internal entrepreneuring to get inventions out of the lab into commercialization, how product manufacturers can get their customers to innovate for them, and the latest strategies for finding, acquiring and managing new technologies from outside their organizations. All the information is presented in one concise, up-to-date, accessible, 195-page report, including figures and tables. One of the most valuable aspects of this report is that almost all of these mini-reports provide names and addresses of the experts, which enables readers to seek advice beyond what is provided in the text.

Managing Innovation for Profit is available from Technical Insights, Inc., P.O. Box 1304, Fort Lee, NJ 07024; (201) 568-4744. 195 pages. Price $190.00; Overseas: $210.00

Gould Awarded Contract for U.S. Army MSE Program

Gould Inc. has been awarded a six-year, $200 million contract to jointly manufacture a French-designed radio as part of the United States Army's multibillion dollar Multiple Subscriber Equipment program (MSE). Under the terms of the agreement, Gould is a subcontractor to SINTRA, a wholly owned subsidiary of Thomson-CSF, Paris, France.

The MSE program will provide automated communications to the Army's mobile and stationary users at corps and division levels. The system includes voice, data and facsimile communications.

rf courses

R&B Enterprises:
EMI and EMP Test Workshops
December 5-6, 1985, Philadelphia (FCC Commercial)
December 12-13, 1985, Philadelphia (MIL-STD-461/462)

Information: Greg Gore, R&B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428; Tel: (215) 825-1960

Interference Control Technologies:
Grounding and Shielding
December 3-6, 1985, New Orleans

TEMPEST-Design Control-Testing
December 2-6, 1985, Sunnyvale

Introduction to EMI/RFI/EMC
December 3-5, 1985, Los Angeles

Fundamentals of EMI/EMC
December 10-11, 1985, Houston

Information: Penny Caran, Interference Control Technologies, State Route 625, P.O. Box D, Gainesville, VA 22065; Tel: (703) 347-0030

Continuing Education Institute:
Microwave Circuit Design: Non-Linear Circuits
December 2-6, 1985, Palo Alto
Information: Helen Hegnsdal, Continuing Education Institute, 10889 Wilshire Blvd., Los Angeles, CA 90024; Tel: (213) 824-9545

The George Washington University:
Electronic Warfare Systems:
December 16-20, 1985, Washington DC
March 10-14, 1986, Washington, DC
July 14-18, 1986, Washington, DC

Military Communications Systems
December 2-6, 1985, Washington, DC

Spread Spectrum Communications Systems
March 3-7, 1986, Washington, DC

Antennas and Arrays
March 17-21, 1986, Washington, DC

Introduction to Receivers
March 17-18, 1986, Washington, DC

Modern Receiver Design
March 19-21, 1986, Washington, DC

Synchronization in Spread Spectrum Systems
April 7-11, 1986, Washington, DC

Information: Merril Ann Ferber, Assistant Director, Continuing Education Engineering Program, The George Washington University, Washington, DC 20052; Tel: (800) 424-9773.

rf calendar

January 21-23, 1986
Advanced Semiconductor Equipment Exposition and Technical Conference
San Jose Convention Center, San Jose, California
Information: Joyce Estill, ASEE '86 Show Manager, Cartlidge and Associates, Inc., 1101 South Winchester Blvd., #M259, San Jose, CA 95128; Tel: (408) 554-6644.

January 21-23, 1986
Electrical Overstress Exposition
Anaheim Hilton and Towers, Anaheim, California
Information: Jim Russell, EOE, 2504 N. Tamiami Trail, Nokomis, FL 33555; Tel: (813) 966-3631.

January 28-30, 1986
Systems Design and Integration Conference
Brooks Hall, San Francisco, California
Information: Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (213) 772-2965.

January 30-February 1, 1986
RF Technology Expo '86
Anaheim Hilton and Towers, Anaheim, California
Information: Kathy Kriner, Cardiff Publishing Co., 6530 S. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522.

March 11-13, 1986
Automated Design for Engineering for Electronics West
Moscone Convention Center, San Francisco, California
Information: Show Manager, ADEE WEST, Cahners Exposition Group, 1350 East Touhy Ave., P.O. Box 5060, Des Plaines, IL 60017-5060; Tel: (312) 299-9311.

April 8-10, 1986
Test and Measurement World Expo
San Jose Convention Center, San Jose, California
Information: Meg Bowen, Conference Director, Test and Measurement World Expo, 199 Wells Avenue, Newton, MA 02159.

April 9-16, 1986
World Market for Electronics and EE '86
Hannover Fairgrounds, Hannover, West Germany
Information: Hannover Fairs USA Inc., P.O. Box 7066, 103 Carnegie Center, Princeton, NJ 08540; Tel: (609) 987-1202.

May 5-7, 1986
36th Electronics Components Conference
Westin Hotel, Seattle, Washington
Information: Tom Pilcher, Electronics Industries Association; Tel: (317) 261-1592.

June 2-4, 1986
Military Microwave Conference
Metropole Hotel, Brighton, England
Information: Roger Marriott, Microwave Exhibition and Publishing, Convex House, 43 Dudley Road, Tunbridge Wells, Kent TN1 1LE; Tel: 0892-44027.

Microstripline High Power Amplifier Design

By Alan K. Tam
Space & Communications Group
Hughes Aircraft Company

Most available RF/microwave Computer Aided Design (CAD) software has been developed for small signal amplifier applications. Touchstone *from EEsof and* Super-Compact *from Compact Engineering are widely used by microwave circuit designers. Such programs are powerful tools for designers who synthesize, analyze and optimize active and passive circuits to meet their specific needs. Many microwave microstripline Low Noise Amplifiers (LNAs) and intermediate power amplifiers ($P_{OUT} \leq +20$ dBm) have been designed using CAE/CAD software. Yet, little software has been developed for large signal amplifier design.*

The Smith chart graphical approach for effective microstripline High Power Amplifier (HPA) design is demonstrated by the author, using a proven L Band HPA design example to illustrate the technique.

The objective of this design was a narrow-band 1.6 GHz ±10 MHz telemetry transmitter HPA meeting the following requirements:

Power Gain	≥7 dB
Power Output	≥45 W (CW)
Efficiency	≥45%
Input VSWR	≤1.5:1
Load Mismatch	∞:1 at all phase angles
In Band Spurs	≤−60 dBc
2nd Harmonics	≤−25 dBc
Subharmonics	≤−35 dBc
Vcc	+28 VDC
Temperature Range	−40°C to +75°C

There are a few key steps that the designer should be aware of regarding microwave power devices and performance tradeoff considerations. Successful high performance HPA design requires an understanding of the electrical characteristics of the power devices. For instance, a bipolar device can deliver more RF power than its GaAs FET counterpart when operated in the L Band. A common base device has better output VSWR, ruggedness and stability at lower frequencies but has less gain than a common emitter device. Furthermore, internally matched devices offer wider operating bandwidth, higher efficiency and larger series input and output impedance to the microwave circuit designer. The MSC 1517-25M device from Microwave Semiconductor Corp., a flange mounted device, was chosen accordingly in this empirical example.

FREQUENCY (GHz)	Z_{in} (Ω)	Z_{cl} (Ω)
1.50	8.6+j13.0	12.1-j3.9
1.55	7.8+j11.7	9.5-j2.7
1.60	8.5+j11.1	8.6-j4.3
1.65	9.5+j11.0	7.2-j5.0
1.70	7.8+j11.7	8.6-j4.3

Table 1. MSC 1517-25M published input/output impedance data

It is important to review some practical circuit design rules that microwave engineers need to follow in order to achieve maximum efficiency and reliability:

Always operate the device within its Safe Operating Area (SOA) by not exceeding the maximum breakdown voltage BV_{CBO} and current I_{CBO} ratings.

The junction-to-case thermal resistance θ_{jc} should be as low as possible for maximum heat transfer under RF operation. Thermal compound should be placed between the bottom side of the flanged package and the ground surface of the housing.

The housing ground surface, always critical for microwave class 'C' amplifier operation, should be polished to avoid any ground loop problems.

Teflon, Fiberglass, Duroid, E10 ceramic and alumina circuit board/substrate materials can be used depending upon the individual application and considerations of cost, performance and reliability.

The specified torque should be used to secure the power device on the unit housing.

Design Implementation Using the Immittance Chart

The series input and output impedances at 1.64 GHz are taken from the manufacturer's data in Table 1:
Z_{IN} = (9.5 + j11.0) ohm
Z_{OUT} = (7.2 − j5.0) ohm
Normalized impedance with respect to a 50 ohm system are:
Z_{IN} = (0.19 + j0.22) ohm
Z_{OUT} = (0.14 − j0.10) ohm

To begin the actual design, normalize the series input and output impedances and plot them directly on the immittance chart (an opposed admittance Smith chart superimposed on the standard impedance Smith chart). For simplicity, a single section low-pass input matching network was used, which is adequate for narrow band amplifier applications (≤5% BW).

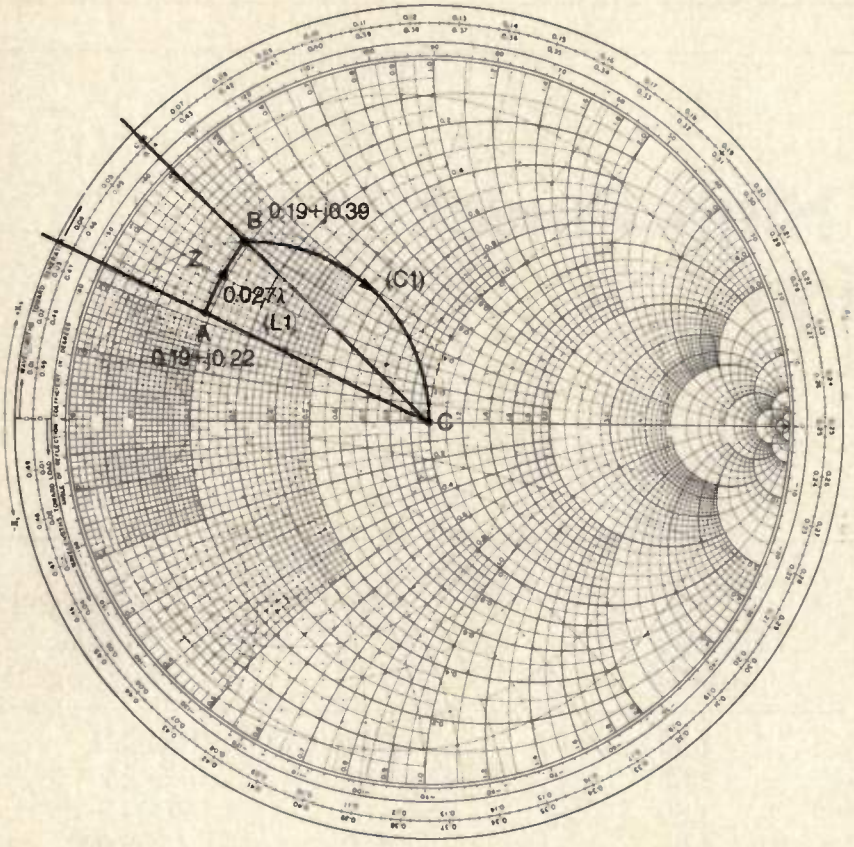

Figure 1. MSC AM-1517-25 input match at 1.65 GHz

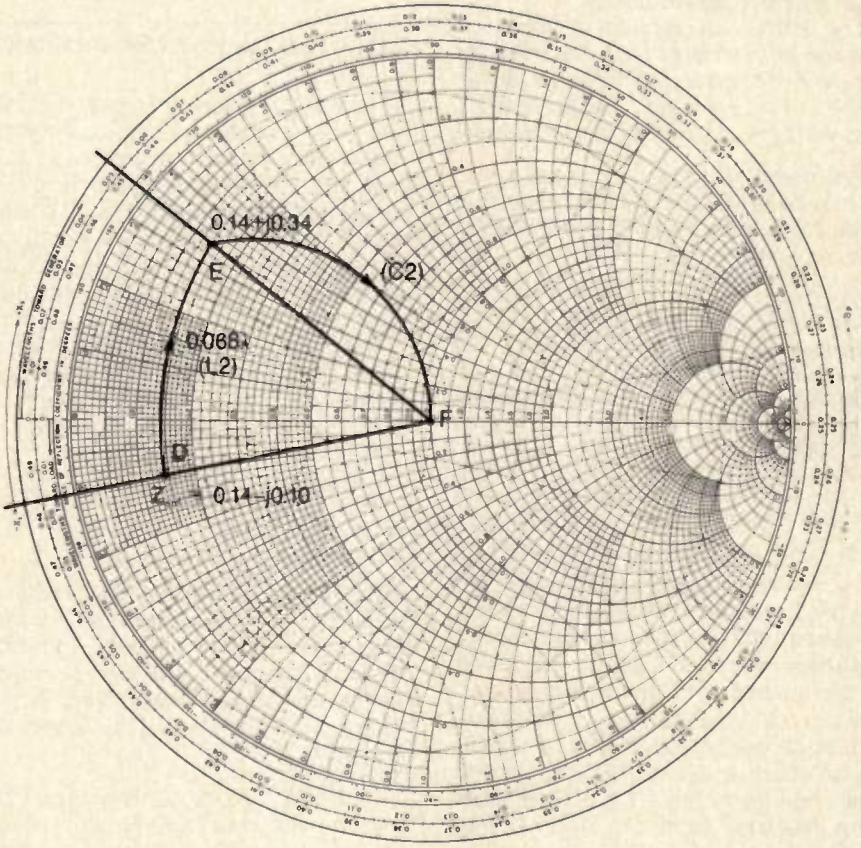

Figure 2. MSC AM-1517-25 output match at 1.65 GHz

Referring to Figs. 1 and 2, L1 and C1 are the input matching elements and L2 and C2 are the respective output matching elements.

L1 and C1 are identified as arcs AB and BC in Fig. 1. The electrical wavelength at 1.64 GHz on a 31 mil Teflon fiberglass board with a relative dielectric constant of 2.10 is given by:

$$\lambda = \frac{C}{\in f} = \frac{1.18 \times 10^{10} \text{ in/sec}}{2.10\ (1.64 \times 10^{9} \text{Hz})} = 4.97 \text{ inch}$$

With this data, line widths were obtained using Compact.

For the input matching network, the electrical length of the 50 ohm transmission line used as L1 is read from arc AB of Fig. 1 as 0.027 λ or 0.134 inch. C1 will be designed as a double-sided open stub rather than a lumped capacitor to provide lower loss, lower cost and better reproducibility. From experience, the characteristic impedance of an open stub should be ranged from 10 ohms to 25 ohms and the overall electrical length should be less than a quarter wavelength. The impedance of C1 as derived from arc BC of Fig. 1 is 40 mmho = 25 ohms (Z_{C1}) The actual impedance of C1 will be doubled due to the double-sided open stub design, so $Z_C = 2Z_{C1} = 50$ ohms. Dimensions of the stub (Fig. 3) are determined using the equation:

$Z_C = -jZ_O \cot\theta$, where (1)

Z_C = capacitive reactance

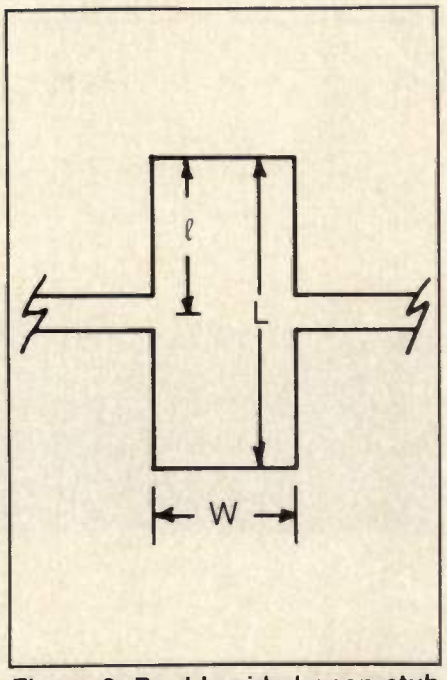

Figure 3. Double-sided open stub dimensions

Z_O = characteristic impedance of stub (w)

θ = electrical length of ℓ

Rearranging (1), and setting $Z_O = 19\Omega$:

$$\theta = \tan^{-1}\frac{Z_O}{Z_C} = \tan^{-1}\frac{19\Omega}{50\Omega} =$$

$\tan^{-1}$ (0.38) = 21.0°

Convert to inches, using:

$$\ell = \frac{\theta\lambda}{2\pi} = \frac{(21.0°)\ (4.97 \text{ in.})}{360°} = 0.290 \text{ in.}$$

L = 2 ℓ = 0.580 in.

W = 0.30 in., for Z_O = 19Ω (using Compact)

The $\lambda/4$ high impedance ($Z_O \cong 80\Omega$) microstripline is incorporated as a shunt inductor to form a DC return path, since the power device is packaged in a common base configuration.

The Output Matching Network design can be accomplished using the same approach. L2, the electrical length of arc DE of Fig. 2, is found to be 0.068 λ or 0.338 inch. The impedance of C2, arc EF of Fig. 2 is 19.2 ohms. Again, for a double-sided open stub, $Z_C = 2Z_{C2} = 38.4\Omega$.

If we set $Z_O = 11\Omega$ and use (1),

$$\theta = \tan^{-1}\frac{Z_O}{Z_C} = \tan^{-1}\frac{11\Omega}{38.4\Omega}$$

$\ell = \tan^{-1}$ (0.286) = 16.0°

Again, convert to inches,

$$\ell = \frac{\theta\lambda g}{2\pi} = \frac{16.0°\ (4.97 \text{ inch})}{360°} = 0.220 \text{ inch}$$

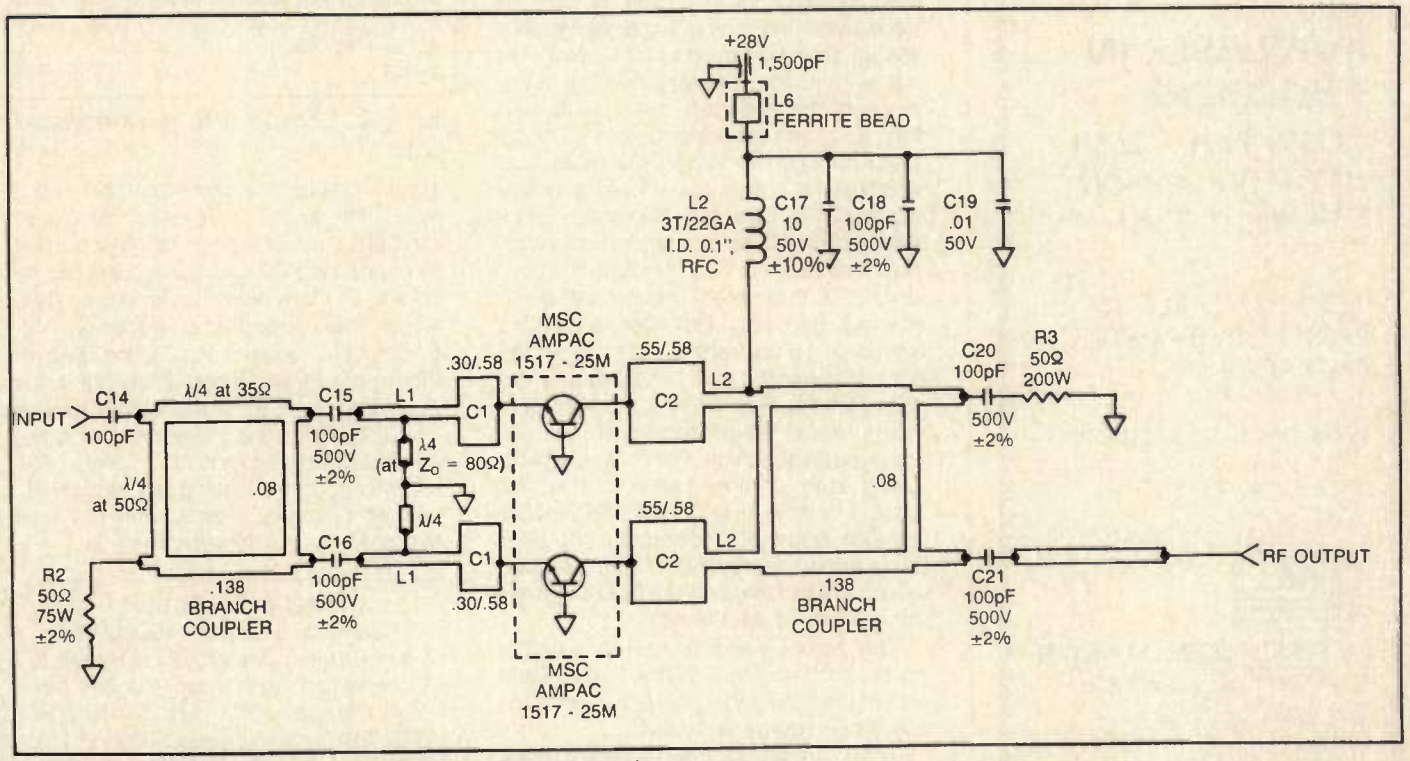

Figure 4. Schematic diagram (layout dimensions)

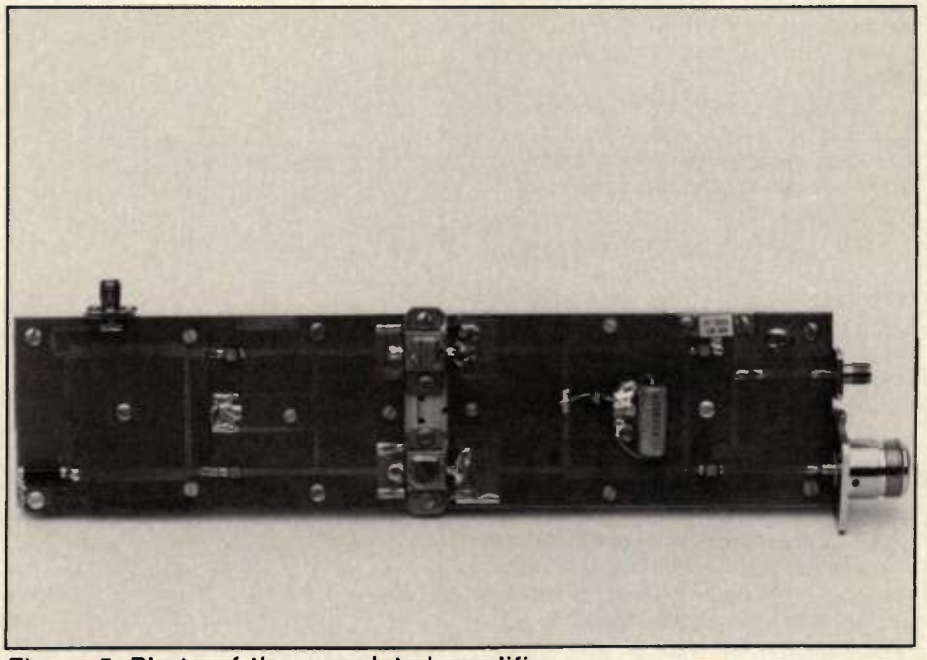

Figure 5. Photo of the completed amplifier

L = 2 ℓ = 0.440 inch

W = 0.55 in, for Z_O = 11Ω

A power combining technique using two quadrature hybrids was adapted for this amplifier. In order to achieve the required 45W minimum power output, two identical 25W class 'C' amplifier stages were paralleled. The quadrature hybrid is essentially a branch coupler in which the series arms are 1/4λ long 50 ohm transmission lines and the shunt arms are 1/4λ long 35.2 ohm transmission lines. The hybrid's function is to split the input and combine the output power while maintaining low VSWR and good isolation. Power devices used in this configuration should be a matched pair with the same DC characteristics to minimize unbalanced power sharing. By using this method the 2nd harmonic component is also greatly reduced compared to a single-ended design. Refer to Figs. 4 and 5, the schematic diagram and the photograph of the unit for layout techniques. Power terminations being used for input and output hybrids should be able to withstand the heat dissipation under RF operation. The ones used are made out of thick film materials which are mounted on the BeO substrate for good heat conduction.

The actual performance data of the completed amplifier is tabulated in Table 2. The performance goals were met using these design techniques.

This immittance chart graphical approach is practical and time saving. The actual results indicate that the input matching network design was perfect, but the output matching was slightly off and the open stub C2 needed to be tuned by adding 6° more electrical length on both sides. This shows that error could be introduced by variations of DuPont Teflon® Fiberglass PCB's dielectric constant, the physical alignment of the output section circuit boards during assembly, or other electrical and mechanical variations. The overall impedance matching design values agreed very closely with the final microstrip layout dimensions.

Frequency (MHz)	1,650	1,640	1,630
Pin (+dBm)	40	40	40
P_{OUT} (+dBm)	47	47	47
Efficiency (77)	44%	43%	43%
Power Gain (dB)	7	7	7
Return Loss (dB)	≤–20	≤–20	≤–20
Spurs (dBc)	<–60	<–60	<–60
2nd Harmonics (dBc)	<–35	<–35	<–35
3rd Harmonics (dBc)	<–35	<–35	<–35
4th Harmonics (dBc)	<–40	<–40	<–40
I_{CC} at + 28 VDC (Amp)	4.08	4.14	4.13

Table 2. L/Band HPA performance data.

About the Author

Alan Tam is Section Head, Microwave Product Design of the Space & Communications Group, Hughes Aircraft Company, P.O. Box 92919, M.S. S72/T301, Los Angeles, CA 90009. His telephone number is (213) 618-2312.

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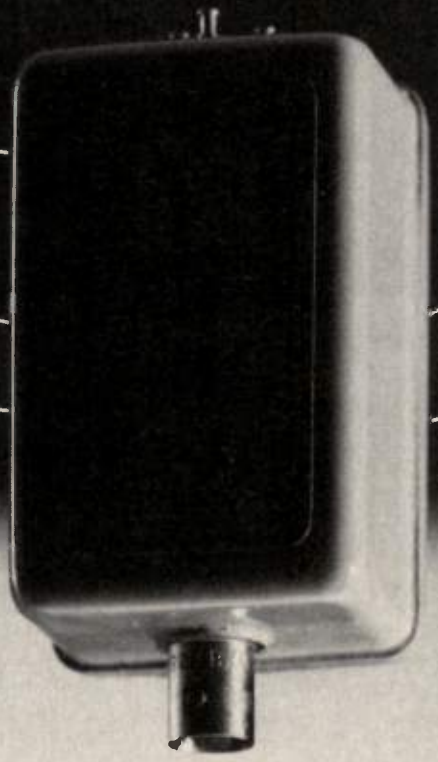

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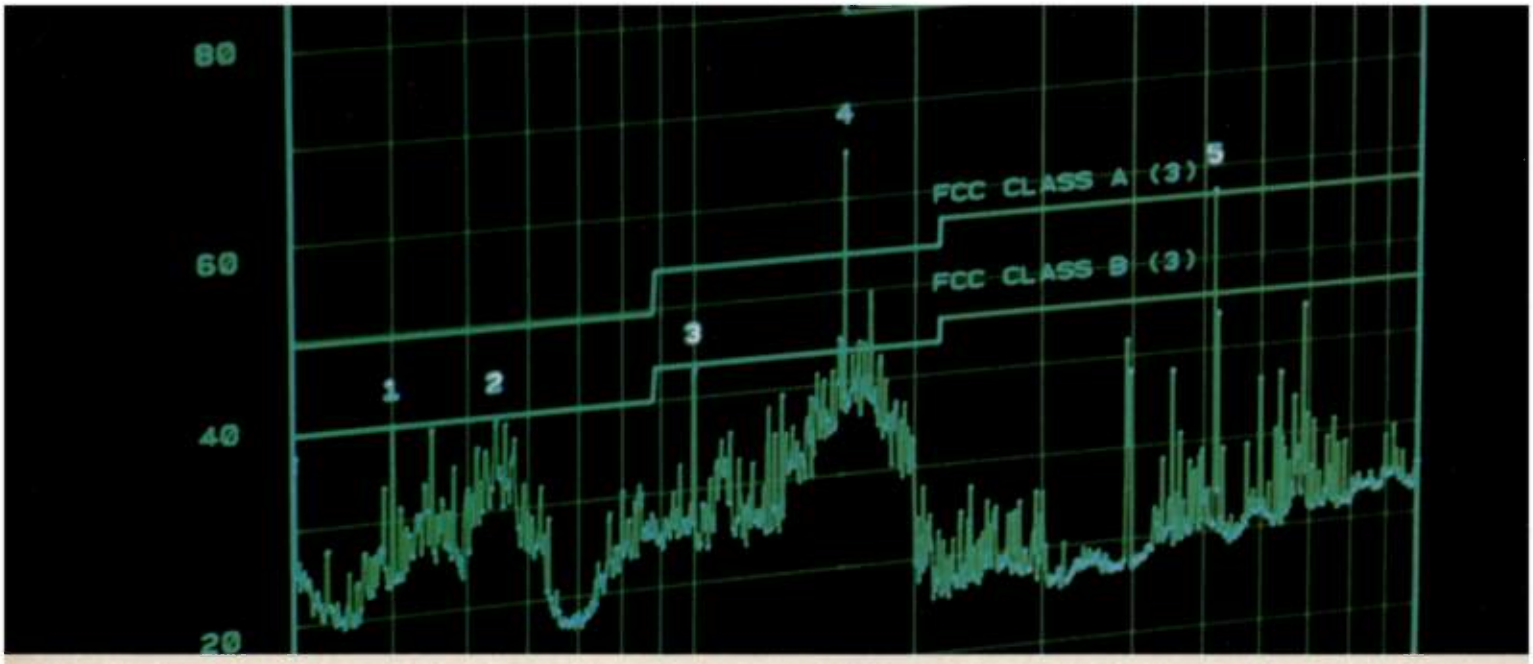

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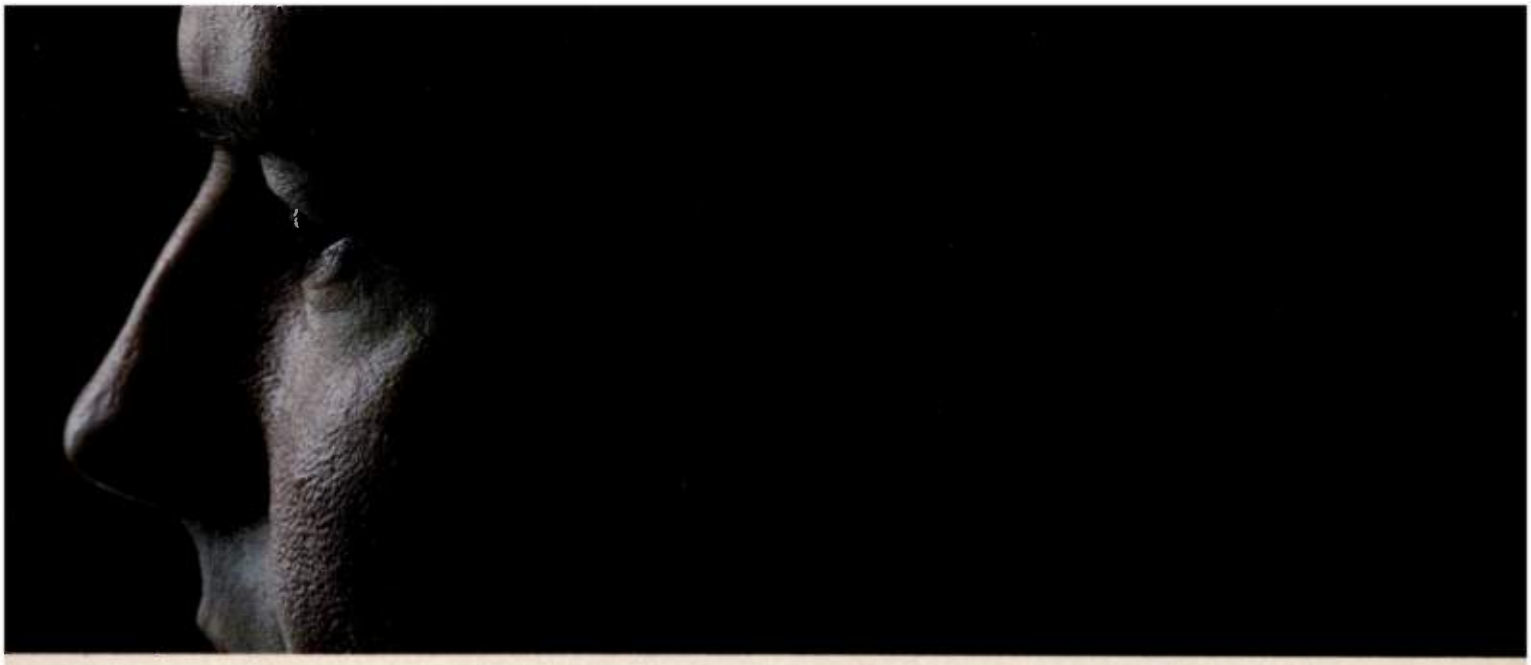

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*CISPR (Comite International Special Des Perturbations Radioelectriques) Publication 16 is the "CISPR specification for radio interference measuring apparatus and measurement methods."

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Military Uses of RF

A look at a multiple-receiver controller system, the use of noise to calibrate and test military electronics, and frequency-hopping by direct-digital synthesis.

During the recent hijacking of an Italian passenger ship a shortwave listener overheard President Reagan in Air Force One talking about the incident with Secretary of Defense Weinberger in another aircraft. (Although the listener was called a ham in newspaper accounts, it is doubtful that the president and the secretary were using an amateur frequency, so SWL would be a more accurate term, whether or not the listener had an amateur license).

White House spokesman Larry Speakes acknowledged that the communication did occur and that the President did not use a secure communications link because there was not enough time to coordinate the two systems. Apparently, the president weighed the risk of an overheard conversation against the time factor and decided the risk was small. His communications specialists undoubtedly knew the conversation could be overheard. In fact, it probably was heard by other SWLs who did not report it to the press.

The occurance is a reminder of the major problem with complex communication technology. The more elements involved in the link the more difficult the system is to use. Although it was not a factor in this event, each separate element that processes communications is one more place where communications can fail.

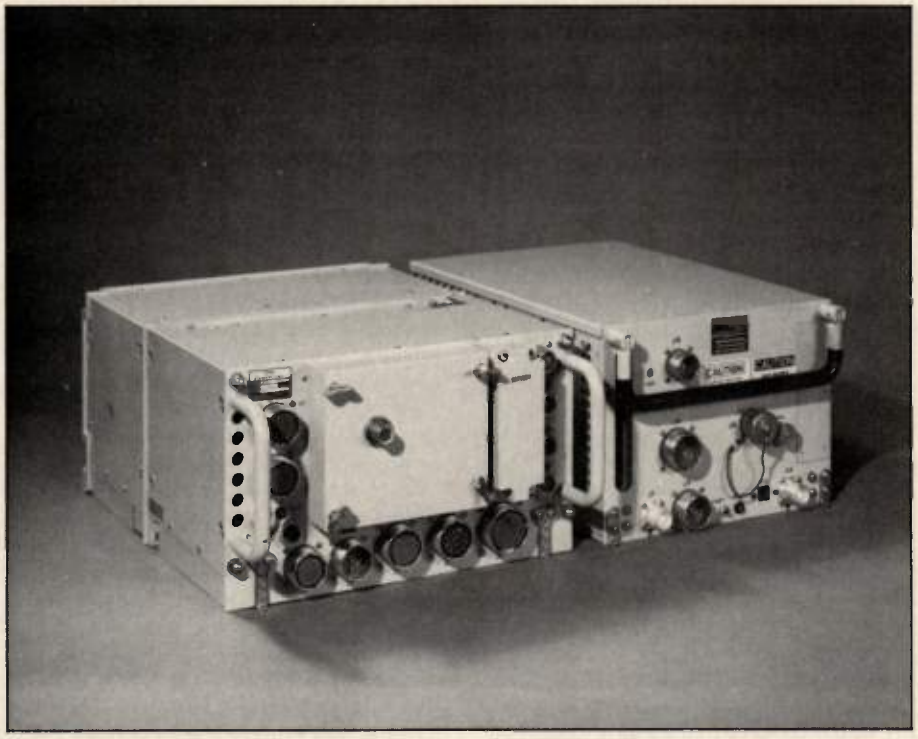
This is one reason military planners are still relying heavily on HF communications. If a major war lasts more than a few days we will probably be bouncing radio signals off the ionosphere instead of satellites. The birds won't be there anymore.

Research runs throughout the lower RF spectrum, from ELF for submarine communications to UHF for video and data transfer, and it is of interest to all military branches. Successful propagation of RF has been well researched, although much remains to be learned about the ionosphere. Most research seems to be directed toward frequency agility to avoid jamming and signal encryption to avoid information compromise. Both research areas bring digital signal processing into the RF field.

This month's Special Report covers a few applications where digital signal processing is enhancing the performance of military communications equipment. Digital design is becoming more and more a part of RF design, and we hope RF design engineers are keeping on top of this trend.

The first article describes the device featured on the cover, Watkins-Johnson Company's new multiple receiver controller, the WJ-8610A. Following up on last month's Special Report, the next article is a brief description of the use of noise in modern communications. The third describes frequency-hopping control by direct-digital synthesis.

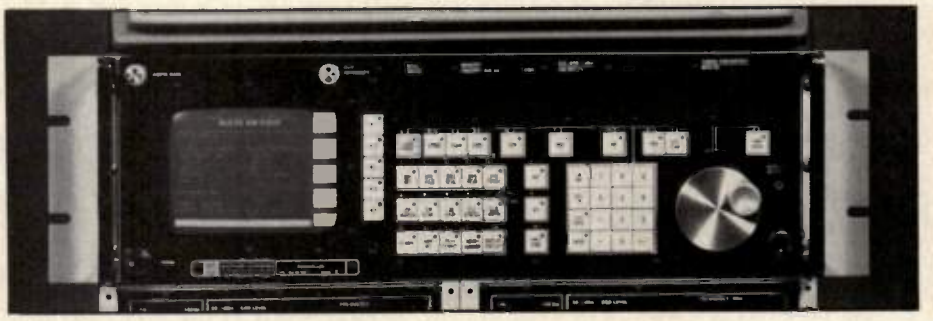
— James N. MacDonald



The Joint Tactical Information Distribution System (JTIDS) Class 2 terminal being produced by Singer's Kearfott Division and Collins Government Avionics Division of Rockwell International for the U.S. Army provides complete tactical information exchange for air defense systems and will be integrated with the Army's Position Location Reporting System. The terminal integrates many communications functions, reducing the weight and size required, and provides real-time, high-capacity, jam-resistant information exchange between combat units within its 300 nautical mile range.

Controlling Multiple VHF/UHF Receiver Systems

By C.E. Dexter and
T.W. Goodell,
Special Projects Division
Watkins-Johnson Co.



As the number of digitally controlled receivers in use at multiple-receiver collection sites grows, the system designer faces a difficult decision in the choice of a controller. If a computer or even a microprocessor is chosen as the multiple-receiver controller, the user has to develop required software. This often proves to be impractical for small collection systems. In a large collection system operated in dense signal environments, a computer appears to be ideal as a multiple-receiver controller. However, in very dense, high-activity signal environments, a central computer can be overloaded with service requests and response commands from a large number of frequency-scanning receivers. In this situation, data collection and operational decisions may be impaired unless some decisions and basic receiver-type routine functions are removed from the computer.

A multiple-receiver controller operating between the central computer and collection receivers can ease the computer workload while providing rapid response to receiver demands. The controller not only expands the communication link, IEEE-488 or other, it also buffers data from the receivers. Many auxiliary functions, such as generating a digitally refreshed display spectrum for a scanned frequency band or queuing intercepted signals also may be handled by the controller. The controller CRT presents a menu-driven alphanumeric display of the status of all receivers and permits operator intervention and control in the event of a central computer failure.

The number of receivers serviced by a central computer can be limited by the number of available bus locations and by the overall system response time. Short duration events such as "pop up" transmissions require rapid system response to such signal parameters as frequency, modulation type and percentage, and signal strength. System response time is limited by both the time required to acquire the signal and the time required to service the active receiver over the bus. All receivers on the bus may require nearly simultaneous requests for service while in the SCAN mode. So much time can be spent on this task that the computer cannot perform its primary analysis function.

Fig. 1 illustrates this problem. In this system, a single computer monitors 60 receivers over an IEEE-488 bus. A bus expander is needed to increase the number of devices per controller to more than 14. The time required to interrogate each receiver for just-tuned frequency is over half a second. Short duration signals cannot be observed or logged by the computer.

A controller between the computer and receiver can do much to relieve this problem. In Fig. 2 the bus expanders have been replaced with receiver controllers. Each controller monitors 10 receivers and reports wanted activity to the computer. With a single command string, the computer can determine the status of up to six receivers, achieving a six-fold reduction in communication time. System programmers can control blocks of receivers with a few simple commands, as opposed to individually servicing each receiver. Distributed processing and the specialized features of the controller simplify programming of system tasks.

System reliability need not be totally dependent upon the proper operation of a single piece of equipment. In some systems the computer may not be needed at all. Often the controller alone is a better choice since it is much more friendly than a computer, while still retaining most computer features. A system controller consists of a microcomputer, keyboard and CRT display. It varies little in these respects from an Apple computer, and is less powerful than an IBM PC. What separates this microcomputer from the others is the unique front panel and the software. The front panel looks and acts like a receiver, even though the receiver is remotely located. The handoff receiver is selected, and the operator may tune and listen to signal activity while watching for any activity on the CRT screen from other receivers with signals present.

The software makes the hardware think it is a controller. Special routines call up each receiver through the IEEE-488 bus and control it or update its status on the alphanumeric CRT screen. Other software routines set up the parameters for putting a number of receivers in the scan mode. Each receiver gets a start frequency, stop frequency and step size. Unwanted signals may be locked out. The controller accepts the 50 dB log video information from the receiver and displays each receiver scan on a digitally refreshed trace on an X-Y CRT. The operator may observe a wide range of signal activity throughout the spectrums selected, place a cursor over the signal of interest with the frequency tuning knob and assign it to a handoff receiver. The headphones and any signal monitor in the system are then connected to this receiver. The operator can listen and select an appropriate IF bandwidth and detection mode before leaving this receiver to the audio recorder. Each signal of interest can be handed off using the cursor control until all receivers are in use.

Other software-controlled auxiliary routines can be chosen, such as antenna select and receiver labeling. Background software tasks aid the operator in distinguishing which receiver has what options and range. Therefore, single sideband signals cannot be accidentally handed off in a receiver without the SSB option.

Some complicated signals or a group of signals may require detailed analysis by an operator. A good handoff receiver with pan sector can ease the analysis task. Pan sector shows the operator a wide panoramic view of signal activity, while a sector of that view is also displayed. An operator can then take the time to use all the features of that versatile receiver to make decisions. Several types of special demodulators such as PSK, FSK and TDM can be used to analyze the signal further.

Auxiliary Functions of the Controller

The controller is capable of far more than receiver control. Other functions as-

sociated with a multiple receiver system, such as audio and video routing and signal-monitor switching, can be a part of the controller's job. Spectrum surveillance through panoramic displays can aid the operator in selecting a signal of interest to pass to a monitoring receiver. To implement this panoramic display, the controller sends the scan parameters to a receiver (start and stop frequency, step size, etc.). The receiver does not stop on the signals, but sends the log video back to the controller.

Another important function of the controller is to let the system computer or operator know when any component or receiver on the bus is malfunctioning. Most good receivers have a built-in test but are unable to distinguish a broken antenna cable from poor sensitivity. The controller queries the BITE function on each receiver and presents the status to the operator or computer. Next, a system test is performed by tuning all receivers to several known transmitted frequencies and comparing signal parameters from each receiver and auxiliary circuits. Any malfunction is reported to the operator, through the alphanumeric CRT, or to the system computer.

The controller can aid the operator in finding certain signals with unique modulation characteristics. Upon acquiring a signal the receiver sends a service request to the controller. The controller asks the receiver for the modulator parameters, such as peak AM, peak deviation, FM offset, etc. The controller compares these parameters with special signal characteristics stored in memory and alerts the operator to a match. Scanning scenarios like this can easily skip standard commercial signals and only stop on signals of sonobuoys, transponders and other transmitters of interest. The receiver signal parameters can also be read directly from the alphanumeric CRT.

Management of Fast-Scan Spectrum Data

A very important auxiliary function of the controller is to manage the many different options, IF bandwidths and frequency ranges of receivers in the system. The controller can display several configuration tables to the operator. By using other menus, such as signal parameter presentations, the operator can hand off wide-spectrum signals to receivers configured with the wider IF bandwidths.

Several types of receivers are available for rapid signal acquisition using IFM, microscan and channelized technology. This article considers only performance typical to a scanning or frequency-step-

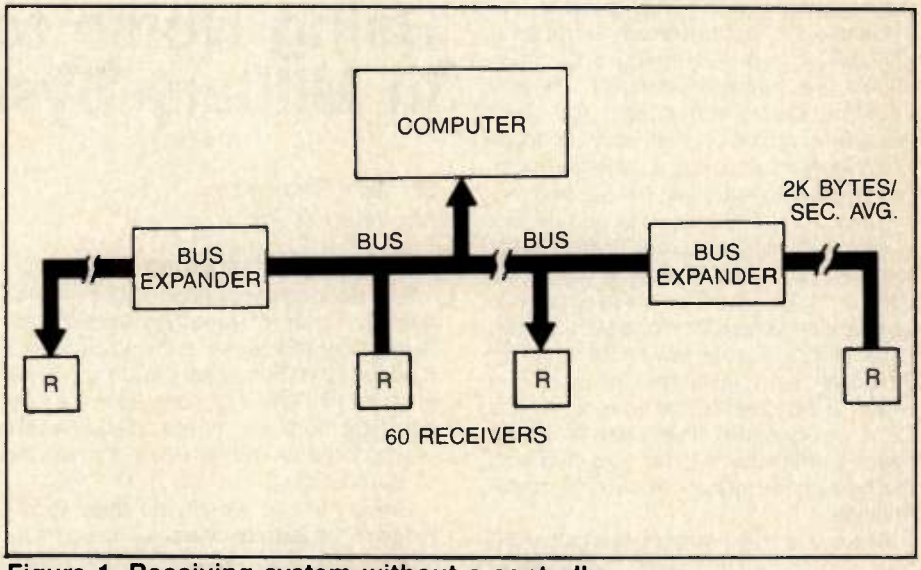


Figure 1. Receiving system without a controller

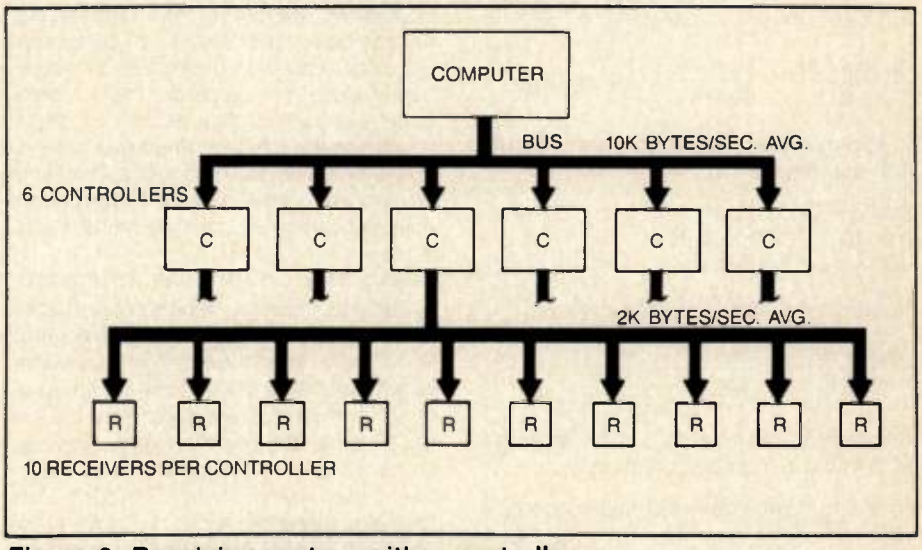


Figure 2. Receiving system with a controller

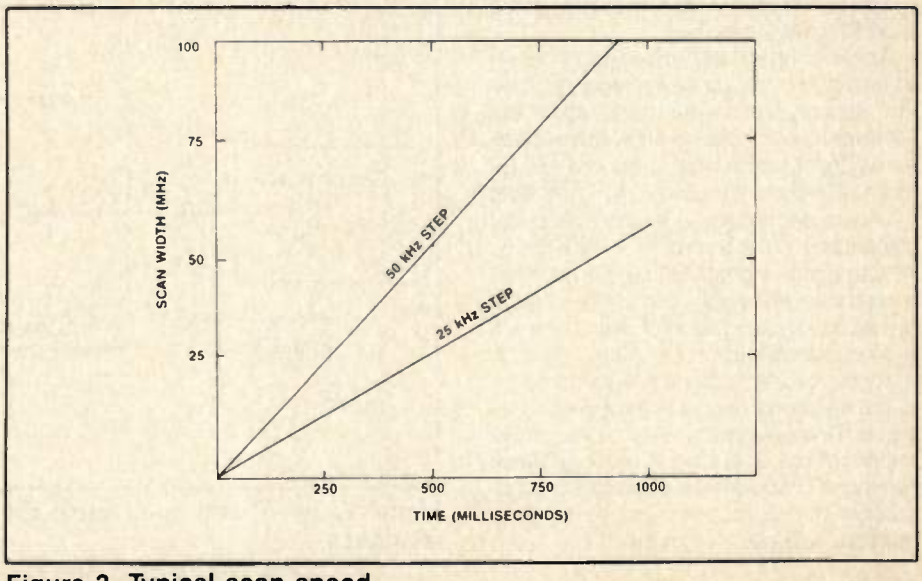


Figure 3. Typical scan speed

stepping superheterodyne receiver.

Ideally, the superheterodyne receiver chosen for a fast-scanning application should be frequency-synthesized and microprocessor controlled. The Fast Scan/Step operation then may be largely software based, using an internal microprocessor. The required time-per-frequency point can be expected to be approximately 400 microseconds. If frequency steps equal to the IF bandwidth being used are taken, a 50 MHz spectrum can be scanned in less than one second with IF bandwidths as narrow as 25 kHz. Fig. 3 shows the relationship of spectrum width, IF bandwidth and scan time. The following example illustrates the scan speed performance to be expected with this type of narrowband superheterodyne receiver.

Assume a requirement to scan a 50 MHz spectrum using an IF bandwidth of 50 kHz. The number of frequency steps will be:

$$\frac{\text{Scan Width}}{\text{IF BW}} = \frac{50 \times 10^6}{50 \times 10^3} = 1 \times 10^3 \text{ Steps}$$

Approximate time per frequency step is 400 microseconds:

Steps × Time/Step =
$(1 \times 10^3) \times (400 \times 10^{-6}) =$
400×10^{-3} Seconds

Number of 5 MHz crossings will be:

$$\frac{\text{Scan Width}}{5 \text{ MHz}} = \frac{50 \times 10^6}{5 \times 10^6} = 10$$

Approximate time for ten 5 MHz crossings at 3 milliseconds per crossing is:

10 × 3 milliseconds = 30 milliseconds

Total approximate scan time will be 430 milliseconds for the 50 MHz scan, using a 50 kHz step size.

Approximately 430 milliseconds is required only if the scanning receiver does not stop on signals encountered. If the receiver must stop on signals above a selected level, additional time will be required. The additional time may vary from 100 microseconds to a few milliseconds, depending on the routine initiated; i.e., AFC to center signal in IF passband, AGC to adjust receiver gain; comparison, measurement for recognition of signal or modulation characteristics, etc. Many, if not all, of these routines can be programmed into the microprocessor resident in each receiver. However, more versatility and flexibility can be achieved if most of these functions or routines are assigned to additional microprocessor capability in a multiple receiver controller.

Using Noise to Advantage in Military Systems

By Tony Ramsden
Micronetics, Inc.

Noise as an Interfering Source

The performance of any system will inevitably suffer in some way from the effects of interference from the environment it operates in. For military systems this is often particularly important, so some way has to be found to simulate different levels of interference and generate a measure of susceptibility.

Since there is usually no prior knowledge of the form or character of the interference, noise is usually the quickest way of finding the weakest point in the system. Sometimes the form of the interfering signal can be predicted, in which case noise that is colored or superimposed on a coherent signal is more appropriate. A particular example of this occurs in digital transmission, which is relatively impervious to noise unless it occurs at the same transmission rate, a likely occurrence if adjacent cables are carrying similar traffic.

Noise as a Calibration Reference

Perhaps the most common application of noise is a calibrated noise source used in conjunction with a Noise Figure Meter, which provides a measure of the sensitivity performance of receivers. Here the levels of signal and noise are extremely low, so an accurate reference of level is essential to the measurement. For such tests the noise being produced by the front end of the receiver is matched to a reference noise source (Fig. 1) by monitoring the receiver output to see how much noise has to be added to increase the output by 3 dB. Since the noise source is accurately calibrated in terms of level and frequency, it is a short step to derive the sensitivity or "noise figure" of the receiver.

These same principles can be extended to the measurement of amplifier and system performance, expanding the applications to almost all electronic systems. Of special interest in the military is the use of built in noise sources (part of the move to BITE, built-in-test-equipment), which now measure the performance of critical amplifiers and receivers continuously on aircraft and in space vehicles and, should it become necessary, even rearrange their functional order.

Noise to Simulate Channel Loading

The logical way to determine if a communications link is working is to test it fully loaded with voice, data, etc., and check it under the most unfavorable operating conditions. It was discovered in the 1950s that White noise simulated actual traffic and of course was much more controllable. The White Noise Test Set has since become the internationally accepted way of determining the performance of all broadband frequency division multiplex systems.

"White" indicates that the spectral density is constant across the band under

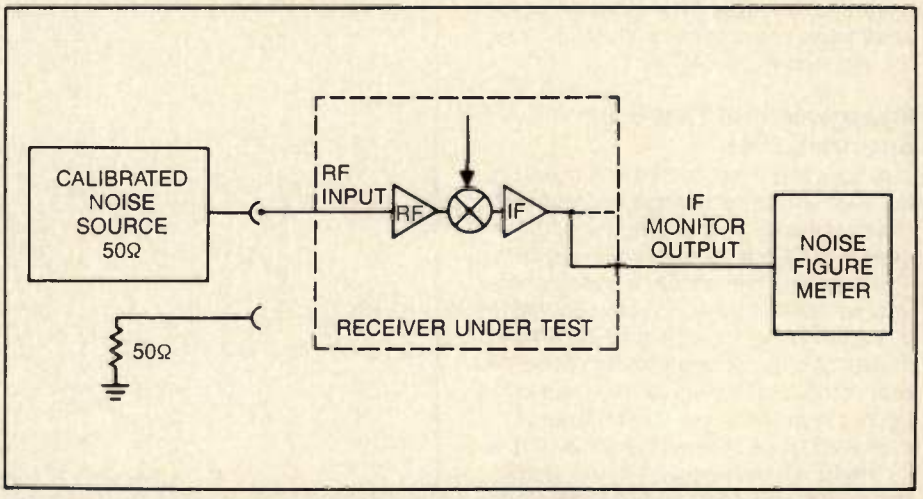


Figure 1. Use of calibrated noise source to measure receiver front end performance

study, while "Gaussian" is a measure of the distribution probability that amplitude peaks reach a certain level. (It is interesting to note that both are capitalized, "Gaussian" after the well known 19th Century German mathematician Karl Frederick Gauss, but also "White" allegedly after R.W. White and J.S. Whyte of the British Post Office, who in 1955, pioneered the use of flat broadband noise to measure interchannel crosstalk on multichannel telephone systems.)

White noise from a Noise Generator is limited to the bandwidth of the system under test and fed to the baseband input at a standard reference level, equivalent to a light channel loading. "Quiet" channels are introduced into the baseband using band stop filters. A narrow band receiver tuned to these frequencies can measure how much noise and intermodulation is being introduced by the transmission system. The test is repeated at higher and higher input levels until the system goes into overload and performance crashes. This is then repeated with other band stop filters, so results are obtained for frequencies at the top, middle and low ends of the baseband. The graphs generated, generally known as "bucket curves," reveal valuable information on the distortions present and direct the user to where they are being introduced.

Noise to Evaluate A/D Converters

Every time an analog signal is digitized errors are introduced, since the continuous function never has a precisely corresponding code. There is always a "quantizing" error which appears at the output as noise. If the digital transmission path is essentially error free, no additional noise will be added to the system until the codes are returned to their original analog form in the D/A converter. It is therefore very important to check the performance of digital modems most critically.

Most A/D converters have compression characteristics built into them, so the signal-to-quantizing noise is essentially constant over the operating range of the analog input. Not to do this would produce very poor performance at low input levels, which would have only a few levels allocated to them. Such compression was once done with a continuous curve; however, with today's components it is more easily performed digitally, where the slope of the characteristic is modified at specific levels, known generally as segmented companding.

When it comes to measuring quantization noise, sine waves once again have severe limitations, although this time the problem is that its amplitude distribution rather than its frequency distribution is so unlike the real signal. Think of the peak of the sine wave as its level is increased. As it meets a new quantizing level the error will be minimal, while between levels it will be at a maximum. The resulting graph will therefore resemble rolling hills, useful for determining if all the quantizing levels are operating, but at the cost of making a vast number of measurements. This problem is further compounded when one adds segmented compression, which effectively superimposes a further range of hills on an already complex graph.

Once again, White noise can simplify testing, since it builds a Gaussian level distribution into each measurement, effectively "blurring" the effects of both quantum step and slope transition. The resulting smooth curve can then be accurately constructed from a relatively few measurements. This technique has been applied to PCM telephone systems for some time; however, its extension to the testing of higher frequency A/D converters, common in the military, is only recently being realized. One problem has been the lack of suitable test equipment, which was limited to White Noise Test Sets designed to evaluate basebands with top frequencies of 13.388 MHz. A few sets were introduced with wider bandwidths, but at a considerable premium in price.

Micronetics' Noise Generators fitted with appropriate band stop filtering meet the demands of this market. With the significant advances in intermodulation performance in the past few years, spectrum analyzers can now make the required measurements with little, if any, pre-filtering, eliminating the need for a specialized receiver.

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Frequency-Hopping with Direct-Digital Synthesis

By Henry Eisenson
Sciteq Electronics

Frequency synthesizers can be judged by any of several criteria and the relative weight of those parameters is determined by the application. In some cases, spectral purity is the overwhelming factor — in others it might be size alone. In every design situation, however, there is usually some combination of tradeoffs because no one methodology is ideal. In many technologies, including military communications and radar, one of the most important criteria is the speed with which the synthesizer can "hop" from one frequency to another, its switching speed.

Of the three synthesis architectures, each has its advantages and disadvantages. PLL is clean and broadband but requires extreme complexity (multiple loops) to generate high resolution, and this technique is ponderous in a world that measures time in fractions of a microsecond. Mix/filter can be clean and broadband, but is complex and costly because of the multitude of reference frequencies that must be generated. The third alternative is direct-digital synthesis (DDS).

With DDS a frequency control word (binary or BCD) controls an accumulator that refers to a program on PROMs to define the signal output. That signal is fed to a D/A converter, the output of which is smoothed (and the clock signal removed) by a low-pass filter. The result is compact, fast and perfectly phase-continuous when frequencies change.

A DDS is driven by a single reference clock, the frequency of which helps determine the output frequency range of the device. Information theory says that two samples per Hz is sufficient to perfectly reconstruct a waveform: therefore, output of the synthesizer is theoretically limited to exactly one-half the clock rate. In fact, that sampling rate is not achievable and the actual output frequency limit of a DDS is always slightly less than half the clock rate.

The limit of today's technology permits a DDS to be clocked at about 76 MHz, with logic and PROMs setting the limit. The maximum output frequency from such a unit is about 38 MHz, though in

practice this is limited to under 35 MHz. Fortunately, the device provides both high resolution and switching speed that is many times faster than any alternative. The operation and very nature of a DDS permits it to change frequencies in a period equal to one clock tick plus the delay introduced by the output lowpass filter. In operation, such a DDS switches between any two frequencies in less than 70 nanoseconds.

Special features, including quadrature output, high-resolution phase rotation, phase reset to 0° and output gating, are all easy with a DDS because control and processing both occur in the digital domain. Because of the way a DDS constructs the output waveform, high resolution is practical and inexpensive. It is relatively easy to achieve a milliHertz, a microHertz, or even a femtoHertz, with no important collateral penalties. The difference appears in the accumulation and logic portions of the machine as a few more ICs. The nature of a DDS also permits remarkable phase noise; in baseband some designs demonstrate <–136 dBc/Hz offset. Spurious output derives primarily from glitch energy in the D/A converter, and present designs are generally limited to about –60 dBc. In many DDS applications where maximum bandwidth and switching speed are design goals –45 dBc spurs is a more realistic objective. The major limitations of a DDS, then, are bandwidth and spurious energy in the output.

Many programs can benefit from synthesizers that exploit the high resolution and fast switching of a DDS while achieving the operating range of one of the more conventional architectures. Hybridization does exactly that. When PLL and DDS techniques appear in the same synthesizer, the result can offer high resolution, compact size, low cost and extraordinary reliability because of the predominance of the digital component.

When mix/filter and DDS are combined, the result is speed. In an industry that defines "fast" as anything under 20 microseconds, the speed of a DDS creates many new opportunities for the design engineer.

The simplest exploitation of the hybrid concept mixes the output of the DDS with an LO and filters the result. This architecture can take advantage of the DDS, moving its operation to a new center frequency. It is practical to use 20 MHz of the output of a 30 MHz bandwidth DDS, mix it with an LO in the VHF range and filter the result. Such a synthesizer can cover any 20 MHz sector of VHF with high resolution, very fast switching, small size and excellent reliability.

As one example, a 100-120 MHz synthesizer can be built with 4 Hz resolution, 150 nanosecond switching, and excellent spectral characteristics. With the clock and the LO references supplied to it, such a product can be expressed in only 24 square inches. It might then become one module of a much more complex synthesizer designed to operate in the microwave region. If the end result must operate in C-band, for instance, it is a relatively simple matter to continue the upconversion as required. Each mix/filter stage can impose a delay due to the characteristics of the filters used. With sufficiently wideband filters these penalties are minimized.

Using such hybrid architecture, it is quite possible to design a microwave synthesizer with switching in a fraction of a microsecond, which defines today's state-of-the-art in frequency hopping.

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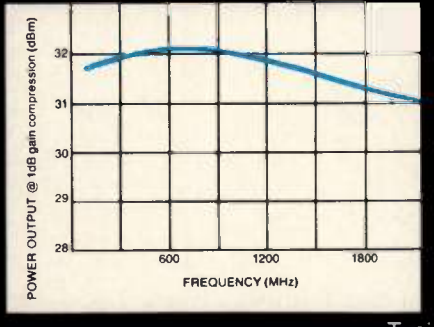
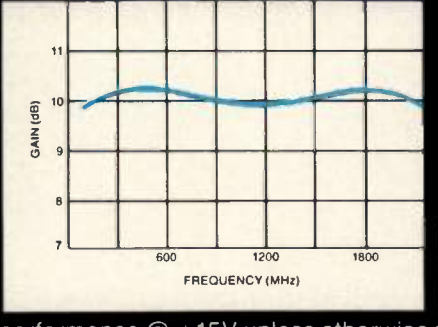
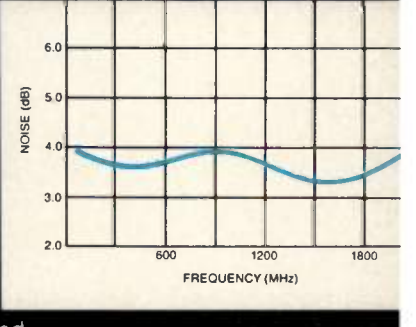


GAIN



NOISE



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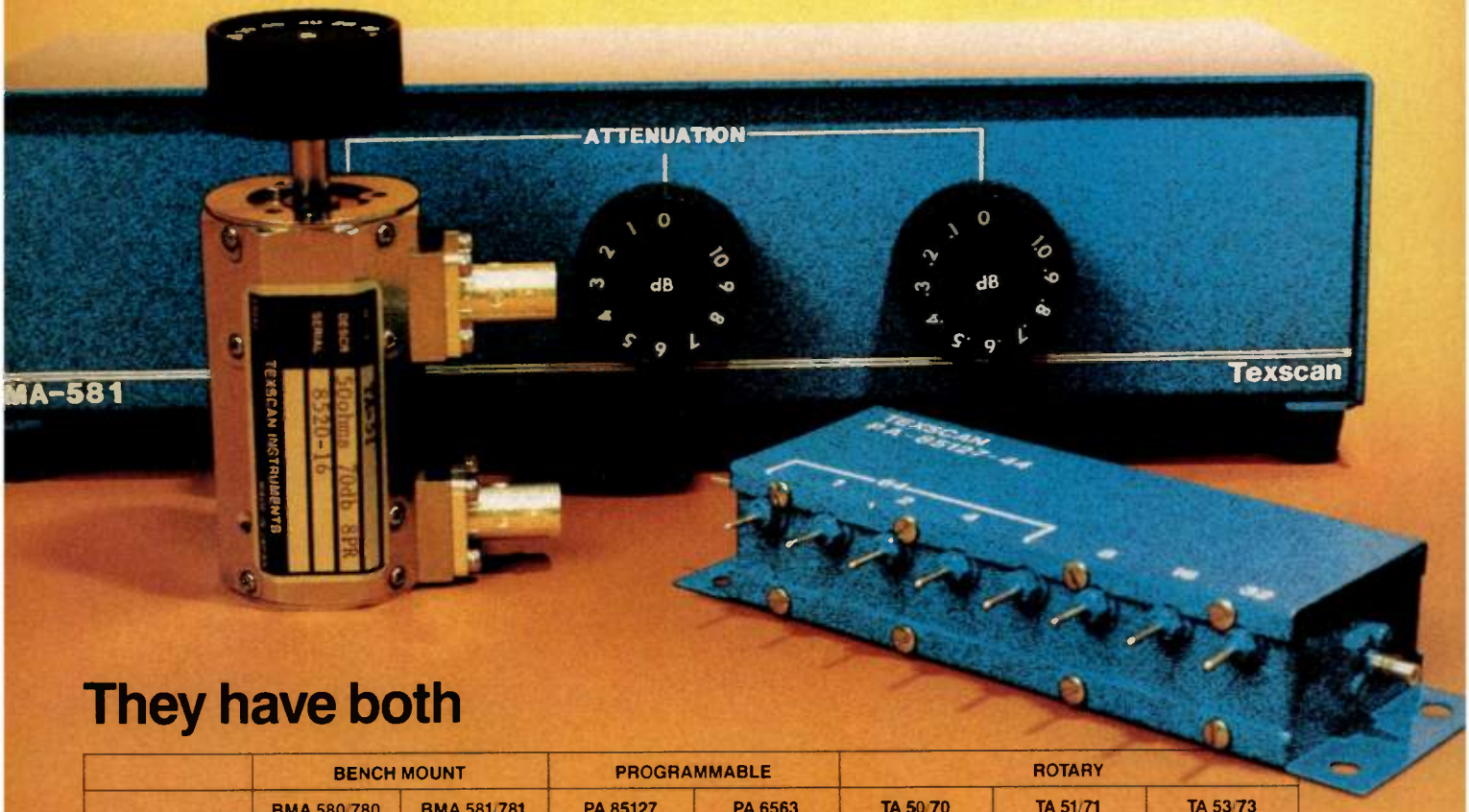

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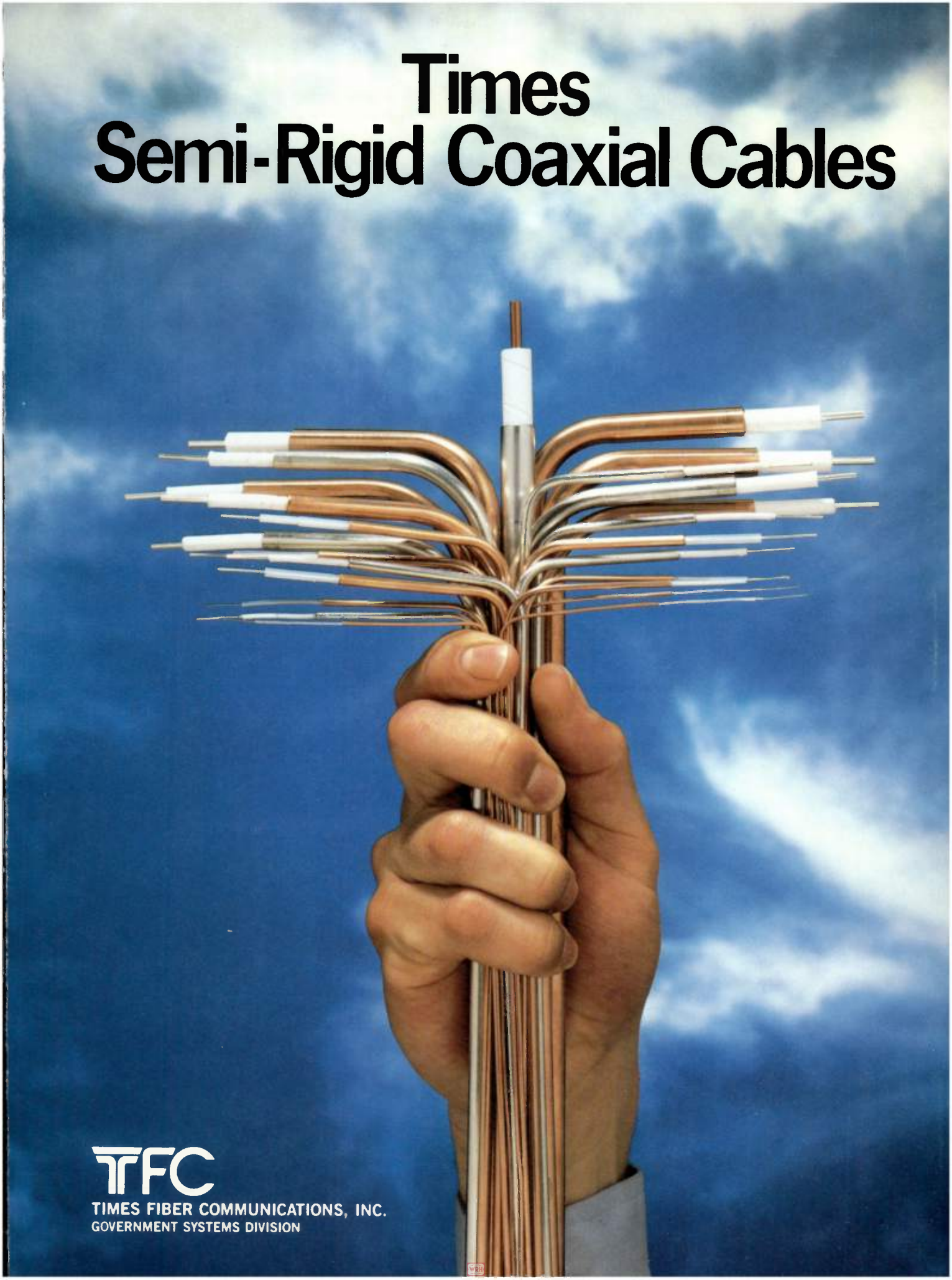
Times Semi-Rigid Coaxial Cables



TFC

TIMES FIBER COMMUNICATIONS, INC.
GOVERNMENT SYSTEMS DIVISION

Times MIL-C-17 semi-rigid cables.

MIL-C-17 is the government specification that defines minimum acceptable standards for military coaxial cables. Over the years, this specification has been revised and upgraded so that it now assures cable buyers of a high degree of quality and reliability within that specification. The latest MIL-C-17 specifications, for example, require cables to meet the following critical tests.

- **Swept Frequency Measurements.** Cables now have to be swept for both attenuation and structural return loss (SRL/VSWR) over the entire frequency band for which their use is recommended, instead of just testing at two or three discrete frequencies.
- **Adhesion Requirements.** Minimum and maximum requirements have been established for adhesion of the dielectric core to center conductor.
- **Bendability Testing** Cables must have the capability of being bent around a mandrel three times the diameter of the cable without deterioration of the outer conductor.
- **Dimensional Stability Requirements.** Cables cannot exceed a specified maximum allowable shrinkback for the dielectric core and outer conductor.
- **Outer Conductor Integrity Test.** The latest MIL-C-17 specification requires a stress-crack resistance test to identify cables with previously undetected defects that could result eventually in outer conductor cracking.

No one is better positioned to provide cables that meet these specifications than Times Government Systems Division. Times has been supplying broadband swept cables for over 25 years. In fact, Times has more MIL-C-17 qualified coaxial cables—flexible as well as semi-rigid—than any other manufacturer in the world.

Table I

MIL-C-17 NUMBER	TIMES P/N	UNIFORM P/N	PRECISION P/N
M17/129-RG401	AA-5011	UT-250A-M17	40129-000
M17/129-00001	AA-5012	UT-250A-TP-M17	40129-001
M17/130-RG402	AA-5013	UT-141SA-M17	40130-000
M17/130-00001	AA-5014	UT-141SA-TP-M17	40130-001
M17/130-00002	AA-5015		
M17/130-00003	AA-5016		
M17/133-RG405	AA-5017	UT-85-M17	40133-000
M17/133-00001	AA-5018	UT-85-TP-M17	40133-001
M17/133-00002	AA-5019	UT-85C-M17	40133-002
M17/133-00003	AA-5020	UT-85C-TP-M17	40133-003
M17/133-00004	AA-5021		
M17/133-00005	AA-5022		
M17/151-00001	AA-5023	UT-47-M17	40151-001
M17/151-00002	AA-5024	UT-47-TP-M17	40151-002
M17/154-00001	AA-5025	UT-34-M17	40154-001
M17/154-00002	AA-5026	UT-34-TP-M17	40154-002

Table II

M17/ NUMBER	TFC NUMBER	INNER CONDUCTOR	DIELECTRIC MATERIAL	DOD (INCH)	OUTER CONDUCTOR	WEIGHT (LBS/FT)	NOMINAL IMPED (OHMS)	CAPACITANCE (pf/FT)	MAX OPER TEMP RANGE (°C)	MAX OPER VOLTAGE (VOLTS RMS)	COMMENTS
/129-RG401	AA-5011	0.0641"SC	PTFE	0.209	0.250" OD Copper Tube	0.085	50.0	29.9 max.	−40 +90	3,000	Swept Attn and SRL from 400 to 18000 MHz
/129-00001	AA-5012	0.641"SC	PTFE	0.209	0.250" OD Tin Copper Tube	0.086	50.0	29.9 max.	−40 +90	3,000	Tin Plated M17/129-RG401
/130-RG402	AA-5013	0.0362"SCCS	PTFE	0.1175	0.141" OD Copper Tube	0.03	50.0	29.9 max.	−40 +125	1,900	Swept Attn and SRL from 500 to 20000 MHz
/130-00001	AA-5014	0.362"SCCS	PTFE	0.1175	0.141" OD Tin Copper Tube	0.03	50.0	29.9 max.	−40 +125	1,900	Tin Plated M17/130-RG402
/130-00002	AA-5015	0.0362"SNCCS	PTFE	0.1175	0.141" OD Copper Tube	0.032	50.0	29.9 max.	−40 +125	1,900	Swept Attn and SRL from 500 to 20000 MHZ
/130-00003	AA-5016	0.362" SNCCS	PTFE	0.1175	0.141" OD Tin Copper Tube	0.032	50.0	29.9 max.	−40 +125	1,900	Tin Plated M17/130-00002
/133-RG405	AA-5017	0.0201"SCCS	PTFE	0.066	0.0865" OD Copper Tube	0.153	50.0	32.0 max.	−40 +125	1,500	Swept Attn and SRL from 500 to 20000 MHz
/133-00001	AA-5018	0.0201"SCCS	PTFE	0.066	0.0865" OD Tin Copper Tube	0.158	50.0	32.0 max.	−40 +125	1,500	Tin Plated M17/133-RG405
/133-00002	AA-5019	0.0201"SC	PTFE	0.066	0.0865" OD Copper Tube	0.152	50.0	32.0 max.	−40 +125	1,500	Swept Attn and SRL from 500 to 20000 MHz
/133-00003	AA-5020	0.0201"SC	PTFE	0.066	0.0865" OD Tin Copper Tube	0.157	50.0	32.0 max.	−40 +125	1,500	Tin Plated M17/133-00002
/133-00004	AA-5021	0.0201"SNCCS	PTFE	0.066	0.086" OD Copper Tube	0.154	50.0	32.0 max.	−40 +125	1,500	Swept Attn and SRL from 500 to 20000 MHz
/133-00005	AA-5022	0.0201"SNCCS	PTFE	0.066	0.086" OD Tin Copper Tube	0.159	50.0	32.0 max.	−40 +125	1,500	Tin Plated M17/133-00004
/151-00001	AA-5023	0.0113"SCCS	PTFE	0.037	0.047" OD Copper Tube	0.045	50.0	32.0 max.	−40 +100	1,000	Swept Attn and SRL from 500 to 20000 MHz
/151-00002	AA-5024	0.0113"SCCS	PTFE	0.037	0.047" OD Tin Copper Tube	0.048	50.0	32.0 max.	−40 +100	1,000	Tin Plated M17/151-00001
/154-00001	AA-5025	0.008"SCCS	PTFE	0.026	0.034" OD Copper Tube	0.026	50.0	32.0 max.	−40 +100	750	Swept Attn and SRL from 500 to 20000 MHz
/154-00002	AA-5026	0.008"SCCS	PTFE	0.026	0.034" OD Tin Copper Tube	0.028	50.0	32.0 max.	−40 +100	750	Tin Plated M17/154-00001

Our semi-rigid standard cables are only the beginning of what we can do for you.

Times Government Systems Division has over 30 years' experience meeting or exceeding MIL-Spec requirements. During this time, we've developed and supplied more than 10,000 types of cable designs. We're ready to put this kind of knowledge and experience to work for you.

Special Semi-Rigid Cables

We can supply a wide range of special semi-rigid constructions including:

- Special size cables with practically any impedance.
- Higher velocity cables with much lower capacitance than equivalent size cables.
- Special center and outer conductors that provide lower loss, lower weight, non-magnetic properties and any other special requirements.
- Special constructions and materials to meet EMP requirements.
- Special constructions for minimum structural return loss.
- More flexible semi-rigid cables for hand forming.

Standard and Special Flexible Cables

Times manufactures a wide range of flexible cables, from standard MIL-C-17 qualified constructions to lightweight, low-loss cables that operate in excess of 40 GHz and non-hosing cables able to withstand 1,000 psi. Please contact the Government Systems Division for a quotation on a standard product or for technical assistance in designing a specialized flexible cable to meet your specific system needs.

Complete Interconnect System Responsibility

Because we manufacture cables and connectors used in virtually every part of an RF transmission system, we are capable of taking full responsibility for the design and manufacture of complete cable assemblies. Times maintains one of the largest RF cable assembly facilities in the country, producing special delay lines and broadband assemblies to exacting swept performance specifications.

By getting involved early in the system development, we can provide cable assemblies that insure optimum system performance, optimum reliability and optimum cost effectiveness. Some of the programs for which Times has designed and supplied special cable assemblies include the F-18, F-16, F-15, F-14, F-4, A-4, E-2C, S3B, Patriot and Cruise Missiles, the Navy's Shipboard SLQ-32 system as well as many submarine and communications programs.

Whatever your requirements, we welcome the opportunity to be of service to you.

TFC

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Times MIL-C-17 semi-rigid cables.

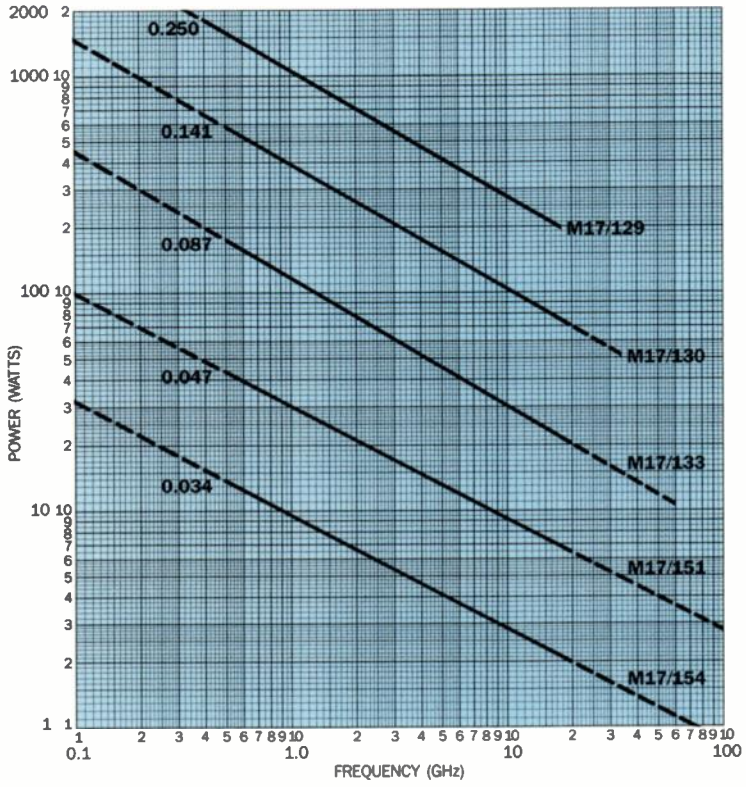

Figure 1—Maximum power handling capability for Times MIL-C-17 Semi-Rigid Cables at sea level and ambient temperature of 25°C.

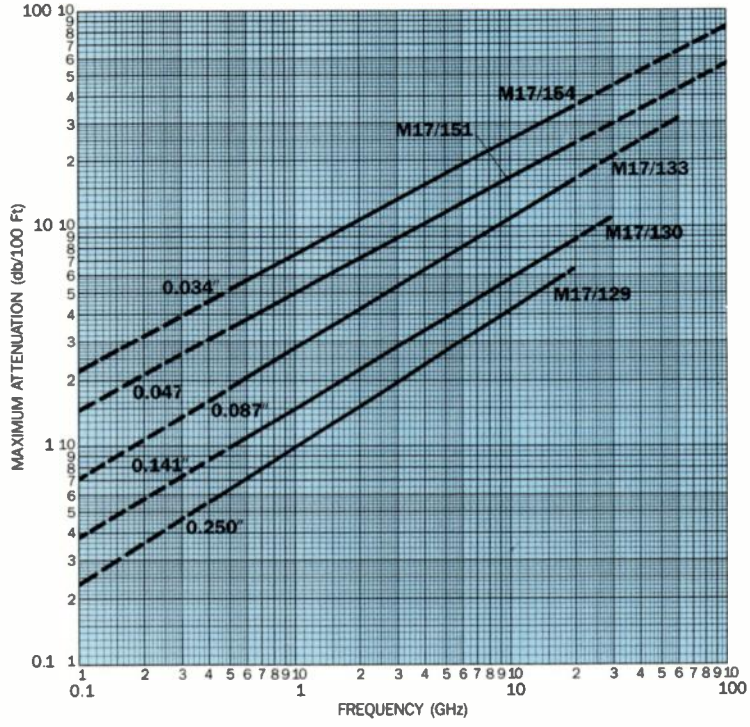

Figure 2—Maximum loss characteristics for Times MIL-C-17 Semi-Rigid Cables at ambient temperature of 25°C.

Times improved semi-rigid cables.

For more exacting requirements than those covered by MIL-C-17, Times Government Systems Division offers a line of *standard* semi-rigid cables that provide several important performance advantages: improved temperature characteristics, greater power handling, better phase performance and lower loss.

Even if your requirements are within MIL-C-17 standards, the superior performance of these improved cables permits much greater flexibility in design and manufacturing. Because of the lower loss of these constructions, a smaller size cable can frequently be used in place of a larger, heavier one. Designers can also reduce the power requirements of their systems or get more power out of existing designs.

These cables feature a teflon tape construction instead of a solid dielectric. Three of the cables use the same standard connectors as their equivalent MIL-C-17 versions. The other four lower loss constructions require different size connectors, but these connectors are readily available.

Table III

TFC P/N	INNER CONDUCTOR	DIELECTRIC MATERIAL	DOD (INCH)	OUTER CONDUCTOR	WEIGHT (LBS/FT)	NOMINAL IMPED (OHMS)	NOMINAL CAPAC-ITANCE (pf/FT)	MAX OPER TEMP. RANGE (°C)	MAX OPER VOLTAGE (VOLTS RMS)	VEL OF PROP. (%)	MIN RECOM BEND RADIUS	CUT OFF FREQ (GHz)
CLX-50086	0.0201" SCCS	EXPANDED PTFE	.058	0.086" COPPER TUBE	.016	50.0	24.8	−65 to +250	1500	82.0	.125	80.7
CLX-50141	0.0362" SCCS	EXPANDED PTFE	.100	0.141" COPPER TUBE	.041	50.0	24.8	−65 to +250	2100	82.0	.250	45.0
CLX-50250	0.0641" SC	EXPANDED PTFE	.178	0.250" COPPER TUBE	.127	50.0	24.8	−65 to +250	3300	82.0	1.25	25.2
CLL-50086	0.023" SCCS	EXPANDED PTFE	.064	0.086" COPPER TUBE	.013	50.0	24.8	−65 to +250	1500	82.0	.125	70.7
CLL-50141	0.043" SCCS	EXPANDED PTFE	.119	0.141" COPPER TUBE	.029	50.0	24.8	−65 to +250	2100	82.0	.250	40.0
CLL-50250	0.074" SC	EXPANDED PTFE	.210	0.250" COPPER TUBE	.091	50.0	25.4	−65 to +250	3300	80.0	1.25	21.1
CLL-50375	0.118" SC	EXPANDED PTFE	.335	0.375" COPPER TUBE	.187	50.0	25.4	−65 to +250	6500	80.0	2.00	13.2

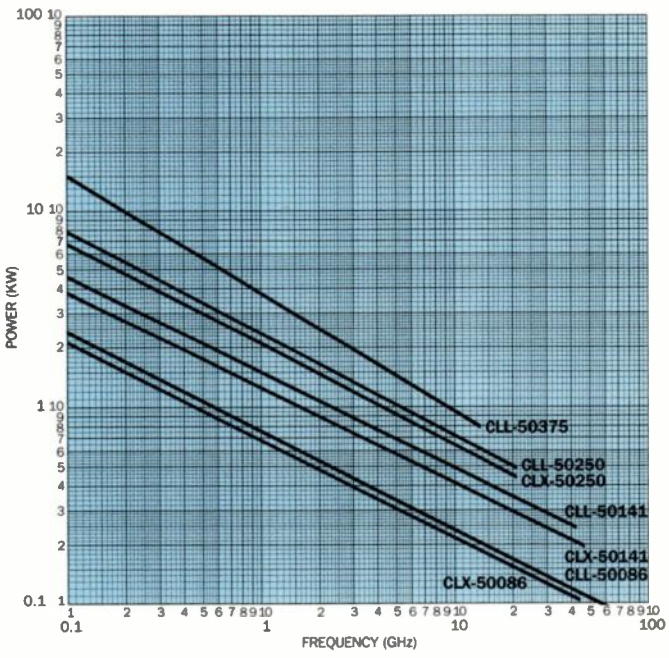

Figure 3—Maximum power handling capability for Times Improved Semi-Rigid Cables at sea level and ambient temperature of 25°C.

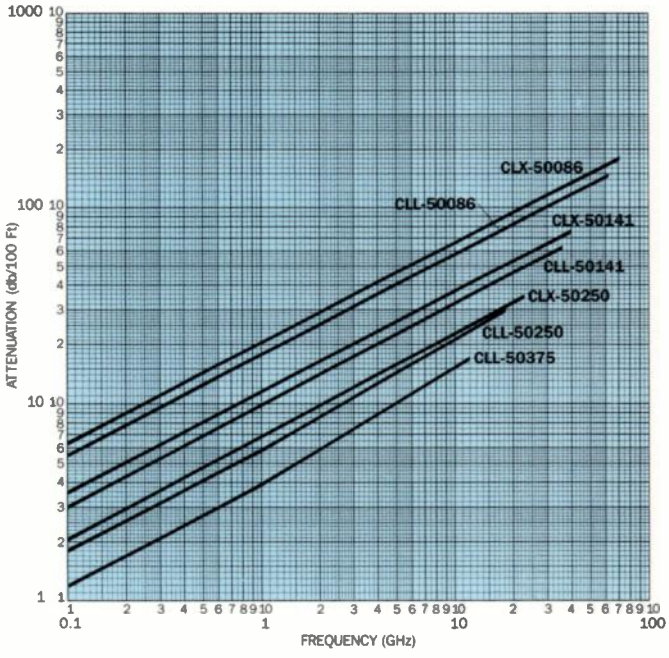

Figure 4—Maximum loss characteristics for Times Improved Semi-Rigid Cables at ambient temperature of 25°C.

For applications that exceed MIL-C-17 requirements.

Although MIL-C-17 covers a broad range of performance parameters, there are many applications that require more exacting performance. For these applications, Times offers a line of *standard* semi-rigid coaxial cables using teflon tape dielectrics (for listing and description see overleaf). These cables offer all the benefits of MIL-C-17 cables with several important advantages.

Better Temperature Characteristics

MIL-C-17 semi-rigid cables are rated from 90°C to 125°C for continuous operation. The solid teflon dielectric used in these constructions has a much higher expansion rate than the copper outer conductor, creating a situation where cracks can occur at higher operating temperatures. The Times teflon tape constructions are rated up to 250°C continuous operation. These tape constructions also provide better dimensional stability after termination.

Lower Loss Characteristics

Times standard teflon tape semi-rigid cables offer up to 30% lower attenuation than conventional solid dielectric cables as shown in Figure 5 below. This improved cable performance permits greater flexibility in transmitter and receiver design. It also reduces amplification requirements, thereby reducing potential noise.

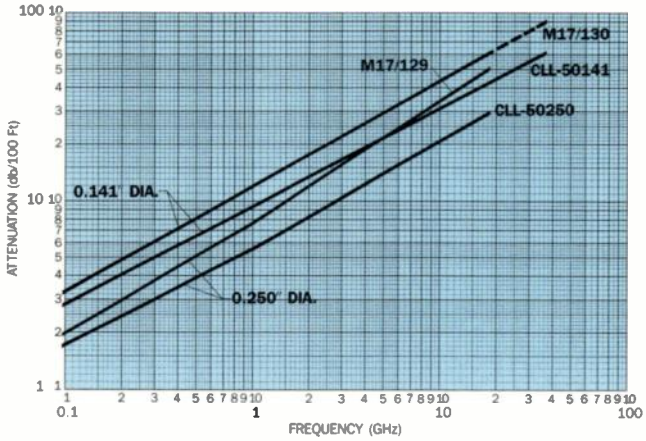

Figure 5—Attenuation of .141 and .250 solid dielectric cables vs taped dielectric cables.

Better Power Handling Capability

Times teflon tape constructions also enhance the power handling characteristics of the cable as shown in Figure 6. The cables are able to run "hotter" than MIL-C-17 cables without destroying the outer conductor. This too provides transmitter designers with a wider choice of design options.

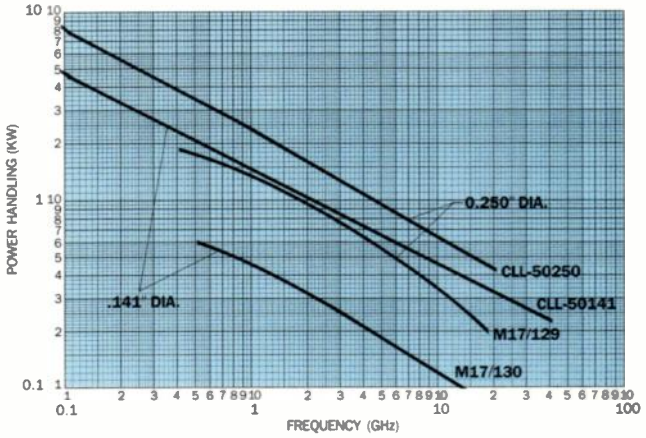

Figure 6—Power handling of .141 and .250 solid dielectric cables vs taped dielectric cables.

Better Phase Stability

More and more systems today require specialized phase characteristics. The change in electrical length with temperature is important in both an absolute sense and in cases where cables must track each other as matched pairs.

Unfortunately, the subject of phase is not covered by MIL-C-17. Moreover, the allowable shrinkback for MIL-C-17 solid dielectric cables can still cause phase problems in many applications.

Figure 7 shows the improvements in phase characteristics available from Times standard semi-rigid teflon tape dielectric cables compared to conventional solid dielectric constructions.

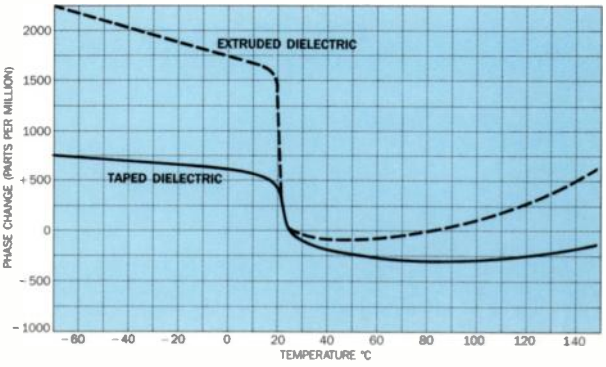

Figure 7—Phase plot of tape vs solid dielectric.

100% Testing

Although MIL-C-17 now requires sweep testing of cables for both insertion loss and structural return loss, it only requires that one sample per unit of product be tested. A unit of product per MIL-C-17 is defined as 5000 feet. For applications requiring a higher degree of reliability, Times can provide 100% sweep testing for both attenuation and VSWR.

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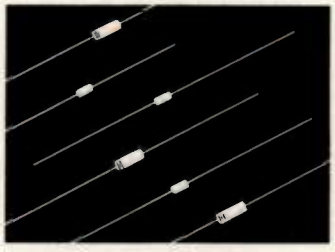

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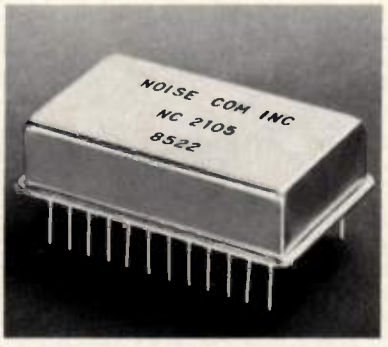

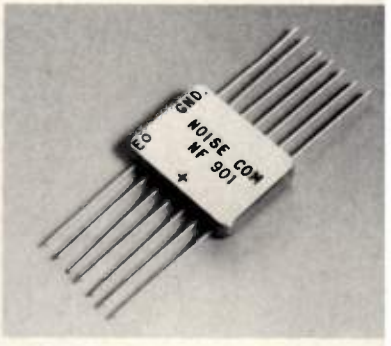

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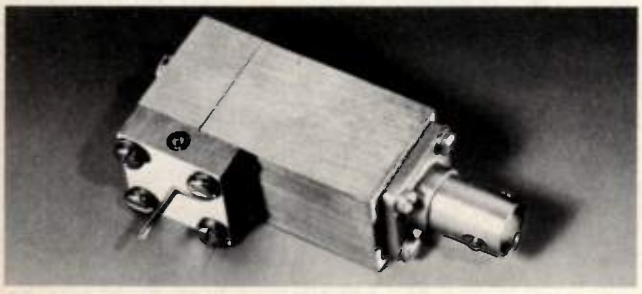

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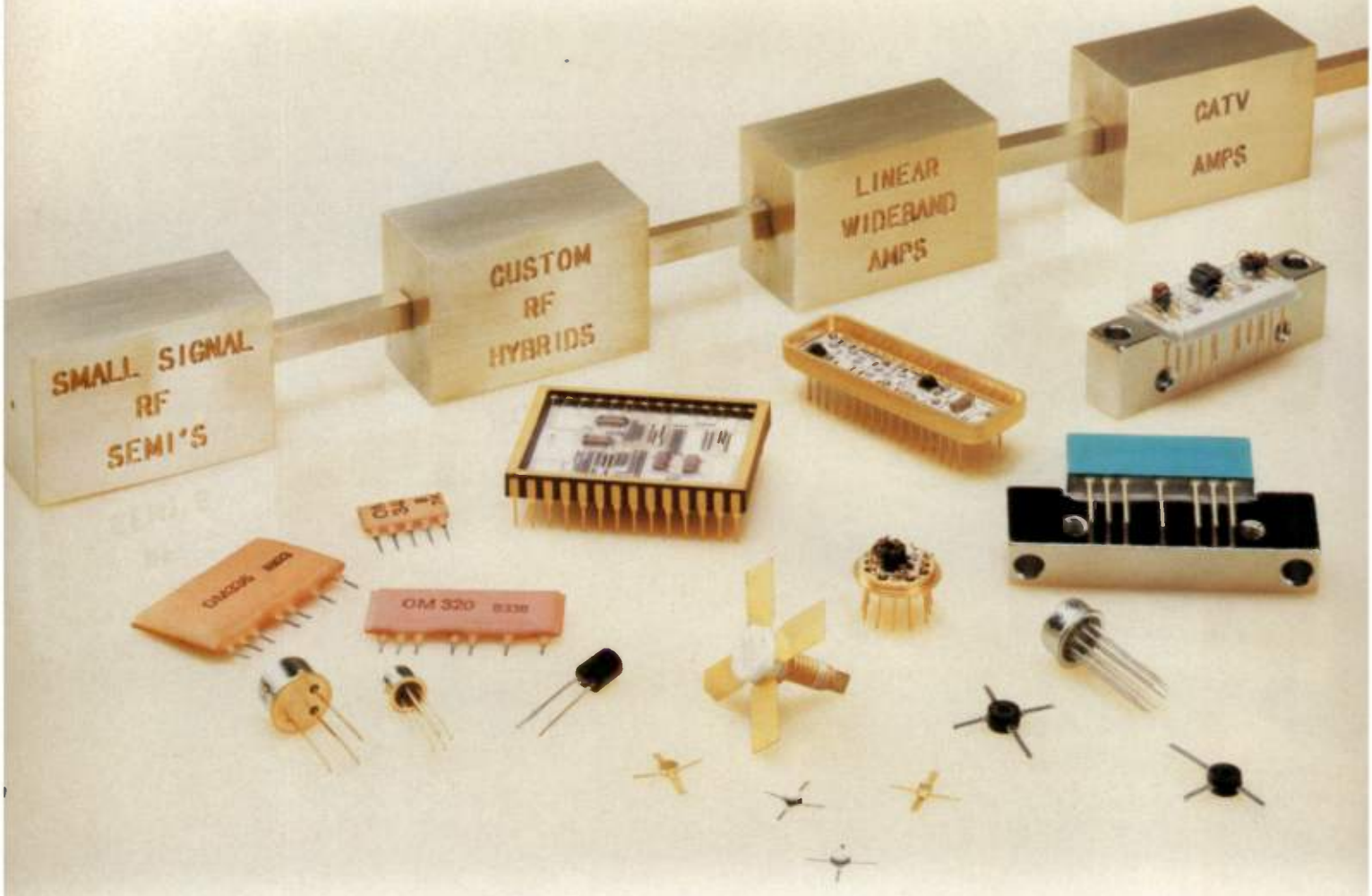

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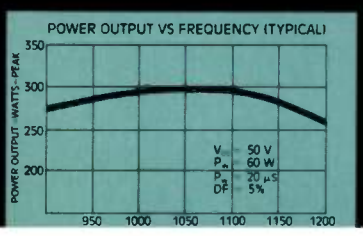

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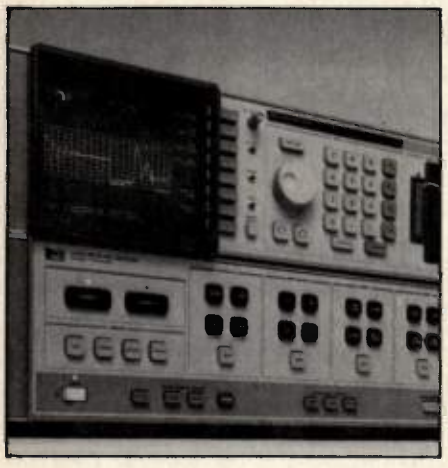
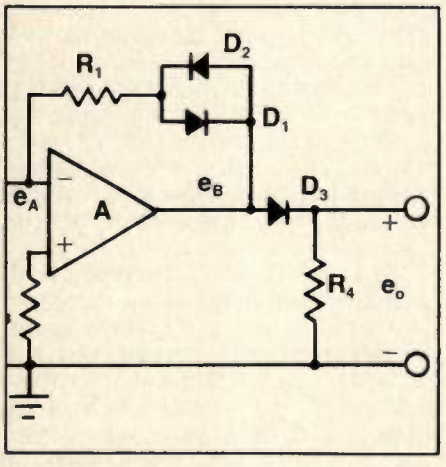


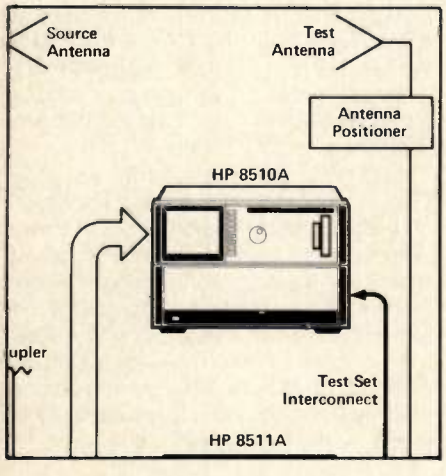
Cover

This month's cover features a representative sampling of Metaramics/W.R. Grace Co.'s line of advanced ceramic-metal packaging assemblies, including standard high power RF and microwave designs and custom designs for Gallium Arsenide, Indium Phosphide and specialized integrated circuit packaging.

Features



Departments



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rf editorial

Growing With The Industry We Serve

James N. MacDonald
Editor

Gary Breed joins our staff this month as Technical Editor. He has been Chief Engineer at four radio and/or television stations during the past 10 years, and we look forward to the viewpoint he will bring to the magazine as a result of this experience. He also has published 13 articles in Broadcast Engineering, from which he has gained an understanding of the requirements of magazine writing. He will assist with staff written articles and will work with authors to prepare their manuscripts for publication.

The addition of a technical editor is part of a substantial increase in Cardiff Publishing Company's commitment to *RF Design* over the past year. First, the magazine went from bimonthly to monthly publication; now we have, in fact, doubled the editorial staff. The latter action is, of course, largely a consequence of the earlier decision. It is also a testimony to the correctness of that decision. There is far too much knowledge being generated in this field to be adequately exchanged every two months.

A business can grow for two reasons — in anticipation of a larger market or as a result of it. Usually both reasons are influential in the decision to expand, and this has been the case with *RF Design* magazine. Publisher Keith Aldrich's faith and understanding of the industry provided the impetus to double the publication frequency. The encouraging response of readers and advertisers has convinced us that the growth has just begun.

The growth of the magazine is not just due to the appropriateness of its content for our readers, although we take a great deal of pride in that content and know from reader comments that it is appropriate. We are part of the growth of the RF electronics industry, in general. We talk about this growth often, because there is much gloom in some parts of the general electronics industry. We want our readers to know that the slump is not industry-wide. Typical of the kind of news that crosses this desk almost every day is the following paragraph from a news release announcing that Raytheon Company's second quarter earnings were up 10.7 percent over a year ago.

"The company's improved performance for the quarter was generated principally by Electronics, Raytheon's largest business segment, which continued to be paced by defense electronics systems."

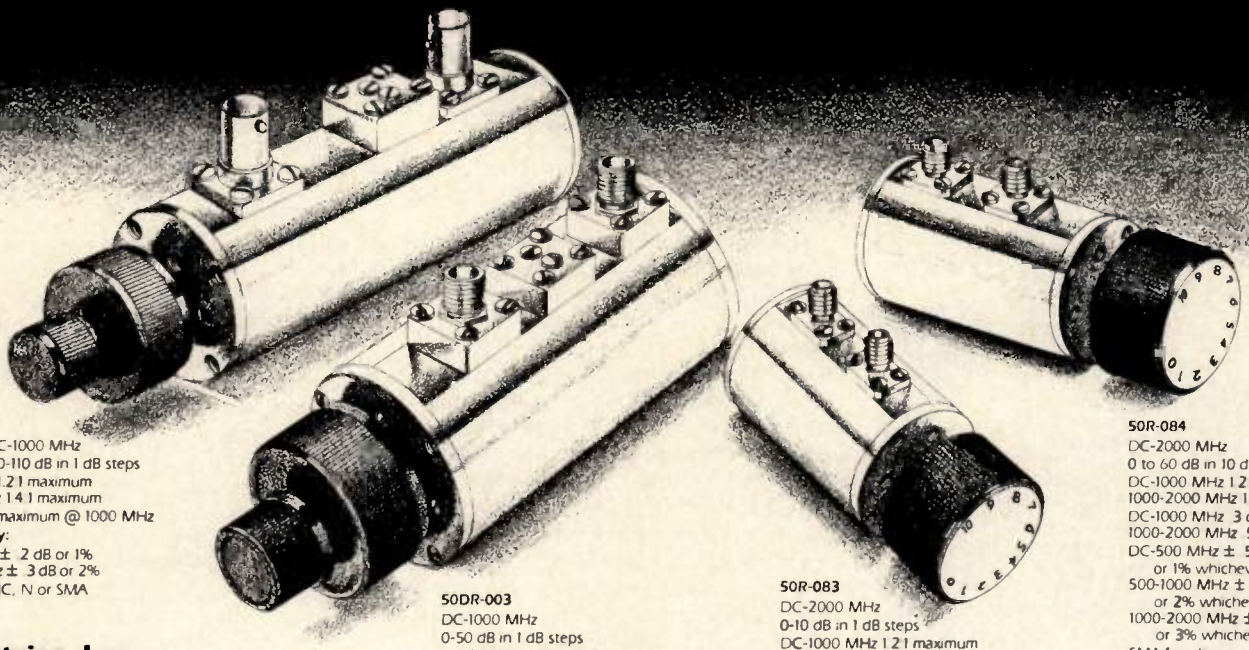
Most defense electronics systems operate in microwave frequencies, but we have mentioned before the increasing interest of the military in the lower frequencies. Other news releases tell similar success stories about commercial RF products. It is our observation that most companies are doing quite well, although some segments of their operations may be curtailed because the particular industry they serve is in a slump.

With this addition to the staff, *RF Design* will be able to expand the scope of its coverage of the electronics industry, and one expansion will be into economic news. In the near future you will see reports on economic activity in the RF sector, helping you keep up with trends.

Many of you will be receiving telephone calls and visits from Gary about editorial matters. For you hams, Gary's call is KSJY. Mine, by the way, is NØFXB.

James N. MacDonald

ROTARY ATTENUATORS



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rf publisher's note

Getting Ready For Tomorrow

By Gary Breed
Technical Editor

Publisher Keith Aldrich has given his space this month to RF Design Technical Editor Gary Breed for an introductory column.

In a lifetime, each of us may get only one or two opportunities to make a major impact in our chosen field, taking part in a major discovery or an important achievement. For many RF design engineers, such an opportunity will present itself in the next few years. Technological knowledge is still growing at an exponential rate, markets for RF-related products continue to expand, and the integration of RF functions into the design of traditionally non-RF equipment continues at a rapid pace. We need to be ready to meet the challenges which are coming our way, to be ready for the rare opportunity to make our mark.

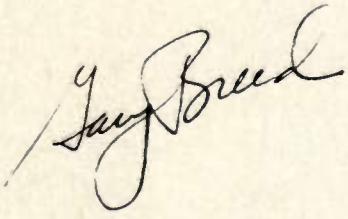
To be able to make such a personal impact on the world of RF, the engineers and managers who are responsible for "getting the work done" need every available tool at their disposal. We all know that engineers need the support of current-generation test equipment, computers and software. We know that ongoing education in the field of RF is necessary. We know that advanced components are becoming available almost daily. But sometimes we forget that the human mind is still the most important tool in the creative design process, and the most important role of the human mind is *COMMUNICATION* with others.

This is where I have seen my own opportunity to make an impact in my chosen field. As Technical Editor, my primary duty will be to see that communication between engineers takes place. *RF Design* is an important participant in the exchange of ideas among the most capable minds in the field of RF: Your minds!

RF Design will be expanding its role in the coming months, with your help. I want to hear from you about your work, and the unique problems you have had to solve in achieving a successful design. In turn, I'll try to find out everything I can about the industry that might affect your work, and see that it is reported to you.

Just as there are no limits to the imagination of mankind, there are no limits on the applications of RF. The boundaries between analog and digital realms become blurred at high frequencies, as is demonstrated by GHz-speed logic devices which have 50-ohm input/output impedances. The combination of optical, digital, video, and RF functions in a single system has taken place in Local Area Networks and common-carrier telecommunications. Automotive electronics, test equipment, consumer electronics, as well as communications equipment will all have combinations of technologies in the future, and RF is the common denominator. We will be exploring in depth these areas of interface between RF and other technologies as our growth allows us to add to our present coverage of RF topics.

Start your own process of communications by sharing your ideas with us. Somebody has the need for your insight, and you can take advantage of the ideas of other engineers. Let's keep the lines open.



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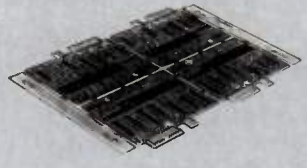

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The TCK Series multi-octave system contains a step motor for remote digital control, virtually eliminating the use of manually tuned filters for remote site applications. The complete TCK Series system can provide continuous tuning over as many as six octaves. It includes two to six TCD Series tunable bandpass filter subassemblies, coupled with two multi-position RF bandswitching units; two power supplies; and an interface card for RS-232, IEEE-488 (GPIB), or 8-4-2-1 parallel BCD.

A self-contained microprocessor-based control provides easy interface with your digital system, and the unit is automatically tunable to any center frequency within the range of the filter array. Specific frequencies can be requested directly in MHz, eliminating the need for specialized user software.

Contact Telonic Berkeley for this complete, state-of-the-art, automatic multi-octave filter system. Call or write today for information on the TCK Series and our complete line of RF and microwave products.

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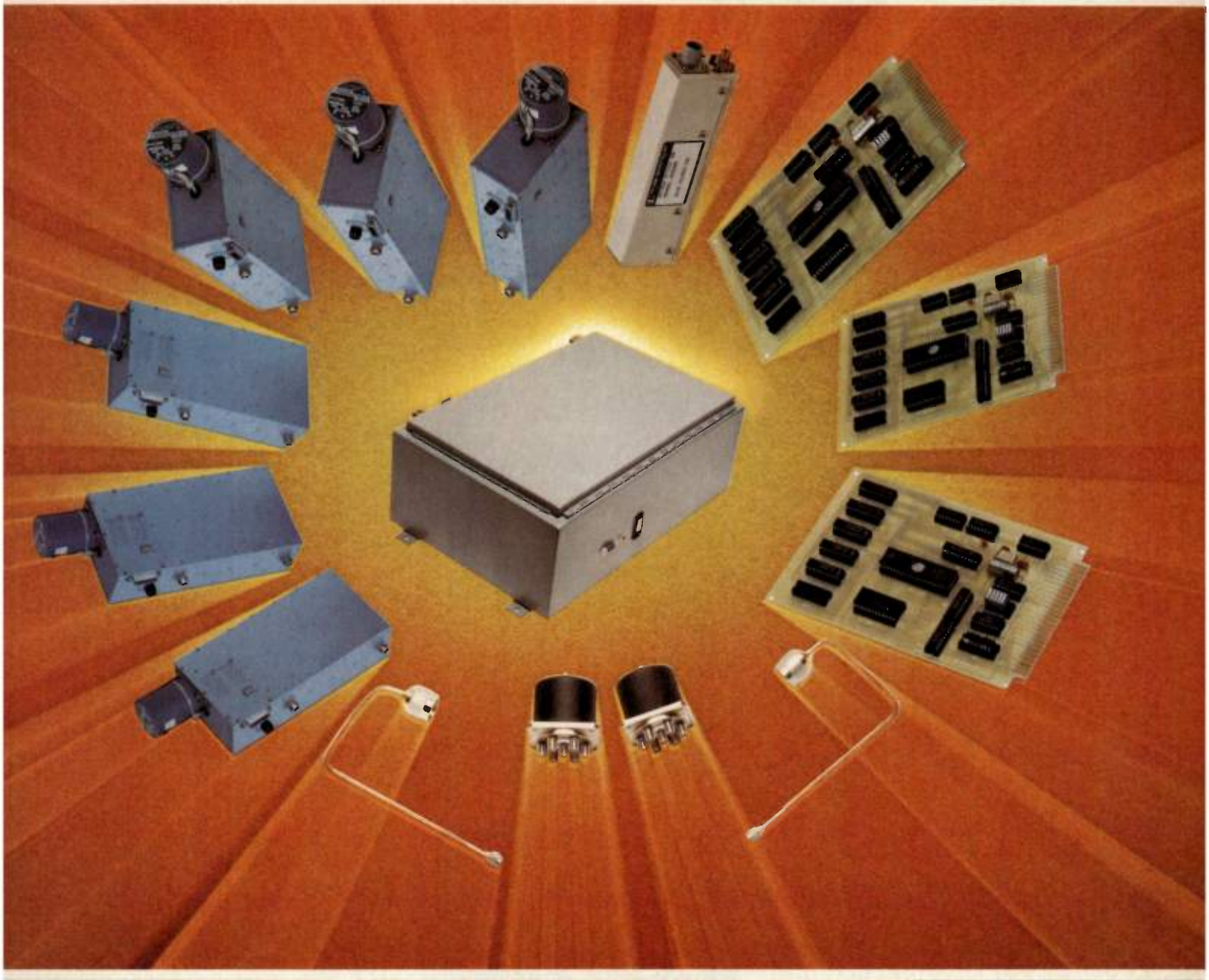

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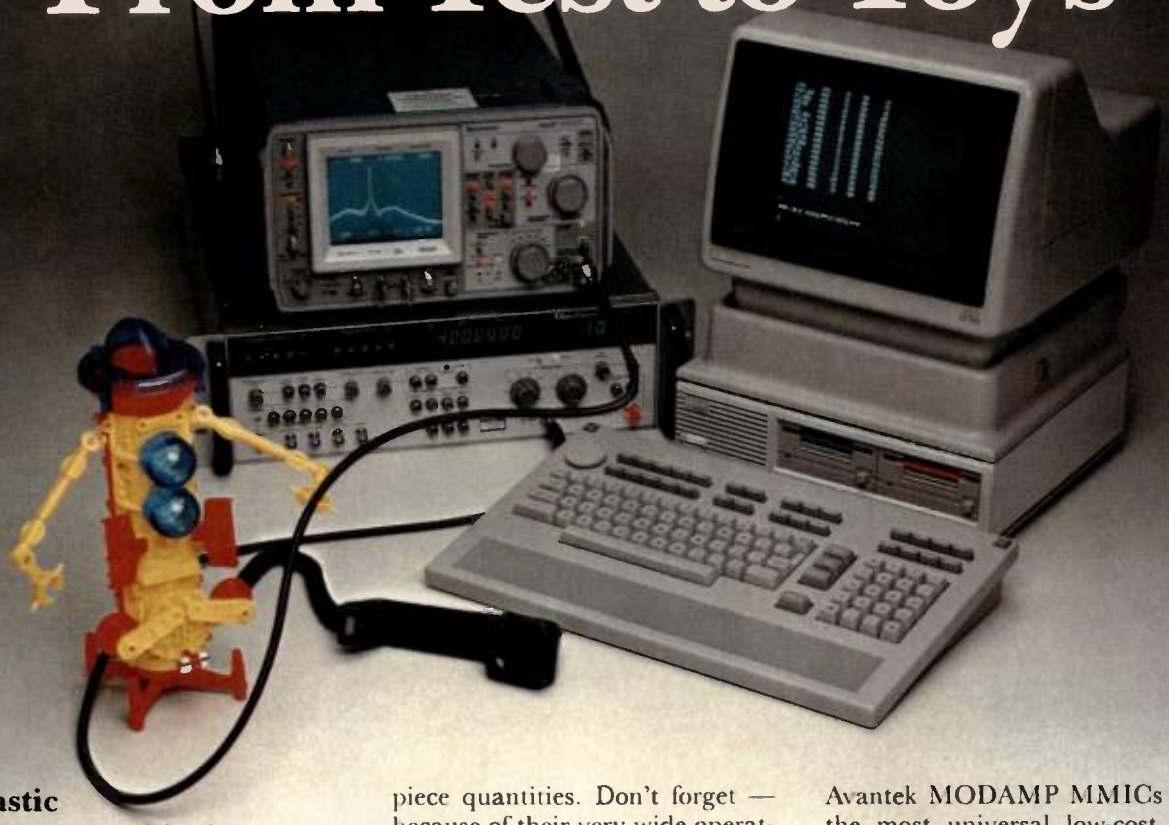
From Test to Toys



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Avantek's series of MODAMP™ silicon monolithic microwave integrated circuit amplifiers are ready to drop into your 50-ohm circuit, with no design problems — virtually no concern for what comes before or after. These MMICs are unconditionally stable and provide cascadable gain blocks at any frequency up to 2 GHz.

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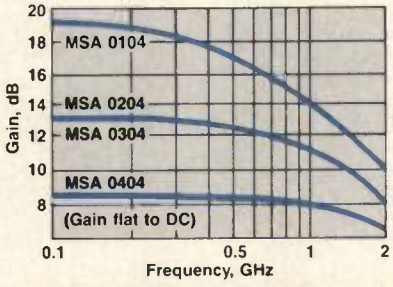

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rf letters

Editor:

I look forward each month to receiving your magazine, *RF Design*. You have been publishing some excellent articles which I find useful in my work.

In order to better utilize the information in some of your articles I clip and save many of them. One obstacle occasionally arises. Two articles which are of interest to me may be located consecutively in your magazine. The last page of the first article is printed on the flipside of the first page of the next article. Would it be feasible to organize your advertisements in such a way as to separate design oriented articles. I do appreciate your keeping individual articles together instead of scattering them out as "continued on pp." throughout your mag. Thanks for the great mag which fills a need.

By the way, have you or are you going to collect the papers presented at the L.A. show and publish them under one cover? It would certainly help us unfortunate souls who did not have the opportunity to attend. Thank you.

E.E. Truckenmiller
Applied Automation, Inc.

The Proceedings of Expo 85 are available for sale. You probably already noticed the ad in last month's issue. — editor

Editor:

In the July 1985 issue, in the article on materials, I take exception to the statement, "Anyway, below 200 MHz GaAs noise increases." There are many amateur radio operators that use high frequency GaAs devices that have low noise figures at, say, 1 GHz, and use them at 144 MHz and get less noise figure.

Most certainly there is a knee in the curve somewhere. I would like to see a more definitive report on this subject.

Lawrence Joy
Magnavox

Photo Credit

We have been informed by the photographer that two of the photographs used on the cover of the July issue are copyrighted. They were not so identified when we received them. It is always our practice to print appropriate credits when we know material is copyrighted. The photographs of the filter and the engineer looking through the microscope were taken by Ken Thompson, 200 E. 95th St., New York, NY 10028. — Editor.

rf news

RF Technology Expo 86 Exhibit Space Sells Out Early

Every exhibit booth for the RF Technology Expo 86 was taken as of August 1. Although the number of booths was doubled from the January 1985 show, they were claimed quickly after promotion began for the 1986 show.

"I've never seen it happen before," said Kathy Kriner, Convention Manager for Cardiff Publishing Company. "Six months before the show and we're sold out."

Nearly half the 150 booths were reserved at the end of the 1985 show by exhibitors there. Exhibitors at the show were pleased with the RF focus of the program and the fact that nearly all attendees were RF design engineers.

The Cardiff Convention Management staff have started a waiting list for booths that may become available. Kriner said a letter would be sent to those who have not returned signed contracts with a deadline for doing so. This amounts to about 30 exhibitors, she said.

RF Design publisher Keith Aldrich said the response shows how difficult it is to judge the demand for this type of show.

"We doubled the exhibit space for this second show and sold it almost immediately. Who knows how many booths we could have filled?"

Aldrich, the show's organizer, will be studying the demand for Expo 86 to try to judge the size of future shows. "We might have to move to a wing of the Anaheim Convention Center in 1987," he said.

OK Industries Forms 'Electronics Division'

OK Industries Inc. has formed the OK Electronics Division to develop and market the company's new family of electronic bench test instruments. To date, the line includes function, sweep and pulse generators, frequency counters, DMMs, digital thermometers and accessories. The division is located at the company's New York headquarters.

Commented David Weltman, OK president: "This division represents a major commitment by OK Industries to the customers and distributors of our new family of test instruments. Rather than being absorbed within our existing production equipment lines, the test instrument program will be separately staffed, marketed and financed to ensure the highest possible levels of product quality as well as customer service and support."

Many of the instruments include capabilities which are not available on other equipment in the same price class. Most of the instruments are list priced at under $500, and even the more sophisticated generators are under $1,000.

"Our objective is to put test instruments within reach for the thousands of lab technicians and design engineers at smaller to mid-size firms who have had to make do with less — or worse, simply do without," Weltman said.

The new family of products will be featured at Wescon '85, November 19-22, in San Francisco.

RFD, Inc. Receives Contract for AWACS Radar Transmitters

RFD, Inc., Tampa, Fla., announces receipt of $3.7 million in new contracts including $1.8 million from Eaton Corp./AIL Division in Deer Park, N.Y., for production of AWACS radar transmitters and for design and production of dielectric resonator oscillators for the B-1B aircraft. RFD, Inc. also received contracts totaling $1.2 million from SATT Communications AB, Stockholm, Sweden, for design and production of airborne radar transmitter systems.

RFD, Inc. is a Tampa-based designer and manufacturer of microwave transmitters, receivers, oscillators and amplifiers for radar and communications systems. RFD, Inc. also manufactures microwave transmitting and receiving components for satellite terminals and telecommunications systems.

Rental Car Cellular Phones

Bell Atlantic Mobile Systems and Budget Rent-A-Car of Pittsburgh have established a new marketing partnership to put cellular mobile telephones in 300 Pittsburgh Budget rental cars by the end of 1985.

The new marketing plan is designed to promote the use of rental cars and cellular mobile telephone service. One hundred rental cars equipped with Alex(SM) cellular telephones are available at six Budget locations. There is no premium fee for renting the phone-equipped cars and customers pay only for their calls, billed at 95 cents per minute.

"Cellular telephones and rental cars are a natural match, since both serve customers who are on the move," said Richard J. Lyons, Bell Atlantic Mobile Systems vice president — marketing and sales. "Until today there has not been a successful plan to serve this market. This program will help make rental-car telephones commonplace, instead of a rarity."

Although cellular phone-equipped rental cars have appeared in various cities

since cellular mobile telephone service first became available in the fall of 1983, the Alex/Budget rental car plan is the first to offer customers a cellular phone without a premium charge in the basic rental price of the car. In the past, customers were not encouraged to use the phones because they were generally available only in luxury class models. The phone-equipped cars in the Pittsburgh Budget fleet are available in intermediate, full-size and luxury models, making the phones more accessible.

"Besides providing rental car customers with the convenience of cellular communications while they are on the road in the Pittsburgh area," said Lyons, "this marketing program also allows customers to get some experience using cellular phones before they make a decision to buy or rent one for their own car."

"There is an Alex in your Budget" is the theme of the joint marketing program. Alex is the trade name of Bell Atlantic Mobile Systems' cellular telephone service. Both companies will promote the phones in a variety of ways. Customers boarding the Budget shuttle buses at Pittsburgh airport will hear messages about the cellular phones over the bus audio systems.

Budget cars equipped with cellular phones come with a special sun visor display that tells customers how to use the phone, depicts the geographic coverage of the cellular system and lists important local numbers to call, such as airlines, hotels and information services.

New HF Frequency Hopping Radio

An HF, frequency-hopping radio system, designed for maximum security and capable of evading jammed channels, has been introduced by Reunert Technology Systems (Reutech). Called the Lancer, it forms part of a radio family that has been used in active combat for over a decade.

A building block approach has been followed in the design of the Lancer system. The basic driver unit can be configured into a portable manpack, as well as 20W and 100W vehicle units with low and high power options. The range offers reliable communications across the complete HF band from 2 to 30 MHz.

The highly sophisticated frequency-hopping facility of the Lancer employs some 200 diffferent code sequences on any one of the 28,000 available center frequencies and between frequency channel steps. The bandwidth employed by the radio while engaged in frequency hopping tracks the bandwidth of the Antenna Tuning Unit. It provides at all times the largest possible number of channels to be included in the hopping coverage.

Together with the long-period non-linear pseudo-random sequences, the hopping facility of the Lancer offers a high measure of security while evading disturbed or jammed channels. The Lancer also has a late entry facility for other stations wishing to join the hopping net.

The Lancer operates in upper side band or lower side band and a CW mode with tone injection. Speech processing provides an increased average speech power at power outputs selectable as 6 or 20 watts (PEP) in the lower power configuration and 20 or 100 watts (PEP) in the high power configuration.

Compact Software Curtails Operations

In a move company officials say is not caused by financial difficulties, Compact Software closed its Palo Alto offices Aug. 8. The company is owned by Comsat Technology Products, a half-billion dollar diversified corporation. Jeffrey L. Rubin, vice president and general manager for Compact Software, said the closure reflected a decision made some time ago by Comsat that the software company did not fit their long-range goals.

In a prepared statement, Compact Software pledged to honor all existing maintenance contracts and any other contractual obligations. "Money is set aside for honoring maintenance contracts," a Compact Software spokesman said. The company will complete its latest version of the PC program, version 3.0, and updates will be sent to qualified customers, the spokesman said.

A spokesman for Comsat verified that the company was seeking to divest itself of operations that did not fit into its corporate plan. Compact Software is one of several companies considered too small by Comsat.

Comsat issued the following statement: "We are still assessing precisely what we are going to do about Compact Software. Earlier this year, we announced that Compact Software was being integrated into a new business, Comsat Technical Services. As this integration takes place we are seeking to strengthen Compact's capabilities and offerings. The business is definitely for sale; we have not reached a conclusion beyond this."

The solution to FCC Part 15 is right at your fingertips.

Introducing the easiest solution to FCC Part 15 UHF transmitter requirements.

For the many applications that use low-power UHF transmitters under Part 15 — wireless security systems, garage door openers, wireless remote controls and short-range telemetry — RFM has developed an easy, rugged, cost-effective solution to transmitter design.

With our SAW resonator stabilized hybrid transmitters, you just add a simple antenna, 9V battery and digital input. Our hybrids do the rest. No need for a protracted rf design effort on your part.

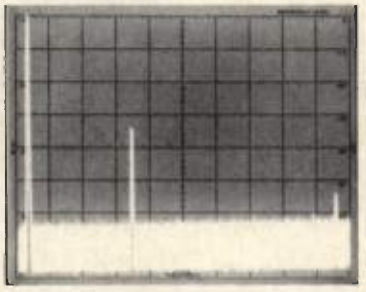
Hybrid oscillators are designed for wireless security products and other remote control devices.

Full operating range.

RFM's hybrid transmitters can be easily adjusted to achieve full legal radiated power (operating range) with a variety of simple wound-coil or print-loop antennas.

Excellent stability and signal purity.

Quartz SAW resonator frequency control assures that our transmitters won't drift out of your receiver's bandpass — or into a military "forbidden band" — despite temperature or battery voltage changes, component aging or body capacitance effects.



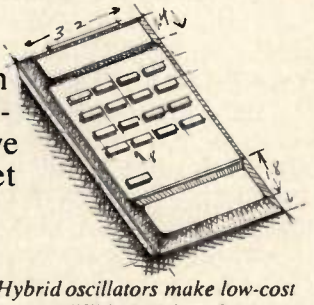
Typical harmonic spectrum of hybrid transmitter.

Also, our transmitters feature low harmonic output and tight modulation bandwidth control. Harmonic radiation above 1000 MHz is well under 125 uV/m @ 3 meters when used with recommended antennas.

The right options. The right support.

Both pulse and FSK modulation options are available to match either superregenerative AM or superheterodyne FM receivers. Matching hybrids are also available for receiver local oscillators (10.7 MHz i-f). Plus, we offer two transmitter output power ranges — for FCC Part 15 Subpart D or Subpart E. All RFM transmitters are fully compatible with CMOS encoder chip drive levels.

At RFM we have a staff of expert rf engineers ready to help you integrate advanced SAW technology into your product. And you can always count on an innovative, cost-effective solution. We didn't get to be the world's volume leader in UHF SAW resonators and hybrids by following the competition.



Hybrid oscillators make low-cost AM/FM UHF-based remote control systems possible.

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Midcon/85 High Technology Electronics Exhibition and Convention
O'Hare Exhibition Center
Rosemont, Illinois
Information: Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (213) 772-2965.

September 11-12, 1985
Mid-Atlantic Electronics Design & Production Exhibition
Valley Forge Convention Center
King of Prussia, Pennsylvania
Information: International Mktg. Services Ltd., 1719 S. Clinton St., Chicago, IL; Tel: (312) 421-7000.

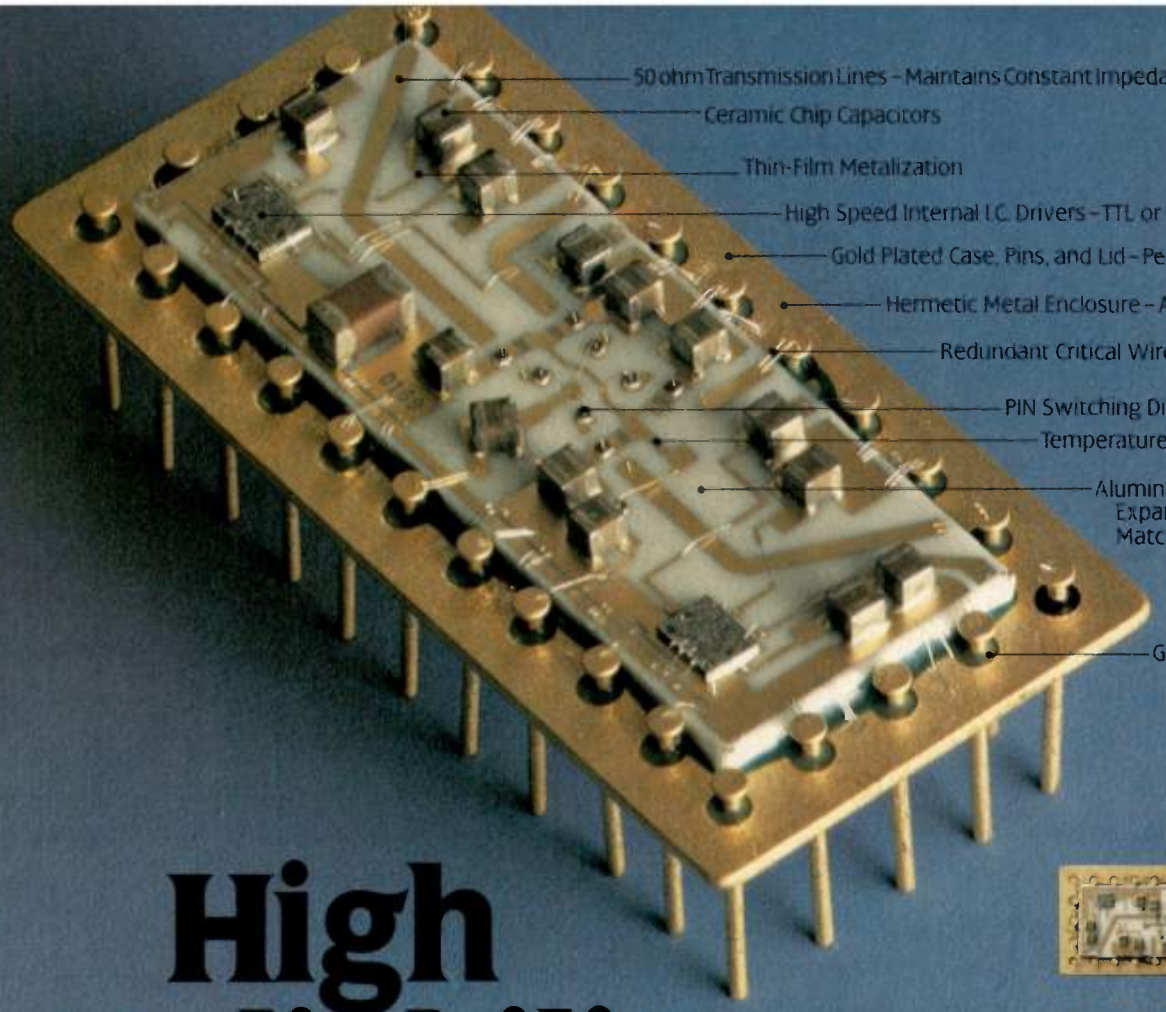
October 8-10, 1985
Electronic Imaging Expo
Sheraton Boston
Boston, Massachusetts
Information: Kathie Hallberg, IGC, 375 Commonwealth Ave., Boston, MA; Tel: (617) 267-9425.

October 21-23, 1985
Fifth International Electronics Packaging Conference
Mariott Hotel
Orlando, Florida
Information: Evelyn Ashman, International Electronics Packaging Society, P.O. Box 333, Glen Ellyn, IL 60137; Tel: (312) 260-1044.

October 22-24, 1985
Northcon/85 High Technology Electronics Exhibition and Convention
Portland Memorial Coliseum
Portland, Oregon
Information: Electronics Convention Management (see Midcon/85).

November 19-22, 1985
Wescon/85 High Technology Electronics Exhibition and Convention
Moscone Center, Brooks Hall/Civic Auditorium
San Francisco, California
Information: Electronics Convention Management (see Midcon/85).

January 30-February 1, 1986
RF Technology Expo 86
Anaheim Hilton and Towers
Anaheim, California
Information: Kathy Kriner, Cardiff Publishing Co., 6530 S. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522.



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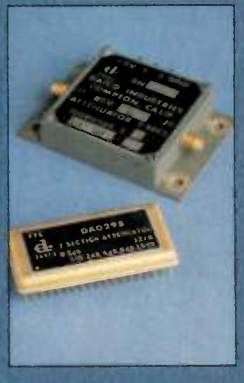

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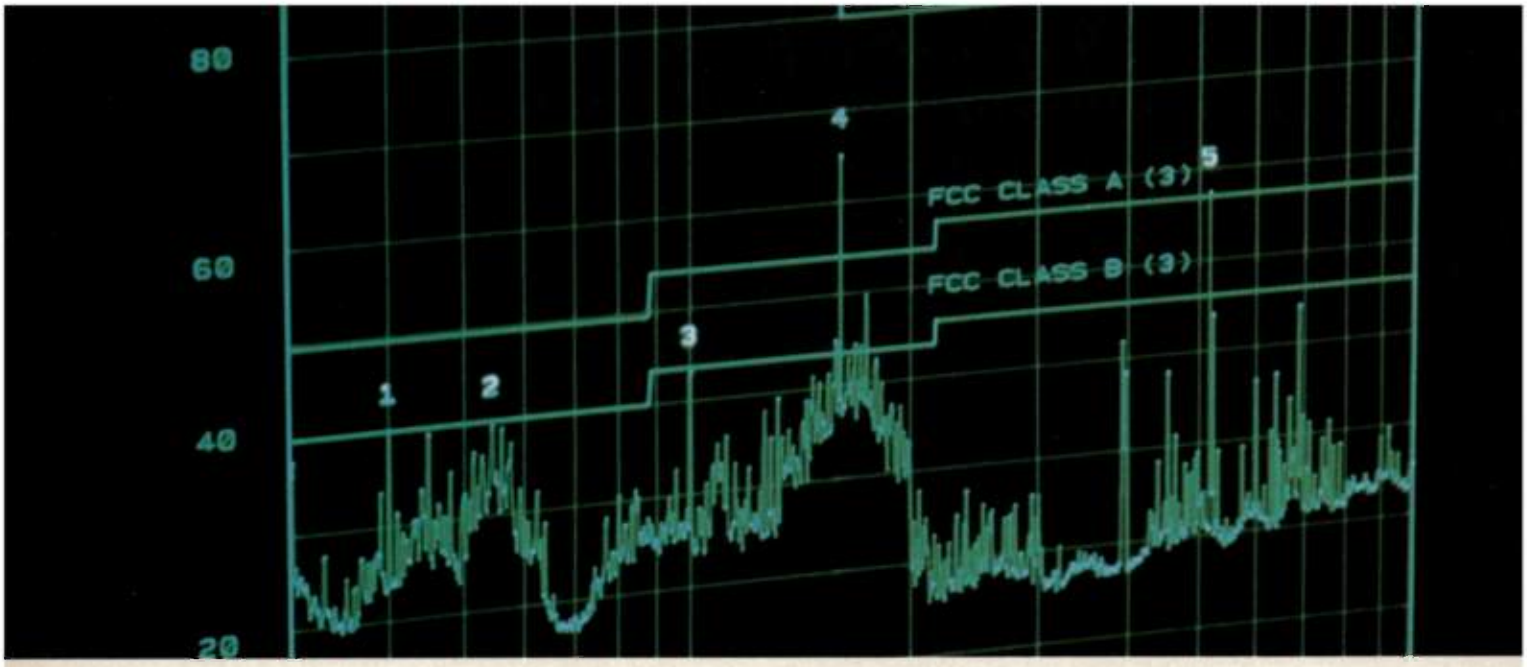

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*CISPR (Comite International Special Des Perturbations Radioelectriques) Publication 16 is the "CISPR specification for radio interference measuring apparatus and measurement methods."

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INFO/CARD 13

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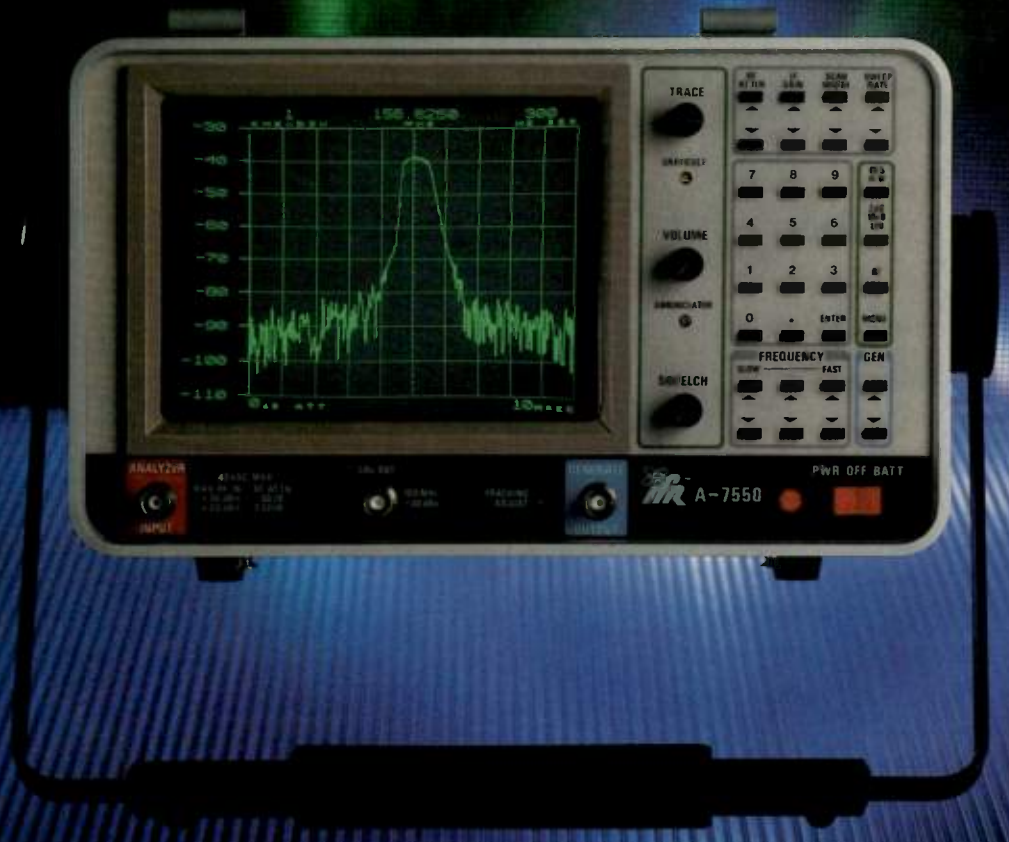

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INFO/CARD 14

The New Look in RF Circuits — Packaging

By James N. MacDonald

In this final part of our series on advancements in RF circuit design we take a close look at two companies specializing in miniature circuits. We interviewed sales and engineering executives at Metaramics and Avantek, two Silicon Valley firms, to learn the directions their companies were taking. We believe what we learned applies to other design houses as well and shows one direction of development in RF circuits.

Metaramics is in Sunnyvale, Calif. We spoke there with sales manager B.J. McDaniel about the company's orientation in the industry.

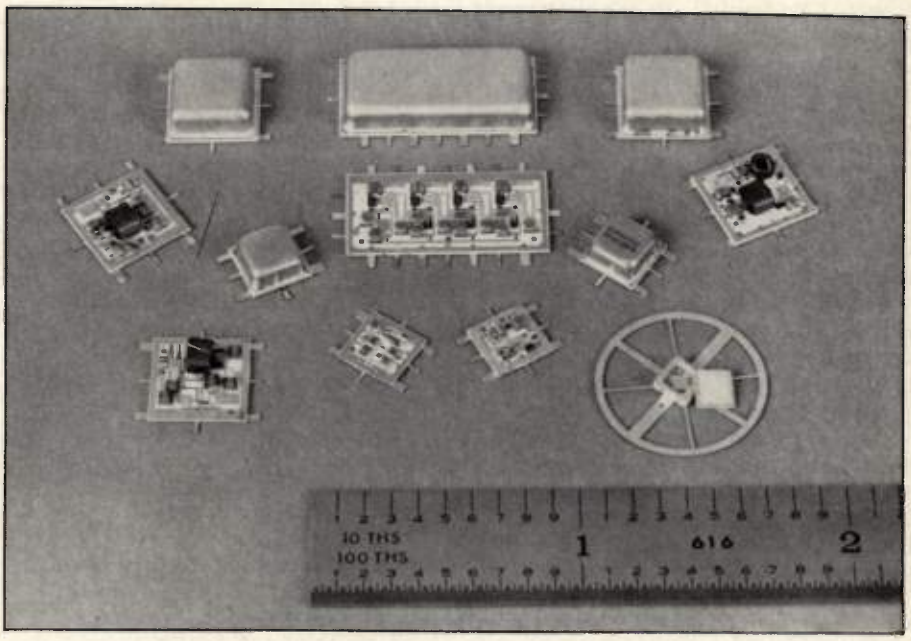
"We are in our sixth year now, a spinoff from an RF transistor manufacturer," B.J. told us. "Our business started with the standard packages and then we expanded into special packages — hermetic packages with multilayer construction, window frames, alconite flanges for larger packages, good thermal dissipation, no cracking of the BeO — the next step of sophistication.

"Next we got into metallization and brazing of high reliability assemblies. We might metallize alumina, fire it, nickel-plate it and braze it into various housings for extremely high reliability connectors. They might be used in medical applications, ordinance, space or even well drilling.

"A fourth area that we are just becoming interested in is integrated circuit packaging. We are specifically looking for applications that require the use of beryllium oxide, rather than alumina. We're looking for thermal situations, where the chip is getting so large that the customer has to find some way of getting the heat out of the package that cannot be solved with conventional methods in alumina packages. Such a part might have a beryllium oxide base and some cofired layers on the top to form the area where the interconnects are.

B.J. explained the process of bonding metal to ceramic.

"In brazing two dissimilar pieces of metal together, a ceramic piece and a metal piece, care has to be taken because the ceramic is very rigid and metals seem to have more expansion capability at temperature. So, when we are building these packages we have to take extreme care that they are matched up in terms of temperature, otherwise as they are starting to cool down the metal may cool faster and crack the ceramic. Both ceramics, alumina and BeO, are susceptible to that problem. They are equal in terms of their modular elasticity.



A few of the PlanarPak devices produced by Avantek, Santa Clara, Calif. For additional information circle INFO/CARD #110.

"We use tungsten and moly-manganese metallization for refractory metal. This is to form an adhesion layer between the surface of the ceramic and the next step, which would be the brazed material. So, we put down the refractory metal, it forms a glassy face with the surface of the beryllium oxide, then we nickel plate that refractory metal, then we're able to braze the ceramic in a housing or lead frame onto the package using either silver or cusil.

"We are a thick film technology house and we have some limits in how close we can make the lines. In terms of 'let's take a standard operation and make it as small as possible' we're not leading the market in that area. But when you are trying to make smaller RF power modules using chip carriers, we're in that field."

In Santa Clara we visited Avantek and spoke with David Herron, advertising manager for the MIC/Semiconductor Division, Northe Osbrink, publications editing manager and Bill Koehn, marketing manager for modular components.

The founders of Avantek started the company in 1965 to serve the market for solid state amplifiers. The technology existed to produce a transistor to operate at 1 GHz, although most higher frequency amplifiers at the time were tube type. They developed their own transistor facility and eventually began doing their own thin film hybrid construction. The company maintains this concept of vertical integration.

Osbrink told us, "We now offer at very economical pricing essentially a complete amplifier in a transistor package. What could be more miniaturized than that? Instead of having to take a transistor and incorporate components around it to turn it into a circuit, you now have something that only needs an input and output voltage to operate as a complete amplifier."

Herron said the Semiconductor Division is taking the functions of these amplifiers and putting them on a single

chip. It is the company's vertical integration that allows them to incorporate these building blocks into various sizes of devices for various functions, he said.

"We're making microwave technology for the RF price. We're taking that expensive sub-micron, semiconductor geometry and selling it to the RF world for the RF price. To do that we have to come up with more functions per block. There are many marketplaces opening up that require the 1 to 2 GHz or 3 to 4 GHz frequency range — TVRO, GPS. Those types of programs perform a lot better if they have the microwave technology. That is why we're moving that way. That is why the whole industry seems to be moving that way."

One of the company's most recent developments is the PlanarPak. This design does not put the substrate in the package, the substrate becomes the package.

Koehn told us, "We're not starting out with a header and putting a substrate on it, we're adding the surface mount leadframe to the ceramic substrate itself.

"It is indeed a surface mounting package up to a certain frequency range, so you don't have to go through other things on your PC board. It lends itself to automated insertion, and the package itself lends itself to automated assembly."

Built around a ceramic substrate, the PlanarPak is compatible with larger substrates of MICs. Designers can add these ready-to-operate amplifiers directly to a circuit. In addition to the hybrid amplifiers already available, Avantek hopes to have switches, detectors, mixers and limiters ready for distribution about the time this issue is published.

Avantek is one of the modern electronics companies moving as fast as possible to meet the future. Company literature says, "Future integrated assembly products will include both microwave and digital processing functions. With this integration, requiring ultrahigh speed digital integrated circuits to support these products, Avantek began expansion of its existing GaAs technology into digital integrated circuits in 1984."

Osbrink summed it up, "The long-term future is absolutely incredible in terms of size and packaging."

Package Types

From the east coast, Howard Levine, vice-president for marketing for Synergy Microwave, Paterson, New Jersey, provided us with a description of traditional package styles and some of their advantages and disadvantages. He concluded with a description of the company's surface mounted package for double-balanced mixers.

In the world of "lumped-element" double-balanced mixers (DC-3.5 GHz), Levine told us, many different package styles are available. To a great extent, the industry has standardized around seven different PC mountable configurations. Examining manufacturers' specifications on the same basic device offered in several packages, one often sees no perceptible difference. However, these performance specifications do not address such issues as ease of mounting, ease of achieving a good "ground" when used in a production environment and quality assurance concerns that may come into play in production.

Mix these details with pricing and space considerations and the user is faced with a maze of choices. When realizing that the packaging represents anywhere from 10% to 85% of the materials cost in a mixer, the decision-making process becomes critical. The selling price of the "same" device in different PC board packages can vary 200%! The following explanation attempts to unravel this situation.

Eight-Pin Relay Header (Full Sized)

Without a doubt, the lowest cost packaging is the 8-pin Relay Header. This traditional package is rectangular, .4" x .8" and varies in available heights. The most typical (and lowest cost) are those of approximately .4" in height.

The Relay Header offers the additional advantage of having the widest diameter (.030") pins. This rigid pin pattern makes production insertion an easy matter. These pins do not bend easily, and the possibility of a bent pin causing a defect in its surrounding glass-to-metal seal is reduced.

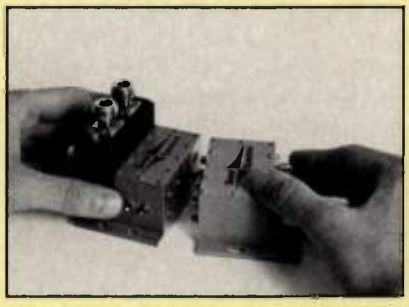
From an electrical performance point of view, the relay header offers (typically) four ground pins spread out around the package, allowing good, consistent grounding. The package's large size does cause some excess wiring length internally, causing 0.5-1.0 dB more conversion loss at the high band edge of devices

Putting it Together

Throughout this series we have described miniature components and the designs developed to mount and connect them on boards and substrates. There comes a time, however, when these devices must be connected to other devices. The advantage gained by miniaturization may then be lost by the space occupied by connectors and cables.

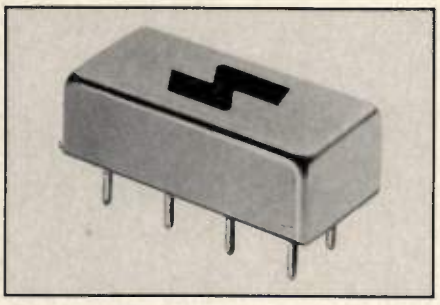
Connector companies are well aware of the need to reduce the size of their products. In this part of the Special Report we look at a new design by a connector manufacturer to allow multiple interconnections in a minimum space. This, too, is part of the new look in RF circuits.

M/A-Com, Omni-Spectra, has developed a modular plug-in connector that allows the system designer to make a variety of connections to a printed circuit board. The OSP module uses low profile, blind mating, plug-in connectors in modules that can be combined as the designer wishes. The connection system can be redesigned easily by rearranging the modules. Omni-Spectra says the modular plug-in concept allows flexibility in packaging design and access for repair without sacrifice in electrical performance or mechanical reliability.

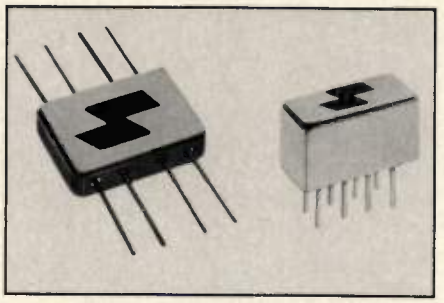


M/A-Com Omni Spectra's family of OSP™ blind mating connectors offer a space saving alternative for the packaging designer. OSP™ connectors are designed for blind mating of modules and components, eliminating cables and threaded RF coaxial connectors. A unique contacting mechanism permits both axial and radial misalignment and low mating forces.

The OSP modular blind mating design is being tested and studied by the Defense Electronics Supply Center as a possible new military standard. For additional information circle INFO/CARD #109.



The 8-pin Relay Header is the lowest cost standard package. The rigid pin design (.030" dia.) makes production insertion easy. Pins do not bend easily, minimizing risk of damage to the glass-metal seal around them.



The 8-pin miniature package (right) is the smallest user of PC board space. It is available in 4-pin or 8-pin configurations. The flatpack (left) offers the advantage of horizontal leads but is the most expensive package.

operating at frequencies above 1 GHz compared to the same circuit in a smaller package. However, the exceedingly low cost allows one to "trade-up" to a more broadband or higher frequency device at a still attractive cost.

What is the drawback? The Relay Header requires two to three times more PC board surface area than any other PC board package. Its "cubic" volume is two to five times that of any other package. However, if the space causes no grief, *this* is the package to use.

Miniature Relay Headers

These devices are .230" x .500", with typical heights from .25" to .4". Devices are available covering most frequency ranges in the .25" height package. Traditionally available in both 4-pin and 8-pin configurations, the 4-pin unit has become much more popular. This package has the unique position of being (along with the TO-5) the smallest user of PC board space, yet it is only second in cost, behind the full-sized Relay Header. This is due primarily to its rectangular configuration, allowing simple and rapid internal construction.

Many users are concerned about the grounding of a 4-pin package. This is a valid concern. However, the 4-pin header traditionally uses ground studs placed at approximate locations (internally only) to keep ground leads short. These pins (again due to rectangular construction) do not really limit useable internal space and, therefore, do not affect cost. The fact is that there *are* only four pins coming out, but circuit grounds are established at several points internally (due to the ground studs), yielding *good* ground performance (unlike other 4-pin packages such as TO-8/TO-5s).

Lastly, the package uses sturdy .020 pins which, though not as "stiff" as the .030 pins of the full-sized relay header, are very good mechanically.

The trade-offs here are cost. The 4-pin miniature costs 30-90% more than the Relay Header. However, this is *still* lower than all other packages. If one can accommodate the .25" height and "plug-in" format and needs small board area and volume utilization, this is the package.

TO-8

TO-8 packages are an old carry-over from the "discrete" transistor packaging of earlier years. They are the next price bracket up from the miniature headers and use typically twice the volume and 70-150% more surface area. The 4-pin TO-8 (.5" diameter) costs more because of the smaller internal space (round shape vs. rectangular), making assembly costs higher.

The presence of only one ground pin often necessitates internal grounds being soldered right onto the header surface. This meets all military requirements, if done properly. However, the susceptibility to damage due to poorly controlled user production process control (reflow overheating in hand soldering operations) is obvious.

The typical .25"-.30" height offers no special advantage compared to lower cost devices, and the configuration requires resistance or laser welding to seal the cover. The hermeticity yield of these processes is not nearly as high as the solder seal of the various relay headers.

The 12-pin version of the TO-8 (.6" diam.) still has the overall volume and surface area detriments of the 4-pin package. However, its larger diameter (.6" vs. .5") allows the typical height to be reduced to .2", shorter than the relay headers or 4-pin TO-8's.

The 4-pin TO-8 offers no real user advantages. Its thinner (.018" diam.) pins are another drawback. The 12-pin does offer a height advantage and is useful where a round package fits the board space better. However, getting proper alignment on twelve .018" pins can sometimes be quite a trick.

TO-5

The 4-pin TO-5 uses roughly the same area and volume as the 4-pin miniature header. The round configuration (as opposed to rectangular) reduces internal usable space by 50% compared to the miniature relay header, driving up the cost. Along with its thinner pins (.018" vs. .020") and Q.A. considerations, this creates a particularly undesirable option.

Flatpacks

Historically, flatpacks are the highest cost of the PC mounted devices. However, they offer many useful features. A .150" height (allowing closely spaced PC cards) and "radial" leads instead of perpendicular "down-pins" allows the part to be assembled by accessing only one side of the board. Flatpacks offer unique performance advantages that justify the high cost (twice the price of the Relay Header).

SMD (Surface Mounted Device)

In June, 1985, Synergy Microwave introduced the first true surface mounted package for double-balanced mixers. The package is approximately the same size as a traditional flatpack, but *without leads*. The mounting surface of the device is an alumina substrate with "wraparound" (top, side, bottom) contacts for RF, IF, LO and GROUND. The device mets all MIL-STD requirements and has several critical advantages:

1) No pins to use up space. Flatpack pins mounted on the surface can take up a space as large as the device itself.

2) No glass-to-metal seals. The traditional stress points for hermeticity and mechanical integrity are the glass-to-metal seals in a flatpack.

3) No need to drill holes or cut notches to achieve true flush surface mounting.

4) Simple production handling — "pick and place," then reflow.

The SMD package is equal or lower in cost than the traditional flatpack. The only tradeoff is slightly higher loss at the high frequency band edge due to the non-metallic package forming an "incomplete" ground-plane. For additional information about these surface mounted mixers and other Synergy Microwave products, circle INFO/CARD #108.

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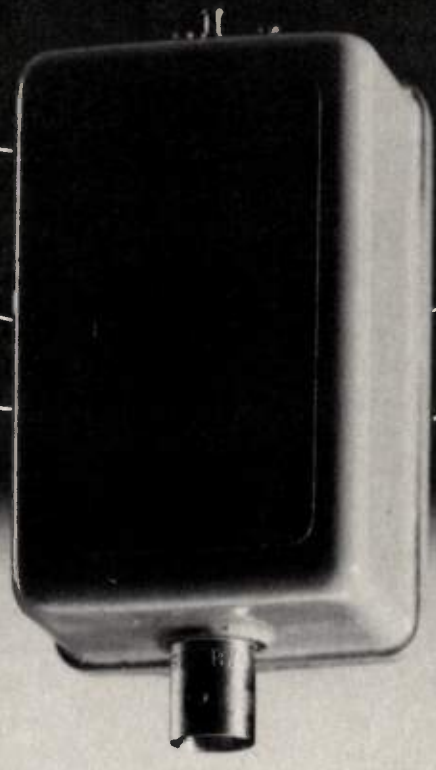

Let's face it. Even in a digital world, many of your design problems are still analog. Like the need to match transmission lines of different characteristic impedances. Or to eliminate ground-loop currents in video lines. Or to filter out common-mode noise in data lines. Applications like these call for specialized signal transformers.

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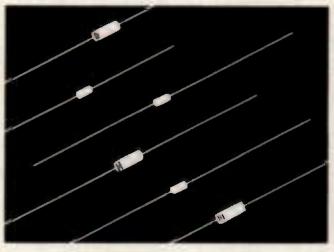

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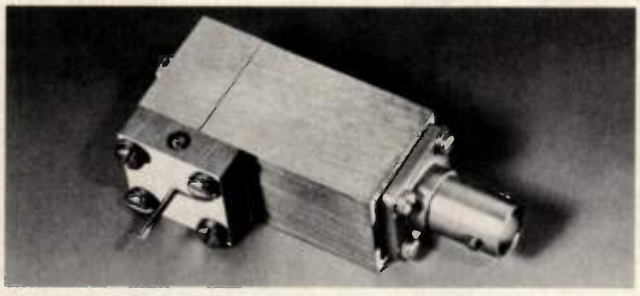

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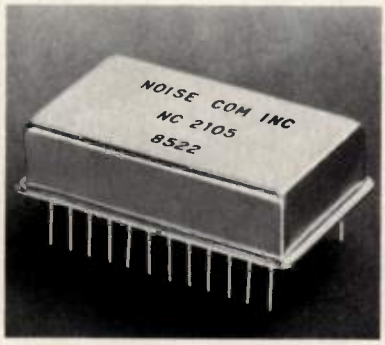

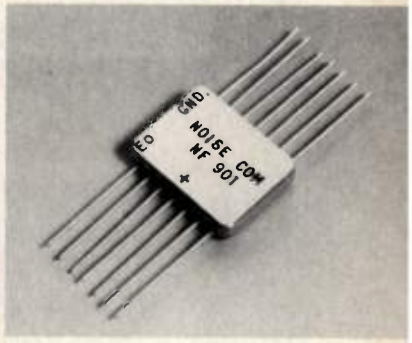

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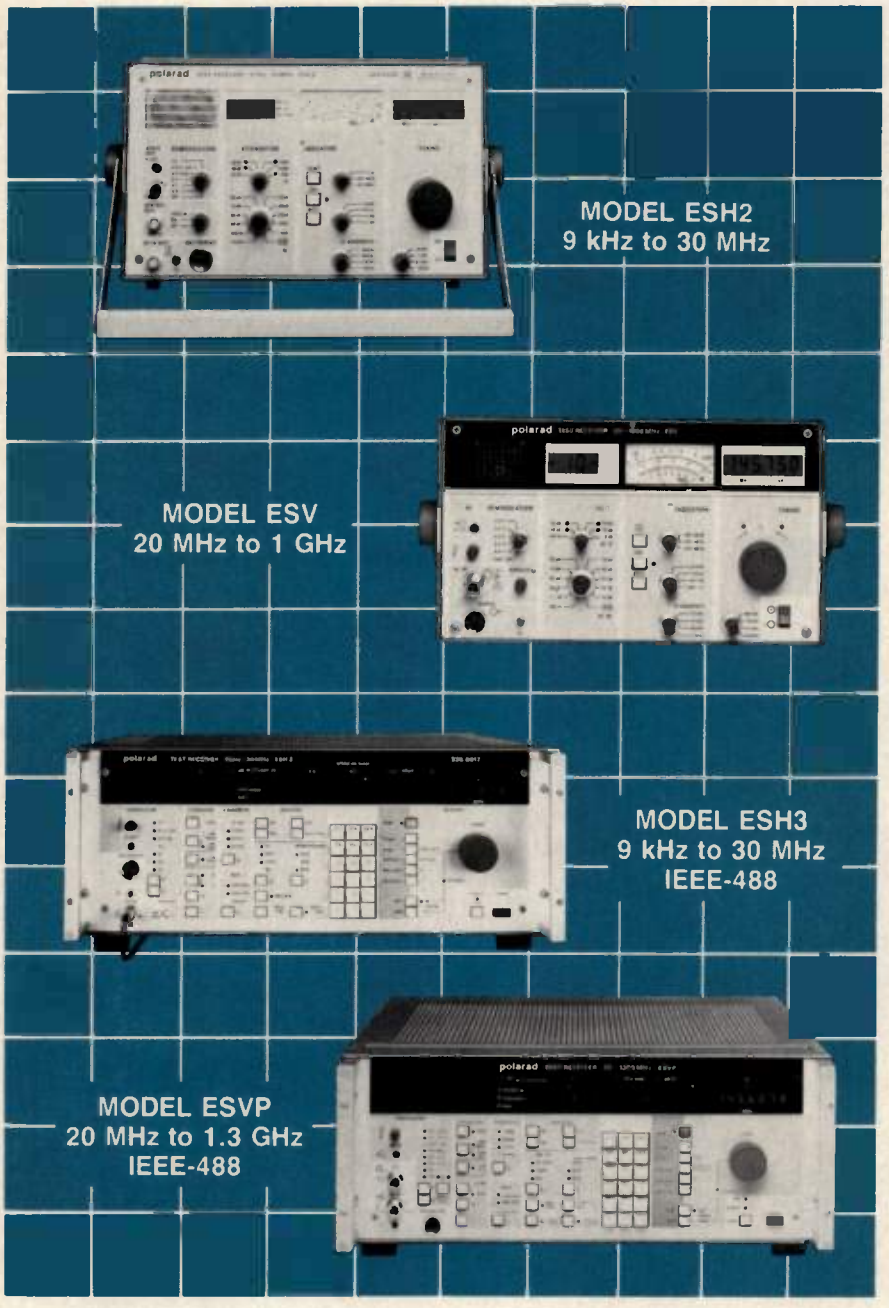

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INFO/CARD 17

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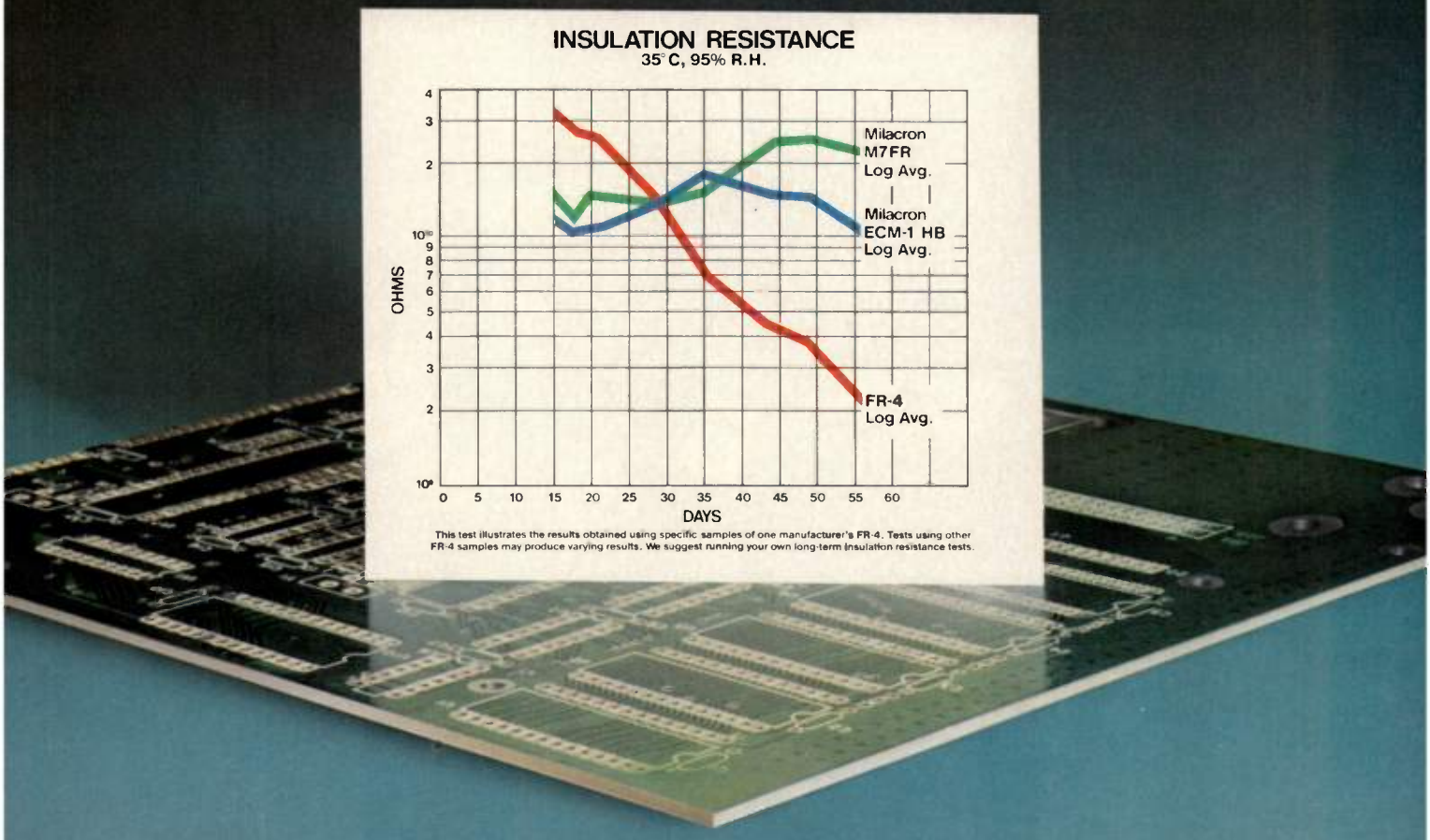

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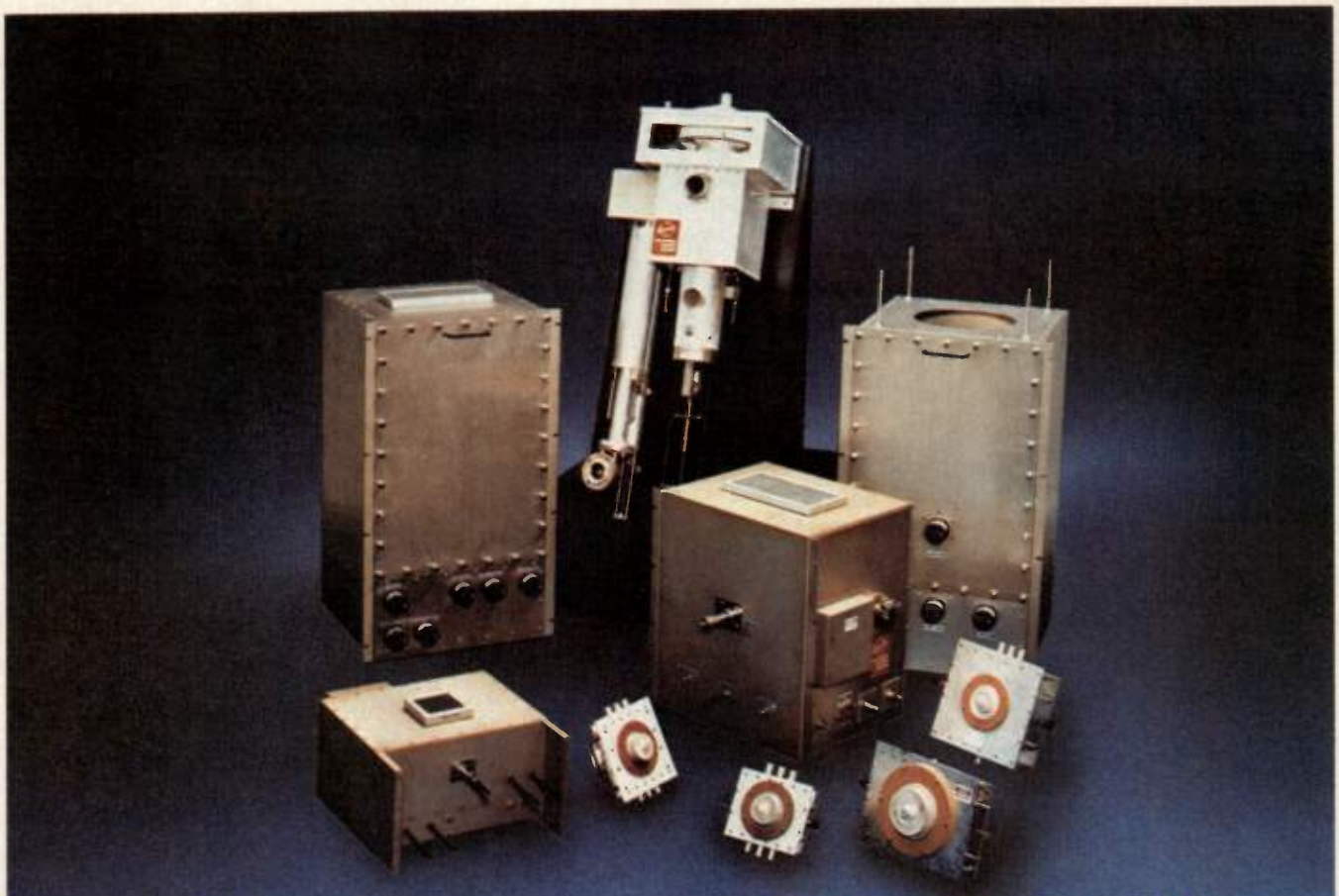

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CV-2225	4CX3500A	86-108	5 kW
CV-2240	3CX10,000U7	54-88	10 kW†
CV-2250	3CX10,000U7	170-227	10 kW†
CV-2400	8874	420-450	300/1250 W*
CV-2800	3CX400U7	850-970	225 W
CV-2810	3CX400U7	910-970	190 W

*pulsed power
†peak sync, or 2.5 kW combined in translator service

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INFO/CARD 19

Wide Dynamic Range Linear Detection

By William C. DeAgro,
Hazeltine Corporation

In many signal processing applications, it is desired to extract the AM of a signal accurately over a wide dynamic range. Such applications may include high fidelity audio and video systems, high accuracy direction finding systems or any signal processing application where signal amplitude is important. Ordinary series diode-resistor detectors are not very linear and can only achieve roughly a 20 dB dynamic range in the linear region; an active detector, however, using nonlinear feedback can yield linear detections exceeding 60 dB dynamic range. The following is a brief discussion and some results of a scheme using an op-amp with nonlinear feedback to achieve a linear detection exceeding 60 dB of dynamic range.

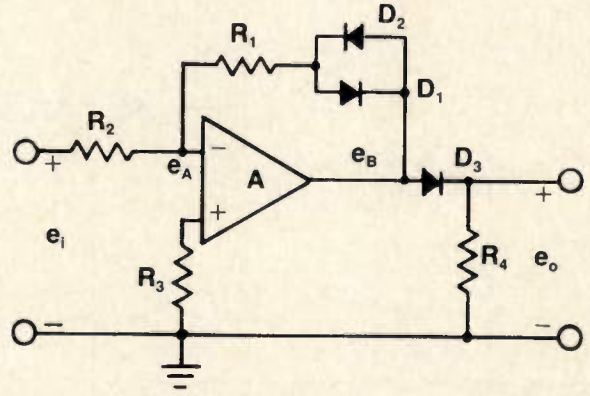

Figure 1. Schematic diagram of wide dynamic range linear detector (without filtering)

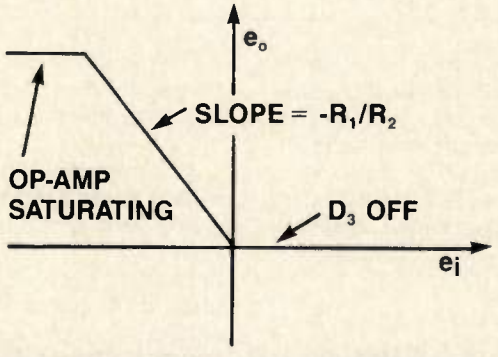

Figure 2. Ideal transfer characteristic of Figure 1

The basic AM linear detector is composed of two parts: a linear half or full wave rectifier and a low pass filter, in succession. In order to achieve wide dynamic range linear detection it is necessary for the rectification portion of the circuit to have an output directly proportional to the input signal level over a wide dynamic range. Therefore, most of this discussion will concern the rectification portion of the circuit.

The schematic in Figure 1 shows the structure of a wide dynamic range linear half wave rectifier. Its function is to produce an output (e_o) that is a linear function of the input (e_i) when the input is negative and no output when the input is positive. The ideal transfer characteristic, e_o vs. e_i, is shown in Figure 2.

The reason this circuit behaves this way is because when e_i is negative, e_B becomes positive, which places D_2 and D_3 in the forward bias region. The gain (e_B/e_i) is given by:

$$\frac{e_B}{e_i} = -\frac{R_1 + r_{D2}}{R_2} \; ; \; A \rightarrow \text{LARGE} + e_i < \phi \qquad (1)$$

and the gain function (e_o/e_B) is clearly given by:

$$\frac{e_o}{e_B} = \frac{R_4}{R_4 + r_{D3}} \qquad (2)$$

Knowing (from feedback theory) that e_A is at virtual ground and setting $R_4 = R_1$ and matching D_2 and D_3 leads to $i_{D_2} = i_{D_3}$ and $r_{D_2} = r_{D_3}$, the overall gain (e_o/e_i) when $e_i < \phi$ is given by:

$$\frac{e_o}{e_i} = \left(\frac{e_B}{e_i}\right)\left(\frac{e_o}{e_B}\right) = \left(\frac{-R_1 + r_{D_2}}{R_2}\right)\left(\frac{R_4}{R_4 + r_{D_3}}\right) = \frac{-R_1}{R_2} \; ; \; e_i < \phi \qquad (3)$$

Clearly when $e_i > \phi$, e_B is less than 0, D_3 is reverse biased and the overall gain is given by:

$$\frac{e_o}{e_i} = \phi \; ; \; e_i > \phi \qquad (4)$$

For large fractional bandwidth type signals sometimes it is desired to use linear full wave rectification to eliminate spectral overlap (with nonbaseband compon-

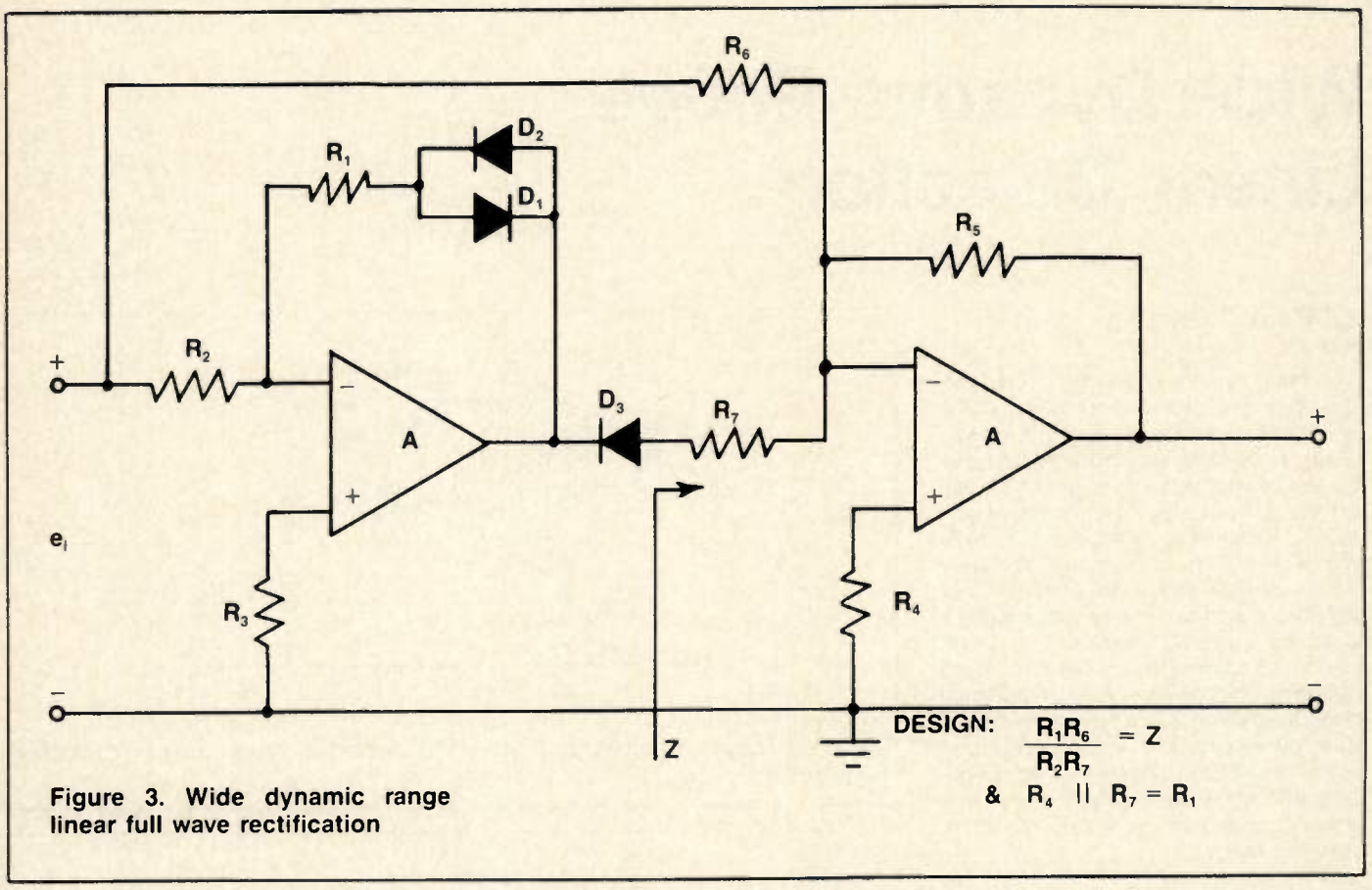

Figure 3. Wide dynamic range linear full wave rectification

ents) without reconverting to a higher center frequency prior to detection, or to reduce the rolloff constraints of the succession filter, as would be required in the half wave rectification type detector. In order to obtain a wide dynamic-range linear full-wave rectifier circuit, an extension of Figure 1 (with D_3 reversed) may be employed as shown in Figure 3. Note that the impedance Z looking into R_7 is roughly R_7.

Therefore, the parallel combination at R_4 and R_7 should equal R_1.

In order to perform the complete detection, filtering of either e_o or e_o is necessary. This can be done by placing a capacitor across R_4 for the half wave rectification type or placing a capacitor across R_5 for the full wave rectification type. The 3 dB radian bandwidth of the filter is the reciprocal of the RC product. If it is necessary to use a sharper rolloff filter (for the larger fractional bandwidth type signals), R_4 may be replaced by an n-pole filter with a passband impedance equal to that of R_1 or an n-pole filter may be placed at the output e_o. Note that the ideal filter would be flat in the passband, have a linear phase characteristic and have a rolloff sharp enough to degrade nonbaseband components to a specified level. Implementation of these higher order filters will not be addressed here.

The circuit of Figure 1 was designed using an NE5538 op-amp made by Signetics. The values for R_1, R_2 and R_4 were 1.1 kΩ and the value for R_3 was 750 Ω. The diodes were all IN5712 Schottky barrier, which have a low turn-on voltage of 0.34V. The filtering was performed by placing a capacitor of 0.01 μF in parallel with R_4 to give roughly a 15 kHz audio bandwidth. A schematic diagram of the practical circuit is shown in Figure 9. Prior to placing the filtering capacitor on the output, the transfer characteristics were plotted on an oscilloscope in X-Y mode and are shown in the oscillograms of Figures 5, 6 and 7. From these figures, it is clear that the rectifier circuit is linear over a dynamic range greater than 60 dB.

To show the performance of the complete detector circuit, a 3 MHz carrier frequency was used with a 10 kHz AM signal with modulation index greater than 1. The input waveform along with the detected waveform is shown in Figure 8.

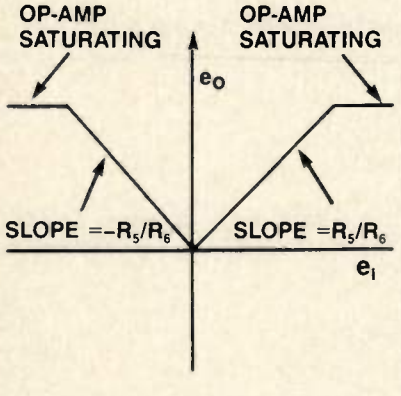

Figure 4. Ideal transfer characteristic of Figure 3.

Conclusions

It was found that the detector circuit built could detect signals in a linear region over a 60 dB dynamic range for roughly 11 kHz bandwidth signals of carrier frequencies ranging from 1 MHz to 4 MHz when using a simple RC succession filter. It is believed that much larger fractional bandwidth signals (e.g. 1/2) could be

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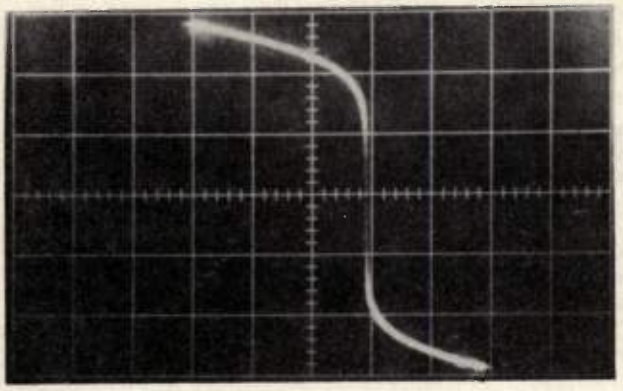

Figure 5. Non-linear characteristic
e_B vs e_i
Y: 5 mV/div
X: 100 mV/div

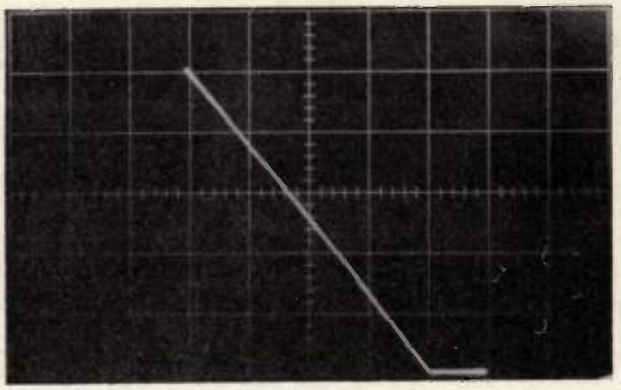

Figure 7. Linear characteristic
e_o vs e_i
Y: 2.5 mV/div
X: 2.5 mV/div

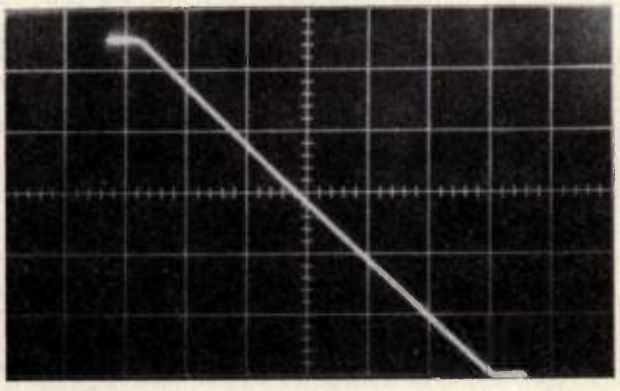

Figure 6. Linear characteristic
e_o vs e_i
Y: 5 V/div
X: 6.3 V/div

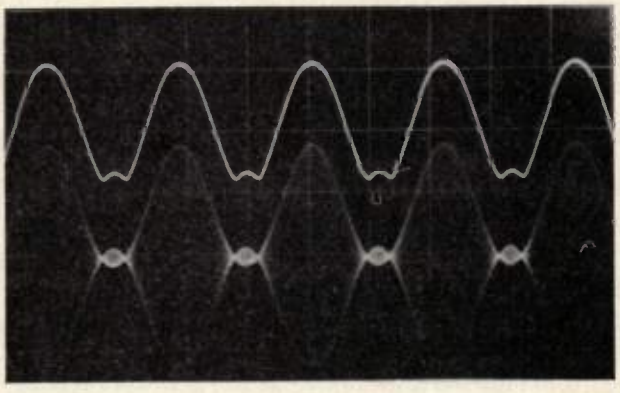

Figure 8.
Upper Trace: Detected output
Lower Trace: Input waveform (3 MHz Carrier, 10 kHz modulation, modulation index > 1)

detected with this circuit if more exotic filtering were employed. In addition, it is believed that much higher carrier frequencies (up to 200 MHz) could be achieved when using state of the art type op-amps. Some of these op-amps may include the Comlinear CLC220AI, the OEI9914A and the Plessey SL541B.

About the Author

William DeAgro is a senior engineer in Research Labs at the Hazeltine Corporation, a defense contractor. Bill has a BSEE and a MSEE from the Polytechnic Institute of New York where he was a Cum Laude graduate and was elected Who's Who Among Students in American Universities and Colleges. Bill is a member of the Association of Old Crows, the International Society of Hybrid Microelectronics, Eta Kappa Nu Association and the Tau Beta Pi Association. Address correspondence to him at Hazeltine Corporation, Cuba Hill Road, Greenlawn, N.Y. 11740.

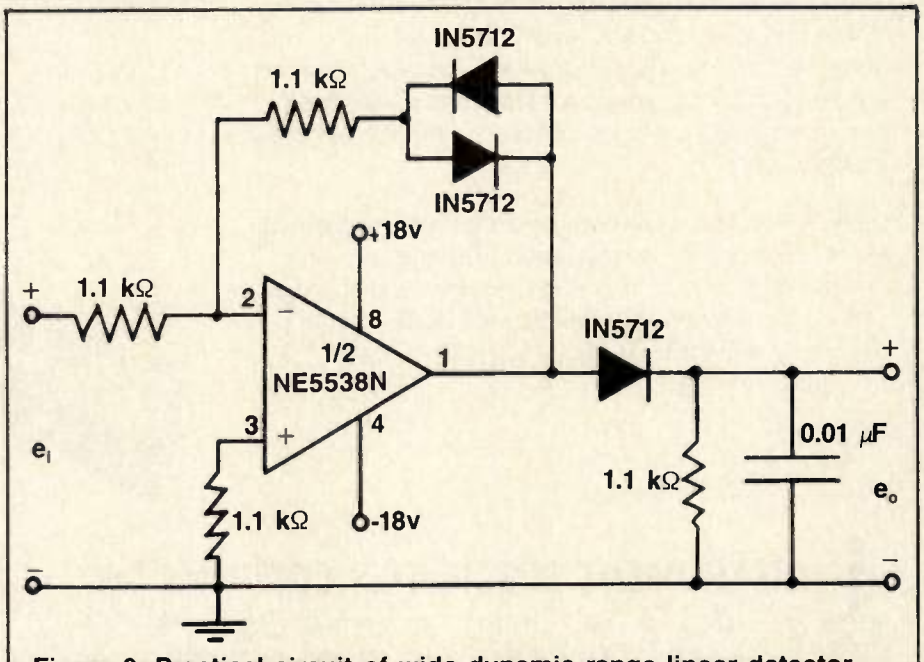

Figure 9. Practical circuit of wide dynamic range linear detector

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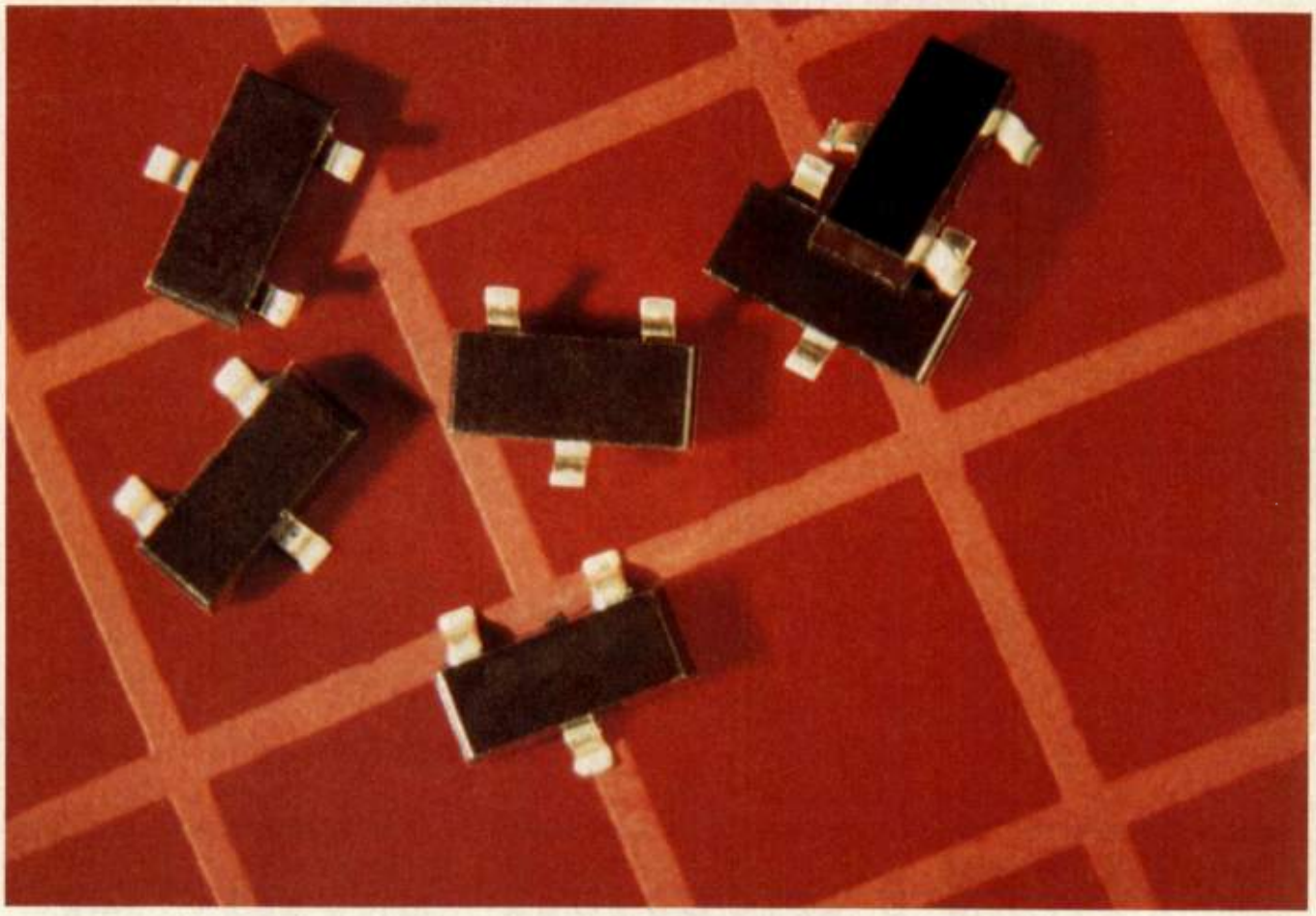

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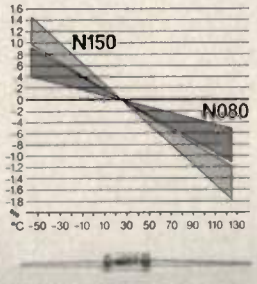

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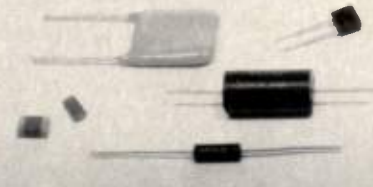

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SAS-200/530	150 - 550 MHz	Broadband Dipole
SAS-200/540	20 - 300 MHz	Biconical
SAS-200/541	20 - 300 MHz	Bicon | Collapsible
SAS-200/542	20 - 300 MHz	Biconical, Folding
SAS-200/550	001 - 60 MHz	Active Monopole
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"Outdoor" Emissions Testing Moves Indoors

Submitted by Keene Ray-Proof

For years, electronic companies have tested their new devices for RF emissions outdoors, and FCC regulations supported that approach. But today, more and more companies are taking their "open field" testing indoors, saving money and actually getting better results. And the FCC is going along, tacitly.

"Ironically, it's electronically 'cleaner' in today's electronic testing chambers than in the great outdoors," says the test engineer of a Colorado telecommunication company. "In fact, with all the satellites and aircraft navigation systems operating out there, and all the microwave telecommunication, the 'pure desert' air suffers from electronic clutter."

The testing is being done in RF anechoic test chambers. "Basically, that means unwanted radio waves can't get in or out; and further, those waves needed to run the test inside them don't echo off any of the walls," explains Keene Ray--Proof's Brian Lawrence.

"We still do the final FCC compliance tests in open space as prescribed by the FCC," says a spokesman for the telecommunications manufacturer. "But the preliminary testing, really the majority of the testing from an operational standpoint, is done in the RF anechoic chamber.

"Compared with driving out to the desert with two truckloads of gear, setting up and knocking down, indoor testing is certainly much more efficient. It's easier to schedule, far more secure and actually 'cleaner' electronically. There's a different ambient level almost every time we go outside, and that takes a lot of time to calibrate for."

The Keene Ray-Proof indoor testing chamber may not appear imposing, but electronically it does the job. It's been in virtually continuous use, sometimes around the clock, for both preliminary FCC qualification testing and product development.

The chamber itself is essentially square with a high ceiling. A computer floor with built-in emissions absorber lets all wiring run underfloor without interfering with test readings. Two manual doors are for personnel entry and moving equipment in and out. The control room is adjacent and attached, but isolated electronically from the test area.

A Non-Reflective Environment

To keep the test space electronically clean and free of RF reflections from the device under test or any instrumentation, the entire exterior of the chamber has a continuous metal skin hidden within it. Even electrical service and telephone lines, doors, ventilation ducts and other penetrations are designed to block passage of unwanted electronic signals.

Availability of such test chambers as pre-engineered modules is a recent development, according to Bob Barbour of Ray-Proof.

"We've built custom RF-shielded chambers for espionage-proof government and defense applications for decades," he said. "It's been a matter of distilling all we've learned into a more or less standard product for commercial application."

Compared with custom RF-anechoic chambers of comparable size and features, the modular test chamber costs 25 to 40% less, and is in place and running in about half the time of a custom facility, he said.

"Considering that every electronic device from Donkey Kong to a space shuttle computer must pass FCC-type 15 testing, the modular RF shielded anechoic chamber should catch on quickly."

The manufacturer's indoor testing methodology is virtually identical to open space testing. The device to be tested is installed on a rotating platform, connected and brought up to operating condition. At the other end of the room, three meters away per FCC test procedures, is a sensing antenna. During the test, the device under test is operated as it rotates through a full 360 degrees. The antenna picks up any emissions and feeds it to analyzers in the control room.

Anechoic materials on the walls and ceiling of the chamber assure that the antenna receives only direct signals from the device under test. No mixture of direct and reflected signals, or any electronic "clutter" from the atmosphere, can affect the testing operation. So far, there has been excellent correlation between in-chamber tests and open space tests.

Whenever the chamber is not in use, calibrations tests are run to determine baseline levels of EM radiation and reflections. But there's not much time for calibration. Sometimes it runs around the clock, something obviously not possible out in the back country.

Although final FCC testing is still done in open space, Keene Ray-Proof expects that to change shortly. The question of in-chamber testing as an acceptable substitute for open space emission testing is now before the FCC.

"Based on our experience so far, there's every reason to allow in-chamber testing as an alternative," the spokesman said. "The correlations between our indoor and open space tests are exceptional."

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INFO/CARD 28

Measuring a Dipole Antenna Radiation Pattern Using Time Domain and Gating

HP 8510 Network Analyzer Can Remove Ground Clutter Effects

By John W. Boyles
Hewlett-Packard Company
Santa Rosa, CA

A classical problem encountered when measuring the far-field radiation pattern of an antenna in a medium-distance range is the degradation that occurs when undesirable reflections (from the ground or nearby objects) are present. To reduce this problem, the source and test antennas are often installed on towers to remove them from reflective objects, RF absorptive materials are used to reduce the amplitude of the reflected signals and diffraction fences are installed in the range in order to null out the reflections and "clean up" the range. These solutions are often limited in their effectiveness and can be prohibitively expensive to implement.

The HP 8510 network analyzer can be used to reduce the effects of reflected signal paths in an antenna measurement and determine the response of the antenna to the main path signal only, without costly range modifications. This is done by using the HP 8510 to measure the swept frequency response of the antenna and compute the Inverse Fourier Transform to give the time domain impulse response. The time domain response allows the user to identify the reflected signal path reponses in time and then remove them with the gating feature. In converting back to the frequency domain, the effects of the responses outside the gate are removed. This article summarizes the results of using this technique to measure the radiation pattern of a standard gain dipole antenna at RF frequencies on a medium-distance antenna range.

The HP 8510 is a microwave network analyzer designed to make S-parameter measurements in the frequency domain. It also has the optional capability to compute the Inverse Fourier Transform of the measured data to give the time domain response. When used with the HP 8511A frequency converter, the HP 8510A can be configured as a general purpose four-channel phase-locked receiver, and it can simultaneously display in real time the frequency and time domain responses of any channel or the ratio of any two channels. One channel of the HP 8511A frequency converter must be used as a reference to achieve phase lock and therefore must have an input signal level between −10 and −50 dBm. The other three channels can be used to measure signals at the reference frequency with a dynamic range of close to 100 dB (−10 dBm max input).

A general block diagram for making antenna pattern measurements with the HP 8510 is shown in Figure 1. The required test equipment includes the HP

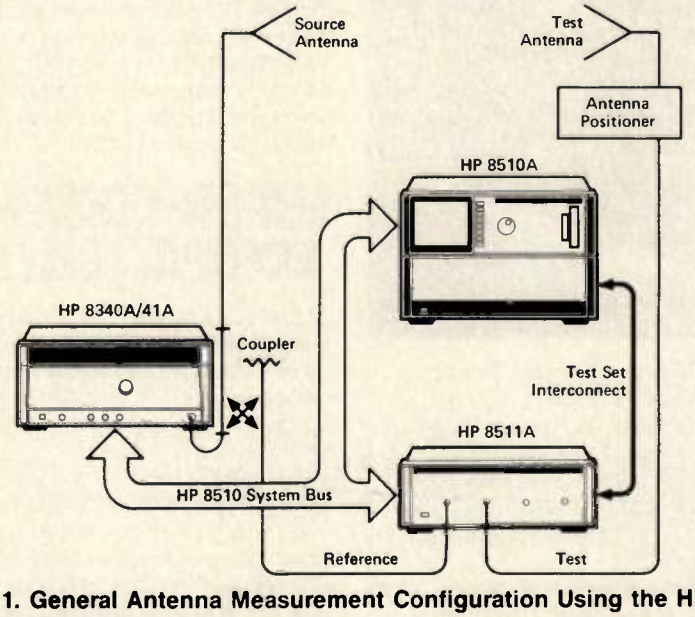

Figure 1. General Antenna Measurement Configuration Using the HP 8510 Network Analyzer.

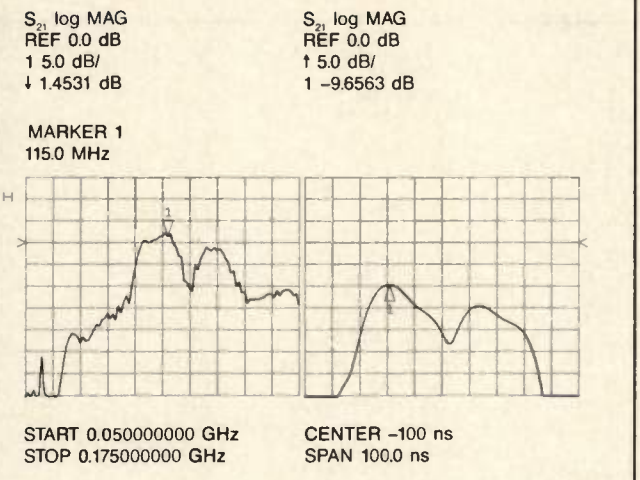

Figure 2. Frequency and Time Domain Responses of Dipole Antenna at Boresight, Measured from 50 to 175 MHz at 101 Points.

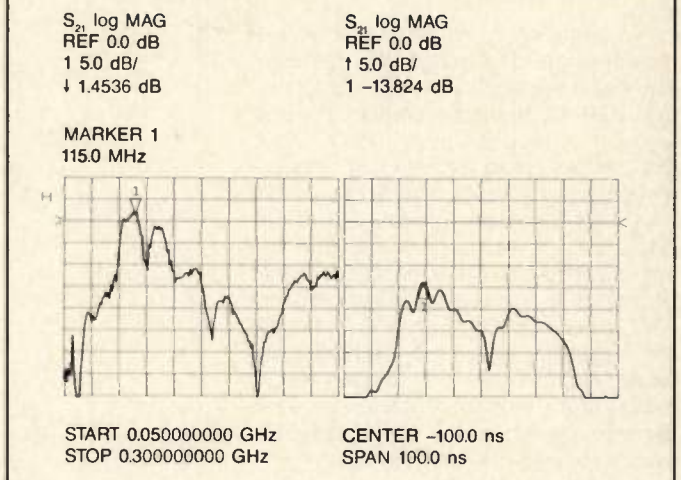

Figure 3. Frequency and Time Domain Responses of Dipole Antenna at Boresight, Measured from 50 to 300 MHz at 201 Points.

8510A network analyzer, a synthesized source (HP 8340A or 8341A) and the HP 8511A frequency converter (test set). The source and test set are controlled by the network analyzer via the HP 8510 system bus. The output of the source is sent through a coupler to the source antenna. The secondary output of the coupler is used to provide the reference signal which is sent back via low loss cable to the HP 8511A. The signal received by the antenna under test is also input to the HP 8511A, and the HP 8510 is set up to display the ratio of the test and reference signals.

To illustrate the gating measurement technique with the HP 8510, consider measuring a dipole antenna (Scientific Atlanta model 15-115). The dipole antenna is particularly difficult to measure because its radiation pattern is only slightly directional in azimuth (with a figure-eight shape) and omnidirectional in elevation. Therefore, the dipole picks up reflections from almost every direction and is particularly sensitive to reflections from the ground. Because of its sensitivity to ground reflections and because it has a calculable (1) radiation pattern with which to compare measured results, the dipole antenna is a good device to test out the new measurement procedure.

The standard way to characterize the far-field radiation pattern of an antenna is to make the measurement at a single (CW) frequency as the positioner is rotated. However, in order to generate a time domain response, the measured data must be taken over a span of frequencies. The time domain respresentation of a CW signal is, by definition, a sine wave. In order to generate an impulse response, the measurement frequency span must be inversely proportional to the desired time domain impulse width.

The frequency domain response of the dipole from 50 to 175 MHz and the corresponding time domain impulse response (Band Pass mode) are shown in Figure 2. The antenna was tuned to 115 MHz. The large amount of ripple in the frequency domain response is caused by interference due to reflections from the ground and other reflective objects within the antenna range.

The time domain display shows the measured transmission response of the antenna as a function of time. Because no calibration was used in this measurement to balance out the phase difference between the test and reference signal paths, the absolute location of the time domain response is somewhat arbitrary. Because the reference signal is routed through cable and the test signal travels a shorter distance through air, the difference in electrical length causes the time domain response to arrive in negative time. However, it is the relative path difference between the time domain responses that is most useful.

Identifying the Time Domain Responses

The plot in Figure 2 shows two major time domain responses that are separated in time by 33 ns, which corresponds to a physical separation of 9.89 m. The first time response is that of the main path signal, and the second response is that of the signal reflected from the ground plane which, because it travels a longer distance, is lower in amplitude and arrives later in time. The 6 dB difference in amplitude between the two responses represents the additional path loss of the reflected signal and also accounts for the large amount of ripple in the frequency domain response.

The required measurement bandwidth and separation between the two responses are determined by the characteristics of the antenna under test. The 50 percent (–6 dB) impulse width of the time domain stimulus is inversely proportional to the frequency span, and for a span of 125 MHz it is calculated (2) to be 9.6 ns. This represents, in the best case, the absolute minimum separation in time that the two responses can have and still be distinguished from one another. However, to use the gating feature effectively to remove the second response, the actual separation should be several times this minimum value to prevent overlapping of the responses.

A second factor to consider, which affects the required separation of the responses, is the bandwidth of the antenna under test. The dipole is a narrow band antenna that has a dispersive phase characteristic which causes its time domain impulse response to be smeared out in time. The result, observable in the time domain responses of Figure 2, is that the actual measured impulse width is more than twice the calculated width.

Figure 3 shows the response of the

same antenna measured over a frequency range of 50 to 300 MHz. Because the measurement bandwidth is doubled, the width of the time domain impulse stimulus is reduced by one half, which results in an improvement in the time domain response resolution. Notice, however, that the overall shape of the two responses is unchanged and that the amount of overlap of the responses is also unchanged. This is because the distributed shape of the response is caused by the dispersive nature of the dipole antenna. This indicates that the only way to decrease the amount of overlap between the two responses is to increase the relative travel time between them by increasing the height of the antenna under test above ground. In this example, there exists some overlap between the two responses, however (as will be demonstrated) they are adequately separated to use the gating feature to remove most of the effects of the second response.

This also indicates that the gating operation can be used to remove only the effects of reflections that are far enough out in time to be beyond the distributed main path response of the antenna. In this measurement, the effect of any signals that are picked up from reflections from the antenna positioner or other close in reflective objects will not be removed. However, the major error is due to the reflection from the ground plane, which is far enough away from the main path response to be removed using gating.

The gating feature of the HP 8510 provides a way to remove the effects of unwanted time domain responses and view in the frequency domain the effects of only those responses that are inside the gate. A gate is a time filter. In Figure 4, the center of the gate is set to the peak of the first time domain response, and the gate span is increased to include all of the first distributed time domain response. With the gate turned on, the second time domain response is removed, and the resulting frequency domain response is that of only the main path signal. As expected, the gated frequency response very closely resembles the ungated response except that the ripple caused by the reflection from the ground plane has been removed.

The two major sources of error in this measurement are the tracking error between the test and reference signal paths and the interference error caused by the signal reflected from the ground. A simple model depicting these measurement errors is shown in Figure 5.

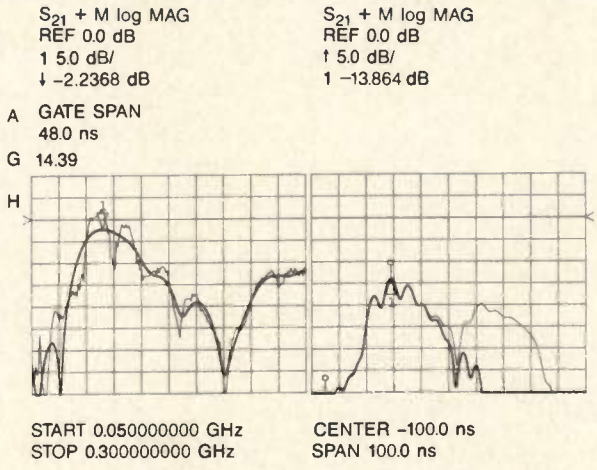

Figure 4. Gated Frequency and Time Domain Responses of Antenna Showing the Removal of the Ground Path Reflection.

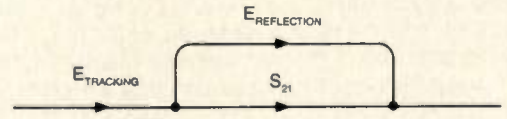

Figure 5. Antenna Measurement Error Model.

The correction for these two errors is accomplished in two steps. The first step is to remove the interference signal (E_{refl}) using gating. Then, assuming that the tracking error (E_{tr}) does not change as the antenna is rotated, it is removed using normalization. The procedure for doing this is as follows:

First, the gated response of the antenna at boresight (main beam) is saved into a memory register of the HP 8510A. Then, as the antenna is rotated, the gated response of the antenna at each angle is normalized to the boresight trace (using the data-divided-by-memory feature of the HP 8510). This gives the response of the antenna relative to the boresight response. Because the tracking error is common to both the measured and stored responses, it is normalized out in the ratio.

To take advantage of the time domain capability of the HP 8510 the measured data must be taken over a sweep of frequencies at each angle of rotation. Therefore, the time to make a pattern measurement is greater with this technique than for a comparable CW measurement. Because of the difference in test and reference path lengths involved the frequency accuracy is critical, and therefore the source (HP 8340A or 8341A) should be operated in the stepped (synthesized) sweep mode. The sweep time for this mode is 50 ms per point, so for a 201 point measurement each sweep will take approximately 10 seconds. However, in addition to the frequency stability of a synthesizer, the stepped sweep mode has the benefit of allowing up to 128 averages without significantly changing the sweep time, which greatly reduces the effects of measurement noise.

Allowing 10 seconds per sweep, 5 seconds to increment the antenna positioner and 1 second to perform the gating operation and record the data, the measurement time is approximately 16 seconds per positioner setting. For a full 360 degree rotation at 5 degree increments, the total measurement time is approximately 19 minutes. If the frequency data is taken at 101 points (5 second sweep time), the total measurement time reduces to 13 minutes. (If the test and reference channel paths are balanced, it may be possible to use the ramp sweep mode, which would reduce the measurement time to approximately 7 seconds per positioner setting (8 minutes total).)

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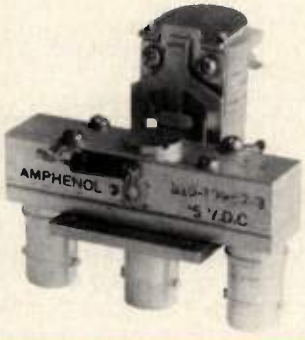

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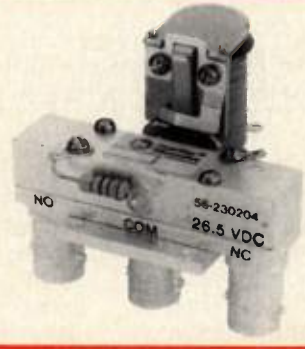

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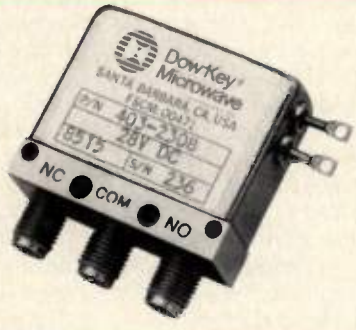

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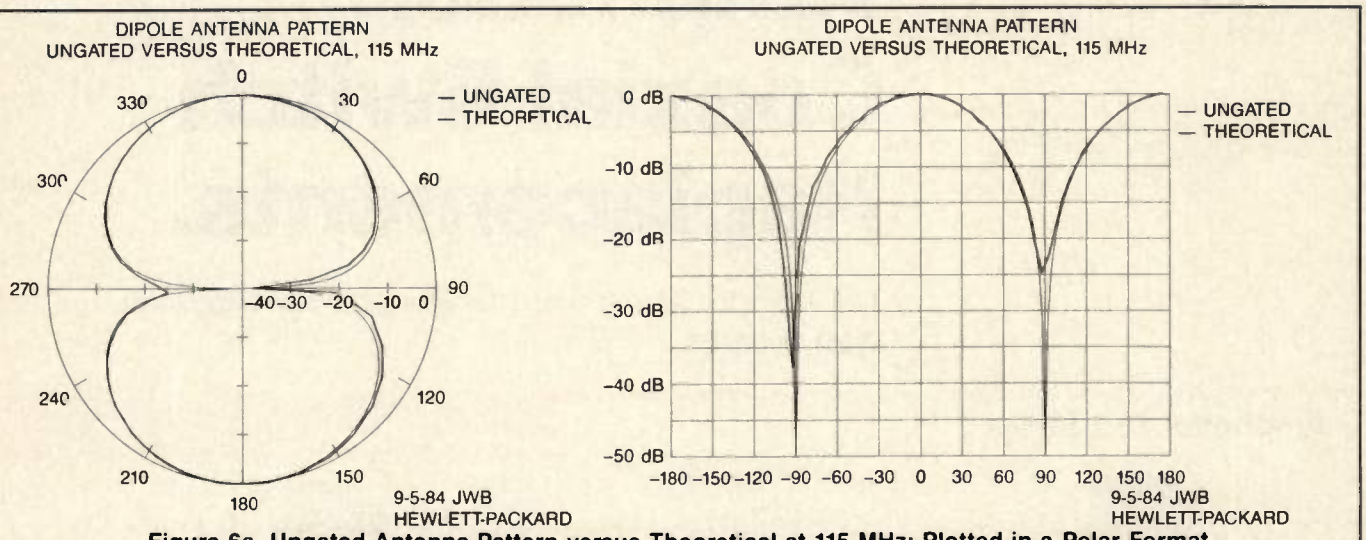

Figure 6a. Ungated Antenna Pattern versus Theoretical at 115 MHz: Plotted in a Polar Format.
Figure 6b. Ungated Antenna Pattern versus Theoretical at 115 MHz: Plotted in a Rectangular Format.

tradeoff for being able to use time domain and gating. If CW frequency testing is desired, the HP 8510 can be used as a CW receiver. However, although the swept frequency measurement technique requires additional time, the radiation pattern of the antenna at 201 frequencies of interest from 50 to 300 MHz can be plotted after only one rotation of the antenna positioner, and the improvements derived from gating more than offset the additional test time.

Measurement Results

The dipole was measured with 201 points from 50 to 300 MHz at each 5 degree increment of azimuth rotation (72 sets of 201 point data). The radiation pattern of the dipole was measured at several frequencies, and both the gated and ungated responses were compared with the theoretical response. (Because the antenna was boresighted visually, the measured antenna patterns were plotted with a small offset angle to correct for the resulting misalignment.)

Fig. 6 shows the measured radiation pattern of the dipole at 115 MHz with no gating, plotted in a log scale with the theoretical pattern. This is the CW measurement. The difference between the theoretical and the ungated pattern is due primarily to the reflected signal from the ground that causes the uneven sidelobes and offset nulls.

Fig. 7 shows the same measured pattern using gating to remove the effects of the ground plane reflection, plotted together with the theoretical response in a log scale. The gated response is virtually identical to the theoretical response with an average disagreement of only 0.18 dB. This improvement in antenna pattern measurement accuracy is due only to gating. (The measured antenna pattern is plotted point to point at 5 degree increments, and because of the offset in alignment the actual nulls at 90 and 270 degrees were not measured.)

A more dramatic improvement in the antenna pattern occurred at 125 MHz. At this frequency, the effect of the ground path interference was more severe. Fig. 8 shows the ungated response. In this conventional CW plot, there is very little resemblance between the measured pattern and the theoretical pattern. Fig. 9 shows the measured antenna pattern obtained using gating. In this case, the gating technique has improved the measurement of the nulls by better than 25 dB.

Fig. 10 shows the antenna pattern measured at 100 MHz without using gating, and Fig. 11 shows the pattern obtained using the gating technique. The improvement with gating is again very dramatic, however at this frequency there is also larger disagreement between the gated and theoretical responses. The gated pattern has a symmetrical shape that is very close to that of the theoretical pattern, however, it also has a rotational offset. The cause of this offset is unknown. Because of the nearly perfect results that were obtained at the resonant frequency (115 MHz), it is assumed that the offset is the result of an imbalance in the antenna at 100 MHz. This would also account for the lack of symmetry in the original ungated (CW) pattern.

In all, the radiation pattern of the antenna at 201 frequencies can be plotted from the data taken from one rotation of the antenna positioner.

Reduced Bandwidth Antenna Pattern

The actual measurement was made with 201 points from 50 to 300 MHz. The first 101 data points (from 50 to 175 MHz) were taken and used to re-compute the antenna pattern of the dipole at 115 MHz using gating. The resulting frequency and time domain responses at boresight are those previously shown in Figure 2. As mentioned, this bandwidth reduction doubles the time domain impulse width which reduces the response resolution, but it also reduces the measurement time. Fig. 12 shows the resultant gated pattern of the antenna at 115 MHz obtained with the reduced bandwidth data. This pattern is virtually identical to the one generated with the wider bandwidth information.

About the Author

John Boyles is an applications engineer for microwave vector network analyzers, Hewlett Packard Network Measurements Division, Santa Rosa, CA 95401. He has a BSEE from North Carolina State University and an MSEE from Georgia Institute of Technology.

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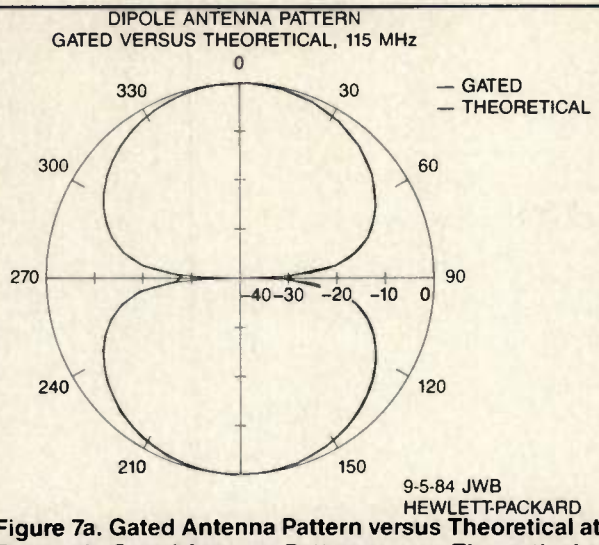
2. *HP 8510 Network Analyzer Operating and Service Manual,* Hewlett-Packard Company, Santa Rosa, CA, 1984, pp.127-149.



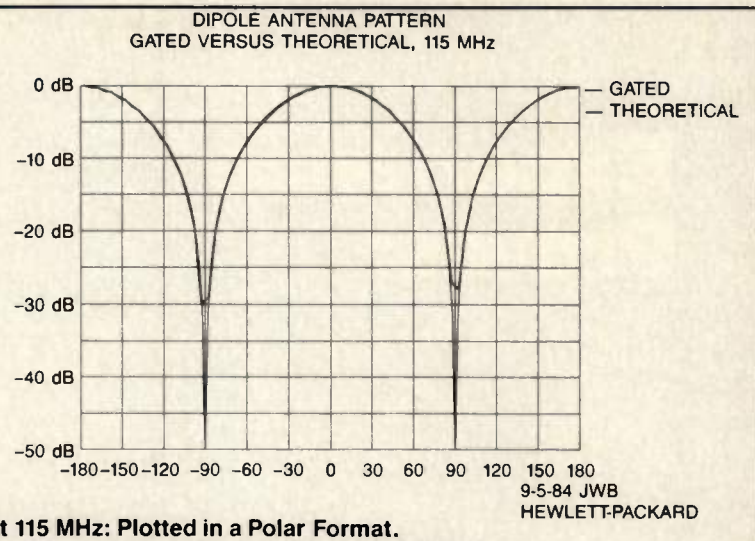
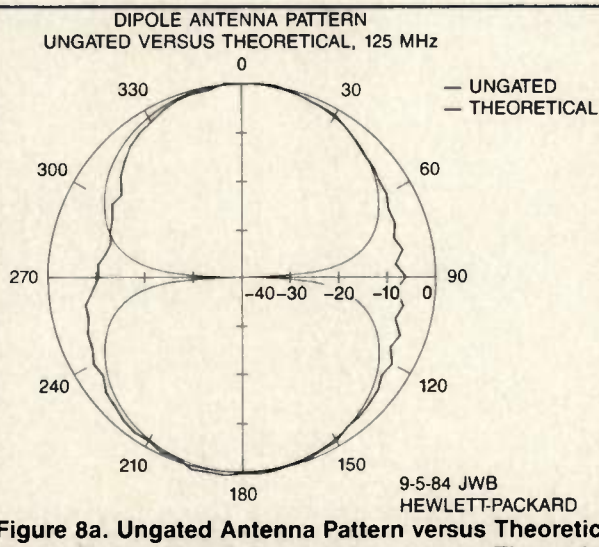


Figure 7a. Gated Antenna Pattern versus Theoretical at 115 MHz: Plotted in a Polar Format.
Figure 7b. Gated Antenna Pattern versus Theoretical at 115 MHz: Plotted in a Rectangular Format.



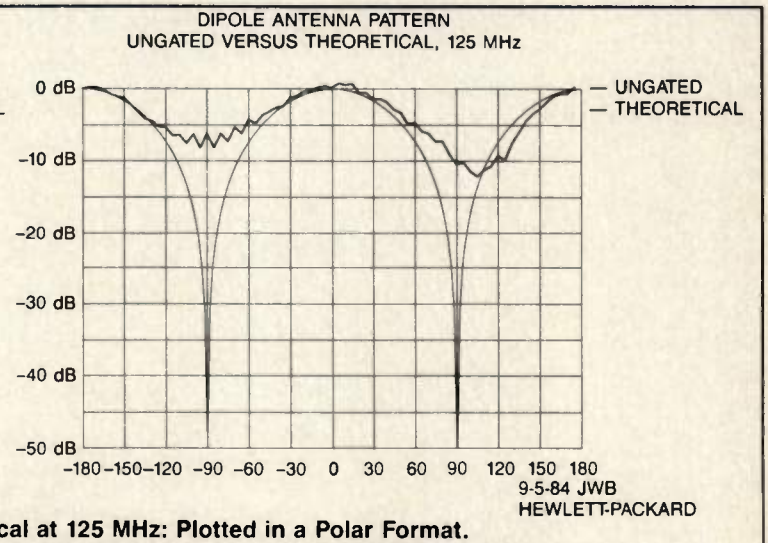
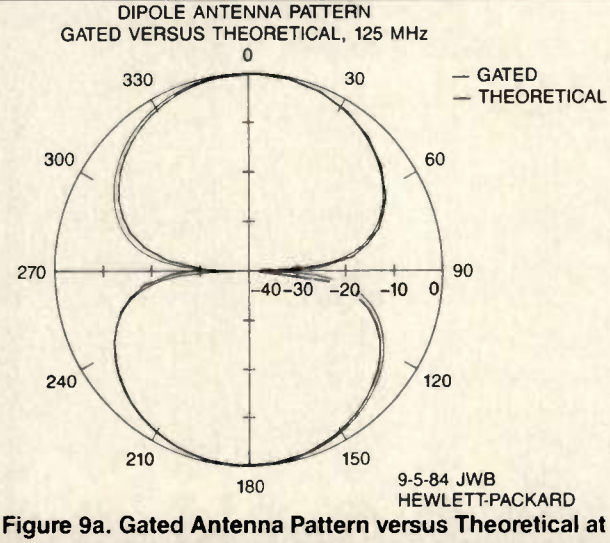


Figure 8a. Ungated Antenna Pattern versus Theoretical at 125 MHz: Plotted in a Polar Format.
Figure 8b. Ungated Antenna Pattern versus Theoretical at 125 MHz: Plotted in a Rectangular Format.



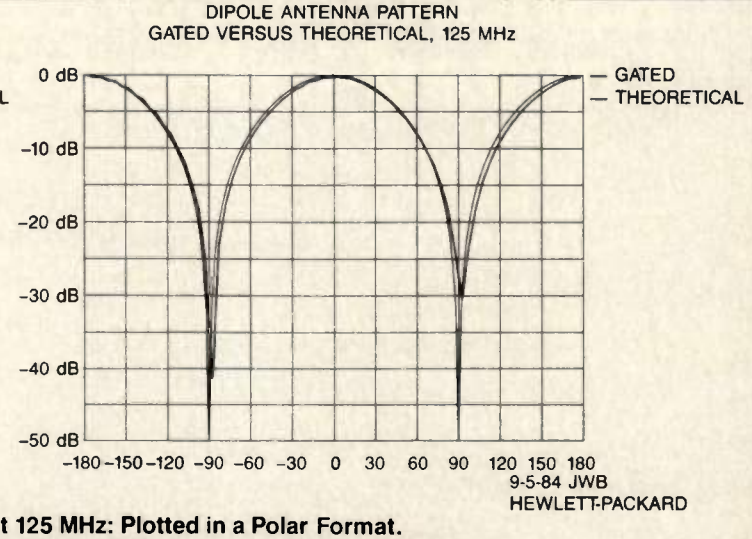
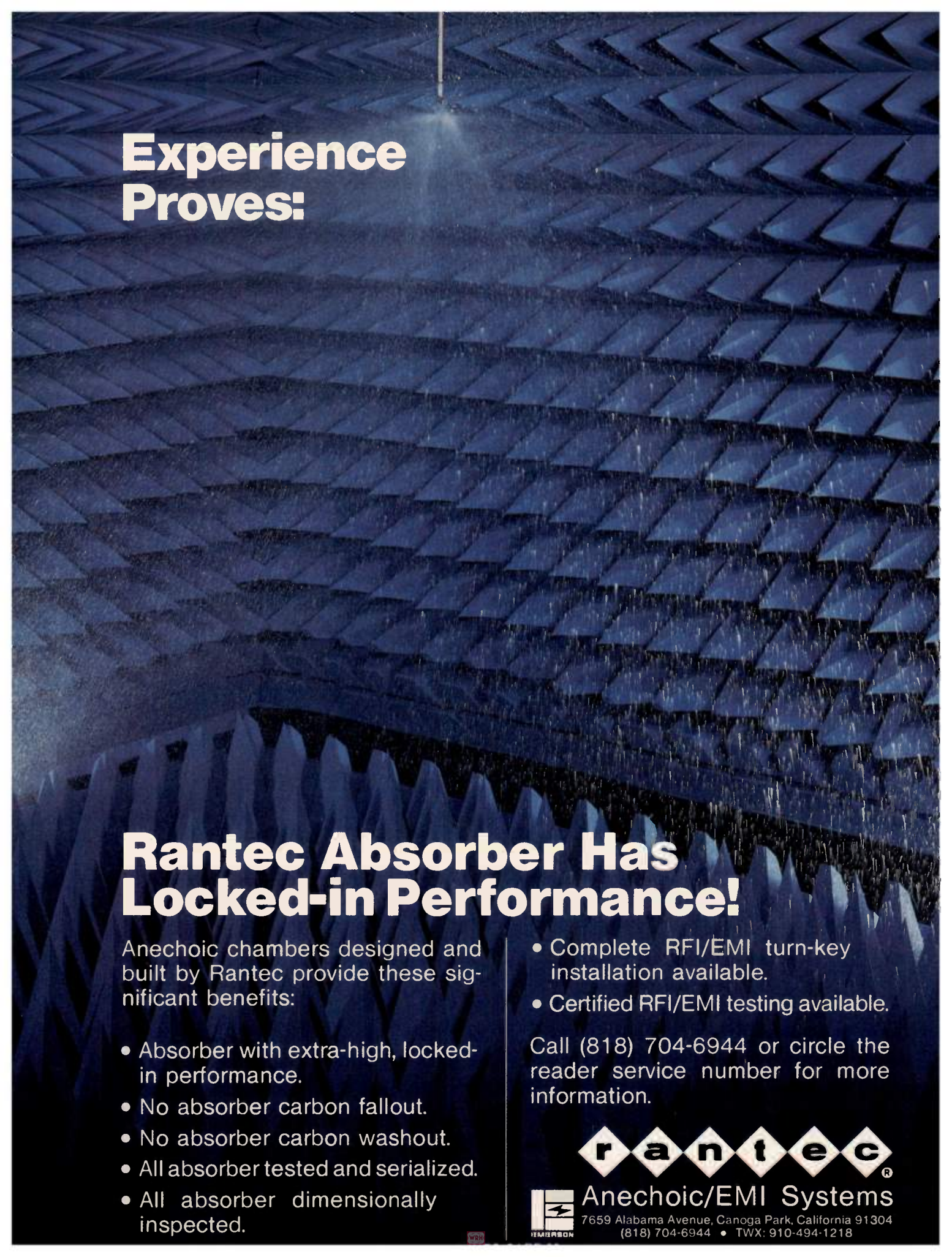


Figure 9a. Gated Antenna Pattern versus Theoretical at 125 MHz: Plotted in a Polar Format.
Figure 9b. Gated Antenna Pattern versus Theoretical at 100 MHz: Plotted in a Rectangular Format.



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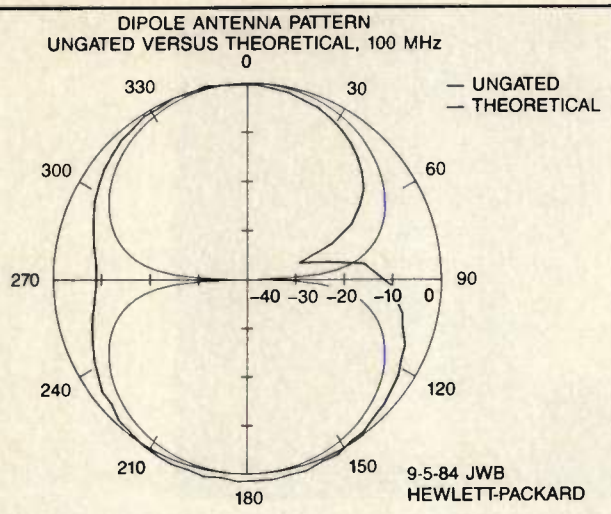


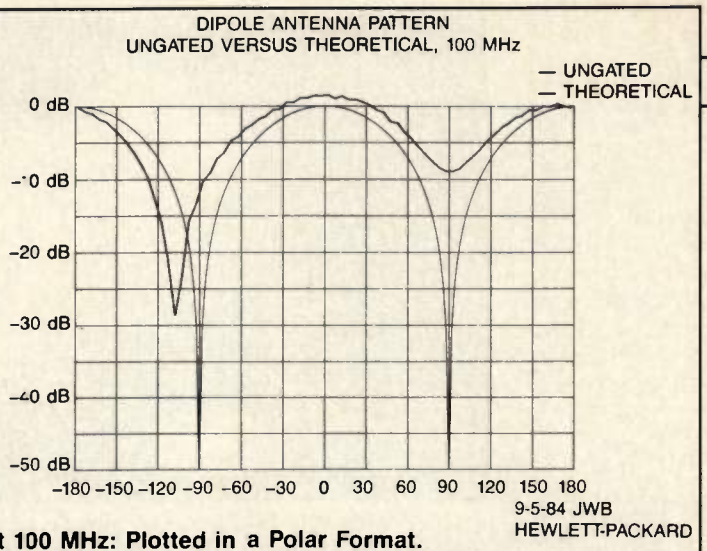
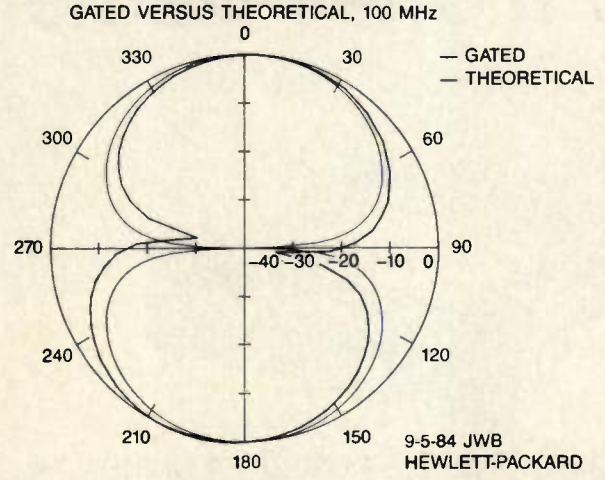


Figure 10a. Ungated Antenna Pattern versus Theoretical at 100 MHz: Plotted in a Polar Format.
Figure 10b. Ungated Antenna Pattern versus Theoretical at 100 MHz: Plotted in a Rectangular Format.



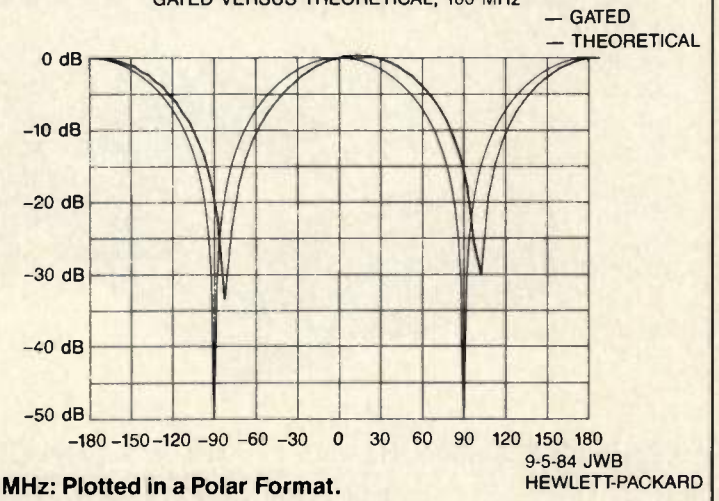
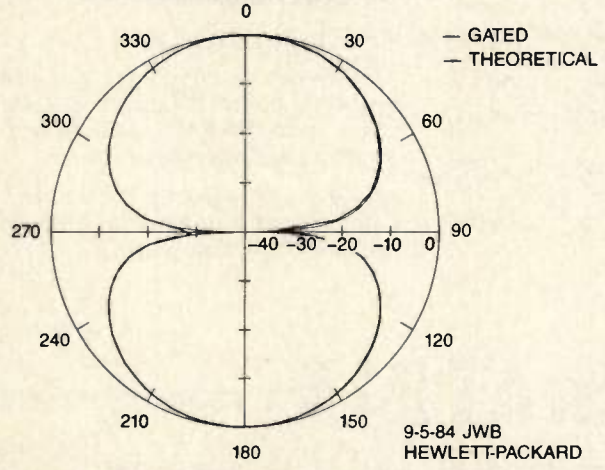


Figure 11a. Gated Antenna Pattern versus Theoretical at 100 MHz: Plotted in a Polar Format.
Figure 11b. Gated Antenna Pattern versus Theoretical at 100 MHz: Plotted in a Rectangular Format.



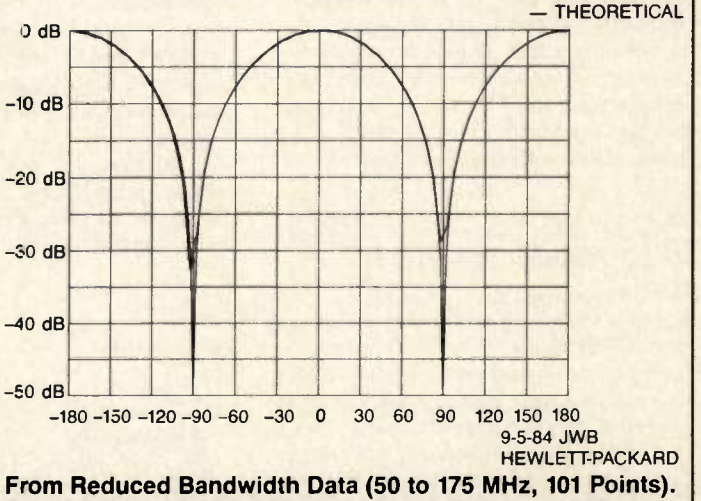


Fig. 12a. Gated Antenna Pattern vs. Theoretical at 115 MHz: From Reduced Bandwidth Data (50 to 175 MHz, 101 Points).
Fig. 12b. Gated Antenna Pattern vs. Theoretical at 115 MHz: From Reduced Bandwidth Data (50 to 175 MHz, 101 Points).

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Specifications

Amplifier Type
Class A Linear All Solid State

Frequency Range
10 KHz — 1000 MHz in two bands

Band 1: 10 KHz — 500 MHz
Band 2: 500 MHz — 1000 MHz

Min. Power Output
10 Watts (40 db (min.) gain)

Harmonic Distortion (Worst Case)
-24 dbc

Input and Output Impedance
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Unconditionally Stable

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Weight
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The M5500: Another One of 'The Dependables' From IFI

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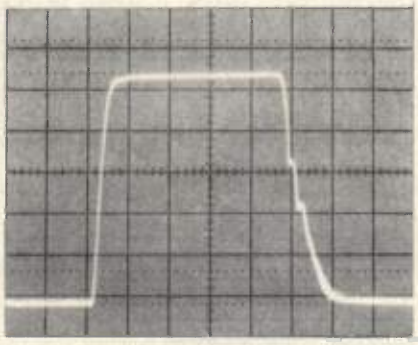

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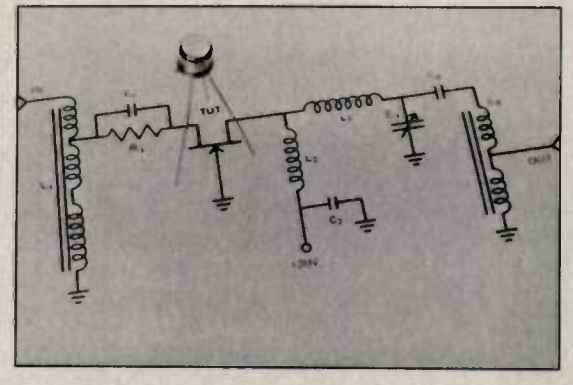

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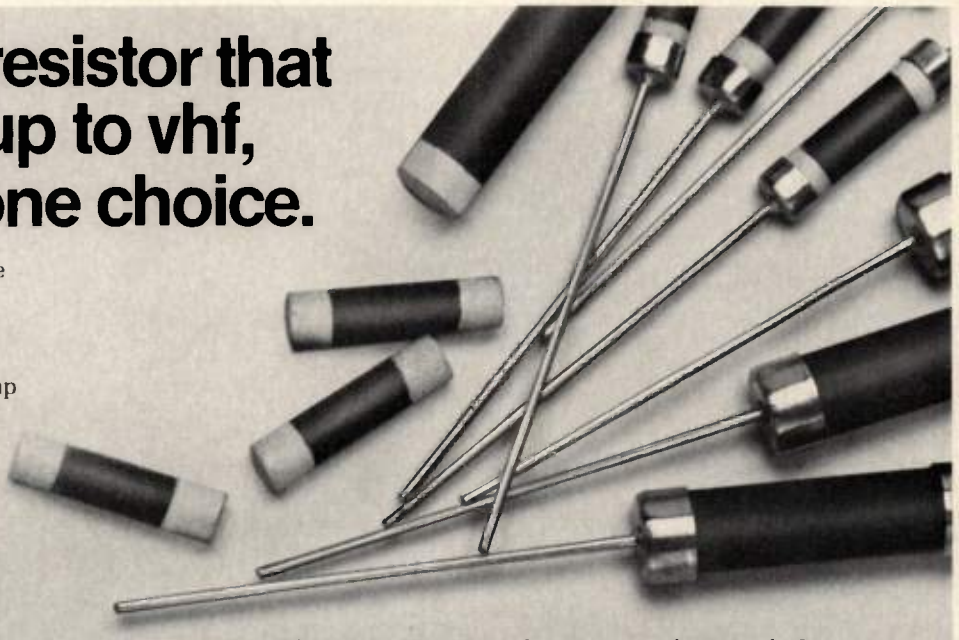

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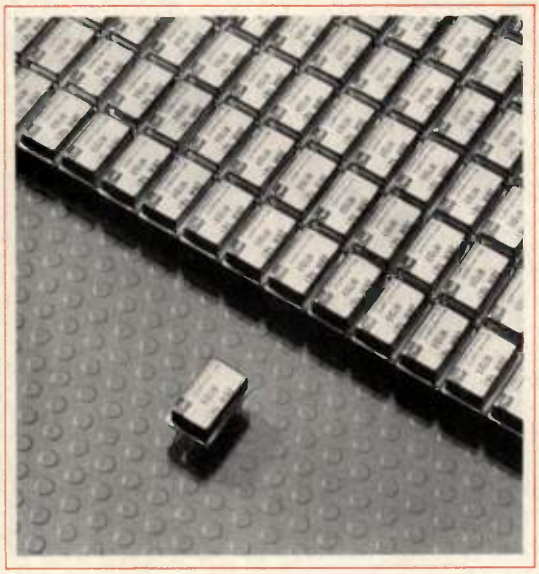

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	Frequency:	1KHz—75KHz	100Hz—100KHz	
	Tolerance:	± .01%, THD ≤5%	± .01%, THD ≤5%	
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TTL CLOCKS Tight Tolerance	Models:	S10C	S10D	S10E
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TTL CLOCKS Stock Frequencies/ Low Cost	Models:	S14R8	S15R8	
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INFO/CARD 36

A New Approach to Op Amp Design

By Scott Evans
Comlinear Corporation

This article describes a high speed op amp topology that offers high frequency performance an order of magnitude faster than conventional op amp designs. One of the results of this design is the elimination of the gain-bandwidth product. Bandwidth remains virtually constant as the gain is changed; as a result, ease of use and predictability of performance have been greatly improved.

Conventional op amps have a differential, high input impedance stage that feeds several subsequent gain stages. The open loop output of the amplifier is $V_o = A(s)[V_1 - V_2]$. (See Figure 1.)

With the feedback connection made, feedback in the form of a voltage is applied to the inverting input. The closed loop gain becomes:

$$\frac{V_o}{V_1} = \frac{\frac{R_1+R_2}{R_1}}{1+\frac{R_1}{A(s)}}$$

By letting $(R_1 + R_2)/R_1 = G$:

$$\frac{V_o}{V_1} = \frac{G}{1+\frac{G}{A(s)}}$$

To see the effect that gain setting, G, has on the frequency response it is instructive to break the open loop gain, A(s), into a ratio of a numerator, N(s), and a denominator, D(s). N(s) contains the zeros of the response and D(s) contains the poles of the response.

$$A(s) = \frac{KN(s)}{D(s)}$$

where K is the DC value of the open loop gain.

Substituting this ratio into the closed loop gain and rearranging:

$$\frac{V_o}{V_1} = G\,\frac{KN(s)}{KN(s)+(G)D(s)}$$

G not only scales the magnitude of the gain (as desired) but also multiplies the effect of D(s) on the closed loop response. The locations of the closed loop poles are now a function of G; thus, if an application requires a large G, the poles will be at a lower frequency than for a low value of G. This is the chief failure of conventional high speed op amp designs. This is a major cause of instability problems in conventional op amps, correcting the problem leads to performance far inferior to data sheet specifications.

Figure 2 shows the closed loop frequency response of a conventional single-pole op amp for various gains. Notice that increasing the gain decreases the bandwidth.

In addition to poor high frequency performance, there are several other severe problems with conventional op amp design.

Compensation — Conventional high speed op amps are instable at most gain settings so compensation must be used. Compensation creates a very low frequency pole that limits bandwidth so severely that the problematic high frequency poles are no longer dominant. Unfortunately, compensation does not allow complete control of the pole and zero locations, so simultaneously optimizing bandwidth, gain flatness and settling time is difficult if not impossible.

External Compensation — Compensation is usually connected external to the amplifier so the designer can tailor the response to the application. Unfortunately, conventional op amps are very sensitive to stray reactance in the PC board layout, temperature, loading and variations in the transistors of the op amp itself that make reliable compensation difficult. In addition, production can become expensive since each op amp compensation network must be individually "tweaked" to the desired response or the op amps must be individually tested and selected.

AC Feedforward — In order to achieve faster rise times and wider bandwidths, conventional op amps often use a technique called AC feedforward. This techni-

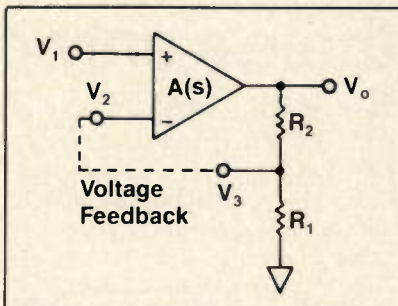

Figure 1. Open loop output

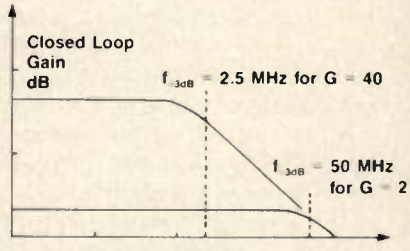

Figure 2. Closed loop frequency response of a conventional single-pole op amp.

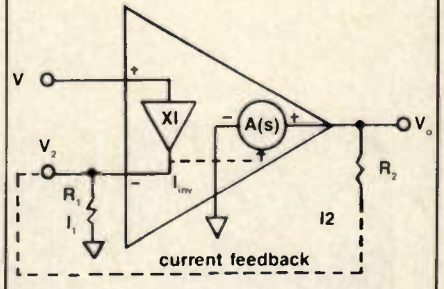

Figure 3. The Comlinear op amp

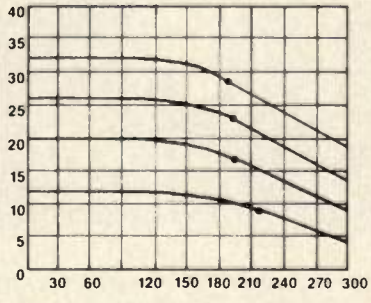

Figure 4. Gain vs. frequency response of the Comlinear op amp.

que cancels a low frequency pole by introducing a zero at the same frequency. Unfortunately, temperature, aging, loading and supply voltages affect pole locations. Pole locations also change with gain setting so the degree of cancellation depends on gain. This is part of the reason why conventional op amp performance is usually specified at a gain of –1. At this gain, the performance is optimal, but it deteriorates rapidly at other settings.

Slew Rate Limiting — In order to obtain high open loop gain, several internal gain stages must be used. As a result, transmit times through the amplifier are large. In addition to reducing the phase margin this also leads to problems when large or fast rise time signals are present at the input. These large or very fast signals can cause an internal gain stage to saturate or be cut off before feedback can propagate back to the input to reduce the error signal. To prevent this behavior the slew rates of the internal stages are simply limited so nonlinear behavior cannot occur before the signal propagates through the amplifier. Consequently, the slew rate and large signal bandwidth of the op amps are reduced severely.

The Comlinear Innovation

Most of the problems with conventional op amps shown are either directly or indirectly caused by the limitation of having G, the gain setting, affect the frequency response. If G could be removed from the denominator of the expression, performance and ease of use could be extended dramatically. This is exactly what Comlinear designers have done. The drawing of the Comlinear op amp (Fig. 3) shows an unusual (and patented) circuit configuration.

The input buffer is a unity gain voltage amplifier that is connected across the inputs of the op amp. In operation, the buffer forces V_2 to equal V_1 *independent of any external feedback through* R_2. This causes the inverting input to have a very low input impedance. When feedback around the loop is applied, the impedance of this node is reduced further and V_2 becomes a "virtual ground" with respect to V_1. This low impedance allows current to flow easily into or out of the inverting input.

The transimpedance amplifier is the gain block inside Comlinear op amps. In operation, the transimpedance amplifier senses the inverting input current (literally the current flowing into or out of the inverting input) and transforms this current into the output voltage. The transfer function of this transimpedance amplifier is A(s); the units are in ohms.

Feedback in the form of a current is applied through R_2 to the inverting input.

A Comparison: Conventional vs. Comlinear

Table 1 shows the mathematical justification of the Comlinear op amp design. As a result of these mathematical operations the closed loop gain equations are in the same form and can be compared directly.

For the conventional op amp:

$$\frac{V_o}{V_1} = G\,\frac{KN(s)}{KN(s)+(G)D(s)}$$

For the Comlinear op amp:

$$\frac{V_o}{V_1} = G\,\frac{KN(s)}{KN(s)+(R_2)D(s)}$$

R_2 has replaced G in the frequency-dependent portion of the transfer function. Since R_2 can be held constant, whereas G cannot, the pole locations and hence the performance can be held constant. ($G=1+R_2/R_1$, so the gain setting can be varied by changing R_1).

The results of this new approach to op amp design are dramatic:

Elimination of the Gain-Bandwidth Product — The frequency response of the Comlinear op amp changes very little when the gain is increased by a factor of 10, from a gain of 4 to a gain of 40. Other specifications are similarly unaf-

The Fallacy of the Gain-Bandwidth Product

The gain-bandwidth product has for years been a key specification for op amps; in fact, the concept of the gain-bandwidth product is a major topic of op amp tutorials. Unfortunately, this often touted specification means little to the engineer who must work with very high speed op amps. For most high speed op amps the gain-bandwidth product is actually very misleading.

The basis for the gain-bandwidth product is the assumption that the open loop gain rolls off due to a single pole. When the assumption is valid, as is the case with some low frequency op amps, the gain-bandwidth product concept is also valid. Having frequency performance depend on gain is troublesome, but at least with a single pole rolloff the bandwidth is easily determined and stability is assured. High speed op amps, however, have several poles before unity gain crossover is reached.

Clearly, a conventional op amp with a gain-bandwidth product of 1 GHz will not yield a bandwidth of 500 MHz at a gain of 2. This is why most manufactures specify their gain-bandwidth products at very high gains, typically 1000.

A much more useful (and accurate) way to show frequency performances is to actually show the performance for various gains. This allows the engineer to fully characterize the amplifier without having to actually test the device. Although the performance of Comlinear amplifiers varies little with changes in gain, Comlinear provides complete specifications for at least three representative gain settings.

$$I_{inv} = I_2 - I_1$$

$$I_{inv} = \frac{V_2}{R_1} - \frac{V_o - V_2}{R_2}$$

Then, since $V_o = I_{inv} \cdot A(s)$ and $V_2 = V_1$ (because of the buffer)

$$\frac{V_o}{A(s)} = V_1\left(\frac{1}{R_1} + \frac{1}{R_2}\right) - \frac{V_o}{R_2}$$

Then, rearranging

$$\frac{V_o}{V_1} = \frac{\frac{R_1 + R_2}{R_1 \bullet R_2}}{\frac{1}{R_2} + \frac{1}{A(s)}} = \frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_2}{A(s)}}$$

Again, letting $1 + \frac{R_2}{R_1} = G$

$$\frac{V_o}{V_1} = \frac{G}{1 + \frac{R_2}{A(s)}}$$

Letting $A(s) = \frac{KN(s)}{D(s)}$

$$\frac{V_o}{V_1} = G\,\frac{KN(s)}{KN(s) + R_2 D(s)}$$

Table 1. Mathematical justification of the Comlinear op amp design.

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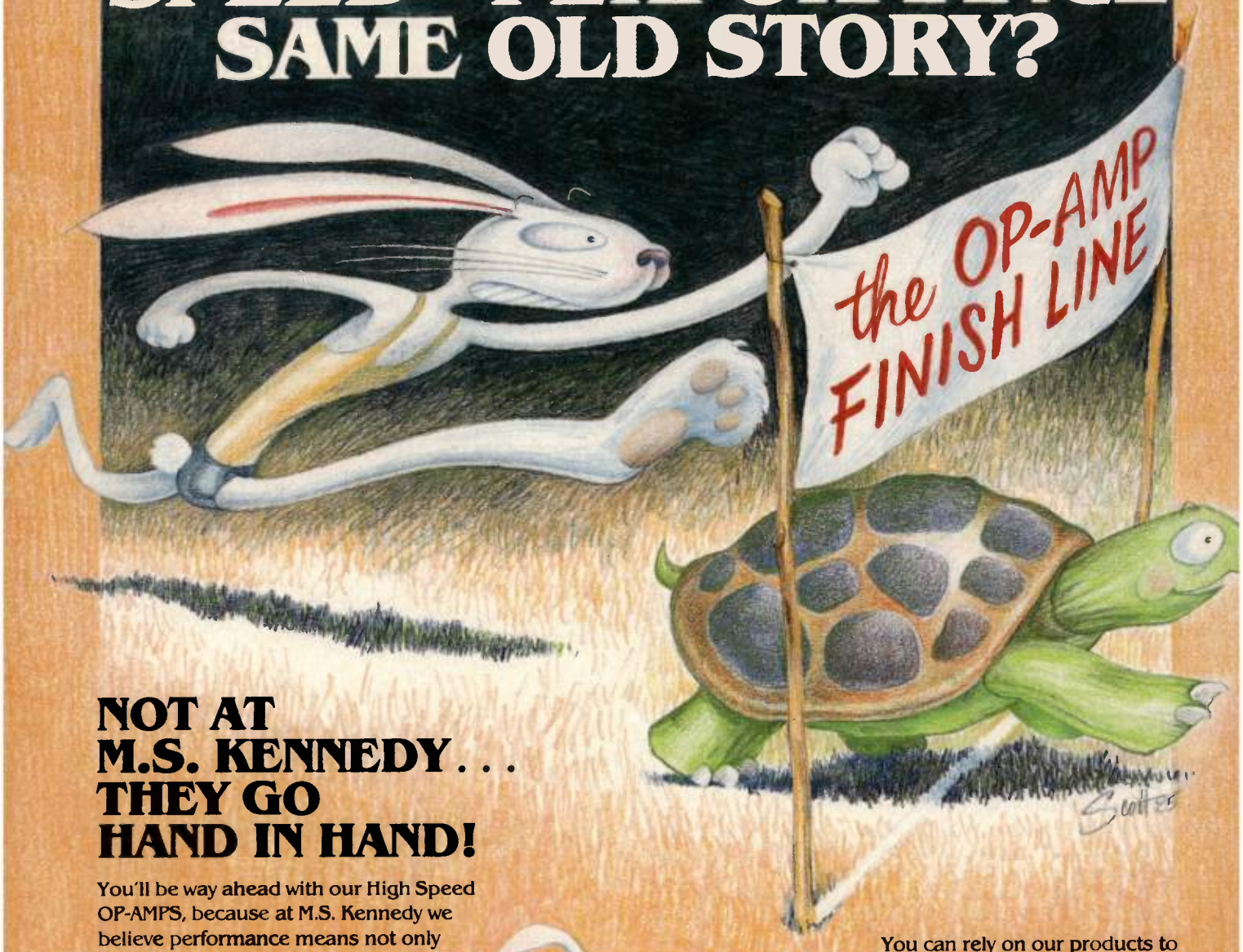

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fected by gain changes. A similar change in gain with a conventional op amp could reduce the bandwidth by a factor of 10, even under ideal single pole conditions. As shown in Figure 4, the –3dB bandwidth remains constant over a wide range of gains. Small second order effects explain the slight deviation in performance from that predicted by the equations.

Excellent Performance — The high speed performance of Comlinear op amps is dramatically better, usually by an order of magnitude, then conventional op amps. A typical rise time for a 5V output step can be as low as 1.6 ns, for example. With a conventional op amp rise times of 30 to more than 100 ns are common. Other outstanding specifications include settling times which can be as low as 10 ns for a 0.2 percent tolerance and slew rates that range from 3000 V/μs to over 7000 V/μs, depending on which model is chosen. (The slew rate was intentionally kept very fast so it would not limit the response of the amplifiers under large signal conditions. Bandwidth, not slew rate, controls amplifier response and keeps it linear.)

Linear Phase — Although phase linearity is a rarely mentioned specification, it is very important for signal fidelity. Comlinear op amps have excellent phase linearity, usually the deviation from linear phase is less than two degrees from DC to over 50 percent of the bandwidth. Conventional op amps, however, must use techniques like AC feedforward which increase bandwidth but degrade phase linearity; thus, signal fidelity is sacrificed.

Predictable Performances — Since most of the specifications are virtually independent of gain setting, the performance of Comlinear op amps remains consistent even with varying circuit configurations. As design requirements change, adjustments in gain usually can be achieved by a change in one resistor; with a conventional op amp a change in gain could require a redesign of the entire circuit.

Internal Compensation — With R_2 fixed and the poles of the frequency response consequently fixed, internal compensation is provided to simultaneously optimize bandwidth, settling time, linearity and distortion. Since the compensation is internal, Comlinear op amps can save time and money in production with no compensation networks to "tweak." Although Comlinear uses an internal high precision resistor for R_2, on many models an external resistor of another value can be used. Since this would change the pole locations, the internal compensation is made accessible to the user through one package pin. One external capacitor is then used to re-optimize the performance.

Standard Usage — Determining the gain for Comlinear op amps is the same as that for conventional op amps, where $G=1+R_2/R_1$. The same ease of use applies equally well to both inverting and differential configurations.

About the Author

Scott Evans is a product marketing engineer for Comlinear Corp., P.O. Box 20600, 4800 Wheaton Drive, Fort Collins, CO 80522. His telephone number is (303) 226-0500.

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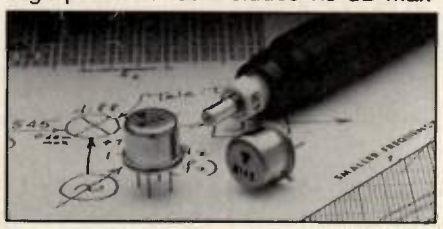

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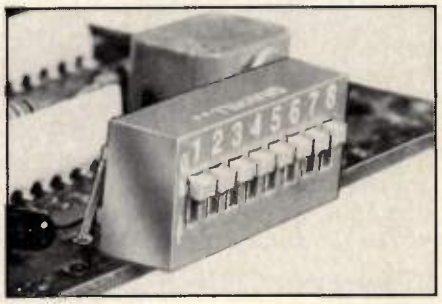
system to allow maximum power to be delivered into any load VSWR. System status and control lines can be accessed via rear panel connection. **American Microwave Technology, Inc., Fullerton, Calif., INFO/CARD #157.**

Precision Laboratory Attenuator

Alan Industries, Inc., now offers a low cost precision laboratory attenuator for measuring receiver sensitivity, signal noise ratio and cross modulation. The first model, the 50BLA20, has a frequency range of DC-300 MHz, VSWR is 1:20 max, and accuracy is ±0.2 dB or 2 percent indicated measurement. Other specifications include impedance, 50 ohm nominal; insertion loss, .6 dB max.; power average, 1 watt; available connector BNC, TNC and SMA and an attenuation range of 0-20 dB in 1 dB steps. Other attenuation ranges of 30, 40, 50 and 60 dB are available. **Alan Industries, Inc., Columbus, Ind., INFO/CARD #159.**

Front Panel Access Dip Switch

Grayhill, Inc., has developed a unique terminal frame allowing front panel access for standard DIP switches normally back panel mounted. When edge mounted on a PC board that is perpendicular to the panel, Grayhill right angle



DIP switches can be operated through a panel cutout. The right angle DIP switch has grown in popularity due to an increasing variety of equipment functions that must be checked before actual operation. **Grayhill, Inc., La Grange, Ill., please circle INFO/CARD #143.**

Microminiature D Series Connector

With contact spacing of 0.050" the Series 50 Micro D Family of connectors from AMP Incorporated is a scaled-down version of the self-polarizing subminiature D connectors. Designed to meet the requirements of MIL-C-83513, the connector is available in eight shell sizes, ranging from 9 through 100 contact positions. All contacts are fully potted and connector assemblies are supplied with flying leads or solid solder posts in either metal shell or all-plastic housings. **AMP Incorporated, Harrisburg, Penn., please circle INFO/CARD #162.**

Hybrid DIP VCXO

The CO-400V Series Hybrid VCXOs are designed specifically for phase locking applications. They provide TTL output at any specified center frequency from 32 kHz through 24 MHz. Deviation over 0 to +5V control voltage ranges from ±30 ppm to ±100 ppm; this deviation is adequate to permit locking onto the specified center frequency over the operating environment (0/50°C to −55/+85°C) for 10-20 years without adjustment. These 0.2" (5.1 mm) high DIP packaged oscillators are available in both 4-pin (Model CO-401V) and 14-pin (Model CO-402V) configurations. They conform to MIL-O-55310 and are available level B screened. The

resistance welded case meets 10-8 atm/cc fine leak testing per MIL-STD-883, while the rugged 3-point mount crystal results in sine and random vibration levels exceeding 20g to 2 kHz. **Vectron Laboratories, Inc., Norwalk, Conn., please circle INFO/CARD #147.**

Precision Test Connectors and Adapters

Gilbert Engineering's GPC-7 (an improved 7mm connector) is a new contact design precisely manufactured and tested to maintain contact forces which assure repeatability during precise calibrated measurements. The contact can be easily removed, cleaned and replaced without damage. A replacement contact is also available. VSWR is 1.003 + .002 (F) GHz per IEEE 287 specification. **Gilbert Engineering, Phoenix, Ariz., please circle INFO/CARD #146.**

Semi-Adjacent Bandpass Filter for the Hyperband

The 4930 (channel) is available for any hyperband channel AA-YY (300-450 MHz). It passes the specified channel

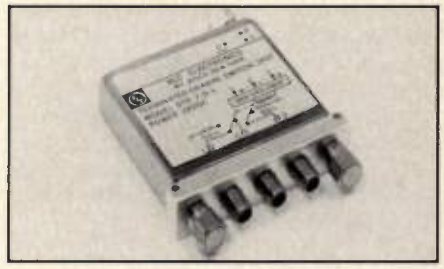
with a 2.0 dB maximum loss and rejects the semi-adjacent channels (2nd channel down and up) a minimum of 25 dB. This bandpass filter can be used to clean up the desired channel at the input of the processor or at the output before combining. Impedance is 75 ohms and the 4930 comes with F connectors. **Microwave Filter Company, Inc., East Syracuse, N.Y., INFO/CARD #145.**

Microwave Synthesis and Analysis Software

EEsof, Inc. announces the release of Linecalc™, the newest product in their expanding line of integrated engineering software. Linecalc is an analysis and synthesis program which provides microwave circuit designers with new ways to explore and adjust values of transmission line parameters. It works like a spreadsheet and provides highly reliable analysis and synthesis of transmission lines. The program uses the same transmission line models as Touchstone™, EEsof's computer-aided analysis and optimization program, to ensure consistent performance. Linecalc analyzes physical parameters and displays the corresponding electrical parameters. The program also synthesizes physical parameters after the engineer specifies the desired electrical parameters. **EEsof, Westlake Village, Calif., INFO/CARD #143.**

Coaxial Switches

RLC Electronics has introduced a line of terminated single-pole, double-throw coaxial switches for termination of the unused switch port. Electrical characteristics feature low insertion loss and .3 dB



max., VSWR of 1.3 max. and isolation of 60 dB min. over the entire frequency range of DC-18 GHz. **RLC Electronics, Inc., Mt. Kisco, N.Y., INFO/CARD #146.**

Line Impedance Stabilization Networks

Fischer Custom Communications, Inc. announces a new Line Impedance Stabilization Network developed for conducting EMI measurements in accord with FCC and CISPR standards. This new LISN is available in currents of 25, 50 and 100 amperes, and can be used for long periods of time without excessive heat generation. The shielded unit contains two LISN networks, providing the user with the capability of measuring a phase and neutral or two phases of a powerline. **Fischer Custom Communications, Inc. Inglewood, Calif., INFO/CARD #144.**

MDS/ITFS Video/Aural Combiner

Series 4869 diplexers combine separate video and aural transmitters to a common antenna output. The design technique used results in high isolation and low insertion loss. Insertion loss for video and aural is .25 dB (max.) and 1.5 dB (max.) respectively. Video/aural isolation is 30 dB (min.). Power relay is 100 W minimum. Input and output connectors are 50 ohm, type N, female. The 4869 is available for any MDS channel (2150 to 2162 MHz) or ITFS channel group A through H (2500 to 2686 MHz). **Microwave Filter Company, Inc., East Syracuse, N.Y., INFO/CARD #141.**

4-Input, 8-Trace, 200 MHz Oscilloscope

Iwatsu Instruments has added a new high quality 4-input, 8-trace DC to 200 MHz oscilloscope to its SS-5700 Series. This dual trace unit, Model SS-5712 is designed to handle fast digital signals, stresing the basic characteristics of wider than specified frequency response, highly

accurate deflection factor and sweep rate, plus excellent linearity. For digital diagnostics, the SS-5712 offers an optional 4-bit combination trigger probe, which can specify 16 trigger conditions and extract the required sequence from a digital circuit when testing the right conditions of a microprocessor. **Iwatsu, Carlstadt, N.J., INFO/CARD #151.**

Four-Section MIC Step Attenuator

A new Four-Section MIC step attenuator with 1, 2, 4 and 8dB bits is available from Daico Industries, Inc. Frequency range of 300-1300MHz is covered with typical switching speed of 300 nanoseconds. This device has an internal TTL driver and operates on +5 V at 40mA maximum DC supply. Other key parameters include insertion loss 2dB typical, VSWR 1.2/1 typical, 50 ohm impedance and +10dBm RF power handling. Operating temperature is −55 to +125°C. **Daico Industries, Inc. Compton, Calif., INFO/CARD #133.**

Microstrip Circuit Design Software

MICRO is an engineering program written for the microstrip designer. MICRO provides the microstrip designer with the ability to analyze and design microstrip circuits. With MICRO you can design

rf products *Continued*

lowpass or bandpass filters, stepped impedance transformers and hybrid rings. MICRO will also analyze or synthesize single or coupled strips and at extreme S/H or W/H will perform a Bryant and Weiss analysis using a dielectric Green's function for better than 1% accuracy. All the synthesis programs in MICRO contain correction factors for fringing field errors and bandwidth shrinkage to provide you with a "real world" design the first time. **THS Engineering, Escondido, Calif., INFO/CARD #100.**

Coaxial Crystal Detectors

The new Micronetics coaxial crystal detectors cover a frequency range of 0.01 to 12.4 GHz and a frequency response within ±0.5 dB absolute. Relative matching excluding bias sensitivity, is within ±0.2 dB. Other specifications include; output impedance, 15 ohms shunted by 10 pF; output polarity, negative (positive optional); connectors, RF input, type N, male; VSWR, values to 12.4 GHz maximum, maximum power, 100 mW peak or coverage. **Micronetics, Inc., Norwood, N.J., INFO/CARD #101.**

Precision Analog Array Family

Solitron Devices, Inc. has announced the development of the first precision analog array family in the industry. Identified as the HTL Series, the devices offer a variety of components including precision thin-film laser trimmed resistors. The typical degree of precision is ±0.005% with a temperature coefficient of 35 PPM/°C. Certain arrays in the family offer a selection of high current components ranging from 0.5A to 5A. The HTL Series is designed for use in military, aerospace, telecommunication, medical and precision industrial applications such as precision op amps, precision references, analog/digital circuits and high current drivers. **Solitron Devices, Riviera Beach, Fla., INFO/CARD #102.**

Ultra Broadband Noise Generating Instrument

Noise Com's Model NC6111 Noise Generating Instrument has 24 octave wide, +10 dBm of Gaussian-white noise within -2.5 dB flatness. It operates from 115 V line voltage at temperature range -10°C to +60°C. It has an output im-

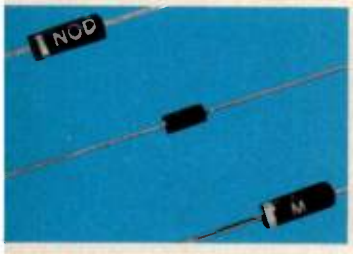
pedance of 50 ohms and the standard unit comes with 10 dB in 1 dB step attenuator. Options are; other attenuator values, 230 V, 50 Hz power-in, resistive power combiner, marker input and higher output levels. **Noise Com Inc., Hackensack, N.J., INFO/CARD #154.**

Voltage Controlled Fundamental Oscillators

The new VCO-100 series of varactor tuned oscillators offer full octave tuning ranges from 25 MHz to 2 GHz in compact TO-8 packages. Model VCO-105 covers 200-400 MHz with a tuning input of 1 to 20 VDC. Power output is +13 dBm into 50 ohms flat to within ±1 dB while power dissipation is less than 180 mW from -55 to +100°C. All units are encapsulated and welded closed for very low microphonic performance in severe military or commercial environments. **Vari-L Company, Inc., Denver, Colo., INFO/CARD #145.**

Microwave Counter makes Automated Measurements Up to 40 GHz

New GaAs technology, combined with the latest concepts in microwave-instrument design, have resulted in a 10 Hz to 40 GHz microwave frequency counter. The HP 5352A offers the same feature set as the HP 5350A (10 Hz-18 GHz) and HP 5351A (10 Hz-26.5 GHz) counters introduced in January. This family of instruments which share the same



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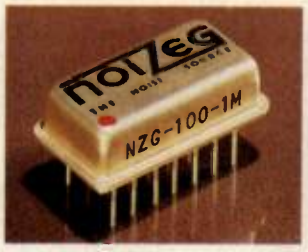


Noise Generators
NZG Series/100 Hz to 5 MHz
Up to 150 mv output/White Gaussian Noise
14 Pin DIP/Small size and weight
Qualified Peak Factor: 5:1 (min)
Frequency Flatness: ± 0.5 DB.

package dimensions, also provides high-speed data transfer, optional low-aging-rate oscillators and a single-input connector for frequency measurements from 500 MHz to the upper limit of each counter. The HP 5352A derives its high-frequency performance from the GaAs sampler first used in the HP 5350A/5351A. The choice of GaAs over silicon (previously used in microwave-frequency designs) was made in anticipation of adapting the design to higher-frequency applications. A GaAs sampler down-converter allows greater control of circuit response. This results in dependable high-frequency characteristics, and, therefore, predictable and repeatable performance at millimeter frequencies. **Hewlett-Packard Company, Palo Alto, Calif., INFO/CARD #156.**

Automatic Test Program Generator

AMS-Advanced MicroSolutions has introduced an Automatic Test Program (ATP) generator designed to automate the process of developing test programs and documentation. With the ATP generator, a test programmer familiar with BASIC language can generate simple ATPs in just a few hours and modify an ATP in minutes. The Generator and ATPs are available for use with the HP 9000 Series 200 Technical Computers and GP-IB (IEEE-488) controllable instrumentation. **AMS-Advanced MicroSolutions, Menlo Park, Calif., INFO/CARD #150.**

High-Speed Silicon-Gate DMOS Analog Switch in Surface-Mount SO-14 Package

The SD5400 family of DMOS analog switches with 1 ns switching time is now available from Siliconix in the surface-mount small-outline SO-14 package. This miniature 14-lead plastic DIP is ideal for hybrid design; it is one-third the size of the standard 14-lead DIP and has been pretested. The SD5400 quad switch array is built on the Siliconix-developed oxide-isolated, silicon-gate DMOS process, which provides greater device stability and reproducibility over metal-gate designs. Available in three grades — SD5400CY, SD5401CY, and SD5402CY — the device is specified for analog signals up to ±10 V, ±5 V, and ±7.5 V, respectively. Drain-to-source leakage current is only 10 nA (maximum), while gate-leakage current is 1 μA (maximum) for all three

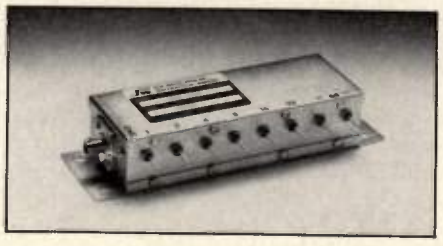
variations. Typical drain-to-source on-resistance is only 50 ohms at a gate voltage of 5 V. The operating temperature range is 0°C to 70°C, and maximum breakdown voltage at 25°C ambient temperature is rated at 20 V for the SD5400CY, 10 V for the SD5401CY, and 15 V for the SD5402CY. **Siliconix, Inc., Santa Clara, Calif., INFO/CARD #155.**

Monte Carlo Analysis Program Offered with Touchstone

Monte Carlo analysis and yield prediction with the capability to vary substrate and measured S-parameters is now available to RF/microwave circuit designers using Touchstone, a computer-aided engineering program from EEsof, Inc. for the IBM PC/XT/AT and HP 200 computers. Manufacturing yield of RF/microwave circuits is projected by selecting certain circuit parameters for random variation. Any parameter that can be optimized can also be used as a toleranced value. For example, tolerances may be assigned to 1- and 2-port S-parameters and 2-port noise parameters to analyze how a random variation in transistor performance affects overall circuit performance. One- and two-port data may be specified as s-, y-, z-, g- or h-parameter data in various formats. EEsof customers who have purchased Touchstone before July 1, 1985 will be sent the Monte Carlo program as part of their software support service. After July 1, Touchstone-MC will be available as an added-cost option to Touchstone. **EEsof, Inc., Westlake Village, Calif., please circle INFO/CARD #154.**

Programmable Attenuator

Specs for Model 50P-076 of JFW Industries are: DC-1000 MHz; 0-127 dB in 1 dB steps; switching speed: 6



milliseconds; connectors; BNC, TNC, N or SMA. **JFW Industries, Inc., Indianapolis, Ind., INFO/CARD #148.**

Main Frame Scope Accepts up to 3 Plug-In Units

Iwatsu Instruments has announced a new, plug-in type general-purpose oscilloscope which allows total flexibility in selecting or changing functions. The SS-8120 accepts up to three plug-in units that provide either a 4-channel 100-MHz oscilloscope, a 4-channel 1-GHz sampling oscilloscope, a 2-channel digital measuring oscilloscope or a 2-channel ultra-high-deflection oscilloscope. The mainframe features a 7 inch dome-mesh CRT and incorporates a character generator so data from the plug-in units can be displayed on the CRT in easy to read values. In addition, the versatility of the SS-8120 is enhanced with signal output terminals provided for the output of vertical signals, timebase signals, gate signals and calibration voltages. **Iwatsu Instruments, Carlstadt, N.J., INFO/CARD #153.**

Bipolar Power RF Transistor

A new high power, class "AB" bipolar RF transistor for military communications and ECM applications is now available from the RF Devices Division of TRW Electronic Components Group. The MRA0204-60 device provides 60 W of CW linear power in broadband applications. Gain is 9.5 dB minimum at 400 MHz and 28 V. The device is usable over a 225 to 400 MHz frequency range. The MRA0204-60 can withstand a 5:1 VSWR load pull at 400 MHz with a power output of 60W. **TRW Electronics Components Group, Lawndale, Calif., INFO/CARD #152.**

Intelligent Impedance and Gain-Phase Analyzer

A new impedance and gain-phase analyzer from Hewlett-Packard Company, the HP 4194A, is an intelligent instrument that makes both impedance and transmission measurements. Frequency coverage is 100 Hz to 40 MHz for impedance measurements and 10 Hz to 100 MHz for gain-phase measurements. The HP 4194A has a 7.5-inch (19 cm) color display for presenting measurement data, making it the first HP instrument with a color CRT. Designed for lab and quality-assurance applications of component manufacturers, and communications and consumer equipment manufacturers, the HP 4194A can be used to evaluate materials, discrete components, ICs and circuits. The analyzer's Auto-Sequence-Program (ASP) function easily can automate the measurement and analysis functions without using a separate computer. **Hewlett-Packard Company, Palo Alto, Calif., INFO/CARD #150.**

Short Form Catalog

A new short form catalog from Ballantine Laboratories, Inc., describes key specifications and features for its broad line of precision electronic test and measuring instruments. Covered are oscilloscopes, both for portable general purpose use and laboratory units; scope calibrators; voltmeters and special purpose instruments; multimeters; counters and counter-timers; and AC calibration standards. Also included are the company's programmable instruments and automated computer-based systems for calibrating oscilloscopes and meters. **Ballantine Laboratories, Inc., Boonton, N.J. INFO/CARD #123.**

Electronics Catalog

The 176-page 1985 edition of the Mouser Electronics Catalog offers over 17,000 items stocked in depth. It serves as an excellent guide for engineers, purchasing agents, or anyone needing quick access to up-to-date product data and pricing of standard stocked industrial electronic components. It includes potentiometers, capacitors, resistors, transformers, lamps, switches, battery holders, jacks, plugs, speakers, knobs, fuses, semiconductors, hardware, tools, test equipment, relays, cabinets, meters and more. **Mouser Electronics, Santee, Calif. INFO/CARD #122.**

Low Pass EMI Filter Catalog

A new 36-page low pass EMI filter catalog is now available from Murata Erie North America, Inc. This new catalog contains complete technical information on the company's high quality EMI filters and filtering systems for MIL spec and other applications. Details on mechanical configurations, electrical specifications and environmental performance are thoroughly discussed. In addition, cross references for Military Part Numbers MIL-C-39014/16, MIL-C-39014/17, MIL-C-39014/18 and MIL-C-39014/19 with Murata Erie part numbers are given. **Murata Erie North America, Inc., Marietta, Ga. INFO/CARD #121.**

Surge and ESD Handbooks

Two handbooks have been announced by KeyTek Instrument Corp., to help modern electronic equipment survive powerline and dataline surges as well as ESD (electrostatic discharge). The Surge Protection Test handbook describes surges conducted via signal lines and the AC power line. The Electrostatic Discharge (ESD) Protection Test Handbook describes ESD itself, prevention techniques and a guide for diagnostic ESD testing. Written in clear basic terms, these handbooks will be helpful to both the experienced engineer and the newcomer to environmental testing. All the necessary information is included to assist a user in hardening his equipment, from the design stage through final acceptance testing. **KeyTek Instrument Corp., Burlington, Mass., INFO/CARD #120.**

Conformal and Molded Axial Leaded Capacitors

AVX Corporation has published a new catalog on conformally coated and molded axial-lead multilayer ceramic (MLC) capacitors. The 20-page publication gives complete specifications for NPO, X7R, and Z5U dielectrics used in conformally coated (SpinGuard™) and molded axial-lead MLC capacitors. Although these MLC capacitors are ideal for low-cost, high-volume applications, redundant testing of capacitance and dissipation factors (D.F.) ensures parametric accuracy of these components. General specifications for each dielectric cover capacitance range and tolerances, operating temperature range and characteristic, and voltage ratings. D.F., insulation resistance, dielectric strength, life test, moisture resistance, thermal shock, and immersion cycling information are also shown for both SpinGuard and molded axial-lead capacitors to help design engineers specify the best capacitor for the application. **AVX Corp., Myrtle Beach, S.C. INFO/CARD #117.**

Beam-Lead and Chip MIS Capacitors Brochure

Alpha Industries, Inc. has released a new 20-page brochure describing their beam-lead and chip MIS capacitors. The brochure includes technical information and data sheets on Alpha's complete capacitor product line, including MIS chip, binary trimming, FET chip mounting, beam-lead, and millimeter-wave beam-lead capacitors. An application note that covers bonding methods and packaging is also included. **Alpha Industries, Inc. Woburn, Mass. INFO/CARD #115.**

INFO/CARD 54

rf courses

FCC Requirements and Test Methods
October 9-10, 1985, Philadelphia
October 30-31, 1985, Boston
Information: Greg Gore, R&B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428; Tel: (215) 825-1965

Selecting Materials and Systems for EMI Shielding
September 26-27, 1985, Columbus, Ohio
Information: Katrinna Fischer, Battelle's Columbus Laboratories, 505 King Ave., Columbus, OH 43201-2693; Tel: (614) 424-5724

Interference Control Technologies

Grounding and Shielding
September 24-27, 1985, Las Vegas
October 15-18, 1985, Philadelphia
November 12-15, 1985, San Diego
November 19-22, 1985, Bermuda
December 3-6, 1985, New Orleans

EMC Design and Measurement
November 11-15, 1985, Orlando

TEMPEST — Design Control — Testing
October 7-11, 1985, Washington, DC
December 2-6, 1985, Sunnyvale

Introduction to EMI/RFI/EMC
December 3-5, 1985, Los Angeles

MIL-STD 461/462 and System Level Testing and Procedures
September 24-27, 1985, San Diego

EMC for Packaging Engineers
October 8-9, 1985, Philadelphia

Fundamentals of EMI/EMC
September 10-11, 1985, Boston
December 10-11, 1985, Houston

Grounds and Shields in Instrument Design
October 1-2, 1985, San Diego
Information: Penny Caran, Interference Control Technologies, State Route 625, P.O. Box D, Gainesville, VA 22065; Tel: (703) 347-0030

Continuing Education Institute

Microwave Circuit Design: Linear Circuits
October 7-11, 1985, Cambridge, Massachusetts
October 14-18, 1985, Zurich, Switzerland
November 4-8, 1985, Palo Alto, California

Microwave Circuit Design: Non-Linear Circuits
December 2-6, 1985, Palo Alto
Information: Helen Hegnsdal, Continuing Education Institute, 10889 Wilshire Blvd., Los Angeles, CA 90024; Tel: (213) 824-9545

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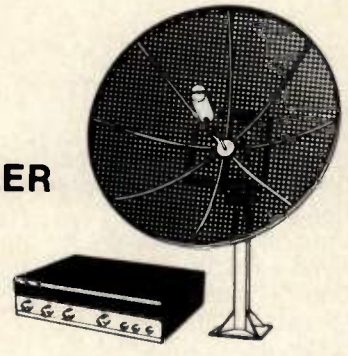

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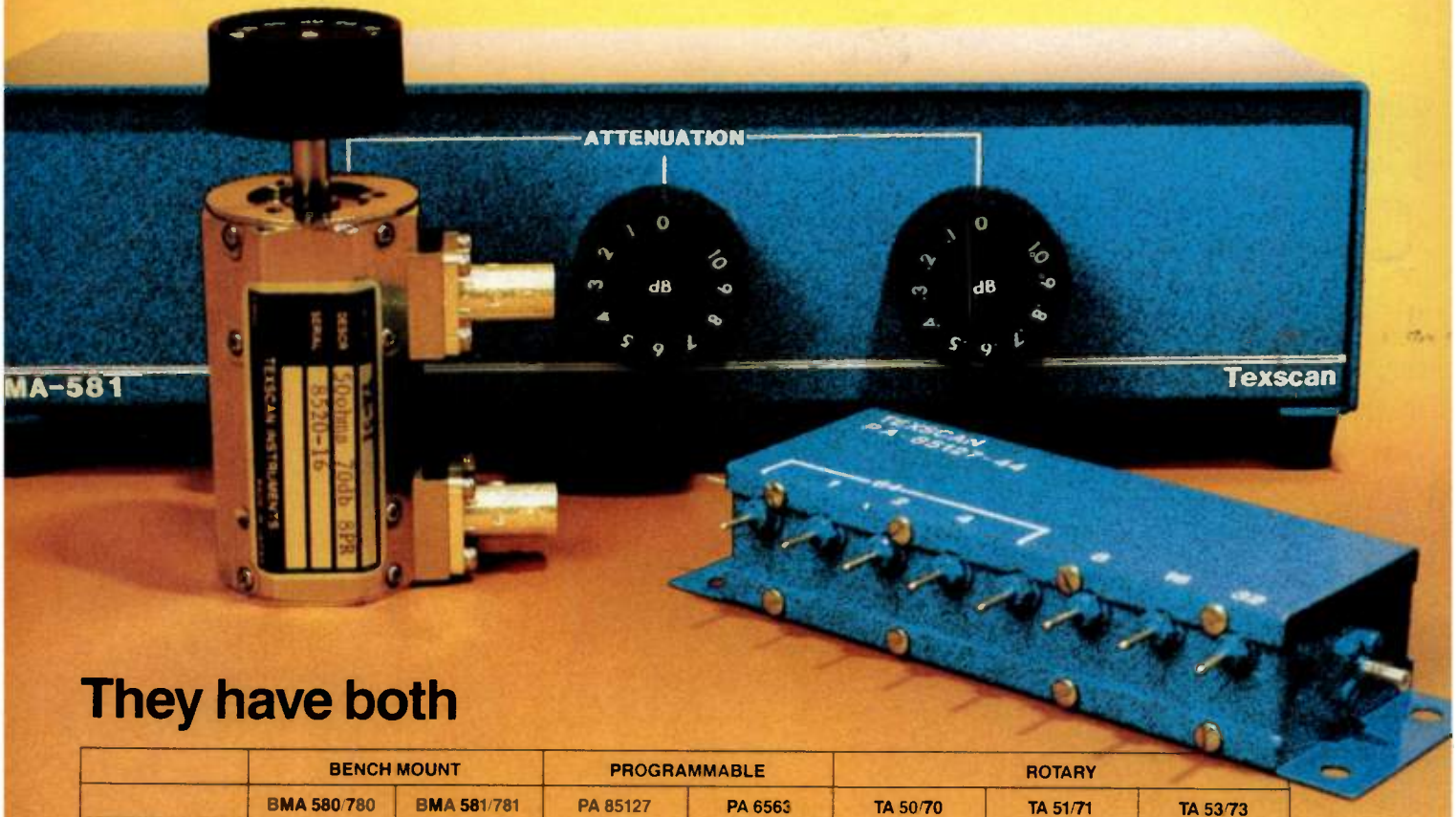
INFO/CARD 58

Specifications vs. Price

Texscan's new attenuators eliminate the choice between good specifications and a good price



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IMPEDANCE	50/75 ohm	50/75 ohm	50 ohm	50 ohm	50/75 ohm	50/75 ohm	50/75 ohm
STEP	1 dB	0.1 dB	1 dB	1 dB	1 dB	10 dB	0.1 dB
ATTENUATION	80 dB	81 dB	127 dB	63 dB	10 dB	70 dB	1.0 dB
FREQUENCY	DC-2/1GHz	DC-1 GHz	DC-1 GHz	DC-1 GHz	DC-2/1GHz	DC-2/1Ghz	DC-1 GHz
CONNECTORS	BNC, SMA or N		BNC, SMA or SMB		BNC or SMA		
PRICE (U.S. DOMESTIC)	$290	$450	$360	$260	$79 BNC $89 SMA	$79 BNC $89 SMA	$79 BNC $89 SMA

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