rf design

ideas for engineers

December 1986

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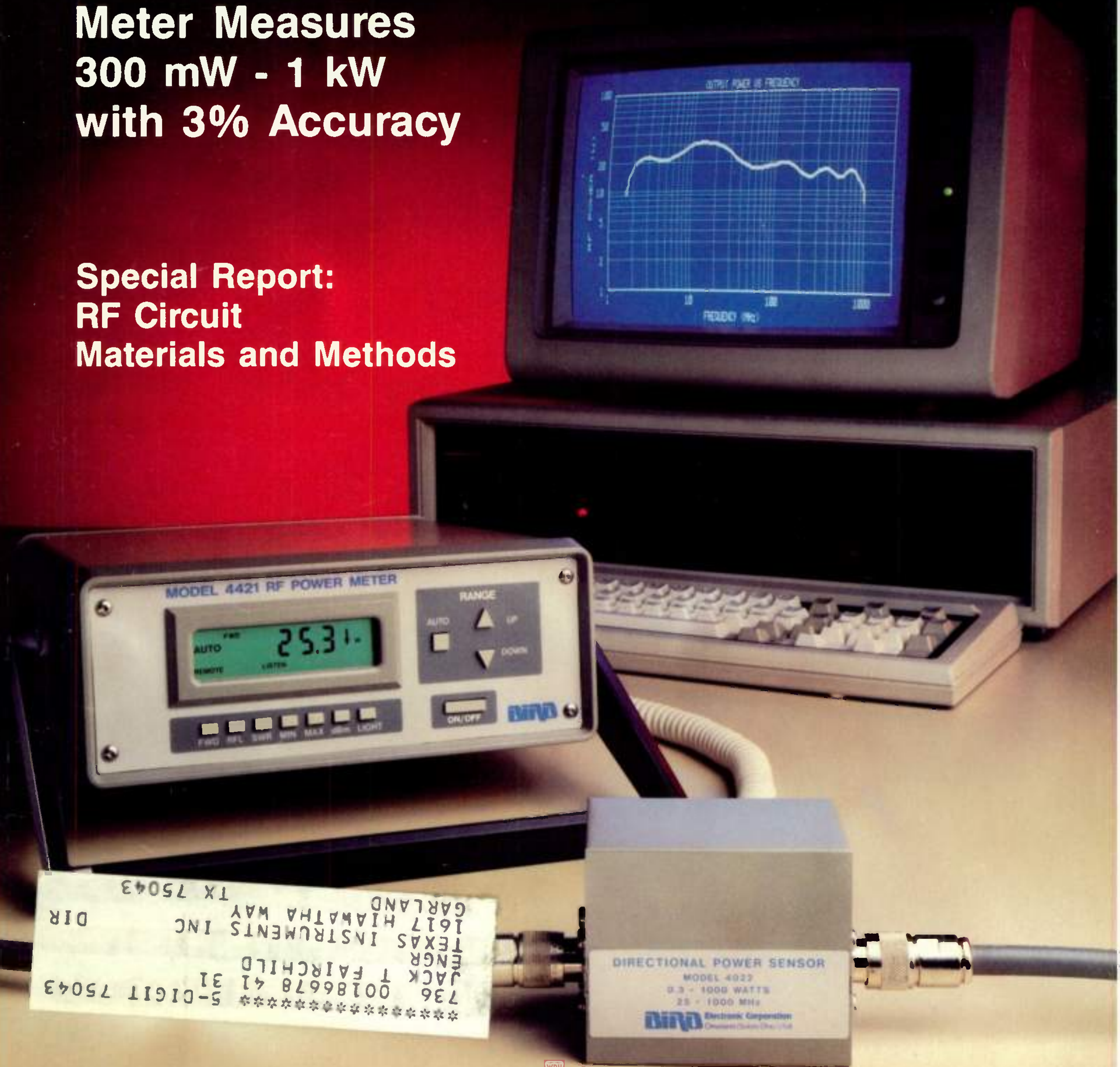
Special Report: RF Circuit Materials and Methods



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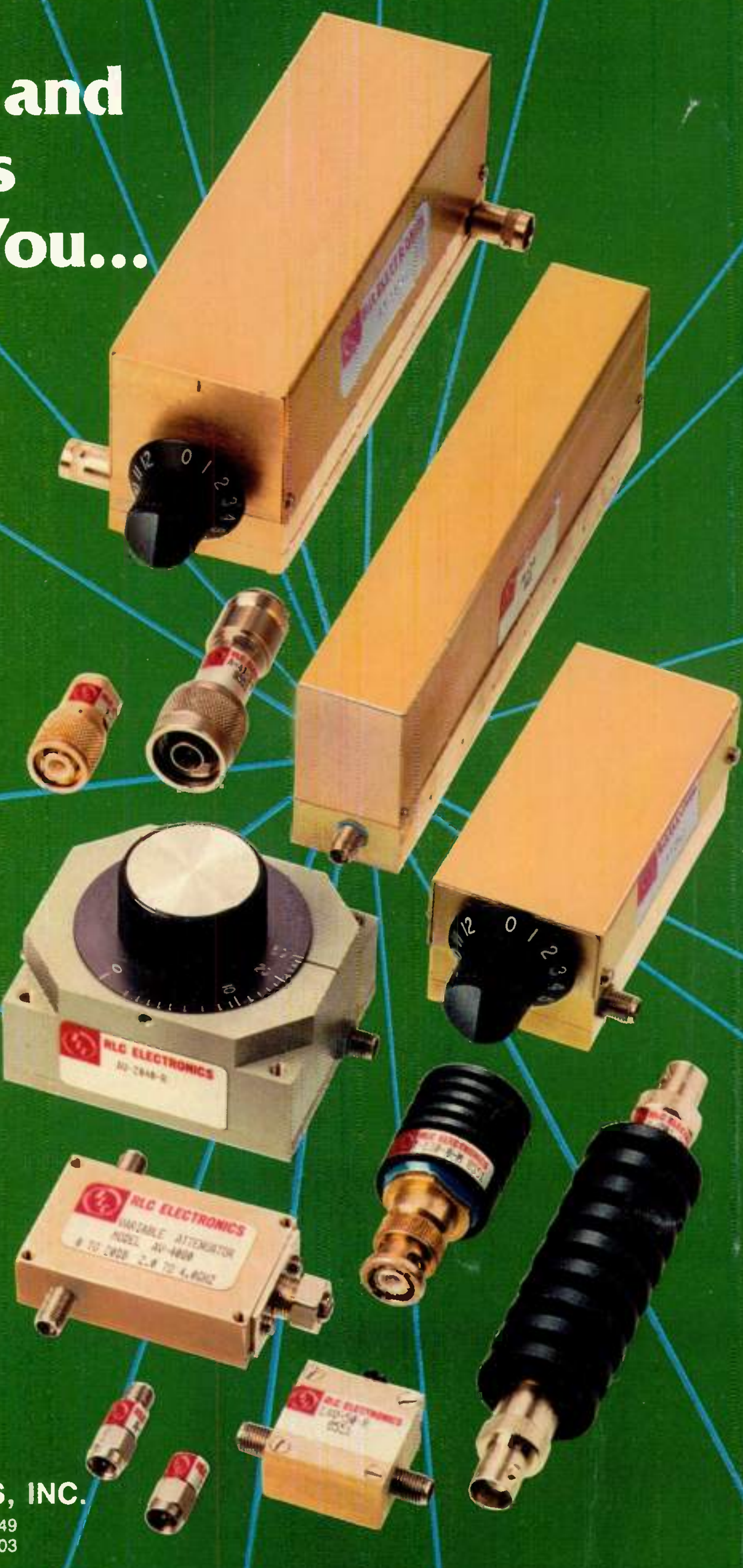

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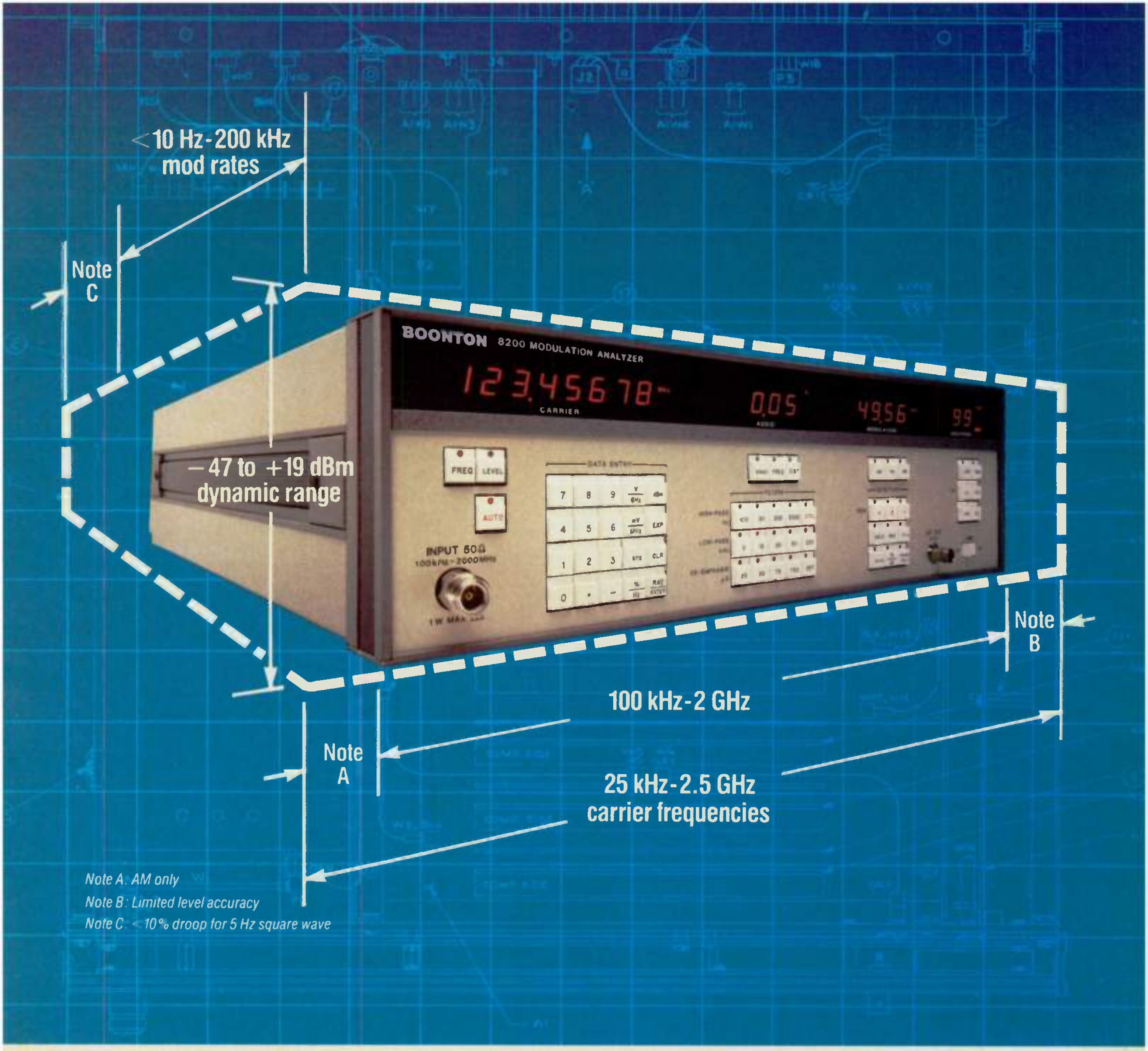

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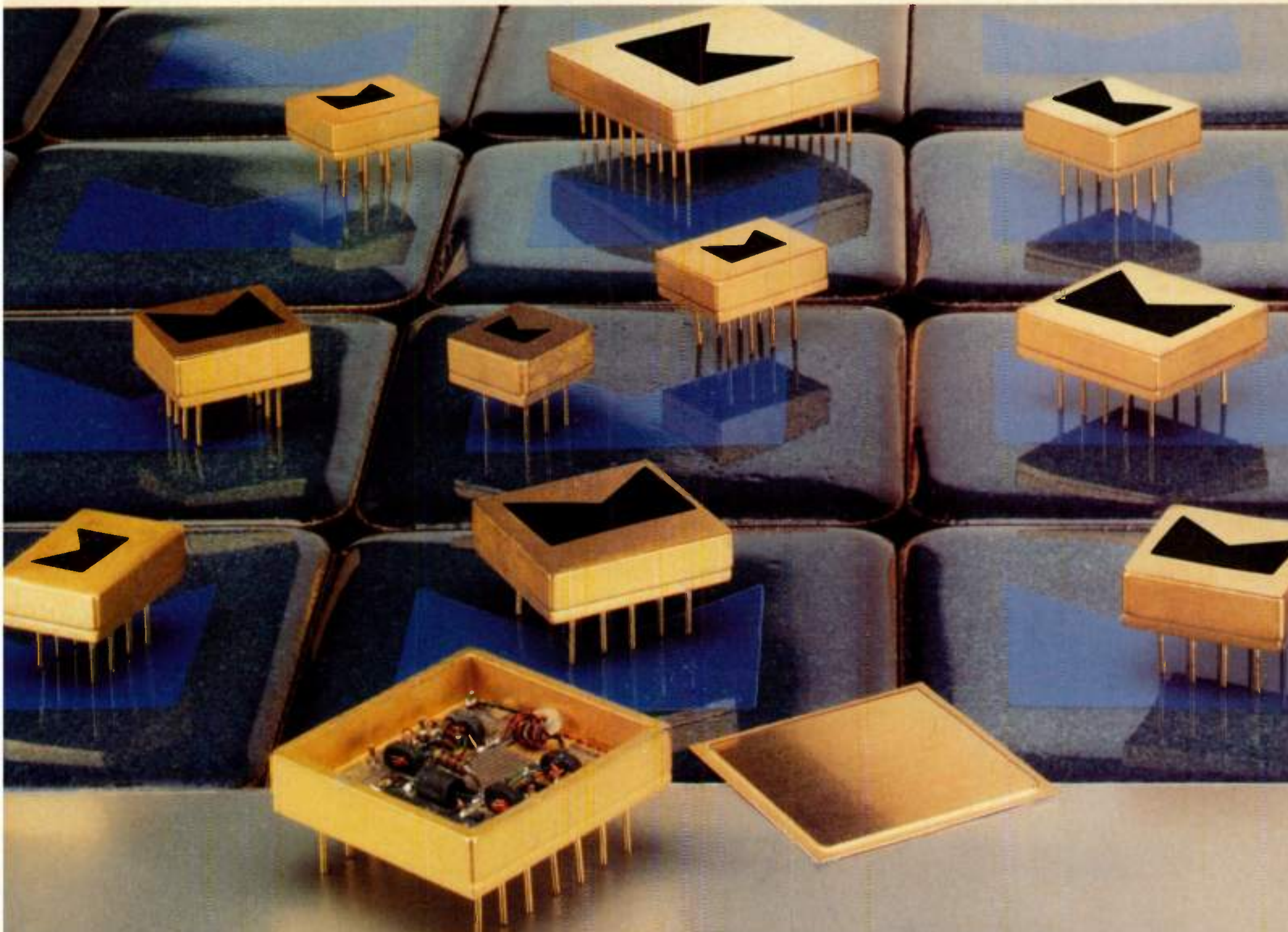

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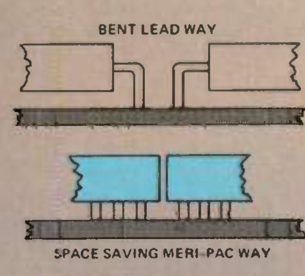

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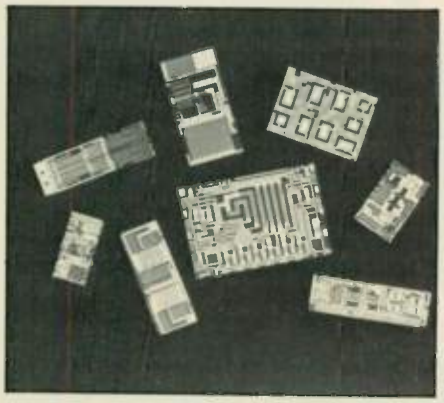
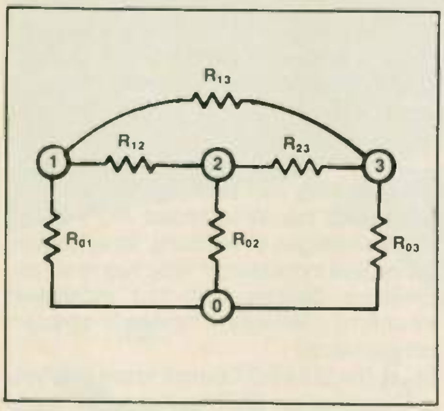
INFO/CARD 3

rf design

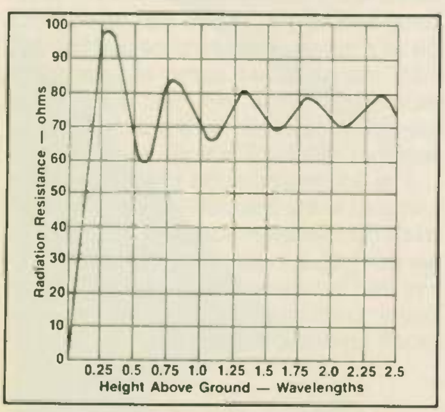
December 1986



Page 23 — Special Report



Page 29 — Nodal Network Analysis



Page 45 — Antennas for EMI Measurement

On The Cover

Bird Electronics' *Precision* Power Meter

The new Model 4421 Power Meter represents a major step forward in in-line power measurement. Bird's engineers have combined individual calibration and interchangeability by placing calibration information in each sampling head. Digital control allows computation of parameters and programmability.

Features

Departments

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Vision and Decision

By Keith Aldrich
Publisher

As another year winds down, we have not only done the customary stock-taking, but on the basis of what it revealed made some moves to strengthen the performance of *RF Design* in 1987.

Perhaps the most meaningful action has been to promote Gary A. Breed to the position of Editor of the magazine, effective with this issue. Readers will recall his byline on many fine staff-written pieces during the past year and a half over the title Technical Editor. Perhaps without realizing it they have also benefitted from his selection of articles and of new product and literature items during the same period. Not that there isn't still room for improvement; some things have been better than others. Now readers will profit from Gary's actual experience on the magazine, as well as from the professional expertise and the talent that made us hire him in the first place.

Important as they are, however, none of these factors accounts for Gary's appointment as editor. That is due to his capacities for *vision* and *decision*.

RF Design has an awesome charter in that it is the only magazine dedicated exclusively to the engineering design function in the radio frequencies. This uniqueness means that, on the one hand, it is possible to "slide by" and win a fair amount of praise for little actual meat. On the other hand, we have more than the usual incentive not to do so, and for the same reason: everyone is depending on us.

Gary Breed meets this burden of responsibility with a tangible vision of what the magazine must do and be. His editorial plan for the next year, for instance, includes an overdue series of overviews on the integration of RF technology with other disciplines: optoelectronics, digital and aerospace. His plan for the directory issue will double its size to include design guide material for RF engineers, as well as listings of RF manufacturers.

While he is pursuing his personal vision, Gary is keenly aware that he must not run his heedless ways, but open every possible avenue of input from other sources: professional societies and engineering schools, as well as authorities in private companies. His capacity for decision will be sorely needed as he sorts through the myriad claims for your attention to determine those with the most merit. You will notice new names on our editorial review board and new associations as he exercises that responsibility.

The long and the short of it is we take our responsibility seriously at *RF Design*. We recognize the hope with which the magazine is being viewed in today's engineering community as the means of satisfying a critical informational need. We are determined to live up to that potential.

Watch for new, impressive editorial achievements for *RF Design* in 1987, with Gary Breed as editor. And please give him every support, with your comment and contributions. It's your magazine.

Keith Aldrich

rf design

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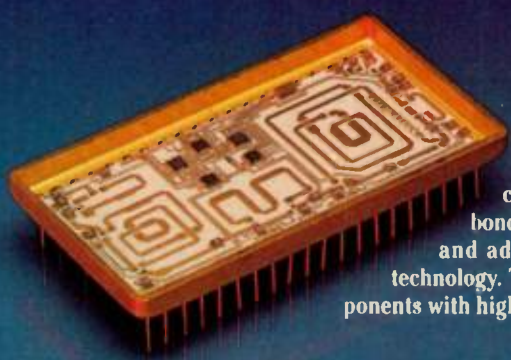
DAICO HIGH RELIABILITY R.F. MIC STEP PHASE SHIFTERS



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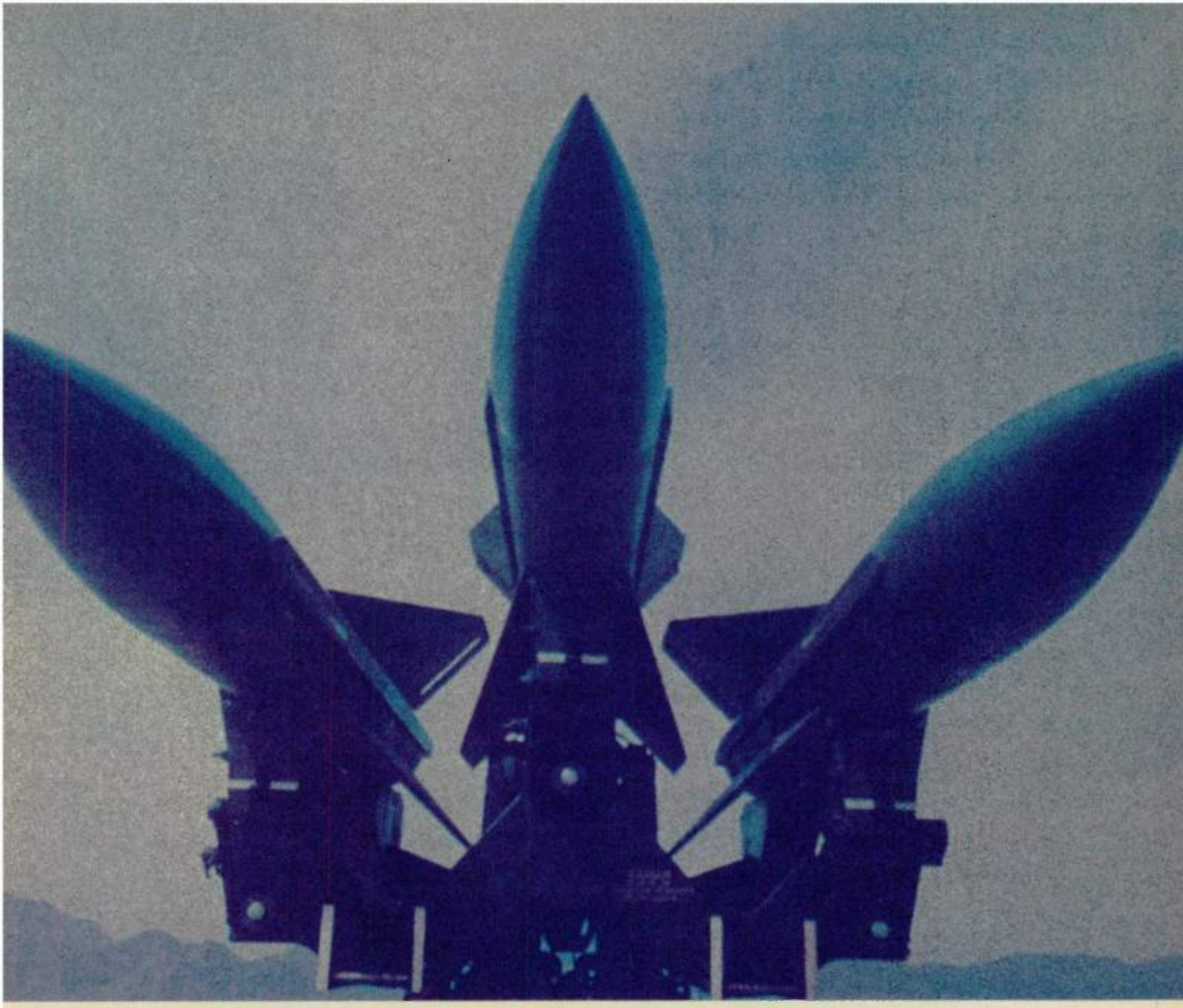

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INFO/CARD 8

rf letters

Letters should be addressed to: Editor, *RF Design*, 6530 S. Yosemite St., Englewood, CO 80111.

Propagation Curves Program Errors Noted

Editor:

I asked for a program listing for your article "100 MHz to 3.5 GHz Propagation Curves" in the *RF Design*, August 1986 issue. Since I have an Apple computer, I converted the program for this machine. While searching for typographical errors, I think I found several errors in the source listing you provided.

The technique I used to find my typographical errors was to plot families of curves on the high resolution graphics. I then made judgement calls to detect gross errors due to my typing. I enclose a copy of my listings to aid these descriptions.

I realize to make these changes properly, I should have gone to the reference documents. However, I offer these changes as pointers to possible defects in the program. This should allow you and the authors to correct the original source program and print any corrections you deem necessary.

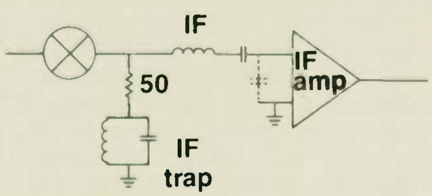
Thank you for the source listing. I appreciate having this program in my library.

Robert L. Toellner
Duncan, Oklahoma

Utility Gain Block Example Faulty

Editor:

The argument is okay, and the article is interesting, but the application example is faulty. [*Page 40, October 1986* RF Design — *Ed.*] (1) Unless it's an image-cancelling mixer, a (single section is OK) image suppression filter is needed between the amp and the mixer. (2) Mixers have all sorts of LO-products coming out the IF port. DON'T use an amplifier to terminate that. A simple filter will let things work properly.



(3) Cheap mixers work — or can work — just as well as expensive mixers. And I don't like amplifiers adding noise to my LO, for a minor point.

H.H. Cross, W1OOP
Needham, Mass.

Lynn Gerig's Response

Editor:

I concur with the four typographical errors and the two judgement calls. Thank you for bringing them to my attention. To users concerned about accuracy of solutions from using my program, I would like to point out that the "errors" apply only to aircraft elevations (VHF antennas at 500' and 40,000'; VHF at 1,000' and 60,000'; UHF at 500' and 80,000'; and UHF at 5,000' and 30,000'). Users desiring to correct their programs should LOAD the program, EDIT or retype the following lines, then SAVE the corrected program:

```
2255 H$ ( 4,12) =
    "135260160294169320183400203500"
2315 H$ ( 5,13) =
    "125180130315157350168374200540"
3005 H$ ( 1, 1) =
    "142010170030178050187100225315"
3265 H$ ( 4,14) =
    "140352160370171385180406210560"
3400 H$ ( 7,11) =
    "131140137288168315178335210495"
3540 H$ (11,13) =
    "137300141485172520183550210670"
```

I apologize to anyone inconvenienced by these typos, and thank you for bringing them to my attention.

Lynn A. Gerig
Monroeville, Indiana

Some Changes Made in SAE Standards

Editor:

Your fine article in the RFI/EMI Corner in the September '86 issue was a welcome item. There are some things I thought you might like to have updated, however.

The name of C63 has been changed. It is now "ANSI-Accredited Standards Committee on Electromagnetic Compatibility, C63."

SAE J551 has been changed to cover the frequency range starting at 30 MHz now instead of 20 MHz for noise from spark-ignition engine vehicles and devices. It now has an appendix covering radiated E-Field and H-Field emissions from electric vehicles over the frequency range from 14 kHz to 30 MHz.

The proposed EMR standard is J1816, "Performance Levels and Methods of Measurement of Electromagnetic Radiation from Vehicles and Devices, Narrowband, 10 kHz-1000 MHz."

Edwin L. Bronaugh
Director — Research & Development
Electro-Metrics
Amsterdam, New York

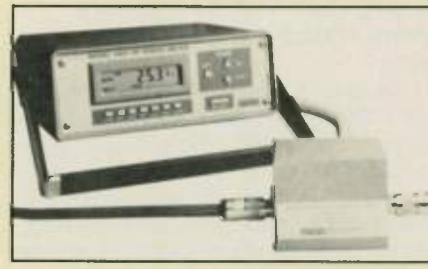
Bird Develops Precision Thruline® Power Meter

The cover of this issue features a new product, and a new level of precision from Bird Electronic Corporation of Solon, Ohio. Their new Models 4021 and 4022 power sensors; with Models 4421 and 4420 digital and analog display units represent a major achievement in non-terminating, non-calorimetric power measurement.

Accuracy of 3 percent is achieved by including a microprocessor and individual calibration PROM in each sampling head. This method allows the rated accuracy to be had over a power range of 300 mW to 1000 W with a single sensor. The Model 4021 sensor covers 1.8 to 32 MHz, the 4022 covers 25 to 1000 MHz. Either sensor may be used with any display unit, since the calibration stays with the sensor. Sensors are warranted for life against burnout.

The display units allow the operator to measure not only forward power, but reflected power, VSWR, return loss; and to track the maximum or minimum value of any of these parameters. Power readings may be in watts or dBm. A rechargeable battery pack allows fully portable operation. The 4420 analog display unit has the interesting feature of a stepper-motor driven pointer, not a conventional analog meter.

As is the case with most current instruments, IEEE-488 interface is an op-



tion, available on a field-installable board. RS-232 interface is also available. The interface cards require operation from the AC line, and are only used with the 4421 digital display unit. For more information, circle INFO/CARD #183.

Three Daves Do Boston

Just as they did in Anaheim for two successive years (at RF Technology Expo), the "new wave" of RF engineers turned out in Boston for RF Expo East. Interviews with three engineering attendees selected at random — by complete coincidence all were named David — revealed heavy involvement with digital techniques as well as RF for two of them.

In the case of *David Halasz* of Bird Electronics, Cleveland, Ohio, his actual title is computer engineer. The title does not mean that he designs computers. Bird is a familiar manufacturer of RF power measurement equipment, and Dave is the principal developer of the new instrument featured on this month's cover. His title means that he is part of the "computer products" engineering group which designs products with microprocessor capabilities. (Other engineering groups at Bird revolve around products like filters, loads and attenuators.) Dave is 25, received his BSEE with digital emphasis from Case Institute and has been at Bird for all of his 1½ years of work experience.

Dave #2 was *David Mortimer* of Spears Associates, Inc., Norwood, Mass., a manufacturer of submarine communications systems in VLF, LF and HF ranges, with a few special purpose systems in higher frequencies. Now 39, this Dave first got involved with RF in the Army after some college

Halasz

Mortimer

Somppi

training in chemistry and physics. The experience led him to go for a BSEE at the University of Massachusetts after his discharge, with as "broad a base as possible in all subjects except digital." Dave's entire 12-year work experience has been at Spears, where he is now a senior engineer, and "not that involved" on a day-to-day basis with engineering design, although it is his first love. He relished going to the sessions and exhibits at RF Expo East as a way of staying in touch and "will be back every year."

Dave #3 was *David Somppi* of Linear Technology, Inc., Burlington, Ontario, a manufacturer of RF bipolar transistors and DMOS devices. This Dave develops broadband amplifier designs to be produced as monolithic circuits. At the next RF Technology Expo in Anaheim (February 11-13, 1987) he will present a paper presenting a new "chip" operating in the 10-500 MHz frequencies, selling for less than $20. At the age of 30 Dave has earned two degrees, a BSEE and a Master of Applied Science with emphasis on EE, both at the University of Waterloo in Ontario, and has an impressive work record at Garrett Manufacturing and Bell Northern Research in addition to three years at Linear Technology. He is excited about his work since he sees more and more functions "going monolithic" as opposed to discrete or even hybrid. He, too, "will be back" at future RF Expos.

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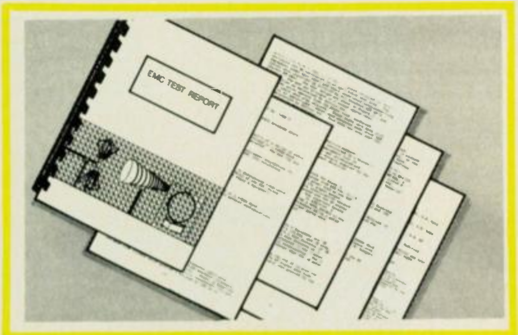

Certified Testing is our name for our automated test program that evaluates the interference control built into the equipment being tested. Available only from Instrument Specialties, it includes state-of-the-art emissions and susceptibility measurements from 20 Hz to 20 GHz up to 20 V/m ... RF gasket evaluation ... FCC/VDE/CISPR and MIL-STD-461A/B tests ... TEMPEST facility measurements per NACSIM 5203 and 5204 requirements ... depending on your needs.

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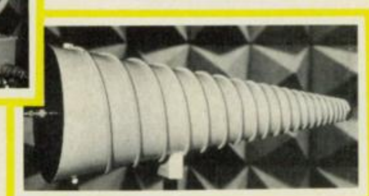
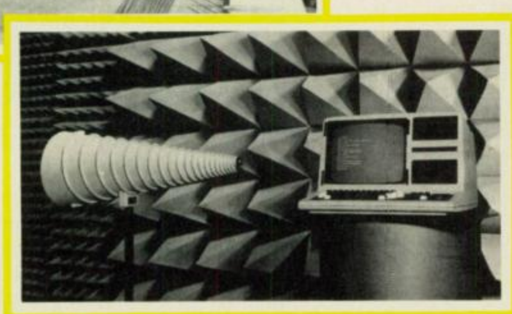


Where do we test?



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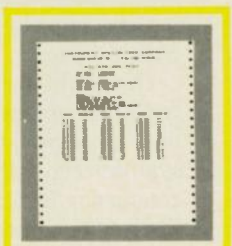

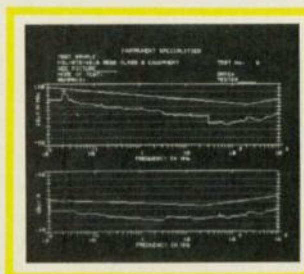

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Nearly 1,200 RF Engineers Attend RF Expo East

The vitality of the RF industry was evident in Boston during the second week of November. RF engineers from all branches of the industry found something informative and interesting at RF Expo East, and manufacturers of RF components and equipment found an audience of engineers wanting to know more about their products.

Of special note was the attendance of engineers from other disciplines. Digital engineers were to be found looking for products and techniques to enhance the high-speed performance of their projects. The optical communications specialists were present, too. As one of them noted, the modulators and demodulators of an optical link are basically RF circuits.

It is clear that many attendees had education as their first priority. Over 150 attended the RF Fundamentals course, taught once again by Les Besser. Attendance at the technical papers was extremely high, with many situations of standing-room-only. Among the best attended papers were those of the tutorial nature. The foundations of amplifier, oscillator and filter design appear to be areas of universal interest among both new and experienced engineers.

Exhibits Highlight Many New Products

Fall 1986 has been chosen by many companies as the time for introduction of new products. Many of the products announced in November *RF Design* had their first public showing at RF Expo East. Among these new products were signal generators from Wavetek, Fluke and Rohde & Schwarz-Polarad; Spectrum Analyzers from Hewlett-Packard and Tektronix; and GaAs and silicon MMICs from Harris Microwave Semiconductor, M/A-Com Advanced Semiconductor and Avantek. New surface mount components

from several companies received close scrutiny by the attending engineers.

A few companies exhibited brand-new products, not previously announced. M/A-Com had the latest additions to their GaAs MMIC switch and attenuator line. Motorola announced a new dual gate GaAs FET transistor in a SOT package, plus their MC3362 dual-conversion FM receiver IC. IFR Systems announced the upcoming introduction of a new spectrum analyzer, featuring coverage to 2.6 GHz, with a vast array of performance and operational features.

At least one new start-up company came to RF Expo East to gain some first-hand experience with the engineers and

companies in the industry: L&M Systems, Inc., of Londonderry, N.H. This new firm will be producing low cost VCO modules in the VHF/UHF frequency range.

Technical Papers Draw Big Crowds

RF engineers are always looking for ways to improve their design and development ability. Papers delivered at RF Expo East included a valuable mix of product applications, basic tutorials and design and development examples. It is hard to highlight any one or two of the papers since all were well-received and most sessions on power amplifier design, oscillators, computer-aided design, frequency synthesizers, mixer design and receiver performance were especially popular.

NBS Has New Measurement Information

One important performance criterion for signal generators is the ability to produce a specified flatness of output amplitude during frequency modulation (FM). The response of a generator to a given range of modulation frequencies can be determined using the Bessel null technique, but manual measurements suffer from high labor costs, errors in finding the null, and lack of assurance that the null found is actually the first Bessel null. NBS has developed an automated procedure which avoids these problems and gives more precise results than manual control. Automated Measurements of Frequency Response of Frequency-Modulated Generators Using the Bessel Null Method (TN 1093) describes the equipment and technique, and lists the program used. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.75 prepaid; order by stock no. 003-003-0278-6.

Also available from NBS is a new "special" measurement service for microwave noise sources in the 2 to 4 GHz range is available. It improves on an older service by providing better accuracy (approximately ±0.07 dB vs. ±0.14 dB) service at any frequency in the range and the ability to calibrate noise sources having the most common connectors (instead of requiring the connector of the test unit to be the same as that on the NBS standard). Inquiries about the availability and cost of the new measurement service should be directed to Edna Jones, Div. 723.10, National Bureau of Standards, Boulder, CO 80303, telephone: (303) 497-3753. Technical inquiries may be addressed to George Counas, (303) 497-3664, or Sunchana Perera, (303) 497-3546, both at the above address.

EIA Quartz Devices Conference Proceedings Available

Proceedings of the Electronic Industries Associations 8th Quartz Devices Conference and Exhibition held August 26-28, 1986, in Kansas City, are now available. The publication contains technical papers on a wide variety of topics, incuding: "Design Algorithm for Bi-Convex and Plano-Convex Crystal Resonators"; "Quartz Tuning Resonator Transducers"; "Review of Surface Mount Technology as it Applies to Quartz Crystal Products"; "The Dependence of the Electroelastic Constants of Quartz on Temperature"; and "Crystal Oscillator Design and Analysis Using Personal Computer."

The 274-page documents may be ordered for the prepaid price of $45 from the Electronic Industries Association's Components Group at 2001 Eye Street N.W., Washington, D.C. 20006.

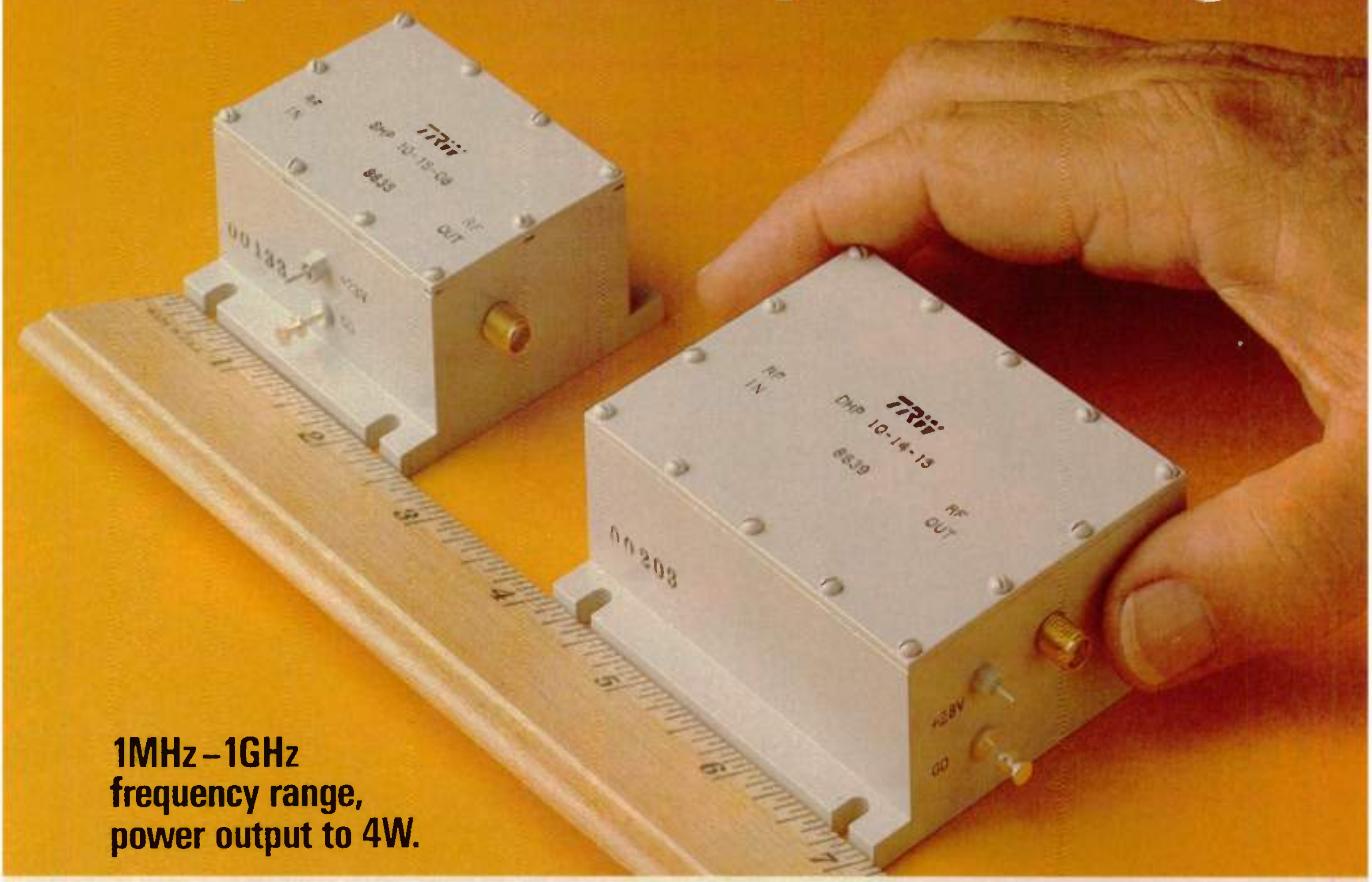
Raymond Heising's popular "Quartz Crystals for Electrical Circuits," is also available at a cost of $25.

Besser Associates Releases New Course Versions

Besser Associates, Inc. has announced a new release of two videotape courses, which provide segmented licensing and purchasing opportunity. The courses covered are: TA-1, "RF/MW Fundamentals" by Les Besser. TECH-1, "RF/MW Fundamentals and Measurement Techniques." For additional information, contact Besser Associates, Inc., 3975 East Bayshore Road, Palo Alto, Calif., (415) 969-3400.

New from TRW...

A broadband, medium-power amplifier in a compact package.



1MHz–1GHz frequency range, power output to 4W.

TRW RF DEVICES has developed two new lines of packaged linear amplifiers that feature...

- Heavy-duty machined housing
- EMI-RFI shielding
- SMA connectors
- Low noise
- High gain (14-36dB)

These new modules are ideal for applications in instrumentation, communications equipment and military systems. And they are lower priced than comparable products.

The SHP series package measures only 7.2 cubic inches; the DHP series package measures 9.8 cubic inches.

All products utilize a push-pull configuration and operate with bias voltages of 15V, 24V or 28V. They also are protected against reverse bias. They meet MIL-SPEC 883, Methods 1004 and 1009, for humidity and salt spray.

Prices (in quantities of 1-9) range from \$240 to \$275 for the nine models in the SHP series. The five models in the DHP series—which feature higher gains and power outputs at comparable frequencies—are priced from \$380 to \$455.

Look to TRW RF DEVICES for the latest developments in RF POWER TECHNOLOGY.

For data sheets, applications assistance or the location of your nearest stocking distributor, contact Don Murray, Sales Engineer:

RF Devices Division
TRW Electronic Components Group
14520 Aviation Blvd.
Lawndale, CA 90260, 213.536.0888

TRW

RF Devices Division
TRW Electronic Components Group

rf calendar

January 12-15, 1987
SMART III
Hyatt Regency, New Orleans, Louisiana
Information: Electronics Industries Association, 2001 Eye St. N.W., Washington, D.C. 20006; Tel: (317) 261-1306

January 29-30, 1987
Measurement Science Conference
Irvine Marriott Hotel, Irvine, California
Information: Dennis Pinnecker, Conference Registrar; Tel: (714) 762-4574.

February 11-13, 1987
RF Technology Expo 87
Disneyland Hotel, Anaheim, California
Information: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6530 So. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522 or (800) 525-9154

February 25-27, 1987
Industry-University Advanced Materials Conference
Colorado School of Mines, Golden, Colorado
Information: Dr. Jerome G. Morse, Advanced Materials Institute, Colorado School of Mines, Golden, CO 80401; Tel: (303) 273-3852

April 1-8, 1987
Electronics and Electrical Engineering '87
Hannover Fairgrounds, Hannover, West Germany
Information: Hannover Fairs USA, Inc., 103 Carnegie Center, P.O. Box 7066, Princeton, NJ 08540; Tel: (609) 987-1202

April 21-23, 1987
Electrical Overstress Exposition
San Jose Convention Center, San Jose, California
Information: Jim Russell, EOE, 2504 N. Tamiami Trail, Nokomis, FL 33555; Tel: (813) 966-9521

April 27-29, 1987
IEEE Instrumentation and Measurement Technology Conference
Sheraton-Boston Hotel, Boston, Massachusetts
Information: Robert Myers, Myers/Smith, Inc., 1700 Westwood Blvd., Los Angeles, CA 90024; Tel: (213) 475-4571.

May 11-13, 1987
37th Electronics Components Conference
Boston Park Plaza Hotel and Towers, Boston, Massachusetts
Information: Tom Pilcher, Electronic Industries Association (see address above)

May 27-29, 1987
41st Annual Frequency Control Symposium
Dunfey City Line Hotel, Philadelphia, Pennsylvania
Information: Dr. R.L. Filler, U.S. Army Electronics Technology and Devices Laboratory, SLCET-EQ, Fort Monmouth, N.J. 07703-5000; Tel: (201) 544-2467.

June 9-11, 1987
IEEE MTT-S International Microwave Symposium
Bally's Grand Hotel, Las Vegas, Nevada
Information: Robert A. Weck, U.S. Army, LABCOM, ETD Lab, SLCET-MH-W, Fort Monmouth, NJ 07703-5000; Tel: (201) 544-4489

rf courses

The George Washington University

Grounding, Bonding, Shielding and Transient Protection
December 8-11, 1986, Ottawa, Canada

Mobile Cellular Telecommunications Systems
December 8-10, 1986, Washington, DC

Wideband Communications Systems
December 15-19, 1986, Washington, DC

SAW Devices and Their Signal Processing Applications
February 23-26, 1987, Washington, DC

Frequency Synthesis
February 9-11, 1987, Washington, DC

Frequency Hopping Signals and Systems
February 23-25, 1987, Washington, DC

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

Georgia Institute of Technology

Principles of Pulse Doppler Radar: High, Medium, and Low PRF
February 10-12, 1987, Atlanta, Georgia

Information: Diedre Mercer, Department of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332; Tel: (404) 894-2547

Besser Associates, Inc.
Principles of RF and Microwave Circuit Design
December 15-17, 1986, Santa Clara, California

Information: Besser Associates, Inc., 3975 East Bayshore Road, Palo Alto, CA 94303; Tel: (415) 969-3400

Interference Control Technologies, Inc.
Grounding and Shielding
December 2-5, 1986, Washington, D.C.

TEMPEST Facilities Design, Installation and Operation
January 27-30, 1987, San Jose, California

Practical EMI Fixes
December 9-12, 1986, Orlando, Florida
January 20-23, 1987, San Diego, California

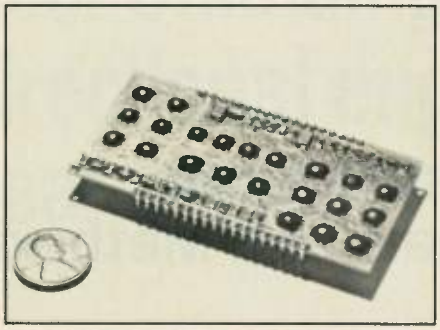
Information: Penny Caran, Registrar, Interference Control Technologies, P.O. Box D, Gainsville, VA 22065

R&B Enterprises
TEMPEST — A Detailed Design Course
February 2-6, 1987, Philadelphia, Pennsylvania

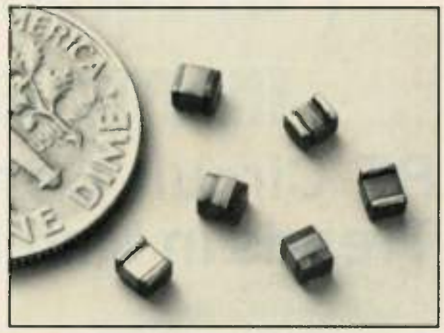
TEMPEST — An Overview for Managers and TEMPEST Officers
February 9-10, 1987, Philadelphia, Pennsylvania

EMI/EMC in the Automotive System
February 9-11, 1987, Dearborn, MI

Information: Greg Gore, R&B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428-2721; Tel: (215) 825-1960



Surface-mounting and hybrid techniques can be combined, as shown in this fiberglass-substrate circuit.



Surface-mounted components, such as these inductors from Coilcraft, are rapidly being incorporated into new RF designs.

tion about this material, please circle INFO/CARD #182.

Although BeO, manufactured in this country by Brush-Wellman, Inc., Cleveland, Ohio, has long been an excellent substrate material, there are toxicity hazards associated with beryllic dust. Maladies similar to emphysema can result from cumulative exposure to dust created by drilling or grinding. Aluminum nitride, a relatively new ceramic, reportedly has about half the thermal conductivity of BeO, and about five times that of alumina. A problem to be overcome with this new material, however, is thick film adhesion. Another new material, silicon carbide, reportedly has a high dielectric constant, approximately 40, but presents some problems with metallization.

RF design engineers are more likely to be familiar with the soft substrates, the flouropolymer composites used in printed circuit boards. Rogers Corp., Tempe, Ariz., has just completed development of a new material for high speed, high capability interconnects. The ROHSI™ (Rogers High Speed Interconnections) seems to offer significant improvement over existing materials. This new material may provide on the order of 1,000 percent improvement in delay-line rise time, 35 percent improvement in characteristic impedance control of flexible materials, and more than 900 percent improvement in in-line connector failure rates, with a 20 percent increase in propagation velocities. The material is intended for high speed digital system applications, but creative RF designers may see other uses for it.

Rogers also offers OHMEGA-ply laminate through exclusive license agreement with OHMEGA Technology, Culver City, Calif. The bi-clad material is made with a layer of copper bonded to a thin layer of resistive material, which is in turn bonded to RT/Duroid laminates. By controlled width and length etch-back, ready-made planar resistors can be realized. Discrete resistors can be eliminated in many applications.

With laminates, the expansion differences among materials, metallic laminations, and mounted components or devices is a critical consideration. Solder and weld joint fatigue in interconnects and poor adhesion of conductors to the substrate are prominent causes for failure. If a substantial amount of power is to be transported or dissipated per unit area, careful design studies are in order.

One of the driving forces in the development of new materials is the trend toward surface mounted devices. Surface mounting, in turn, is driven by the need to automate the assembly process. It can be shown that surface mount technology, properly approached, can more than double productivity and increase the quality index of components tenfold or more.

Labor inputs can be reduced substantially by using robotics for assembly and testing. Multifingered, programmable robots with vision, connected computer brains, and human-like dexterity can perform an almost unlimited variety of assembly tasks. With robots, picking, placing, and soldering at interstage step speeds of more than 50 inches per second with location repeatability of less than +/− 0.005 inches is possible.

When surface mounted, devices must be held to the board until soldered, especially with double-sided mounting. Epoxies, silicones, polymides and acrylics are among the materials currently used for this purpose. With line widths and spacing in the order of small fractions of an inch, the use and reliability of adhesives is critical. However, the use of adhesives brings new problems. The dielectric properties of the adhesive, the amount used, and the puddle spread may lead to unexpected losses, mismatches, etc. Overcoming this problem may require new adhesive fixing routines that preclude or minimize liquid flow.

Standardization — The Major Problem in Surface Mounting

Surface mountable hybrid circuit components have been available for almost 20 years in various limited types. Today, the numbers are in the order of tens of thousands, active and passive. Few package manufacturers, however, have attempted to standardize package sizes or footprint geometry, or to provide a measure of control of the characteristic impedance of the package feedthroughs. Now the Electronics Industries Association (EIA) and the Institute for Interconnecting and Packaging Electronic Circuits (IPC) have come together to develop and propose standards for surface mount devices and systems.

The three main objectives established by a joint council of the two organizations include: 1) coordination and endorsement of surface mount technology standards publication; 2) examination and assessment of the technology and guidance to government and industry; and 3) promotion and information dissemination regarding endorsed standards and new developments in SMT.

Perhaps the work of this council will provide the standardization to allow maximum use of surface mount technology. Designers will then have maximum flexibility in using new materials. For more information about the Surface-Mount Council, contact the EIA or IPC at the following addresses:

Electronic Industries Association
2001 Eye Street, N.W.
Washington, D.C. 20006
Attn. Max Moore

Institute for Interconnecting and
Packaging Electronic Circuits
7380 Lincoln Avenue
Lincolnwood, IL 60646
Attn. Tony Hilvers

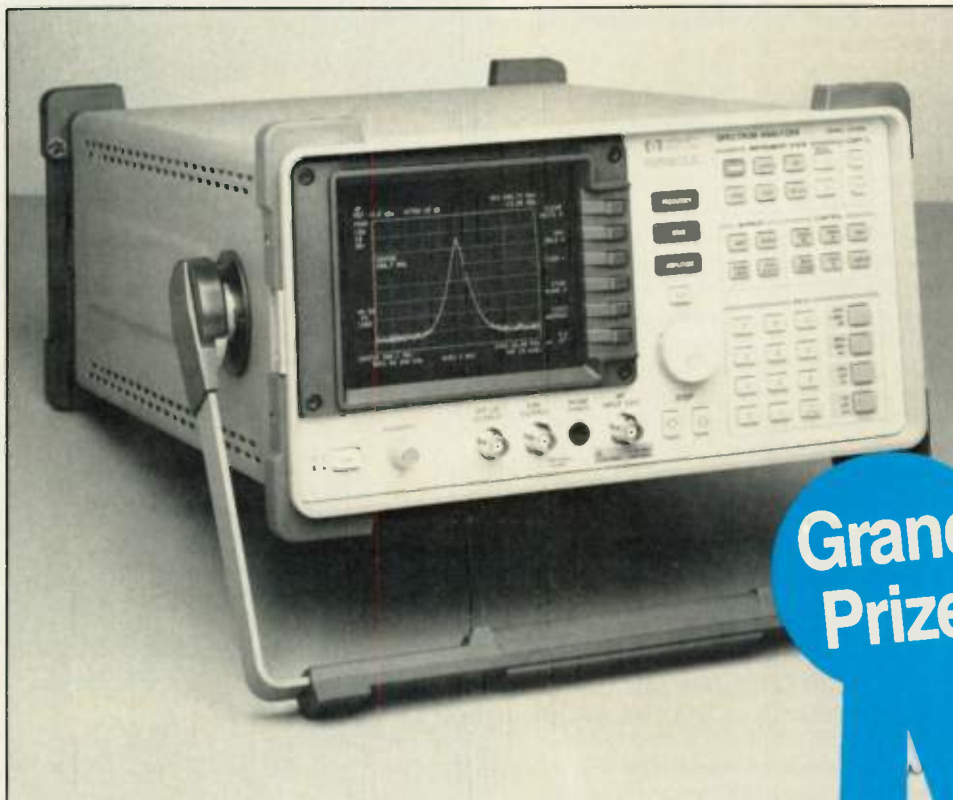
About the Author

Dick Wainwright is chief scientist at Cir-Q-Tel Inc., 10504 Wheatley St., Kensington, Md. 20895-2695. He has many years of experience in the design and manufacture of packaged filters and hybrid circuits.

SECOND ANNUAL

RF DESIGN

Hewlett-Packard 8590A



Grand Prize

- 10 kHz to 1.5 GHz
- 30 pounds (13.5 kg), Small and Sturdy
- Direct Printer and Plotter Output
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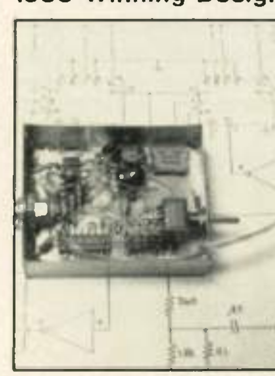
1986 Winner

Dan Baker
Tektronix

"Wow! I can't believe I won. I am extremely flattered that a respected publication such as yours found my design worthy of first prize."

Dan Baker
Tektronix

1986 Winning Design



Calibrator Circuit

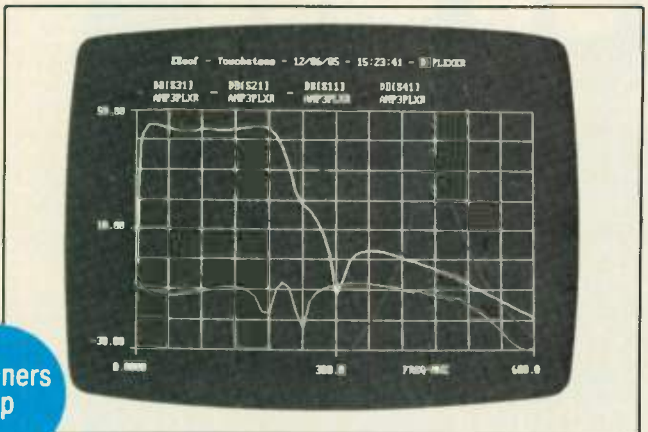
Entry Rules

1. Entries shall be RF circuits containing no more than 6 single active devices (tubes or transistors), or 4 integrated circuits, or be passive circuits of comparable complexity.
2. The circuit must have an obvious RF function and operate in the below-2 GHz frequency range.
3. Circuit must be the original work of the entrant.
4. If developed as part of the entrant's employment, entries must have the employer's approval for submission.
5. Components used must be generally available, not obsolete or proprietary.
6. Submission of an entry implies permission for *RF Design* to publish the material. If published, the entrant will receive the normal per-page author's honorarium.
7. Deadline for entries: **March 31, 1987.** ***RF Design*, 6530 S. Yosemite St., Englewood, CO 80111**

CONTEST

Prizes valued at over **$18,000**

EEsof



Runners Up

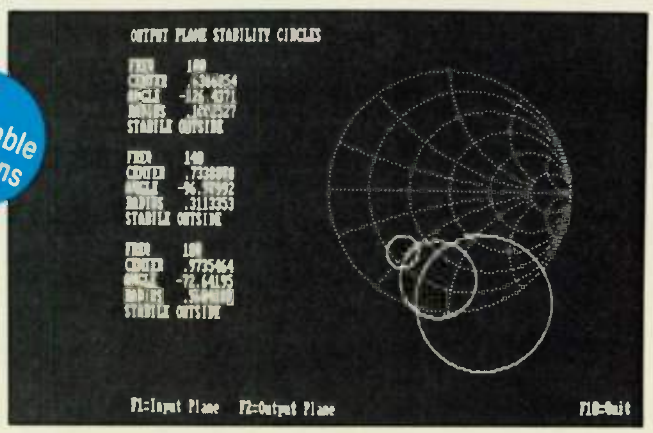
Touchstone/RF gives you everything you need for circuit design, simulation and analysis. It's the most advanced program there is for computer-aided RF design. You use it in your own office, on your own PC.

The new model 4421 RF Power Meter from Bird Electronic measures forward and reflected RF power with an impressive ±3%-of-reading accuracy — performance that fully rivals slower calorimetric methods.

Runners Up

BIRD
Electronic Corporation

4 Honorable Mentions



Circuit Busters
SuperStar, a major extension of STAR, will change the way you design circuits. SuperStar has the power and flexibility to simulate a wide variety of RF and microwave circuits without compromising ease of use, speed of execution, accuracy, and affordability.

Judging Criteria

Each entry will be evaluated in three categories, each having equal weight:

1. **Originality:** The purpose of the contest is to reward engineers for their unique design contributions. Each design will be evaluated according to its similarity to work by others, unusual application of a device or technique, and other judgments of its contribution to the advancement of the engineering craft.
2. **Engineering:** Engineering is the application of technology to solve a problem or meet a design goal. Entrants should clearly identify how their circuit was created in response to such a need. Judges will evaluate performance, practicality, reproducibility and economy.
3. **Documentation:** Communicating ideas to others is the business of *RF Design* and a necessary part of good engineering. Each entry will be judged on its description, analysis and graphical material. Each circuit should have a complete list of components, explanation of functions, and a summary of performance and test data.

Network Analysis on the Personal Computer

A Program for Nodal Analysis of RF Circuits

By Bert K. Erickson
General Electric Co.

This BASIC program will compute the frequency response and input impedance of a linear network composed of resistors, capacitors, inductors, op-amps, bipolar and FET transistors. The program allows a personal computer to verify the response of RF circuits before hardware models are assembled. In comparison with commercial programs currently available, this program is deliberately abbreviated to provide more than adequate "number crunching" ability, while eliminating seldom used features.

The program presented here was written for an IBM PC computer connected to an OKIDATA Model 84 printer. This computer could handle 58 nodes and for a 5 node network it took 4 seconds to calculate and print the response at each frequency. With the exception of the printer instructions, the program should run on all computers that are compatible with Microsoft BASIC. Units of *hertz, ohms, microfarads, henrys,* and *seconds* are used for all values. This program also includes techniques for calculating the time delay and input impedance.

The network illustrated in Figure 1 shows how the program can be used. To get started, assume the program has been LOADED and RUN. The element format will appear on the screen. Enter Y for printed results or press ENTER for a screen display only. Enter Y for time delay or press ENTER to omit the listing (which will allow the program to run faster). Press ENTER to omit the impedance header. Enter the highest node in the diagram for the number of nodes. To store an inductor element in memory enter L1 then type 1, 2, 1.59154 and press the ENTER key again. "L1 1 2 1.59154" will be printed if printed results were requested. Proceed to enter all elements in this manner.

```
L1 = 1  2  1.59154
R2 = 2  0  10000

Network has 2 nodes
Input & output nodes are 1 , 2

Frequency response with linear frequency increments
Frequency range is 100 , 2350 , 450

  FREQ          DB        PHASE      DELAY (SEC)
1.00E+02      -0.04       - 5.7       1.58E-04
5.50E+02      -1.15       -28.8       1.22E-04
1.00E+03      -3.01       -45.0       7.96E-05
1.45E+03      -4.92       -55.4       5.14E-05
1.90E+03      -6.64       -62.2       3.45E-05
2.35E+03      -8.14       -66.9       2.44E-05

Frequency response with log frequency increments
Frequency range is 100 , 2350 , -6

  FREQ          DB        PHASE      DELAY (SEC)
1.00E+02      -0.04       - 5.7       1.58E-04
1.88E+02      -0.15       -10.6       1.54E-04
3.54E+02      -0.51       -19.5       1.41E-04
6.65E+02      -1.59       -33.6       1.10E-04
1.25E+03      -4.09       -51.3       6.21E-05
2.35E+03      -8.14       -66.9       2.44E-05

F = 1 0 2 1
L = 2 3 1.59154
R = 3 0 10000

Network has 3 nodes
Input & output nodes are 1 , 2

Input impedance with linear frequency increments
Frequency range is 100 , 2350 , 450

  FREQ         REAL       IMAG       AMPL      ANGLE
1.00E+02     10000.0     1000.0    10049.9      5.7
5.50E+02     10000.0     5500.0    11412.7     28.8
1.00E+03     10000.0    10000.0    14142.1     45.0
1.45E+03     10000.0    14500.0    17613.9     55.4
1.90E+03     10000.0    19000.0    21470.9     62.2
2.35E+03     10000.0    23500.0    25539.2     66.9
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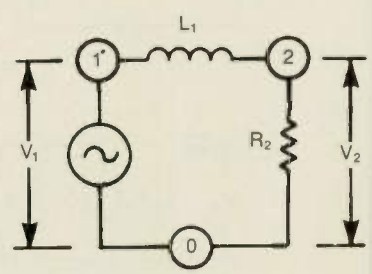

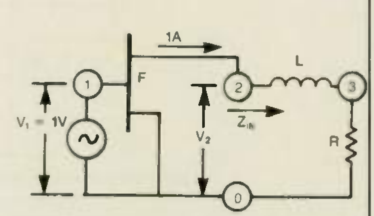

Figure 1. Frequency response and input impedance of a simple network.

Since element values, like capacitors in parallel between a pair of nodes, are automatically added by the program, a mistake must be corrected by subtracting the wrong value and adding the correct value. Any number of elements can be paralleled between two nodes.

After the network has been described, enter E to exit then type "1, 2" and press the ENTER key again to designate node 1 as the input and node 2 as the output. Type start, stop, and increment frequencies followed by ENTER for a set of linear frequencies, or start, stop, and −D for a set of D logarithmic frequencies. The computer will now proceed to display the frequency response. Voltages are measured with respect to ground or reference node zero. The normal input is 1 volt rms applied between the input node and ground. To specify a current input, apply the 1 volt input to the gate node of the FET transistor having a gain of 1 A/V. This technique is used in the lower part of Figure 1 to compute the input impedance, where the values are listed under the impedance format header.

Since accurate values for the input impedance are difficult to present on a 32 column screen, printed values may be preferred. The frequency range and I/O node assignments can be changed after each run. However, each element requires the loading subroutine to direct values to numerous memory locations, so for these changes the user is advised to start over. A revised program has been compiled to store the element values on a disk file where they can be modified and stored individually. However, with each disk operating system requiring a different revision, they are not included at this time.

Program Description

Several versions of this program have been published (1, 2, 3, 4). Mason and Zimmermann described how to solve network problems with the indefinite admittance matrix. Schnider is usually given credit for the algorithm. Niemeyer added an inductor and transmission line elements and Steincross retrieved the elements from a disk file. These programs written for the HP 9825, the HP 9830, and an Apple II computer with an Apple Pie editor did have a few unique instructions not found on most modern desktop computers. An attempt is made here to provide a program that can be used on a variety of personal computers, stressing user instructions and printout format. This program has a time delay column for the frequency response, an input impedance subroutine, and an improved arctan conversion. Certainly features like S-parameter conversion and disk editors have value, but in a first edition the objective is to present the basics first.

To assist readers who desire to change this program, several sets of diagrams have been made to show each element first as a computer model, then with high frequency modifications, and finally in a matrix. While a linear circuit is easy to describe with an indefinite matrix, the analysis has seldom been recommended. However, with desktop computers available to evaluate the ratio of selected determinants, the ratio of nodal voltages can be readily calculated to analyze the network. A resistor network will be described in detail to show that the data entry task is simple enough to be done by inspection. The transistor models that follow use a 3X3 matrix to satisfy three simple equations. Subscript manipulations may be of interest, but the description is too long to be included here.

A 4-terminal resistor network is shown in Figure 2a along with its indefinite admittance matrix. Notice that the sum of all the elements in any row or any column equals zero and that we could easily assign values by inspecting the network. Now if node zero becomes the common terminal, then $V_0 = 0$ and all voltages are measured with respect to this node. By applying Kirchhoff's current law, all elements of the row and column corresponding to the common terminal can be deleted and the network and its matrix have the form shown in Figure 2b.

Conductances for this resistor network are stored in array A and then transferred to array P. Inductor values are stored in arrays B and Q, and capacitor values in arrays B1 and Q1. Lines 1850 through 2040 perform the storage and lines 1330 through 1350 perform the transfer. The FET transistor is usually used in the com-

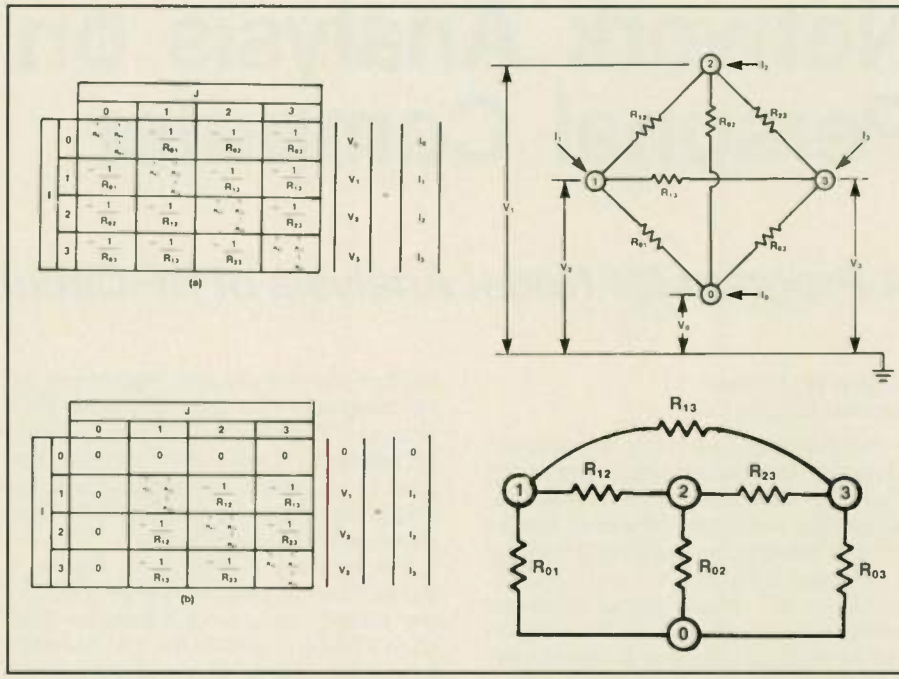

Figure 2. Resistor nodal network and its indefinite admittance matrix.

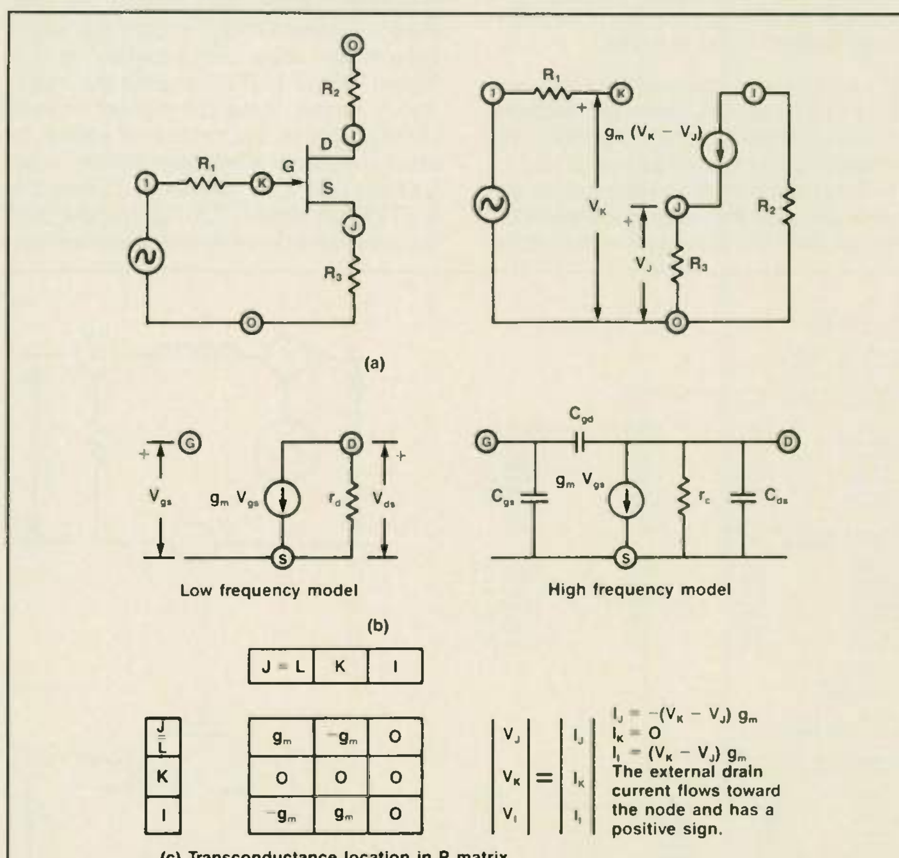

Figure 3. FET circuit notation, computer representation, equivalent circuits, and unsymmetrical admittance matrix.

mon source configuration illustrated in Figure 3a. Here the gate, source and drain terminals are represented by nodes K, J and I, respectively, as they are designated in the computer program. The equivalent circuit in Figure 3a, which the computer simulates, may seem oversimplified. However, when the low and the high frequency models shown in Figure 3b are considered, it is obvious that additional capacitors can be inserted between the nodes to provide the high frequency model. Values for these interelectrode capacitors are listed on most FET data sheets. The section of the conductance matrix shown in Figure 3c shows where the transconductance values would be located if they were the only elements in the matrix. To satisfy the simple FET equations, g_m in column I of the passive matrix was moved to column K of the FET matrix by increasing the number of coefficients from 9 to 16 by letting subscript J = L and then storing selected g_m values with lines 2050 through 2110. This subroutine is also used for the bipolar transistor and the op-amp.

The bipolar transistor is usually used in the common emitter configuration illustrated in Figure 4a. In the hybrid model, $h_{ie} = r_{bb'} + r_{b'e}$ and at low frequencies the source resistance is often so much greater than $r_{bb'}$ that $r_{b'e} = h_{ie}$ is a good approximation. When the computer model is compared to the low and high frequency models of Figure 4b, one additional node will allow all additional components to be installed in the high frequency model. Values for these components can be found on data sheets in the hybrid parameter section. Values for the conductance matrix shown in Figure 4c are stored in a 2-pass process. The conductance between nodes J and K is stored first by shifting the value of subscript I to L, then destroying the value of I and replacing it with K. With I = K there will be 16 coefficients again and selected values of conductance will be stored by lines 1850 through 1920. The transconductance is now inserted between the correct FET nodes by recalling the original value of I from L, then replacing the value of L with J. The matrix is now identical to the transconductance for the FET and values are stored by lines 2050 through 2110.

The op-amp model shown in Figure 5 consists of a differential amplifier having its gain and output resistance assigned from the keyboard. In this model, the source is converted to its Norton equivalent circuit, and after the conductance between nodes I and J is stored by lines

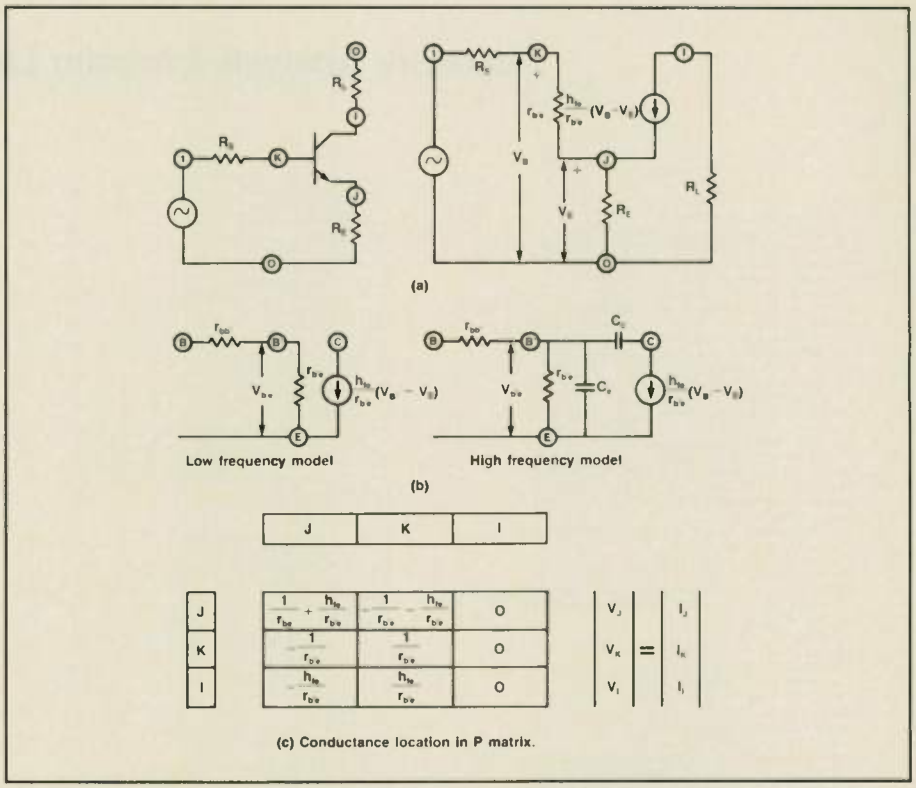

Figure 4. Bipolar transistor notation, computer representation, equivalent circuits, and unsymmetrical admittance matrix.

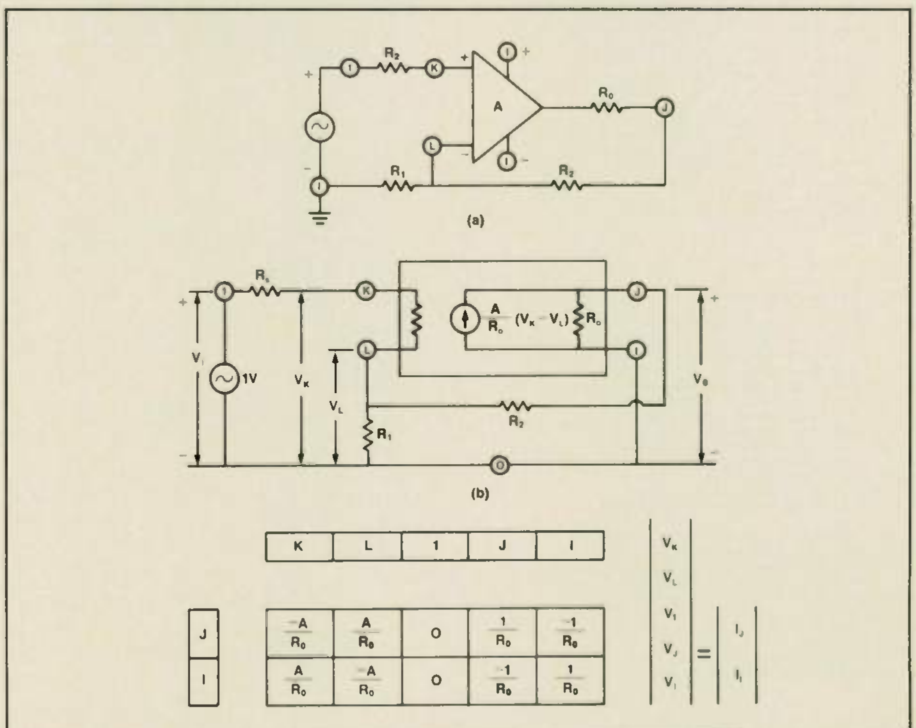

Figure 5. Low frequency OP AMP circuit notation, equivalent circuit, and admittance matrix array.

Network Analysis Program Listing

```
1000 '     NAME: NETWORK
1010 CLEAR:CLS:GOSUB 2850
1020 INPUT"Enter number of nodes";Y:PRINT
1030 DIM A(Y,Y),B(Y,Y),P(Y,Y),Q(Y,Y),B1(Y,Y),Q1(Y,Y)
1040 PI=3.14159265:LCTEN=20/LOG(10)
1050 INPUT"Enter element symbol ";Z$
1060 E$=Z$:Z$=LEFT$(Z$,1):S$="RCLAFNE"
1070 Z=INSTR(1,S$,Z$):IF Z=0 THEN 1090
1080 ON Z GOSUB 1100,1130,1160,1260,1190,1220,1310
1090 PRINT"Enter symbol from list!!!!!!":GOTO 1050
1100 INPUT"Nodes & ohms are";I,J,V
1110 IF PR THEN GOSUB 3110
1120 V=1/V:GOSUB 1850:GOTO 1050
1130 INPUT"Nodes & ufds are";I,J,V
1140 IF PR THEN GOSUB 3110
1150 V=V*1E-6:GOSUB 1930:GOTO 1050
1160 INPUT"Nodes & henrys are";I,J,V
1170 IF PR THEN GOSUB 3110
1180 V=-1/V:GOSUB 1990:GOTO 1050
1190 INPUT"G,S,D,Nodes & A/V are";K,J,I,V
1200 IF PR THEN GOSUB 3120
1210 L=J:GOTO 1300
1220 INPUT"B,E,C,beta & B-E ohms";K,J,I,B1,V
1230 IF PR THEN GOSUB 3130
1240 L=I:I=K:V=1/V:GOSUB 1850
1250 I=L:L=J:GOTO 1290
1260 PRINT"For the OP AMP enter IN+,-,OUT+,-,Gain,ohms"
1270 INPUT K,L,J,I,B1,V:IF PR THEN GOSUB 3140
1280 V=1/V:GOSUB 1850
1290 V=B1*V
1300 GOSUB 2050:GOTO 1050
1310 PRINT:'   Compute I/O ratios
1320 INPUT"Input & output nodes are";E,F
1330 FOR I=0 TO N:FOR J=0 TO N
1340 P(I,J)=A(I,J):Q1(I,J)=B1(I,J)
1350 Q(I,J)=B(I,J):NEXT J:NEXT I
1360 IF PR THEN 3150 ELSE 1460
1370 PRINT:INPUT"Want printed results  Y/N";Z$:PRINT
1380 IF Z$="Y" OR Z$="y" THEN PR =1 ELSE PR=0
1390 INPUT"Want time delay list  Y/N";Z$:PRINT
1400 IF Z$="Y" OR Z$="y" THEN ND=0 ELSE ND=1
1410 INPUT"Want impedance format Y/N";Z$:PRINT
1420 IF Z$="Y" OR Z$="y" THEN OR=1 ELSE OR=0
1430 INPUT"Want new I/O nodes    Y/N";Z$
1440 IF Z$="Y" OR Z$="y" THEN 1450 ELSE 1460
1450 INPUT"Input & output nodes are";E,F
1460 PRINT:PRINT"The frequency range is"
1470 INPUT"Start, end, increment";G,H,D
1480 IF PR THEN GOSUB 3180
1490 PRINT:IF OR=0 THEN GOSUB 3200
1500 IF OR=0 AND PR THEN GOSUB 3210
1510 IF OR THEN GOSUB 3380
1520 IF OR AND PR THEN GOSUB 3400
1530 IF D<0 THEN F2=-D ELSE F2=1+(H-G)/D
1540 IF D<0 THEN D=-((H/G)^(1/(-D-1)))
1550 F1=G:FOR I1=1 TO F2
1560 I2=0:IF ND OR OR THEN 1580
1570 FOR I2=0 TO 1
1580 W=2*PI*F1:D1=E:D2=F:GOSUB 2660
1590 V=D1:U=D2

1600 IF(-1)^(E+F)>0 THEN 1620
1610 U=U-180
1620 D1=E:D2=E:GOSUB 2660
1630 IF V=0 OR D1=0 THEN 1650
1640 V=V/D1:DB=LCTEN*LOG(V)
1650 U=U-D2:IF U>180 THEN U=U-360
1660 IF U<-180 THEN U=U+360
1670 IF OR THEN 1700
1680 IF PR=0 AND I2=0 THEN GOSUB 3240
1690 IF PR AND I2=0 THEN GOSUB 3300
1700 IF OR AND PR=0 THEN 3450
1710 IF OR AND PR THEN 3510
1720 DU=U1-U:U1=U:IF ND THEN 1760
1730 F1=F1*(1+1E-5):NEXT I2
1740 U2=DU/U3/360*1E5
1750 IF PR THEN 3360 ELSE 3290
1760 IF PR THEN PRINT#-2 ELSE PRINT
1770 '
1780 IF D<0 THEN F1=-U3*D ELSE F1=U3+D
1790 NEXT I1:IF PR THEN GOSUB 3610
1800 PRINT:INPUT"Want to continue  Y/N";Z$
1810 IF Z$="Y" OR Z$="y"THEN 1370
1820 PRINT"**Now in basic mode**"
1830 END
1840 '   Form element matrices
1850 IF I=0 THEN 1890
1860 A(I,I)=A(I,I)+V
1870 IF J=0 THEN 1900
1880 A(I,J)=A(I,J)-V:A(J,I)=A(J,I)-V
1890 A(J,J)=A(J,J)+V
1900 IF I>N THEN N=I
1910 IF J>N THEN N=J
1920 RETURN
1930 IF I=0 THEN 1970
1940 B(I,I)=B(I,I)+V
1950 IF J=0 THEN 1900
1960 B(I,J)=B(I,J)-V:B(J,I)=B(J,I)-V
1970 B(J,J)=B(J,J)+V
1980 GOTO 1900
1990 IF I=0 THEN 2030
2000 B1(I,I)=B1(I,I)+V
2010 IF J=0 THEN 1900
2020 B1(I,J)=B1(I,J)-V:B1(J,I)=B1(J,I)-V
2030 B1(J,J)=B1(J,J)+V
2040 GOTO 1900
2050 IF I<>0 AND K<>0 THEN A(I,K)=A(I,K)+V
2060 IF J<>0 AND L<>0 THEN A(J,L)=A(J,L)+V
2070 IF J<>0 AND K<>0 THEN A(J,K)=A(J,K)-V
2080 IF I<>0 AND L<>0 THEN A(I,L)=A(I,L)-V
2090 IF K>N THEN N=K
2100 IF L>N THEN N=L
2110 GOTO 1900
2120 '    Compute determinant
2130 IF N>1 THEN 2150
2140 D1=A(N,N):D2=B(N,N):RETURN
2150 D1=1:D2=0:K=1
2160 L=K
2170 S=ABS(A(K,K))+ABS(B(K,K))
2180 FOR I=K TO N
2190 T=ABS(A(I,K))+ABS(B(I,K))

2200 IF S>=T THEN 2220
2210 L=I:S=T
2220 NEXT I
2230 IF L=K THEN 2310
2240 FOR J=1 TO N
2250 S=-A(K,J)
2260 A(K,J)=A(L,J)
2270 A(L,J)=S
2280 S1=-B(K,J)
2290 B(K,J)=B(L,J):B(L,J)=S1
2300 NEXT J
2310 L=K+1
2320 FOR I=L TO N
2330 S1=A(K,K)*A(K,K)+B(K,K)*B(K,K)
2340 S=(A(I,K)*A(K,K)+B(I,K)*B(K,K))/S1
2350 B(I,K)=(A(K,K)*B(I,K)-A(I,K)*B(K,K))/S1
2360 A(I,K)=S:NEXT I
2370 J2=K-1
2380 IF J2=0 THEN 2440
2390 FOR J=L TO N
2400 FOR I=1 TO J2
2410 A(K,J)=A(K,J)-A(K,I)*A(I,J)+B(K,I)*B(I,J)
2420 B(K,J)=B(K,J)-B(K,I)*A(I,J)-A(K,I)*B(I,J)
2430 NEXT I:NEXT J
2440 J2=K:K=K+1
2450 FOR I=K TO N
2460 FOR J=1 TO J2
2470 A(I,K)=A(I,K)-A(I,J)*A(J,K)+B(I,J)*B(J,K)
2480 B(I,K)=B(I,K)-B(I,J)*A(J,K)-A(I,J)*B(J,K)
2490 NEXT J:NEXT I
2500 IF K<>N THEN 2160
2510 L=1
2520 J2=INT(N/2)
2530 IF N=2*J2 THEN 2570
2540 L=0
2550 D1=A(N,N)
2560 D2=B(N,N)
2570 FOR I=1 TO J2
2580 J=N-I+L
2590 S=A(I,I)*A(J,J)-B(I,I)*B(J,J)
2600 T=A(I,I)*B(J,J)+A(J,J)*B(I,I)
2610 T1=D1*S-D2*T
2620 D2=D2*S+D1*T
2630 D1=T1
2640 NEXT I
2650 RETURN
2660 N1=N:N=N-1:I=0
2670 FOR K=1 TO N
2680 IF K<>D1 THEN 2700
2690 I=1
2700 J=0
2710 FOR L=1 TO N
2720 IF L<>D2 THEN 2740
2730 J=1
2740 A(K,L)=P(K+I,L+J)
2750 B(K,L)=W*Q(K+I,L+J)+Q1(K+I,L+J)/W
2760 NEXT L:NEXT K
2770 GOSUB 2130
2780 N=N1
2790 B1=SQR(D1*D1+D2*D2)

2800 IF D1=0 AND D2=0 THEN 2840
2810 IF D1<0 AND D2=0 THEN 2830
2820 D2=360/PI*ATN(D2/(B1+D1)):RETURN
2830 D2=180
2840 RETURN
2850 '       Info about program
2860 PRINT"The Network Element format is"
2870 PRINT"R      (Resistor)   "
2880 PRINT"From node #, to node #, ohms"
2890 PRINT"C      (Capacitor)  "
2900 PRINT"From node #, to node #, ufds"
2910 PRINT"L      (Inductor)   "
2920 PRINT"From node #, to node #, hrys"
2930 PRINT"F      (FET)        "
2940 PRINT"Gate,Source,Drain,Gain(A/V)"
2950 PRINT"N      (NPN)        "
2960 PRINT"Base,Emit,Coll,Beta,B-E ohms"
2970 PRINT"A      (OP AMP)     "
2980 PRINT"+IN,-IN,+OUT,-OUT,Gain,Ohms out"
2990 PRINT"E      (Exit)       "
3000 PRINT"Input node #, Output node #"
3010 INPUT"Press enter to continue";Z$:CLS
3020 PRINT"For log freq, use -# for number"
3030 PRINT"of frequencies wanted":PRINT
3040 INPUT"Want printed results  Y/N";Z$:PRINT
3050 IF Z$="Y" OR Z$="y" THEN PR=1 ELSE PR=0
3060 INPUT"Want time delay list  Y/N";Z$:PRINT
3070 IF Z$="Y" OR Z$="y" THEN ND=0 ELSE ND=1
3080 INPUT"Want impedance format Y/N";Z$:PRINT
3090 IF Z$="Y" OR Z$="y" THEN OR=1 ELSE OR=0
3100 RETURN
3110 PRINT#-2,E$;" =";I;J;V:RETURN
3120 PRINT#-2, E$;" =";K;J;I;V:RETURN
3130 PRINT#-2, E$;" =";K;J;I;B1;V:RETURN
3140 PRINT#-2, E$;" =";K;L;J;I;B1;V:RETURN
3150 PRINT#-2:PRINT#-2,"Network has";N;"nodes"
3160 PRINT#-2,"Input & output nodes are";E;",";F
3170 GOTO 1460
3180 PRINT#-2:PRINT#-2,"Frequency range is";
3190 PRINT#-2,G;",";H;",";D:RETURN
3200 PRINT"    FREQ       DB     PHASE     DELAY":RETURN
3210 PRINT"**Wait for the printed results**"
3220 PRINT#-2:PRINT#-2,"    FREQ              DB       ";
3230 PRINT#-2,"PHASE      DELAY(SEC)":RETURN
3240 U3=F1:PRINT USING"##.##^^^^";F1;
3250 IF V=0 OR B1=0 THEN 3270
3260 PRINT USING"####.#";DB;:GOTO 3280
3270 PRINT"   inf";
3280 PRINT" ";:PRINT USING"####.#";U;:RETURN
3290 PRINT" ";:PRINT USING"##.#^^^^";U2:GOTO 1770
3300 U3=F1:PRINT#-2,USING"##.##^^^^";F1;
3310 PRINT#-2,"   ";:IF V=0 OR B1=0 THEN 3330
3320 PRINT#-2,USING"####.##";DB;:GOTO 3340
3330 PRINT#-2,"   inf";
3340 PRINT#-2,"     ";
3350 PRINT#-2,USING"####.#";U;:RETURN
3360 PRINT#-2,"     ";:PRINT#-2,USING"##.##^^^^";U2
3370 GOTO 1770
3380 PRINT"Input or transfer impedance is":PRINT
3390 PRINT"   FREQ       REAL      IMAG":RETURN

3400 PRINT"**Wait for printed results**"
3410 PRINT#-2,"The input or transfer impedance is"
3420 PRINT#-2:PRINT#-2,"    FREQ              REAL";
3430 PRINT#-2,"           IMAG         AMPL";
3440 PRINT#-2,"     ANGLE":RETURN
3450 U3=F1:D=(180+U)*PI/180
3460 PRINT USING"##.##^^^^";F1;
3470 IF V=0 OR B1=0 THEN 3500
3480 PRINT USING"#######.#";V*COS(D),V*SIN(D)
3490 GOTO 1770
3500 PRINT"    inf       inf":GOTO 1770
3510 U3=F1:D=(180+U)*PI/180
3520 PRINT#-2,USING"##.##^^^^";F1;
3530 PRINT#-2,"  ";
3540 PRINT#-2,USING"#######.#";V*COS(D);
3550 PRINT#-2,"  ";
3560 PRINT#-2,USING"#######.#";V*SIN(D);
3570 PRINT#-2,"  ";
3580 PRINT#-2,USING"#######.#";V;
3590 PRINT#-2,"  ";
3600 PRINT#-2,USING"####.#";U*180/PI:GOTO 1770
3610 PRINT#-2:PRINT#-2:RETURN
```

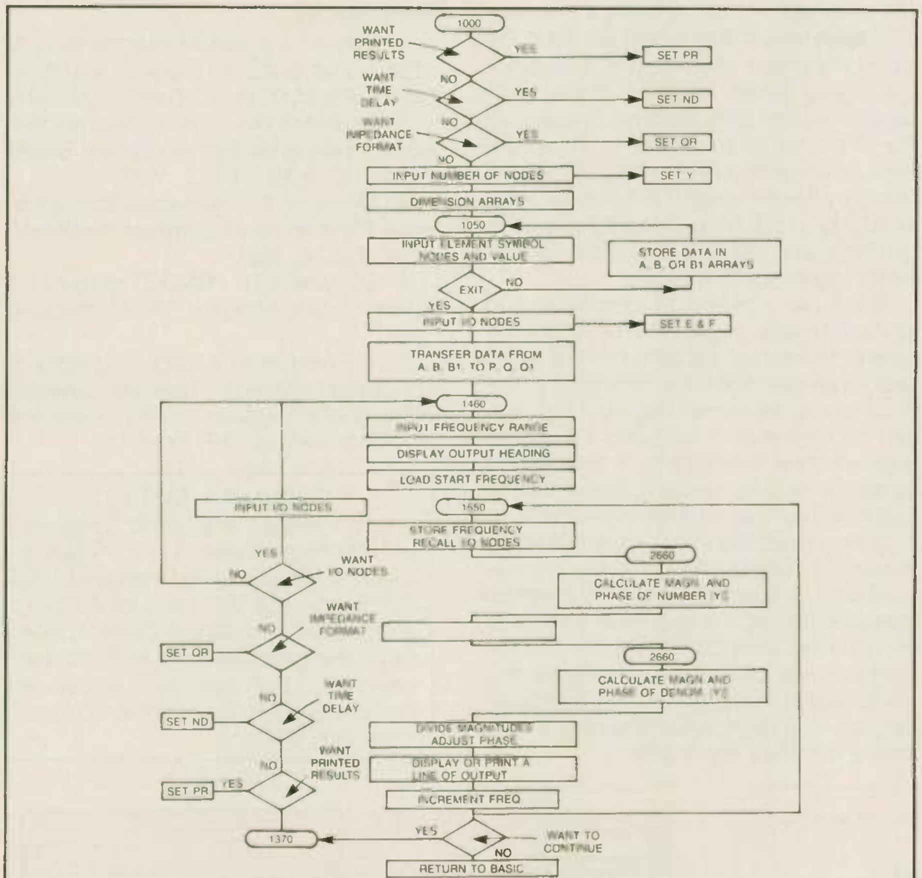

Figure 6. Flow diagram for the network program.

1850 through 1920, the current generator is stored by the FET subroutine at lines 2050 through 2110. While all ideal linear op-amp circuits are readily simulated, the high frequency response is complicated by slew rates and exponential functions that require more components in the differential amplifier.

Figure 6 is a functional flow diagram for the program. This diagram shows most of the keyboard inputs that are available. Not shown are several fault instructions that prevent the user from losing the program. The matrix analysis subroutine is directed by some properties of the indefinite admittance matrix. Assuming that each element of the nodal matrix is a short circuit admittance and that the matrix is not degenerate, we then define I_{rq} as the current that flows into terminal r and out of terminal q and that there are no additional external currents. The potential difference between terminals, $E_{km} = E_k - E_m$. The open circuit transfer impedance E_{km}/I_{rq} is then given by

$$z_{rq}^{km} = \frac{E_{km}}{I_{rq}} = \frac{|Y|_{rq}^{km}}{|Y|_q^m}$$

when k = r and m = q, the driving point impedance is

$$z_{rq}^{rq} = \frac{E_{rq}}{I_{rq}} = \frac{|Y|_{rq}^{rq}}{|Y|_q^q}$$

Since the first order cofactors of an indefinite matrix are all equal, dividing the transfer impedance by the driving point impedance gives the voltage ratio

$$\frac{E_{km}}{E_{rq}} = \frac{|Y|_{rq}^{km}}{|Y|_{rq}^{rq}}$$

where the cofactor $|Y|_{rq}^{km}$ is $(-1)^{r+q+k+m}$ times the determinant of the submatrix formed by deleting rows r and q and columns k and m in the indefinite matrix. The subscripts and superscripts must be in ascending order or else the number of transpositions must be counted. Delete row q to designate node r as the terminal where the current enters the network and node q as the terminal where the current returns to the source. The input will then be in the denominator of the transfer function. Delete column m to designate node m as the voltage reference. The voltage at node k will then be the output voltage in the numerator. In the program, nodes m and q both correspond to node zero, and row zero and column zero are deleted as the elements are stored. In the analysis subroutine the row and column to be deleted are preselected and all cofactors are evaluated by the same instructions.

The program does not evaluate the denominator cofactors for the transfer and driving point impedances, however values can be obtained by setting the input current equal to 1 with an FET conversion, then the impedances are equal to the node voltages. The matrix reduction program with its complex numbers is too long to be described here, but notice that at line 1580 the input and output nodes are recalled to evaluate the $|Y|_{E}^{F}$ submatrix, and then at line 1620 the input node is recalled twice to evaluate the $|Y|_{E}^{F}$ submatrix. The magnitude division is performed at line 1640, and the phase is adjusted at lines 1650 and 1660.

The time delay was originally a one line instruction dividing $\Delta\phi$ by Δw, however it was accurate only for small increments of frequency and the first value did not exist. When Akima and Przedpelski reviewed the program (5), they astutely suggested that the phase should be calculated at the listed frequency and again at a frequency slightly offset to obtain better time delay. The program includes this option. For the network in Figure 1, where the time delay is $RL/(R^2 + w^2L^2)$ the values listed by the computer had a mean error of 0.02% and a 0.1% standard deviation of the errors which is not bad for a first order digital approximation.

Since the inclusion of time delay and printed results makes the program run slower, the default status is no time delay and no printer. When the cofactor is evaluated where the sum of the input and output nodes is odd, it acquires a negative sign which is modified by a 180 degree phase shift. The result obtained needs clarification. The transmission line subroutine would likely be appreciated by many RF engineers and could be described in a future article. This program has reproduced the results of examples found in the literature and has verified the performance of circuits assembled and measured in the laboratory. It is quite user friendly and somewhat forgiving if keyboard mistakes are made. rf

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5. A. Przedpelski is consulting editor of *RF Design* and vice president, development, of ARF Products, K. Akima is on the technical staff of ARF Products.

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F1001	Single ended, low noise, low gain compression	13	20	175	0.4	28	30	19.5	3.7	AA	3.5	ACR. VMIL20FT PHI DV2820S	1 F1A
F1001B	Single ended higher gain	16	20	175	0.8	28	30	19.5	3.7	AA	3.5	PHI DU2820S	1 F1B
F1002	Single ended, low noise, low gain compression	13	40	175	0.8	28	60	39	7.4	AA	2.1	ACR. VMIL40FT PHI DV2840S	2 F1A
F1002B	Single ended, higher gain	16	40	175	1.6	28	60	39	7.4	AA	2.1	PHI DU2840S	2 F1B
F1003	Single ended, low noise, low gain compression	13	60	175	1.2	28	90	58	11	AM	2.1	ACR. VMU60FT PHI DV2860U	3 F1A
F1003B	Single ended, higher gain	16	60	175	2.4	28	90	58	11	AM	2.1	PHI DU2860U	3 F1B
F1004	Single ended, low noise, low gain compression	13	80	175	1.6	28	120	78	15	AT	1.0	ACR. VMIL80FT PHI DV2880T	4 F1A
F1004B	Single ended, higher gain	16	80	175	3.2	28	120	78	15	AT	1.0	PHI DV2880T	4 F1B
F1005	Single ended, low noise, low gain compression	13	80	100	1.6	28	120	75	15	AM	1.0	MOT.MRF172 PHI DV2880U	4 F1A
F1005B	Single ended, higher gain	16	80	100	3.2	28	120	78	15	AM	1.0	PHI DU2880U	4 F1B
F1006	Single ended, low noise, low gain compression	12	120	175	2.4	28	180	117	22	AV	0.7	ACR. VMIL120FT PHI DV28120T	6 F1A
F1006B	Single ended, higher gain	14	120	175	4.8	28	180	117	22	AV	0.7	PHI DU28120T	6 F1B
F1007	Push-Pull higher gain-bandwidth product	13	20	400	0.8	28	30	19.5	3.7	AK	1.75	ACR. UMIL20FT	1+1 F1B
F1008	Push-Pull higher gain-bandwidth product	13	40	400	1.6	28	60	39	7.4	AK	1.05	ACR. UMIL40FT PHI UF2840G	2+2 F1B
F1009	Push-Pull low noise less gain compression	11	150	200	1.6	28	120	78	15	AH	0.5	ACR. VMIL150FT	4+4 F1A
F1012	Push-Pull higher gain-bandwidth product	10	100	500	2.4	28	90	58	11	AH	0.6		3+3 F1B
F1013	Single ended higher gain-bandwidth product, smaller footprint	13	20	550	0.8	28	30	19.5	3.7	AP	3.5		1 F1B
F1014	Single ended higher gain-bandwidth product, smaller footprint	13	40	400	1.6	28	60	39	7.4	AP	2.1		2 F1B
F1015	Push-Pull higher power higher gain-bandwidth	13	100	500	3.2	28	120	78	15	AH	0.5		4+4 F1B
F1016	Push-Pull, smaller footprint, higher gain-bandwidth	13	20	400	0.8	28	30	19.5	3.7	AQ	1.75	ACR. UMIL20FT	1+1 F1B
F1018	Push-Pull, smaller footprint, higher gain-bandwidth	10	100	500	2.4	28	90	58	11	AD	0.6	PHI UF28100V	3+3 F1B
F1020	Push-Pull, very high power, small footprint, high gain-bandwidth	10	130	400	4	28	150	97	18	AR	0.45	PHI DU28200M	5+5 F1B

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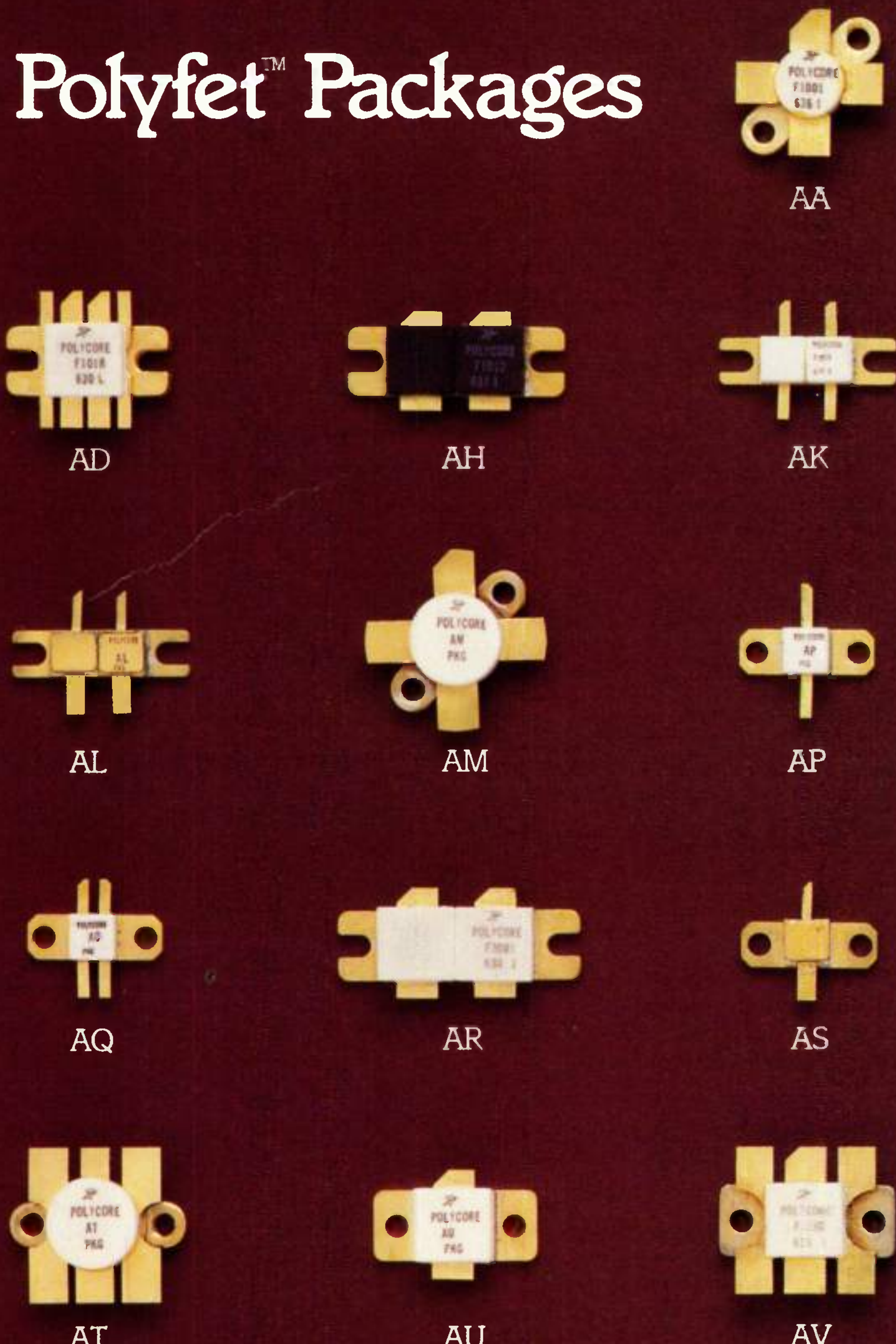

F3000 SERIES SUPERPOWER HF to VHF

Polyfet Part #	Features	Gain (dB) Min.	Po (Watts)	Test Freq. MH2	Gm (MHO) Min.	Voltage	TYPICAL Ciss	Coss	Crss	Type	Θjc °C/W	Cross Reference Part Number	REMARKS Chip Compliment
F3001	Push-Pull linear, high power	13	150	300	3.5	28	200	120	20	AR	0.5		1+1 F3A
F3002	Push-Pull linear, high power	13	300	175	7	28	400	240	40	AR	0.4		2+2 F3A
F3003	Single Ended high power, linear	13	100	300	3.5	28	200	120	20	AU	1.0		1 F3A
F3004	Single ended high power, linear	13	100	300	3.5	28	200	120	20	AT	1.1		1 F3A
F3005	Single ended high power, linear	13	100	110	3.5	28	200	120	20	AM	1.1	MOT.MRF174	1 F3A
F3006	Single ended high power, linear	13	150	110	7	28	400	240	40	AM	0.8	MOT.MRF140	2 F3A
F3007	Single ended high power, linear	13	160	175	7	28	400	240	40	AU	0.7		2 F3A
F3008	Push-Pull linear, high power	16	300	175	4	50	400	180	30	AR	0.4		2+2 F3B
F3009	Push-Pull linear, high power	10	160	300	2	50	200	90	15	AR	0.5		1+1 F3B
F3010	Single ended high power, linear	16	175	110	4	50	400	180	30	AM	0.8	MOT.MRF150	2 F3B
F3011	Single ended high power, linear	16	100	110	2	50	200	90	15	AM	1.1		1 F3B
F3012	Single ended high power, linear	16	100	110	2	50	200	90	15	AT	1.1		1 F3B
F3013	Single ended high power, linear	13	100	300	3.5	28	200	120	20	AV	1.0		1 F3A
F3014	Single ended high power, linear	13	160	175	7	28	400	240	40	AV	0.7		2 F3A
F3015	Single ended high power, linear	16	100	175	2	50	200	90	15	AV	0.7	PHI DVD150T	1 F3B
F3016	Single ended high power, linear	16	160	175	4	50	400	180	30	AV	0.7		2 F3B

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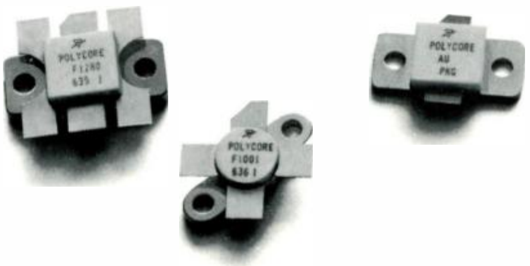
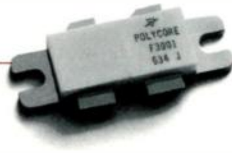


F1000 SERIES HF to 1GHz (continued)

Polyfet Part #	Features	Gain (dB) Min.	Po (Watts)	Test Freq. MH2	Gm (MHO) Min.	Volt-age	TYPICAL Ciss	Coss	Crss	Type	Θjc °C/W	Cross Reference Part Number	REMARKS Chip Compliment
F1021	Push-Pull, high power, higher gain-bandwidth product, small footprint	13	100	400	3.2	28	120	78	15	AK	0.5		4+4 F1B
F1022	Push-Pull, high power, high gain-bandwidth product-small footprint	10	100	500	2.4	28	90	58	11	AK	0.6		3+3 F1B
F1027	Push-Pull, very high power, high gain-bandwidth product-small footprint	10	150	400	4.8	28	180	117	22	AR	0.4		6+6 F1B
F1028	Single ended, low noise, low gain compression	13	60	175	1.2	28	90	58	11	AA	2.1	MOT.MRF138 MRF171	3 F1A

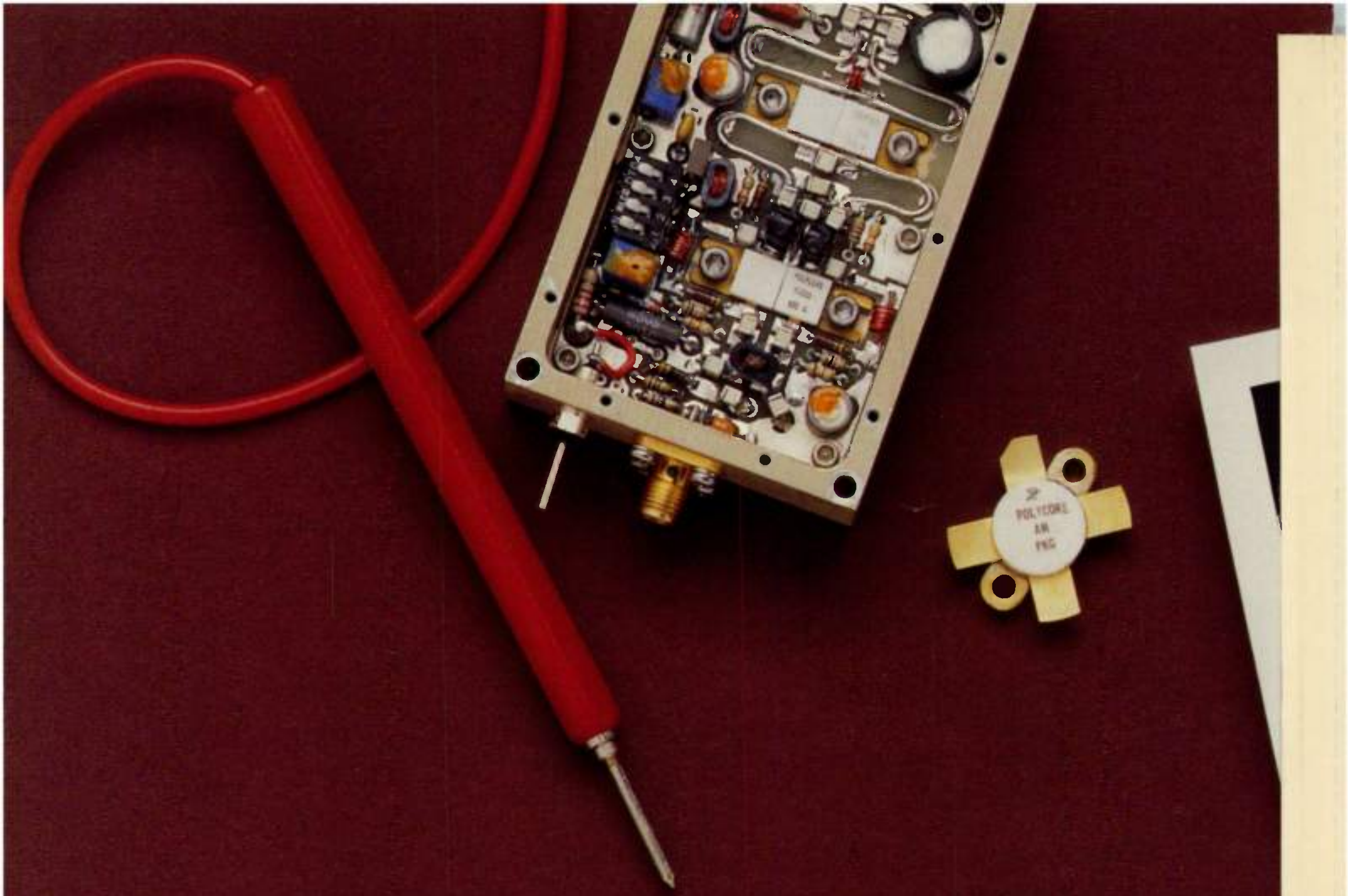


F1200 SERIES MOBILE HF to 1GHz

Polyfet Part #	Features	Gain (dB) Min.	Po (Watts)	Test Freq. MH2	Gm (MHO) Min.	Volt-age	Ciss	Coss	Crss	Type	Θjc °C/W	Cross Reference Part Number	REMARKS Chip Compliment
F1201	Single ended, high-gain, low noise, small footprint	10	10	500	0.8	12.5	30	35	5	AP	3.5		1 F1C
F1202	Single ended, high gain low noise, small footprint	10	20	500	1.6	12.5	60	70	10	AP	2.1		2 F1C
F1207	Push-pull, high gain, low noise	10	20	400	0.8	12.5	30	35	5	AQ	1.75		1+1 F1C
F1208	Push-pull, high gain low noise	10	40	400	1.6	12.5	60	70	10	AK	1.05		2+2 F1C
F1260	Industry standard	10	60	225	3.2	12.5	120	140	20	AT	1.0	PHI DUR60T	4 F1C

F2000 SERIES HF to 2GHz

Polyfet Part #	Features	Gain (dB) Min.	Po (Watts)	Test Freq. MH2	Gm (MHO) Min.	Volt-age	Ciss	Coss	Crss	Type	Θjc °C/W	Cross Reference Part Number	REMARKS Chip Compliment
F2001	Single ended, DC-thru microwave, low noise, high power	10	2.5	1000	0.2	28	7	5.5	1	AP	10.0	PHI UF2804	1 F2A
F2002	Single ended, DC-thru microwave low noise, high power	10	5	1000	0.4	28	14	11	2	AP	6.0	PHI UF 2804	1 F2A
F2003	Push-Pull DC thru microwave high power, low noise	10	5	1000	0.2	28	7	5.5	1	AQ	6.0		1+1 F2A
F2004	Push-Pull DC thru microwave high power, low noise	10	8	1000	0.4	28	14	11	2	AK	3.0	PHI UF2804G	2+2 F2A
F2005H	Push-Pull, solder seal DC thru microwave low noise, high power	10	10	1000	0.4	28	14	11	2	AL	3.0		2+2 F2A
F2008H	Single ended, solder seal DC thru microwave high power, low noise	10	2.5	1000	0.2	28	7	5.5	1	AS	10.0		1 F2A
F2009H	Single ended, solder seal DC thru microwave high power, low noise	10	5	1000	0.4	28	14	11	2	AS	6.0		2 F2A
F2012H	Single ended, Solder Seal DC thru microwave high power, low noise	10	10	1000	0.8	28	28	22	4	AS	4.2		4 F2A
F2013H	Single ended, solder seal DC thru microwave high power, low noise	10	20	1000	0.8	28	28	22	4	AL	2.1		4+4 F2A
F2015	Single ended, solder seal DC thru microwave high power, low noise	10	4	1000	0.2	28	7	5.5	1	AP	10.0		1 F2A



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A UHF Movement Detector

By David C. Huisman
Tait Electronics

Here is another entry from the First Annual RF Design Contest, a UHF circuit for the detection of motion. The author describes the principles of doppler shift detection, and presents a circuit operating at 1.2 GHz as a practical application.

This circuit will detect movement of objects in an area up to about a 4 m radius (50 m²), and can be used as an alarm for house, garage, car, shop or office. It could even be linked to a microprocessor to detect movement in various sectors of a building and control mechanical devices in response to the presence or absence of personnel.

The device works by using the doppler shift principle. To better understand how it works, we can consider a moving object as a transmitter-receiver for RF signals. As shown in Figure 1 (page 43), a UHF signal from the oscillator at a frequency f_o is radiated by the antenna. It is reflected back by the moving object and returns to the antenna at some f_o'. If the object is moving toward the antenna, f_o' is greater than f_o, and vice versa. When there is no movement, $f_o' = f_o$.

By placing a diode in the circuit, it will perform a mixing function between the frequencies f_o and f_o'. The predominant frequencies resulting from the mixing action are: f_o, f_o', $(f_o + f_o')$, and $(f_o - f_o')$. Of these four, the low "beat frequency" (f_b) is $f_o - f_o'$, which can be amplified and used to trigger other circuitry. The remaining frequencies are bypassed to ground by an R-C filter network. Only the sub-audible tone f_b is passed on to the remaining circuits.

Beat Frequency Derivation

The difference or beat frequency f_b can be computed from the following relationships:

$$f_b = f_o - f_o'$$

$$f_o' = f_o\left(\frac{c - 2v}{c}\right)$$, from the doppler formula

therefore,

$$f_b = f_o - f_o\left(\frac{c - 2v}{c}\right)$$, then

$$f_b = f_o\left(\frac{2v}{c}\right)$$

For example, let $f_o = 1.2 \times 10^9$ Hz, velocity $v = 2$ m/s, and $c = 3 \times 10^8$ m/s. From the above equation, $f_b = 16$ Hz.

The average human body movement is around 1.5 m/s, while a person "creeping around" might be 0.5 m/s. A detection range of 0.2 to 18 m/s was chosen to cover nearly all possible human movement.

These velocities convert to f_b frequencies of 1.5 to 100 Hz. Therefore, values for R-C filtering throughout the detection circuit were chosen according to these calculated values.

Circuit Description

The diagram of the UHF movement detector is shown in Figure 2. The oscillator is a standard UHF design which delivers about 10 mW at 1.2 GHz. R1 and R2 bias the base of Q1 to 1.2 volts via L2. Collector current is set by R3 to about 30 mA. C2 couples the base of Q1 to the stripline circuit. Tuning is provided by Cv1, and C1 plus C1a decouple the collector. R2 and R3 are not decoupled as this could cause instability.

Mixing of f_o and f_o' is provided by Schottky diode D1. Only the $f_o - f_o'$ product passes through the filter of R4, C3 and C3a to the amplifier. Unwanted frequencies are bypassed to ground by R4, C2 and C3.

Q2 is a simple one-transistor amplifier. C4 and C7 reduce gain below 1.5 and above 100 Hz. This band of frequencies is amplified and passed on to the level detector. Two comparators of IC1 provide level detection. The trigger voltage is set by R7, Rv1, R8 and R9. It is adjustable from 8 to 60 mV by Rv1.

Positive voltage swings above trigger level cause IC1a output to pull low, while negative swings cause IC1b to pull low. C8 decouples IC1 from the power supply and R10 is a pull-up resistor for the open collector output of IC1.

The oscillator part of the circuit must be constructed on double sided PCB. The prototype was constructed on fiberglass PCB; different PCB material will alter the stripline inductance. A number of track-pins are required around the stripline to ensure connection to the groudplane on the underside of the board.

The prototype dimensions for the stripline are 3.0 cm long and 5 mm wide. The antenna was cut from a piece of 1 mm diameter wire 8 cm long. By experiment, the best place found to mount the antenna and diode was in the center of the stripline 5 mm from the grounded end (Figure 3). As required for circuits at this frequency, all component leads should be kept as short as possible to avoid unwanted stray capacitance and inductance. A 6 mm hole is drilled in the board to accommodate mounting of Q1 with minimum lead length.

Operation

Cv1 is adjusted for maximum voltage at the anode of D1. Rv1 is set by experiment to the best detection range. In the prototype an LM317 regulator was used to provide 10 volts with good regulation. As a point of interest, the circuit has been set up in a car with the sensitivity pot Rv1 set to minimum. Shaking the car or moving around close by (outside), even near windows, did not trigger the detector. With the doors open, the unit still did not trigger until an arm or other object entered the car's interior cavity. rf

About the Author

David C. Huisman has the honor of being the most distant entrant in the RF Design Contest. Mr. Huisman is employed at Tait Electronics Ltd., and can be reached at 32 Richardson Terrace, Christchurch 2, New Zealand.

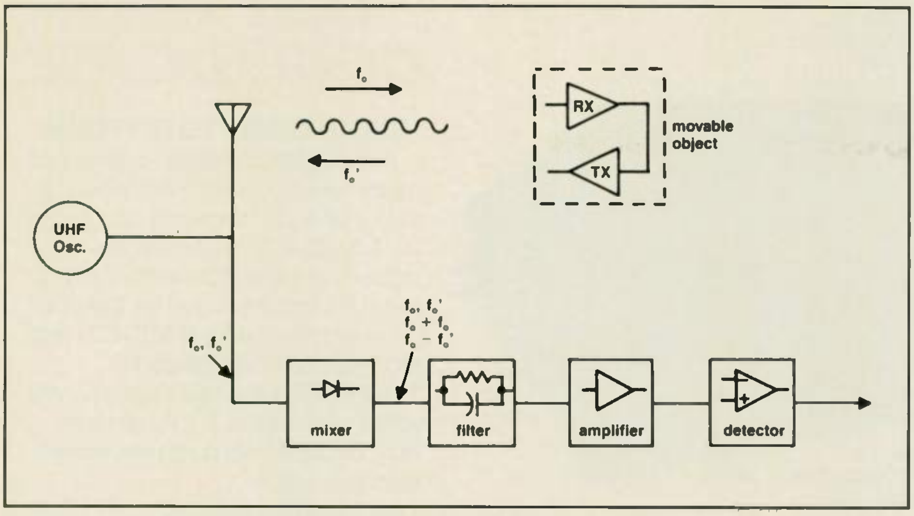
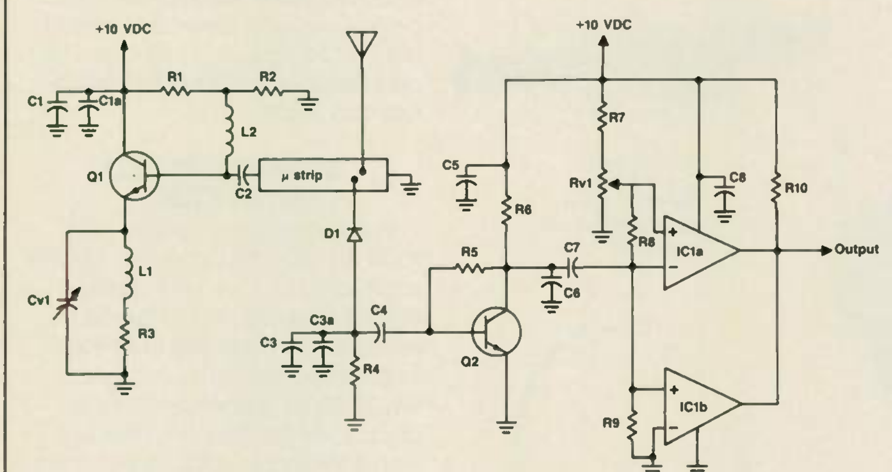


Figure 1. Block diagram of movement detector system.



Parts List

R1	3.9 k	C1	1 nF	D1	ISS97 or other Schottky type
R2, 4	1 k	C1a	470 uF	Q1	MRF961
R3	100	C2	47 nF	Q2	BC548
R5	2.2 M	C3a	1 uF	Cv1	2-7 pF miniature
R6	6.8 k	C4	22 uF	IC1	LM339 comparator
R7	100 k	C5, 8	100 uF	L1	5 turns 0.86 mm wire on 3.5 mm core
R8, 9, 10	22 k	C6	100 nF	L2	4 turns 0.86 mm wire on 3.5 mm core
Rv1	1 k	C7	10 uF		

Figure 2. Circuit diagram of movement detector.

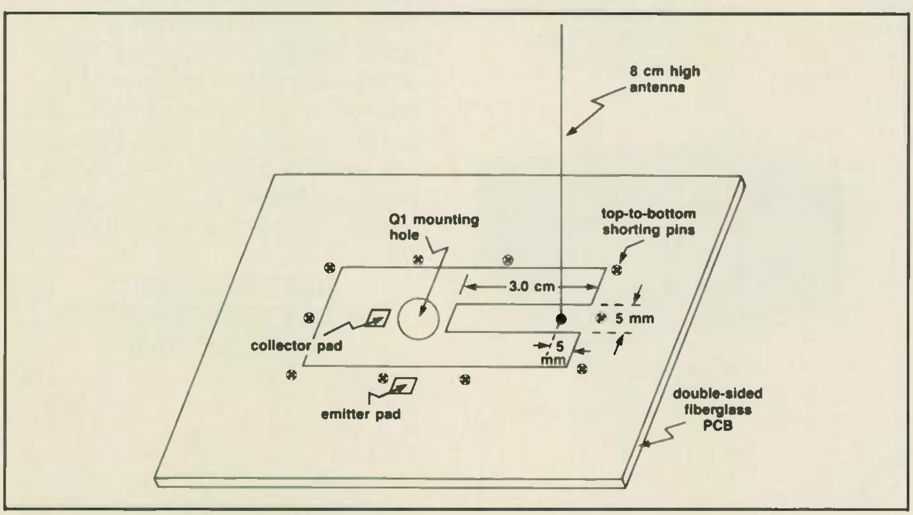
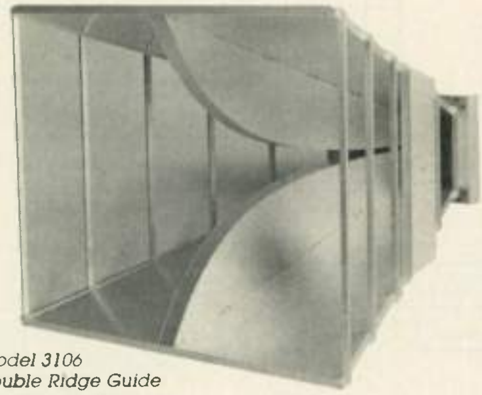


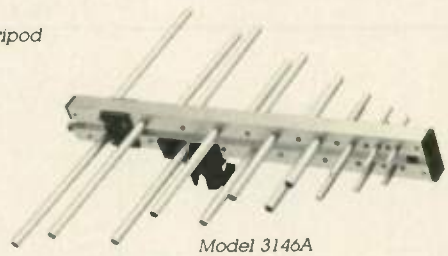
Figure 3. Construction layout of movement detector.

Model 3115 Double Ridge Guide
1–18 GHz
Model 3116 Double Ridge Guide
18–40 GHz

Model TR3 Non-Metallic Tripod
22.68 kg capacity



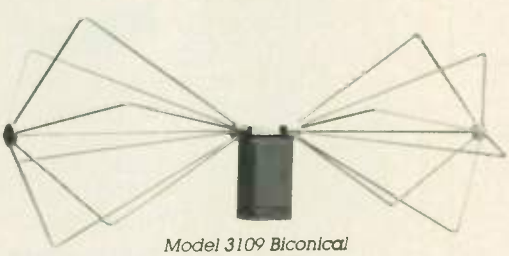
Model 3106
Double Ridge Guide
200 MHz–2 GHz



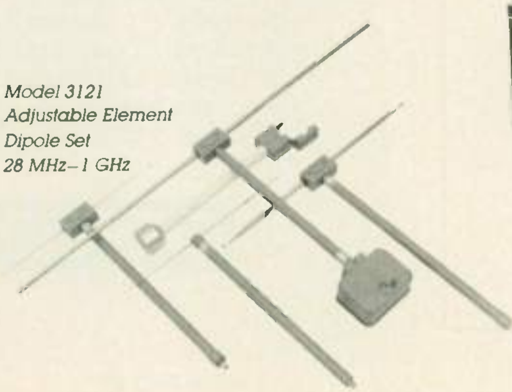
Model 3146A
Log Periodic
300 MHz–1 GHz
four other models available

Model 1060 Turntable
with controller and IEEE-488 bus option
1–7.6 meter diameter available

Model 6502
Active Loop Antenna
10 kHz–30 MHz



Model 3109 Biconical
20–200 MHz
three other models available



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Dipole Set
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INFO/CARD 25

Antennas for EMI Measurements

Part II: Characteristics of Specific EMI Antennas

By Edwin L. Bronaugh
Electro-Metrics,
Div. of Penril Corporation

Electromagnetic Interference (EMI) measurements involve absolute, not relative, values of radiated field intensity. To achieve reasonable measurement accuracy, the response of the antenna must be known and must be reproducible in the test environment. This second (and final) part of the author's examination of antennas reviews the specific types of EMI antennas and the characterization of their performance in EMI measurement situations, beginning at low-frequencies.

Two types of antennas are typically used below 30 MHz: electric field antennas and magnetic field antennas. The electric field antennas are electrically short monopole (rod) and dipole antennas, and the magnetic field antennas are electrically small loop antennas (either air or "iron" core loaded).

E-Field antennas are designed so that their lengths are no more than 15 percent of a wavelength at the highest frequency of use. This would be 1.5 m at 30 MHz. The actual length and diameter of such antennas are selected to five convenient values for their effective lengths (heights) and impedances. For example, the "41-inch rod" antenna which has been used for many years has, up to 30 MHz, a 0.5 m effective height and an impedance essentially equal to that of a 10 pF capacitor. The antenna factor is 6 dB plus the "loss" encountered in transforming the open circuit output voltage of the rod to the typical 50 ohm impedance of the EMI meter. The transformation may cause the total antenna factor to be almost 60 dB at 10 kHz. Some of these antennas are made *active* by including high impedance preamplifiers at the base of the rod to make a "lossless" transformation. These antennas often have an antenna factor very nearly 6 dB. The active antenna, however, is subject to overload in high-strength E-Field environments.

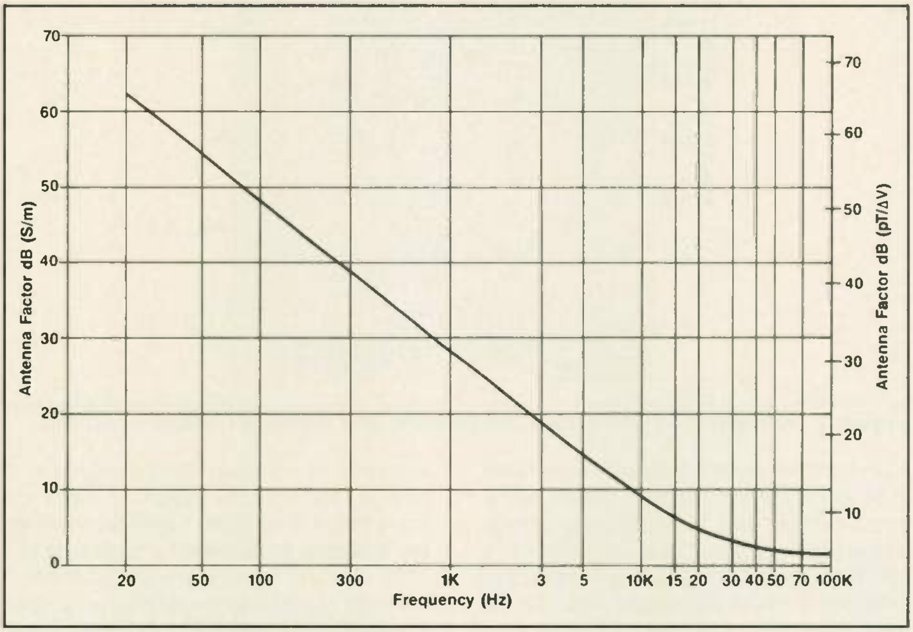

Figure 1. Typical loop antenna factor.

Magnetic field antennas are usually some type of loop antenna, although active magnetic field antennas have been made using Hall-effect devices and other magnetic field sensing elements. The loop antenna is usually designed so that its diameter is less than 5 percent λ at the highest frequency of use. This would be a diameter of less than 0.5 m at 30 MHz, but loops that are just less than 0.6 m in diameter are often used (5). The antenna factor of a loop antenna is inversely proportional to the area of the loop, the number of turns on the loop, the magnetic permeability of the core of the loop and the operating frequency. If the loop is loaded in an impedance that is smaller than its self-reactance, the frequency dependence is eliminated. When this is done with passive circuits the antenna factor is higher than it would be for an unloaded loop. As with E-Field antennas, active circuits (current amplifiers) are sometimes used to terminate the loop to keep the antenna factor low while achieving flat frequency response. The active circuits, of course, are subject to overload in high-strength magnetic fields. For most EMI measurement loops the core of the loop is air, although several ferrite-loaded active loop antennas have been made which perform as if they were much larger than their actual physical size.

Low frequency antennas used in EMI measurements often have a frequency dependent antenna factor which is inversely proportional to frequency. Such antennas are called derivative-sensors because their output voltages or currents are proportional to the time derivative of the field strength. Other low frequency antennas have antenna factors that are constant versus frequency. These antennas are called integrating sensors because their output voltages or currents are proportional to the time integral of the field strength. As long as only narrowband field strengths are being measured it makes no difference which type of sensor is used. The results are the same within the measurement and calibration errors. However, if pulsed field strengths are being measured, only an integrating sensor will give the true peak value of the pulsed field. The derivative-sensor will give peak values proportional to the maximum rate of change of the pulsed field. Examples of derivative-sensors are loop antennas directly driving load impedances greater than their self-reactances and monopole (dipole) antennas directly driving load impedances lower than their self reactances.

Intervening impedance transformation networks may modify the characteristics of the antenna. Figure 1 shows the antenna factor of an Electro-Metrics Model

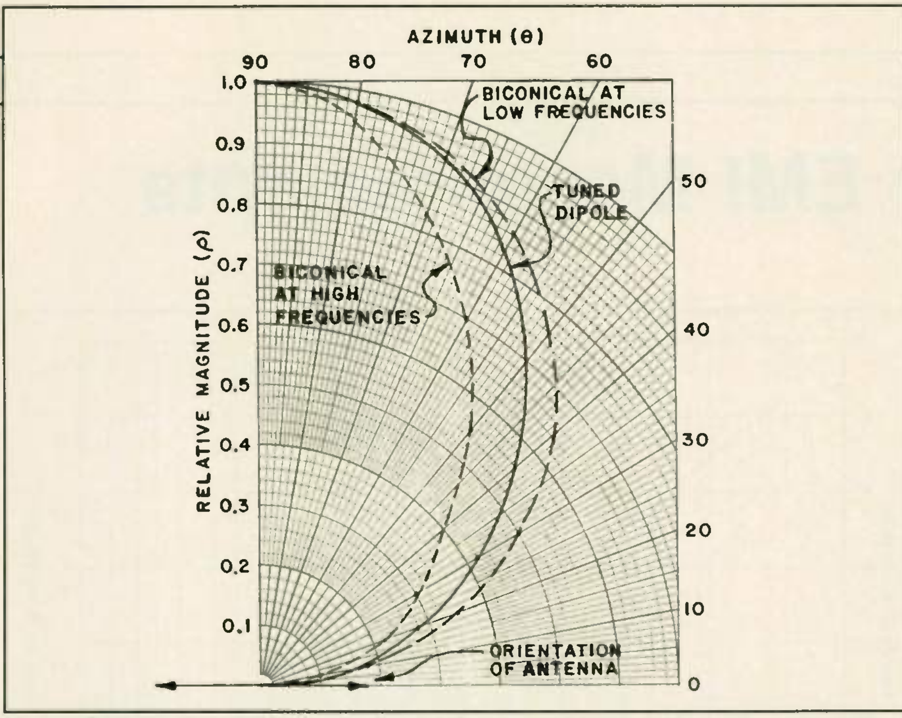

Figure 2. Radiation patterns for tuned dipole and biconical dipole antennas.

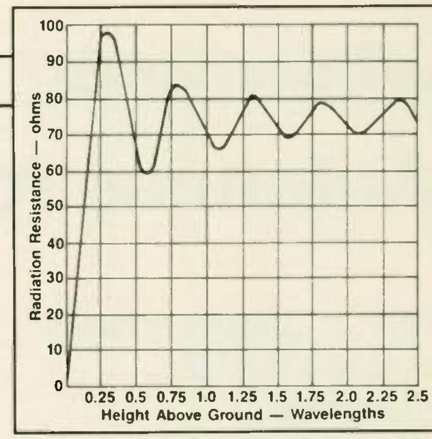

Figure 3. Variation of radiation resistance of a horizontal half-wave dipole antenna with height above a metallic ground plane.

ALP-10 as an example. When terminated in 50 ohms it is a derivative-sensor below about 50 kHz and an integrating sensor above that. When this loop antenna is combined with an equalizing (integrating) amplifier, such as Electro-Metrics PCA-10, the combination becomes an integrating H-Field antenna system with an essentially constant antenna factor of +13 dB (S/m) up to 50 kHz.

Mid-Frequency Antennas

In the frequency range from about 20 or 30 MHz to 100 or 200 MHz dipole antennas are usually used. These may be wide-bandwidth dipole antennas, such as the biconical dipole antenna, or tuned (half-wavelength) dipole antennas. The typical radiation (reception patterns) for these antennas are shown in Figure 2.

Tuned dipole antennas that are resonant at one-half wavelength are a special case of the general dipole antenna. Under the proper conditions, these "half-wave" resonant dipole antennas have certain theoretically predictable characteristics. The effective length, L_e, is λ/π when the antenna is immersed in a *plane-wave* field (3), and the feed-point impedance, Z_a, is purely resistive if the antenna is far enough from ground or other obstacles. Z_a equals R_a, which is about 73 ohms for an infinitely thin antenna but is normally much less, ranging from 55 to 65 ohms, depending upon the length-to-diameter ratio for a physically realizable antenna.

If the antenna is removed from free-space conditions and brought close to the ground, it begins to couple to its image in the ground. This causes its feed-point impedance to vary cyclically above and below the free-space value with the amounts of variation increasing as it is brought closer to the ground. Finally, the impedance is reduced significantly when the antenna is very near the ground (3). This effect is most pronounced for horizontally polarized antennas and can cause the impedance to drop to a few ohms when the antenna is less than one-tenth of a wavelength (one metre at 30 MHz) above the ground, as seen in Figure 3. In typical EMI measurements below 100 MHz the antenna heights usually range below one wavelength. Below 50 MHz they range below one-half wavelength. The wide variations in antenna impedance implied by Figure 2 for typical EMI measurements cause commensurate changes in the antenna factors used to determine the values of the EMI field strengths.

Biconical dipole antennas are another special case of the general dipole antenna. Their performance is usually difficult to predict on the basis of theory so experimental or empirical work is relied upon for the determination of biconical dipole antenna performance (6). The coefficient factors that comprise the antenna factor for biconical dipole antennas are similar to those of the tuned bipole antenna, but with different values.

The effective length of the biconical dipole antenna is found differently in different parts of its operating frequency range. At frequencies where its length is shorter than one-half wavelength, equation (4) from (3) approximates its effective length.

$$L_e = (\lambda/\pi) \tan [\pi/2 (L/\lambda)] \quad (4)$$

The length of the antenna, L, is the only new term in this equation. At frequencies where the biconical antenna is longer than one-half wavelength its effective length can be estimated from data in (6) and (7). As with the tuned dipole antenna, the effective length is defined for fields which are planar across the dimensions of the antenna. The shorter the antenna is physically, the closer it can be to the source of the field and the ground while still satisfying the "planar" definitions.

The ubiquitous military standard biconical dipole antenna is about 1.38 m long and its cone angle is about 26 degrees. According to biconical antenna theory, its near field region is contained within a sphere centered at the center of the antenna and having a diameter equal to the antenna length; thus, it can be used with the center as close as 1.0 m to the ground or to the source. Theory also indicates that the "design center" frequency of the military standard biconical antenna is 150 MHz and that it could be expected to perform as designed from about 75 MHz up to 300 MHz. To have been designed to work over 30 to 200 MHz its design center frequency would have been about 77 MHz and it would have been over 2.5 m long. This would have made it more unwieldy in a shielded enclosure and it could not have been used vertically polarized at a height of 1.0 m above the ground plane, so a compromise was made by shortening it. It works as an electrically short dipole antenna up to about 75 MHz and as a biconical dipole antenna above that frequency.

The feedpoint impedance of the biconical dipole antenna is a complex quantity that depends upon the cone angle and length of the antenna. It has been determined empirically by Brown and Woodward (6) and others, and has been published in (6) and (7) and others. Some typical values of the feed-point impedance of a biconical antenna are 2 – j240 ohms at the lower end, 48 + j10 ohms near the middle, reaching 240 + j12 ohms in the upper part, and dropping to 130 – j30 ohms at the upper end of the frequency range. These values are only examples for

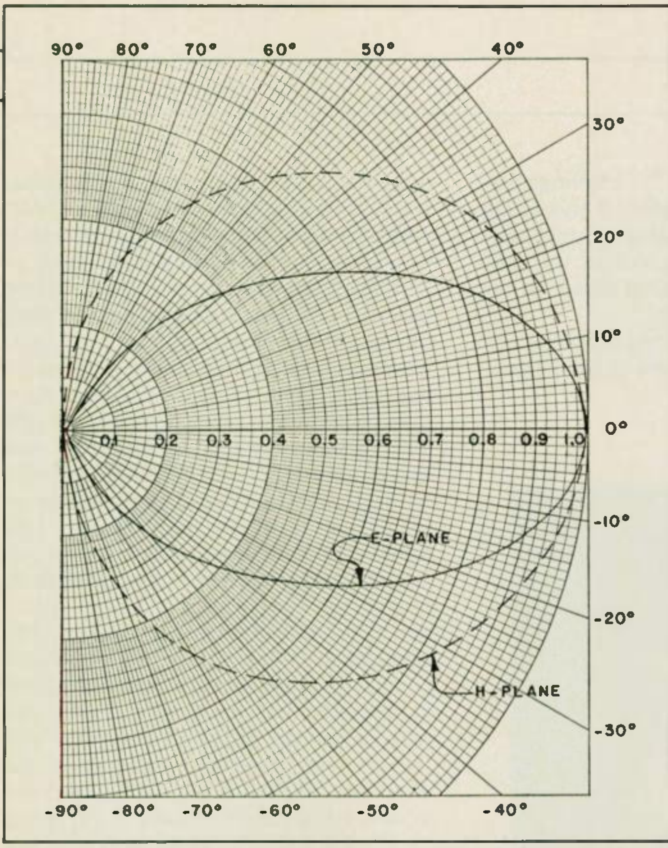

Figure 4. E-Plane and H-Plane radiation patterns for planar log periodic dipole array antennas.

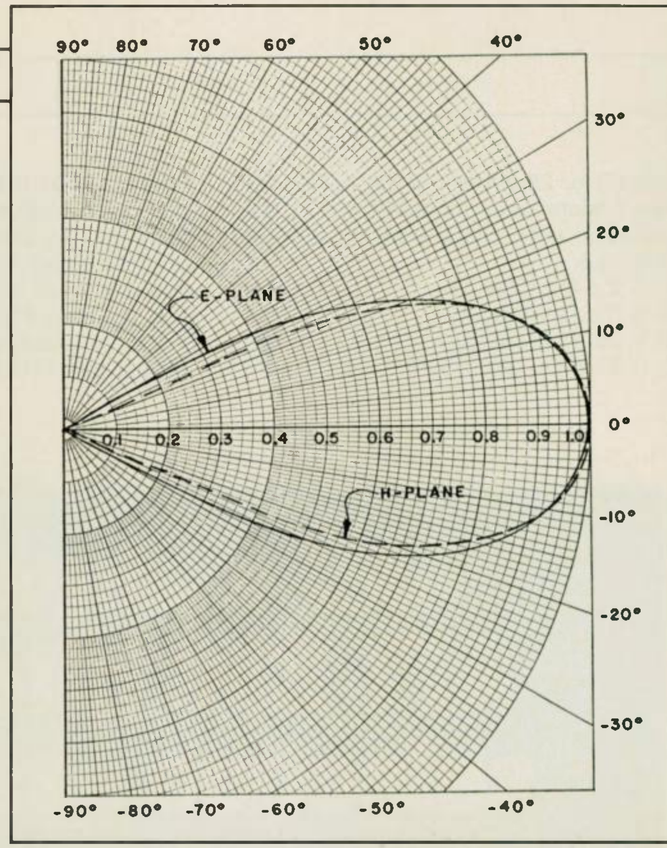

Figure 5. Typical E-Plane and H-Plane radiation patterns for double ridged guide (horn) antennas.

one particular biconical antenna design and vary with the antenna parameters. One important characteristic of the biconical antenna is that its impedance is much less affected by its height above ground than tuned dipoles and other long, relatively thin antennas. This is demonstrated indirectly in measurements reported in (1) and (8).

The BALUN used in the typical military standard biconical antenna is inherited from the Empire Devices (Singer Metrics) DM-105-T1 antenna. This BALUN is specified in the U.S. Government drawing for the biconical antenna. It was designed to be a 1:1 BALUN and is made of sections of coaxial transmission line. Because of stray reactance effects the voltage transformation ratio is different from 1:1 at many frequencies within the range of the biconical antenna. This changes the performance of the antenna in a way that defies prediction by calculation. A reliable program is the practicable way to determine the biconical dipole antenna factors (1).

VHF, UHF and Microwave Antennas

Above 100 or 200 MHz complex array antennas and aperture antennas are often used. Simple tuned and broadband dipole antennas are also used but are not as popular because their low gains require more sensitive EMI meters to achieve good field strength measurement sensitivities. However, array antennas and aperture antennas which have higher gains than simple dipole antennas also have narrower radiation (reception) patterns. If used too close to the source of EMI, array and aperture antennas may not achieve their designed gains. Array and aperture antennas must have designed gains and patterns appropriate for their uses. The gain of an antenna is related to its radiation pattern and its antenna factor is related to its gain, so a relationship may be established between the antenna factor and the geometry of the test setup in which it is used.

A deceptively simple expression which relates maximum gain with measurement distance is shown in equation (5). This is a coarse, but quite useful approximation.

$$g \leqslant d\pi/\lambda \qquad (5)$$

where: g is the maximum allowable gain;

d is the measurement distance; and

λ is the wavelength of the measured field.

For planar log periodic dipole arrays equation (5) underestimates the maximum allowable gain by a factor of 8 π, but for aperture antennas it approximates reasonably well the gain required for the antenna to satisfy the commonly used relationship of $d \geqslant 2\,D^2/\lambda$ mentioned earlier.

Another needed factor accounts for the beamwidth of the antenna, its gain, and the measurement distance. A useful approximation to estimate the antenna E-plane half-power beamwidth is:

$$\Theta_E \cong 160/\sqrt{g} \qquad (6)$$

Combining equation (6) with equation (5) gives another useful expression in equation (7).

$$\Theta_E \cong 160/\sqrt{\lambda/\pi d} \qquad (7)$$

where: Θ_E is the angular width of the main antenna pattern lobe between the −3 dB points in the E-plane, in degrees.

In using equation (7) it is tacitly assumed that the antenna has the maximum gain allowed by equation (5).

To assure a reasonably accurate measurement of the field strength emanating from the source is should fit within the "3 dB" or half-power beam. Much better measurement accuracy will be obtained if the source is small enough to subtend only 25 or 20 percent of this arc. This is all related by equations (8) and (9) below. If the actual antenna gain is known and is less than the maximum allowed, use equations (8a) and (9a). Where the maximum allowable antenna gain is used (again, the tacit assumption mentioned above), use equations (8b) and (9b). The source length or width S is given in equation (9) for 25 percent of the half-power beam width which is within the −1 dB points on the E-plane patterns of most antennas.

$$S \leqslant 2\ d \tan (80/\sqrt{g}) \qquad (8a)$$
$$S \leqslant 2\ d \tan (80\ \sqrt{\lambda/\pi d}) \qquad (8b)$$
$$S \cong 0.5\ d \tan (80/\sqrt{g}) \qquad (9a)$$
$$S \cong 0.5\ d \tan (80\ \sqrt{\lambda/\pi d}) \qquad (9b)$$

If the actual patterns of the antennas are known they should be used. It should be noted that the source length S includes any intentional reflection from the test setup, such as the ground plane on an FCC open area test site.

Log periodic dipole array antennas are another special case of the general dipole antenna. These antennas are typically used at the higher frequencies in EMC measurements, e.g., 100 MHz or 200 MHz to 1 GHz, so they are fairly small physically. This gives them the advantage of being usable much nearer the ground and other obstacles compared to physically larger antennas, while still operating in "planar" field conditions. These antennas have gain compared to a simple dipole antenna since they are a multi-element array. The gain is usually about 7 dB to 8 dB (isotropic) or about 5 dB to 6 dB referred to an ideal half-wave resonant dipole. This means that their radiation (reception) pattern is smaller than that of a simple dipole, and in this way they are similar in operation to aperture antennas. The beamwidth (the angle subtended by the half-power points in the main pattern lobe) of a typical log periodic antenna is 70° to 80° in the plane of the elements (E-Plane) and 120° to 150° in the plane perpendicular to the elements (M-Plane) (Figure 5), and the front-to-back ratio is usually in the range of 10 dB to 30 dB. These antennas are well balanced and matched to 50 ohms because of inherent qualities of their design. The VSWR is usually much less than 2:1. More information may be found in (9).

Equation (3) must be modified for these antennas to take into account their gain, so it is better to use an equation which includes several of the factors in equation (3) implicitly:

$$AF = 6 - 20 \log (\lambda/\pi) + 10 \log(120/Z_L) - 10 \log(g) \qquad (10)$$

The gain g of the antenna relative to isotropic is the new term in this version of the equation. Note that the term for impedance matching is simpler, implicitly including N, while g implicitly includes A_b. This is usually further simplified to:

$$AF = -30 + 20 \log f_{(MHz)} - 10 \log g_i \qquad (11)$$

Double ridged guide antennas are aperture or horn antennas. While they are not basically an extension of the general dipole antenna, they can be described in terms of the same equations. These are relatively large antennas used primarily for transmitting test fields for radiated susceptibility (immunity) measurements, but they may also be used for receiving. The gain in the versions usually used in EMC is less than 6 dB referred to an ideal half-wave resonant dipole. the beamwidths are about 50° (E-plane) and 45° (H-plane) (Figure 5), and the front-to-back ratio is usually much more than 10 dB. The "BALUN" used is a double-ridged-waveguide-to-50-ohm coaxial transition, so matching is usually good with VSWR well under 2:1. Equation (11) also applies to these antennas. rf

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About the Author

Edwin L. Bronaugh is Director of Research and Development at Electro-Metrics, a Division of Penril Corporation, 100 Church Street, Amsterdam, N.Y. 12010. Mr. Bronaugh is recognized as a leading authority on electromagnetic compatibility (EMC), and is a member of several EMC standards committees.

A Complex Impedance Meter

Simple Instrument Measures Both R and X

By Carl G. Lodström
Dow-Key Microwave Corp.

The voltage-current relationships along a transmission line are well known. The author has taken these principles and developed a very simple means of indicating the complex nature of an RF load, with an X-Y oscilloscope display that approximates a Smith chart. One of the entries in the First Annual RF Design Contest, the enthusiasm of the author for his idea comes through clearly as he describes the instrument!

The idea of this instrument was conceived through the better understanding of the Smith chart that I was able to receive in the late '70s. It took a few years, until around 1980, to get around to building one, verifying the concept. I remember that it was an antenna that defied tuning, and a 2-meter (145 MHz) version of the instrument was built.

As is apparent in the Smith chart, all mismatches reflect power. At an open end of a transmission line a voltage maximum will occur. This corresponds to a point at the right edge of a Smith chart. At a shorted end there will be a voltage minimum (the left edge), and in the case of a perfect match, there will be equal voltage along the line (chart center). Correspondingly, loads with some imaginary part, inductors and capacitors combined with the load, will move vertically from the center, inductors up and capacitors down. They will not move on a straight line, like their resistive counterparts, but along some resistive circle, the unity circle if the resistive part is a match. In the vicinity of the center, this vertical movement is approximately a straight line. How do we detect and indicate these deviations, then?

A wise man, Magnus Koch at the Chal-

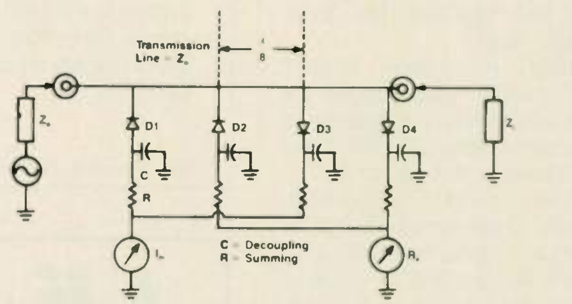

Figure 1(a). Basic schematic of impedance meter.

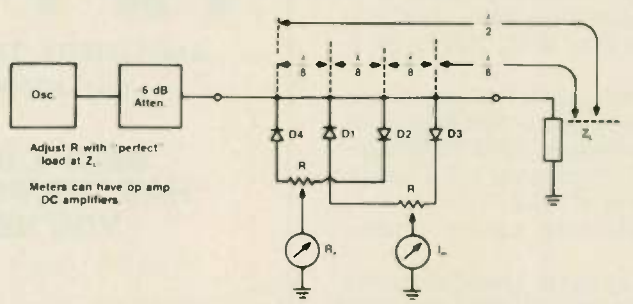

Figure 1(b). Circuit with measurement plane outside "unknown" connector. Note diode numbering change.

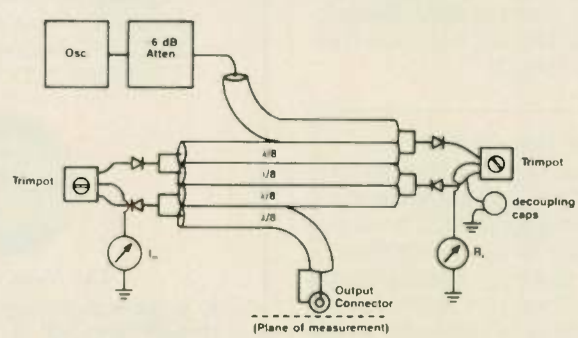

Figure 1(c). Practical construction method.

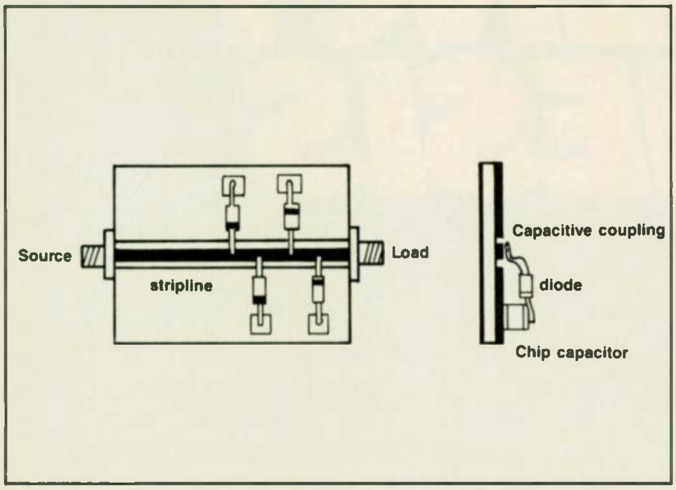

Figure 2. Possible microwave construction method.

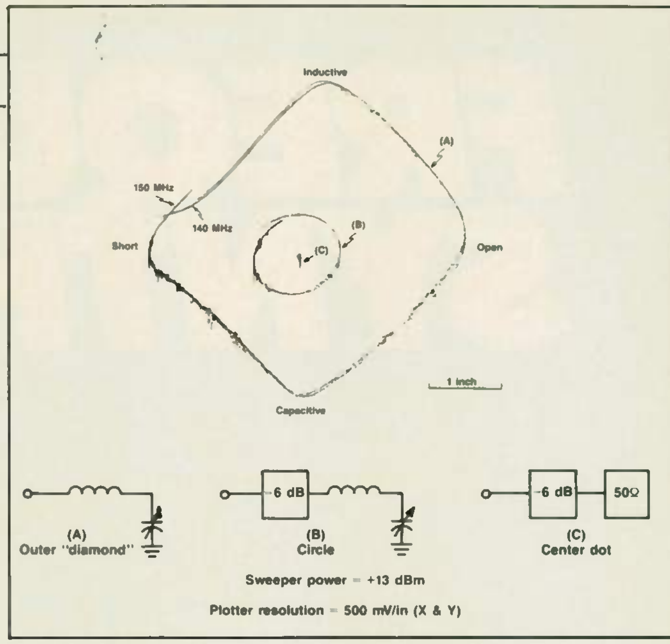

Figure 3. Display of "reference" measurements.

mers U. of Technology, Göteborg, Sweden, once told me, "If you can measure something with a bridge, do it!" As the years have gone by, I have found them to be words of wisdom, and they certainly apply here. A bridge, how to make a bridge that can detect in what direction something takes off on a Smith chart?

One does not have to! As you go along a transmission line away from, say a shorted end, you start at the leftmost end, and we all know that after $\lambda/8$, looking back, we will see an inductance with $j\omega L = Z_0$. After another $\lambda/8$, making $\lambda/4$ total, it looks like an open circuit, and so on. After one turn around the chart we have traveled $\lambda/2$ along the line. Let us now put four little detector diodes, monitoring the voltage on the line, spaced $\lambda/8$ apart, one in each "compass direction" around the chart. Well, you say, you can not do that! It introduces a mismatch! True, but all four diodes do the same. Since they are mutually cancelling, *at that frequency*, plus a little line loss, it does not matter.

Let us excite the line and try various loads at the other end. The last diode is to be positioned where the loads will be applied, or an integer multiple of $\lambda/8$, in which case the indicators will change sign and label.

Referring to the basic schematic (Figure 1), let us look at a short circuit. D4 will obviously get no voltage at all to detect, but D2 will get twice the normal. D3 and D1 will not see any change. Due to the way D2 and D4 are turned, a negative voltage will appear at their summing point. An open circuit will produce the opposite effect, with a positive voltage from D4 and no voltage from D2. In both cases, D1 and D3 will detect equally strong signals, but of opposite signs, so their sum is zero. In a similar way it works for imaginary deviations. Just imagine the chart rotated 90 degrees!

The beauty of the Smith chart, or at least one of them, is preserved is this apparatus. It is the fact that near perfect loads will be treated especially carefully and accurately. Also, the concept is clearly not limited to 50 ohm lines. One can imagine the use of perhaps a 5 ohm line in a test fixture for measuring transistor input impedances.

A limitation is the bandwidth. I would say that the function is very satisfying within a 10 percent band centered around the design frequency. That is certainly more than enough for most "band" operations, be it ham radio, cellular mobile, radar, microwave link or CB. An exception from the bandwidth limitation is, of course, the well-matched load, which will appear as such no matter what the frequency.

The maximum possible frequency of operation that can be achieved remains to be determined. The diodes have to be operating, of course, and can always be spread by multiples of $\lambda/8$ if physically necessary, but the bandwidth will suffer. Hewlett-Packard has been kind enough to supply me with some zero bias diodes good to 10 GHz, but in spite of a lot of care, they got damaged by static electricity. Using regular "hot carrier" diodes will work to at least 1 GHz, but a signal level of at least −15 dBm is necessary for good signals. A possible method of building the instrument for microwave frequencies is shown in Figure 2.

Practical Aspects

It may be more desirable to have the test plane outside the connector, as opposed to just behind it. This is possible by just adding some line after the last diode. This may actually be the preferred method, since all the diodes then will be mounted in an identical manner on the line, thereby balancing each other better. They will then have to be permutated, changing the order from 1-2-3-4 to 4-1-2-3.

It is also possible to measure remote (100λ) objects. By leaving the end of the line open, one can determine to what extent the chart is rotated, and either change the frequency slightly to get the open located on the right, or add some cable, or just remember the position. The insertion loss of the cable limits the sensitivity, of course, but I have derived useful information about a load with a 20 dB attenuator in line and +10 dBm excitation. This corresponds to a VSWR of 1.02:1 or 40 dB return loss. With the same level of excitation I can detect the difference between a "perfect" load and one of 70 dB reflection. To observe that mismatch on a Smith chart, you would have to use a microscope, since it corresponds to a distance from the center of half the thickness of a human hair.

Displaying the voltages on an X-Y oscilloscope (or a plotter for swept signals) is very convenient. It then becomes apparent that the outline of the displayed field, corresponding to the circular border of the Smith chart, is not really circular, but somewhat diamond shaped. Should this be disturbing, a 6 dB attenuator can be left on the measurement port. It is "transparent" enough to make good measurements through. It also provides the necessary DC return path for the diode currents, which may not be present in the load or source.

The matching impedance of the source is not critical at all. A mismatch there reflects part of the power back to the source, but what travels down the line is what counts. With zero bias diodes it

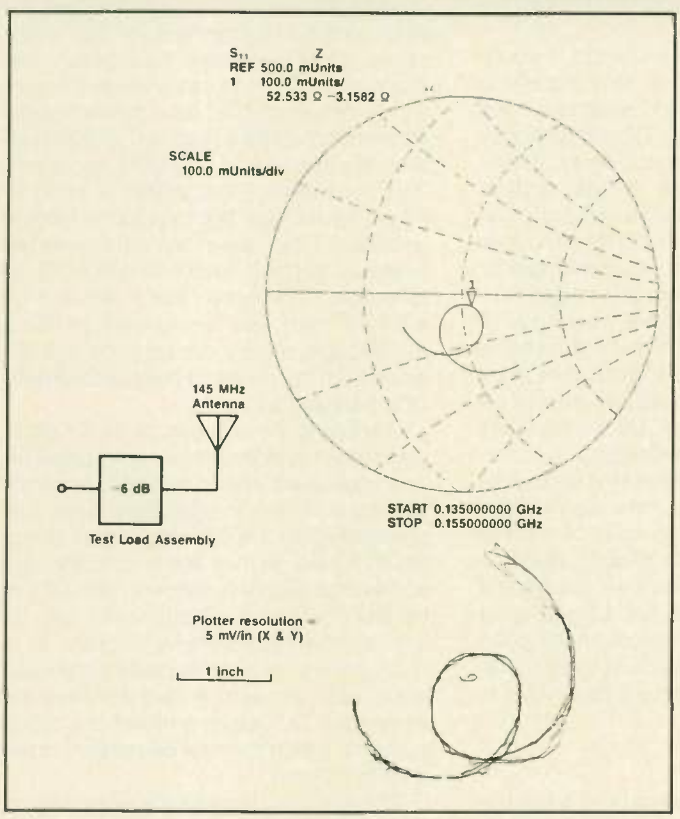

Figure 4. Top plot from HP8510 Network Analyzer. Bottom plot of same load by impedance meter. Note similarity of shape.

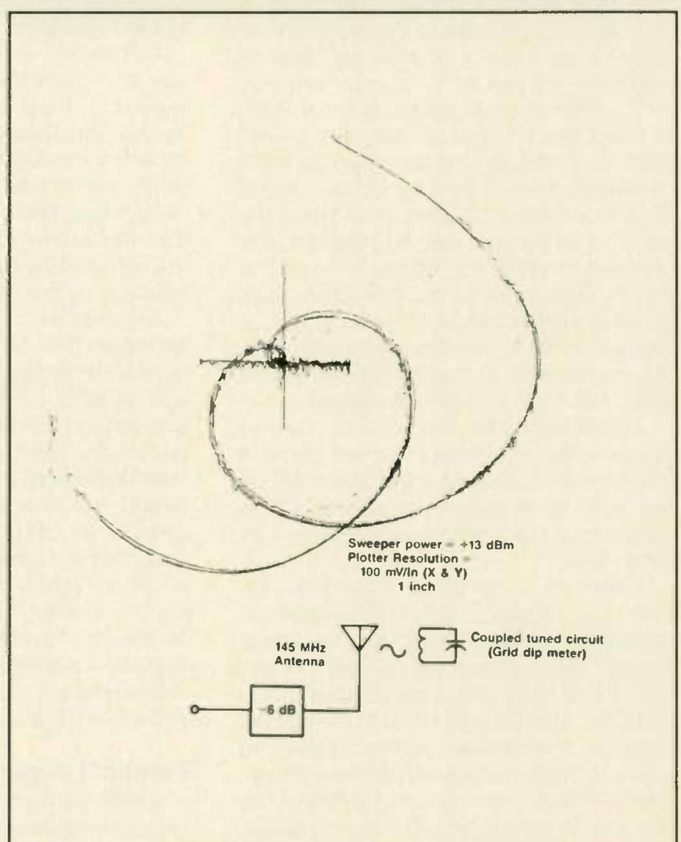

Figure 5. Effects of an additional tuned circuit, coupled to the antenna.

should be possible to use a regular signal generator for the source, with levels of 1 mV (−47 dBm), and measure receiver inputs without driving them into non-linear regions.

Substituting the "perfect" load with a resonant circuit opens up a few interesting applications. The output from the jX detector becomes very sensitive to changes in frequency, being zero at resonance. This can be used to measure deviation, modulation, PLL step response and maybe even phase noise. The higher the Q of the attached resonant circuit, the more sensitivity. A VCO can be locked to a cavity or a stub, by feeding back the DC signal.

Another application could be a distance meter, connecting both outputs to an UP/DOWN counter, with an antenna for a load. The sine/cosine information in the reflected signal will run the counter up or down, and one count for every half wavelength will be gathered. This may be a good detector for doppler radar burglar alarms, eliminating false alarms from objects that are just swinging back and forth in the wind.

To conclude, a detector has been described that in sensitivity far exceeds the common VSWR meter and furthermore provides information about the complex nature of the load, while still being of the same simplicity as a VSWR meter. The tradeoff is bandwidth. Also, it has other potential uses, as outlined, that a VSWR meter has not.

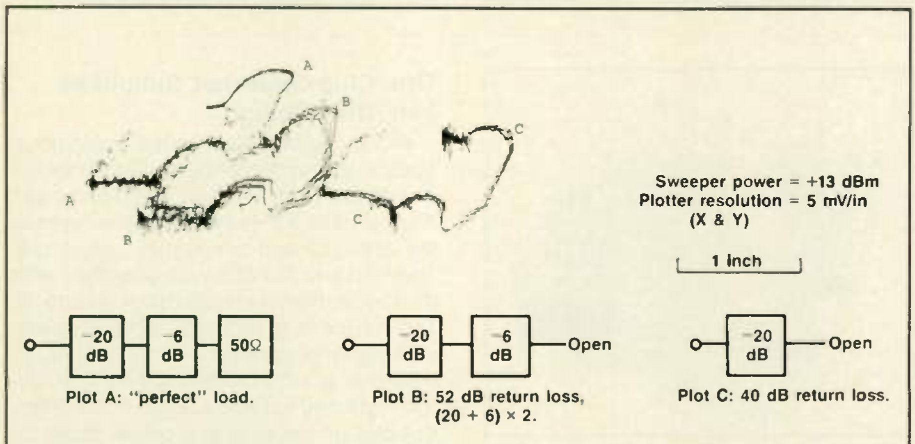

Figure 6. Sensitivity demonstration — High sensitivity display can discern difference between "perfect," 52 dB return loss and 40 dB return loss loads.

Acknowledgements

To Magnus Koch, as mentioned above, and to Ingvar Svensson, my teacher at TGG, Goteborg, who had the ability of explaining the Smith chart so vividly that this concept surfaced in one of his more absent-minded students' mind! If all teachers were like him, this world would be a much better place. rf

About the Author

Carl Lodström is applications engineer at Dow-Key Microwave Corp., 1110 Mark Avenue, Carpinteria, CA 93013-2918. He has an Electronics Engineering degree from the Techical Gymnasium of Göteborg, Sweden, and is amateur radio operator SM6M0M/W6.

Tektronix Introduces Low-Cost Spectrum Analyzer

Tektronix, Inc. has introduced a new generation VHF/UHF spectrum analyzer priced at $8,250, the 10 kHz to 1.8 GHz TEK® 2710. Weighing under 20 pounds, the 2710 provides a wide 5 MHz IF bandwidth filter, 10^{-5} frequency accuracy, four-trace digital storage, full marker/delta marker control, a comprehensive time domain measurement capability, and many other "built-ins."

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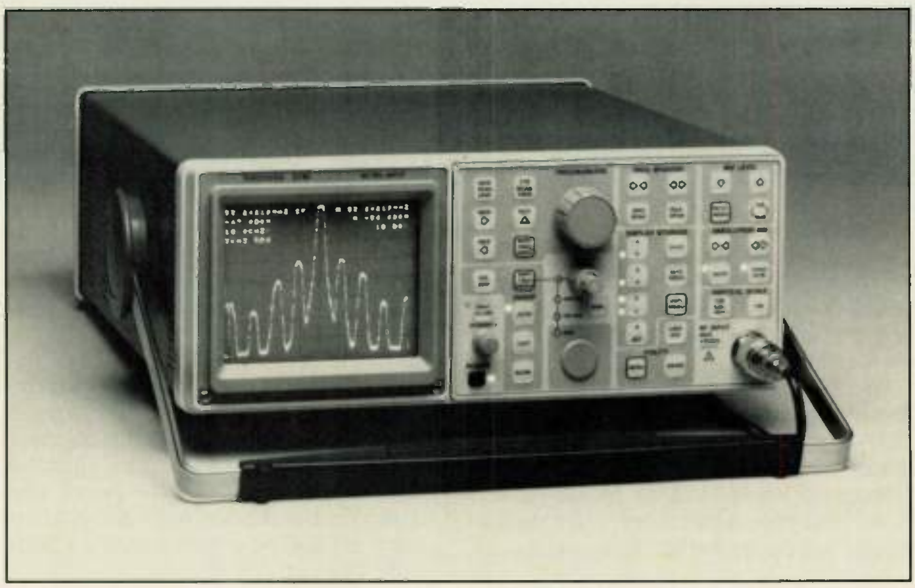
Sensitivity is −117 dBm at 3 kHz RBW. A built-in preamp may be switched into the conversion chain which will boost sensitivity to −129 dBm. An additional 10 dB of sensitivity is available if the 300 Hz resolution option is included.



The spectrum analyzer provides a comprehensive time domain capability that has particular value in making communications measurements. Included are one microsecond to 2 sec/div sweep in a 1-2-5 sequence for maximum flexibility in expanding the display, analog display for gray scale enhancement, and 5 MHz system bandwidth (including CRT) that minimizes amplitude measurement distortion. AM/FM detectors with audio amplifier, speaker and headphone jack permit listening to demodulated audio. An optional video monitor mode permits viewing the demodulated, rasterized video on the CRT of the spectrum analyzer.

Also included are marker/delta markers with front panel control for peak find, next right and next left maneuvers. Other marker-related functions are available via a FREQ/MKR menu. Markers function in both the time and frequency domain and include off-screen measurement capability. The digital storage display includes four-trace capability. A, B and C displays may be stored and viewed, with the D display always remaining current. Additional options available at product announcement include Centronics™ interface, battery operation and rackmount configuration. GPIB and RS232 interfaces and a tracking generator will be available at a later date.

The TEK 2710 Spectrum Analyzer U.S. catalog price is $8,250. **Tektronix, Inc., Beaverton, Ore. INFO/CARD #201.**

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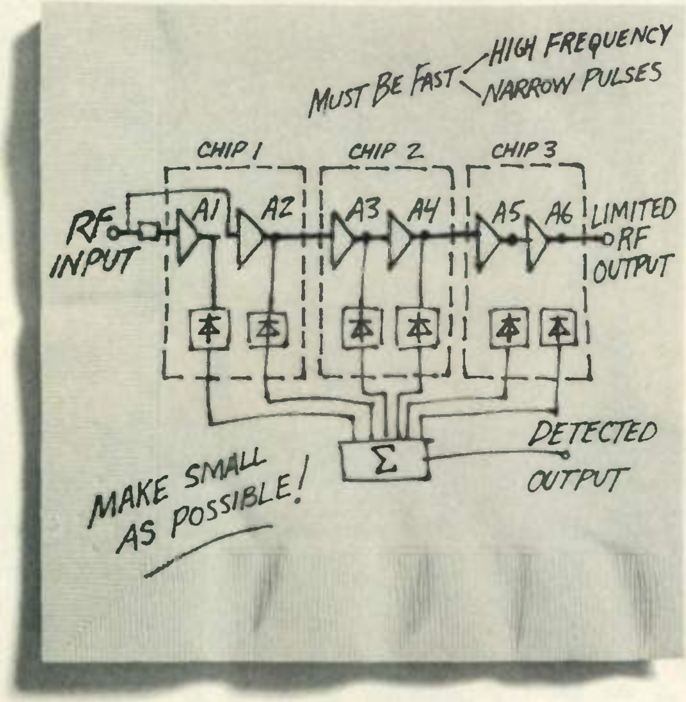

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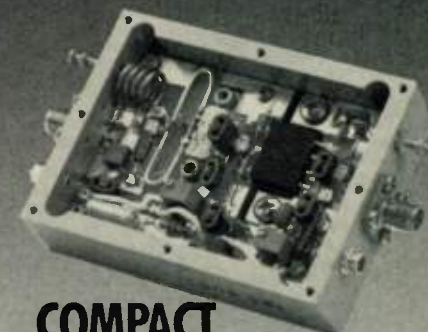

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Sizes start at 2" x 3" x 0.75." For more complete information and discussion of your high power RF amplifier needs, contact Epsco, RF Division, 31355 Agoura Road, Westlake Village, CA 91361. (818) 889-5200. Telex: 18-3378.

EPSCO

INFO/CARD 34

Ceramic Substrates Have Ultra-Smooth Surface

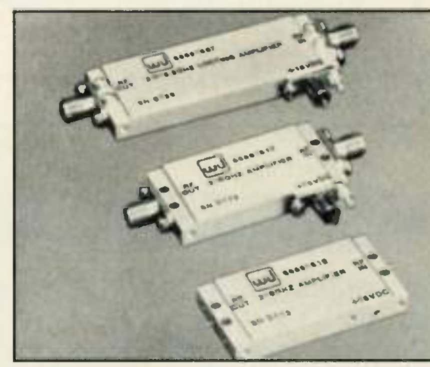
A new line of ceramic substrates for the deposition of thin film microwave circuits is now available from Kyocera International, Inc. The new A493 substrate material has an ultra-smooth surface finish required for the fine-line deposition of thin film microwave circuits. It is made from 99.6 percent aluminum oxide with a grain size of less than 1.5 microns giving it a uniform surface finish of 3.0 micro-inch CLA and a volume resistivity greater than 10^{14} ohm-cm. **Kyocera Substrate Division, San Diego, Calif. Please circle INFO/CARD #200.**

4 GHz Transistor Features Microplastic Package

Hewlett-Packard has introduced the second in a series of microplastic, high-performance transistors, the HXTR-3625. This NPN bipolar transistor utilizes HP's HPAC-100P package for a low-priced alternative to ceramic, microstrip-style packaged devices. It is designed for applications up to 4 GHz. The typical transducer gain is 14.8 dB at 1,000 MHz with an associated minimum noise figure of 1.6 dB. Maximum stable gain is 21 dB. The HXTR-3625 is $1.35 each (2500 qty.). **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #198.**

Medium-Power Amplifiers Feature Small Size

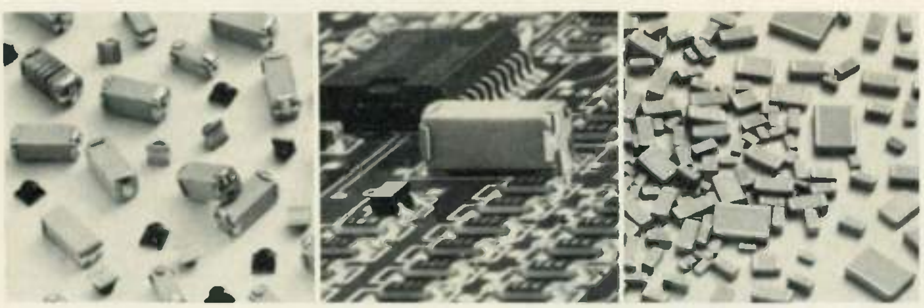
The latest series of GaAs FET medium-power amplifiers from Watkins-Johnson Company offers outstanding power-to-size ratio for the 1.7 to 5.2, 2 to 6 and 2 to 8 GHz frequency ranges. Twenty-five models with gain from 13 to 48 dB are



available with output power (1 dB GCP) from ¼ watt to 1 watt. Gain flatness is ±1 dB, maximum and noise figures range from 5.0 to 7.0 dB, maximum. The amplifiers are provided with field-replaceable SMA connectors or can be used in a drop-in fashion when the connectors are removed. A finned heat sink and an extra mounting plate are provided with each unit for convenience. **Watkins-Johnson Company, Palo Alto, Calif. Please circle INFO/CARD #197.**

25-watt Amplifier Covers 10 kHz to 100 MHz

The Model 25A100 is a new solid-state benchtop amplifier introduced by Amplifier Research. The 25A100 delivers 25 watts minimum saturated output power throughout the four-decade frequency band of 10 kHz to 100 MHz, and 20 watts linear power measured at less than 1 dB gain compression at the same bandwidth. Only one milliwatt of RF input signal is needed for rated output. The unit occupies just 14½ × 6½ × 8 in. of benchtop space, and weighs only 21 lbs. (9.5 kg).



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FOR SPACE, MILITARY AND COMMERCIAL APPLICATIONS...

DC-50 GHz

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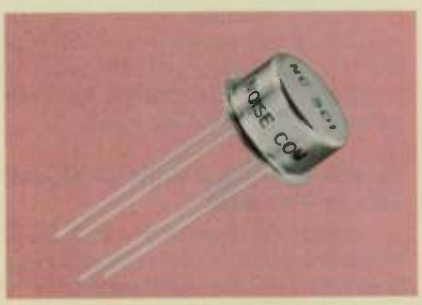
•Glass • Ceramic • Beam-Lead
•Hermetically Sealed •MIL-STD-202
•Audio •VHF •UHF •RF •MW •MM

TYPICAL STANDARD MODELS	
NC 100 Series	up to 3 MHz
NC 200 Series	up to 500 MHz
NC 300 Series	up to 11 GHz
NC 400 Series	up to 50 GHz

ALL ARE IN STOCK

DROP IN MODULES FOR BITE

Self energized in TO-8
Ideal for self testing of receivers
50 ohms, 30 dB ENR min,
35 dB ENR typ.



TYPICAL STANDARD MODELS	
NC 501	up to 500 MHz
NC 502	up to 1 GHz
NC 503	up to 2 GHz
NC 504	up to 3 GHz
NC 505	up to 4 GHz
NC 506	up to 5 GHz

ALL ARE IN STOCK

BROAD BAND AMPLIFIED MODULES

PLUG-IN, DUAL-IN-LINE
24 or 14 PIN, 150mv out

TYPICAL STANDARD MODELS	
NC 2101	up to 20 kHz
NC 2102	up to 100 kHz
NC 2103	up to 500 kHz
NC 2104	up to 1 MHz
NC 2105	up to 10 MHz
NC 2106	up to 20 MHz

MOST ARE IN STOCK

HIGH-OUTPUT:

+10 dBM, 50 ohms
SMA or BNC output

TYPICAL STANDARD MODELS	
NC 1101A	up to 20 kHz
NC 1107A	up to 100 MHz
NC 1108A	up to 500 MHz
NC 1109A	up to 1 GHz
NC 1110A	up to 1.5 GHz

Other frequency ranges
and output levels available

MOST ARE IN STOCK

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SMA, N, TNC Output Connectors

TYPICAL STANDARD MODELS	
NC 3100 Series	up to 18 GHz 15.5 dB ENR, noise figure meter compatible.
NC 3200 Series	up to 18 GHz 30-35 dB ENR, high noise output.

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111 Moore St.
Hackensack, N.J. 07601
(201) 488-4144
TWX 910-380-8198

Price of the Model 25A100 RF amplifier is $2,000. **Amplifier Research, Souderton, Pa. INFO/CARD #196.**

Gasket Tapes For EMI and RFI Shielding

Soft, compressible GORE-TEX Gasket Tapes are now available in electrically conductive versions for use in EMI and RFI shielding applications. These carbon-filled products exhibit superb sealability and will compress to a thin gasket that will completely fill microscopic flaws in the sealing surfaces. These new tapes are high in conductivity, exhibit a high degree of conformability and have excellent attenuation characteristics across a wide frequency range. **W.L. Gore & Associates, Inc., Elkton, Md. Please circle INFO/CARD #195.**

Sweep Generators Offer Choice of Bands

Systron Donner's 1900 Series of sweep generators feature single band architecture. This approach allows the user to select a sweeper covering only the required frequency range without the expense of unnecessary frequencies. The result is a lower price without sacrificing any performance features. The 1900 Series features the CW frequency accuracy of a synthesizer. Spectral purity often exceeds synthesizer performance. Typical single side band phase noise in a 1 Hz bandwidth at 6 GHz is −90 dBc. Harmonics are −20 dBc typical and maximum spurious response is −60 dBc. Price is based on selected frequency ranges and starts at $4,995. **Systron Donner/Instrument Division, Concord, Calif. INFO/CARD #194.**

SMD Digital Attenuator for 1 to 4 GHz

KDI Electronics has announced the availability of a new thick film digital attenuator designed for operation to 4.0 GHz. The DAC236 is a 3 bit device and features 0 to 30 dB attenuation in 6 dB increments. Accuracies are ±0.25 dB/bit and ±0.5 dB

cumulative over the entire attenuation range. The circuit is also available with other attenuation ranges in both 3 and 4 bit versions. Insertion loss is 2.0 dB typical and 2.5 dB worst case and VSWR is less than 1.5:1. Maximum input RF power level is +20 dBm. **KDI Electronics, Inc., Whippany, N.J. INFO/CARD #193.**

Varactor-Tuned Oscillator Covers 550 to 775 MHz

Avantek, Inc. announces the LNO-550 Varactor-Tuned Oscillator designed specifically for low noise performance in the 550 to 775 MHz frequency range. Phase noise is typically −112 dBc/Hz at 10 kHz from the carrier and −128 dBc/Hz at 1 MHz from the carrier. It has a minimum of +10 dBm output power and all specifications are guaranteed over the −54° to +85°C military temperature range. The LNO-550 requires 50 mA at 12 VDC.

rf products Continued

It is packaged in a hermetic, TO-8V transistor case. The LNO-550 is priced at $325 each (1 to 9). **Avantek, Inc., Santa Clara, Calif. INFO/CARD #192.**

500 Volt Chip Capacitors

New 500 WVDC monolithic ceramic chip capacitors are designed for applications where elevated voltages are a design requirement. These units are available in NPO and X7R dielectrics with capacitance values from 470 pF to 0.15 uF. These capacitors are supplied in a variety of configurations including sizes 1206, 1210, 1808, 1812 and 2221. Standard units are available with terminations of palladium or nickel barrier with soldered coat. Prices range from $1.89 to .29 (1000) depending upon size and value. **Johanson Dielectrics, Inc., Burbank, Calif. INFO/CARD #191.**

3.0 GHz "SMA" Attenuators Are Low-Cost

Elcom Systems, Inc. announces a series of low-cost miniature 50 ohm coaxial type SMA attenuators suitable for lab testing and production use. They are available in 1 thru 9 dB in 1 dB steps and

RADIATION HARDENING

The Battlefield Demands It.
DoD Requires It.
We Provide It!

IRT's Hybrid Nuclear Event Detector:

- ☐ Detects multiple nuclear detonations
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- ☐ Remembers event/initiates system recovery
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San Diego, CA 92121;
619/450-4343, Ext. 694

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INFO/CARD 41

TURN YOUR HP 8566* SPECTRUM ANALYZER INTO A POWERFUL NETWORK ANALYZER.

Turn your HP 8566* Spectrum Analyzer into a powerful network analyzer with scalar frequency response function. Align filters and amps in minutes!

AVCOM's model MTG-3600 Tracking Generator outputs a -5 dBm (typical) tracked RF signal from less than 100 KHz to over 1.5 GHz. Flatness ±1.5 dB typical. IF feedthru below -65 dBm typical. L.O. is a phase locked cavity oscillator referenced to an ovenized crystal oscillator. $1865

AVCOM's model MTG-321 Tracking Generator outputs minimum -10 dBm from 2 GHz to 5 GHz. $1350

AVCOM Tracking Generators can be ordered with output frequency offset (by the amount of the device under test IF frequency for example), to meet specific application requirements.

CUSTOM SPECTRUM ANALYZERS

AVCOM manufacturers low cost Spectrum Analyzers covering portions of the spectrum to 5 GHz for specific dedicated applications. Resolution Bandwidths as low as 5 KHz., Dynamic Ranges to 70 dB. Rack Mount or Portable. Priced from $1965 (PSA-35A)

* Other analyzers can be used, call with your specifications.

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RICHMOND, VIRGINIA 23236
TELEPHONE (804) 794-2500
FAX: 804-794-8284 TELEX: 701-545

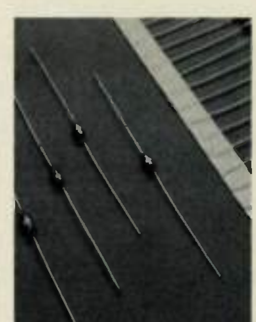
INFO/CARD 42

Coilcraft RF inductors

- Most items shipped from stock
- Custom values and styles available
- Designed to meet MIL specifications
- Experimenters kits available

Surface mounted
Close tolerance chip inductors from 30 nH to 1000 uH. High Q and high current models. Tuneable chips, surface mount transformers and toroids also available.

Tuneable
The industry's broadest range of variable inductors. From .05 to 1100 uH. Shielded or unshielded. 10 mm or 7 mm packages conserve board space.



Conformal coated
Close tolerance axial lead chokes, totally encapsulated in a durable epoxy coating. Lower cost than molded types. No molding stress to break wires.

Call 312/639-6400

Coilcraft

1102 Silver Lake Road, Cary, IL 60013

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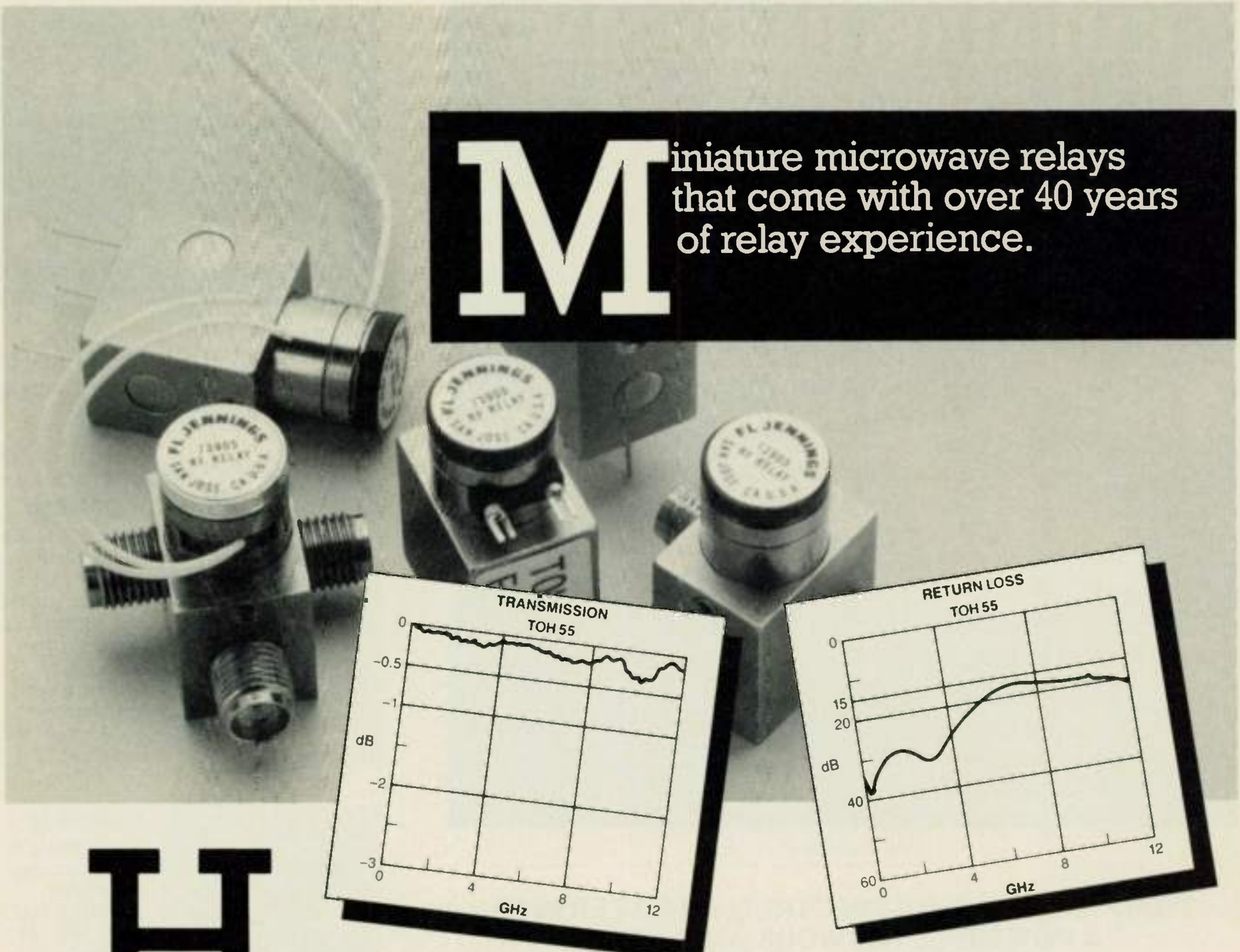
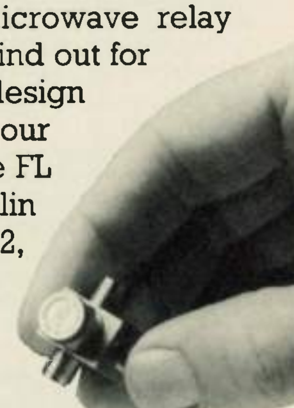


Miniature microwave relays that come with over 40 years of relay experience.

Here is a welcome addition to the microwave relay market from a company that has spent over 40 years developing high frequency relays. Our new TOH Series offers designers a microwave relay with small size and outstanding performance, that can be used for a variety of applications where stringent impedance matching and isolation are required. Typical applications include antenna switching, radar, communications, radio telephones, and cable TV systems.

Both PCB mount and SMA mount models are available in frequency ranges from DC to 2.5 GHz. Operating voltages of 6, 12, 24, and 28 VDC can be ordered with your choice of coil terminals, PCB terminals, flying leads, and solder lugs. Rugged construction assures long life (tested to over 2.5 million cycles), and materials used meet strict mil-spec requirements.

We felt the time was right to show you what 40 years of relay experience can provide to the microwave relay market. Now you can find out for yourself by asking for design assistance or a copy of our brochure. Call or write FL Jennings, 970 McLaughlin Ave., San Jose, CA 95122, (408) 292-4025.



DIVISION OF FL INDUSTRIES

FL JENNINGS

INFO/CARD 64

10 thru 20 dB in 2 dB steps. Attenuation accuracy is 0.5 dB from DC to 2.5 GHz, and 1 dB to 3.0 GHz. VSWR is less than 1.35:1 at 3.0 GHz, averaging 1.2:1 over the band. The design utilizes gold plated connectors and high reliability MIL resistors in a silver plated housing. Elcom Systems Model AT-53/SMA costs $15.00 each. **Elcom Systems, Inc., Boca Raton, Fla. INFO/CARD #190.**

New Couplers, Mixers, Power Dividers and Modulators

Synergy Microwave Corporation has recently introduced several new RF products. Surface-mounted power dividers include the SPD-1 (1-500 MHz) and SPD-2 (.01-100 MHz) MIL-Spec devices, with their comercial counterparts, the SPD-C1 and SPD-C2. These devices offer 20 dB isolation and maximum 1.0 dB insertion loss. The SMD mixer line now includes nine models covering 1-2500 MHz with LO power requirements from +7 to +23 dBm. The SDC surface-mount directional couplers include models covering 50 kHz-1000 MHz with 10, 15 and 20 dB coupling. These are packaged in Synergy's .500" × .375" × .150" package (MIL-STD). Another new addition is a group of bi-phase modulators for carrier frequencies of 800-2500 MHz and modulation frequencies up to 200 MHz, in flatpack or SMA connectorized packages. One dB compression points are either +1 or +10 dBm, with phase balance of 5.5° maximum and typical insertion loss of 4 dB. **Synergy Microwave Corporation, Paterson, N.J. INFO/CARD #184.**

RF Power Transformers Handle up to 1 kW

RF power transformers, power splitters and combiners designed and manufactured for frequencies 0.1 to 175 MHz have 1 kW power handling capability up to 30 MHz, 500 W to 100 MHz and 300 W to 175 MHz. Some types of splitters-combiners and transformers are available from stock. Others have delivery from 2 to 12 weeks. **RF Power Systems, Inc., Phoenix, Ariz. INFO/CARD #188.**

High Q Multi-Turn Ceramic Trimmer Capacitors

The Mini-Trim series of high Q multi-turn ceramic trimmers are suited for RF and microwave applications including mobile radio, instrumentation and satellite ground stations. These units feature Johanson's patented one-piece self-locking constant torque drive mechanism. These units have a unique solderless construction which allows them to withstand elevated soldering heat, excessive tuning and rough handling. Capacitance range is 1.5 to 7.5 pF and a Q at 100 MHz of >5000. Price is $3.95 (100). **Johanson Manufacturing Corporation, Boonton, N.J. INFO/CARD #187.**

New Limiter Discriminators Announced

The newly designed LDD Series of Limiter Discriminators achieves high performance in FM demodulation. These units include a two-stage limiter, a delay line discriminator, and a DC coupled video amplifier. Center frequency is available from 30 MHz to 160 MHz and linearity is better than 1 percent. The units operate from ±12 VDC. 50, 75 and 93 ohm impedances are available. The LDD Limiter Discriminators are available in standard models or custom designed. **International Microwave Corp., Stamford, Conn. INFO/CARD #186.**

Transmission Line and Waveguide Synthesis Program

Webb Laboratories introduces a new transmission line and waveguide synthesis/analysis package. TRANSCAD allows 40 transmission structures to be analyzed or synthesized, including single and coupled suspended substrate stripline, single and coupled microstrip with anisotropy, dispersion, loss and enclosure effects included; edge-coupled, broadside-coupled and variable-overlap-coupled stripline, coplanar waveguide, slotline and many other strip type geometries. Also included in Version 1.0 are wireline structures, as well as coaxial configurations, rectangular waveguide, circular waveguide (TE01, TE11 and TM01 modes), single- and double-ridged waveguide and others. TRANSCAD operates on IBM PC/XT/AT and compatible machines with 384K RAM and DOS 2.0+, and is priced at $895 per copy. **Webb Laboratories, North Lake, Wis. INFO/CARD #219.**

Linear Circuit Analysis Program Gets Update

With version 4.3, LCAP has increased capabilities. The new features added are: time domain analysis, log sweep, "zoom lens" graphics, an improved matrix analysis routine that gives lower round off error, and increased speed. Analysis time of less than 1 second per frequency is typical with the standard IBM-PC. LCAP's regular features include: full-screen editing, nodal circuit notation, high resolution graphics, library of active devices, and S-parameter analysis. LCAP (for IBM-PC, 256K) is priced at $95. LCAP-87 (8087 Version) is $150. **RF Engineering, Norwich, N.Y. INFO/CARD #220.**

Software for Open-Site EMI Measurements

Hewlett-Packard Company has announced the HP 85870A open-site EMI measurement system (OEMS) software, designed to reduce the time required for radiated-emission compliance tests made at outdoor sites using HP spectrum-analyzer/EMI receivers. The software records information on each signal, including frequency, field strength and amplitude deviation from specified limits. It also stores factors such as antenna height and turntable positions, as well as operator comments. The test limit library contains as examples FCC Part 16 Subpart J, VDE 0871, FTZ 1046, and CISPR Publication 22 radiated-emission limits. Price of the HP 85870A software is $5,000. **Hewlett-Packard Company, Palo Alto, Calif. INFO/CARD #218.**

Interdigital Bandpass Filter Design Program

A second program, INTERDIG, in the software series "Microwave Components Hardware," has been released for use on HP series 200 desktop computers. INTERDIG allows a microwave engineer to obtain all internal dimensions of a quarter-wave interdigital filter by entering a few electrical and physical specifications. Based on exact approximation and synthesis methods, INTERDIG permits design flexibility such as choice of round-rod or rectangular-bar resonators, doubly or singly terminated designs, short or open circuited end resonators, and tapped or transformer input match. Price is $749. **MCH Associates, Thousand Oaks, Calif. INFO/CARD #217.**

SAE Standards Catalog is Available

The new SAE Standards Catalog is a comprehensive guide to the most current automotive and aerospace standards documents available. Of special note is the introduction of three new standards products: Individual Ground Vehicle Standards, SAE Ground Vehicle Standards Service (a quarterly service), and Ground Vehicle Standards on Microfiche. The SAE Standards Catalog is available free of charge. **Society of Automotive Engineers, Inc., Warrendale, Pa. Please circle INFO/CARD #214.**

Data Sheet Describes Attenuators "In-A-Cable"

A two-page data sheet from Micro-Coax™ Components, Inc. describes "In-A-Cable" subminiature attenuators, which are integrated into a semi-rigid cable assembly. A table lists and describes general technical data such as SWR, temperature and power sensitivity, peak voltage characteristics, dimensions and weight. Another table lists materials and specifications for all attenuator parts. A third table indicates mechanical and environmental characteristics. Micro-Coax Components' "In-A-Cable" subminiature attenuators are available in two cable diameters: 0.0865" (UT 85) and 0.141" (UT 141A). **Micro-Coax Components, Inc., Collegeville, Pa. INFO/CARD #213.**

Microwave Semiconductor Catalog

A new short form catalog describes a wide range of microwave diodes. The catalog includes PINs, limiters, Schottky mixer, Schottky detector, planar tunnel detector and general purpose guard ring Schottky diodes. There is also information about MIS capacitors (1.5 to 250 pf) and thin film resistors. **Virtech Microwave, Inc., Los Gatos, Calif. Please circle INFO/CARD #212.**

Precision Substrate Fabrication Services

A new catalog and capabilities brochure is available from Accumet Engineering Corporation, a single-source fabricator of precision substrates for microelectronic, scientific and industrial applications. The convenient reference guide features sections on lapped and polished substrates in commercial and MIL-SPEC grades for use in both thick and thin film circuits. Materials described include alumina, beryllia, fused silica, and specialized dielectrics. **Accumet Engineering Corporation, Hudson, Mass. INFO/CARD #211.**

Guide to RF Coaxial Connectors

A comprehensive reference guidebook for anyone specifying RF Coaxial Connectors is available from Automatic Connector, Inc. The 28-page handbook includes a short glossary, band designation data, typical coupling nomenclature including a comparative chart of cost, voltage, VSWR range and coupling method. Various connector series include BNC, BNC Twinax, UHF, N, Twinax and SMA, SMC, SMB types to cable assembly for virtually every clamping style in use today. **Automatic Connector, Inc., Commack, N.Y. INFO/CARD #210.**

Application Specific MLC Catalog

Olean Advanced Products announces a new product catalog, providing in-depth technical information on the Division's application specific multi-layer ceramic capacitor (MLC) components in EMI Suppression Arrays, High Energy Discharge

Capacitors, Discoidal and Feed-Thru Filters, SMPS Output Filters, High Voltage MLC Chips, High Reliability MLCs, and many other advanced areas. **Olean Advanced Products, Division of AVX Corporation, Olean, N.Y. INFO/CARD #209.**

Microwave Material Brochure

A four-page brochure featuring Di-Clad® 810 ceramic-PTFE 10 DK composite laminate for microstrip and stripline circuitry is available to microwave engineers from Keene Laminates. Typical properties, such as dielectric constant, dissipation factor and copper foil bond strength are contained in a specifications and test methods chart. Di-Clad 810's thermal coefficient of dielectric constant is illustrated in a line graph. **Keene Laminates, East Providence, R.I. Please circle INFO/CARD #208.**

Catalog Features Coaxial Switches

DB Products, Inc. announces a new Microwave Switch catalog, featuring 15 series of coaxial switches, with detailed specifications, schematics, outline drawings and available options for each. The catalog also includes detailed ordering instructions to specify series, connectors, voltage, function, polarity and other options. **DB Products, Inc., Pasadena, Calif. INFO/CARD #207.**

Noise Figure Application Note

An application note which discusses the noise measurement of high frequency devices is available from the Electronic Instrumentation Division (EID) of Eaton Corporation. the application note details the test configuration used by the Eaton 2075-2A Noise-Gain Analyzer to measure the noise performance of receivers or mixers whose IF frequencies are greater than 1850 MHz. Additionally, the technique used for measuring the noise performance of any device under test at arbitrarily high input frequencies is also described. **Eaton Corporation, Electronic Instrumentation Division, Los Angeles, Calif. INFO/CARD #206.**

Ultraminiature Connector Handbook

A new handbook describing the use of an ultraminiature line of connectors and cables for high density miniature packaging is offered by Microtech, Inc. The connector line includes ultraminiature coaxial connectors; 2, 3, 4, 7 and 12 contact circular connectors; ultraminiature in-line 2, 3, 4 and 6 contact connectors; and miniature PC board strip connectors with 10, 22 and 50 contacts. Special miniature coaxial cable and multi-conductor cable is available for use with the connectors. **Microtech, Inc., Boothwyn, Pa. Please circle INFO/CARD #205.**

Catalog Introduces Mail Order Division

Global Specialties has announced the establishment of a Mail Order Division to market their complete line of electronic testing and prototyping equipment. A full-line catalog, including ordering instructions, an order form, and a postage-paid return envelope has already been mailed to a selected list of potential end-users throughout the country. An 800 number for direct telephone orders is also featured. All Global instruments, logic test and solderless breadboarding products are included in the new catalog. **Global Specialties, New Haven, Conn. Please circle INFO/CARD #203.**

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION (Required by 39 U.S.C. 3685)

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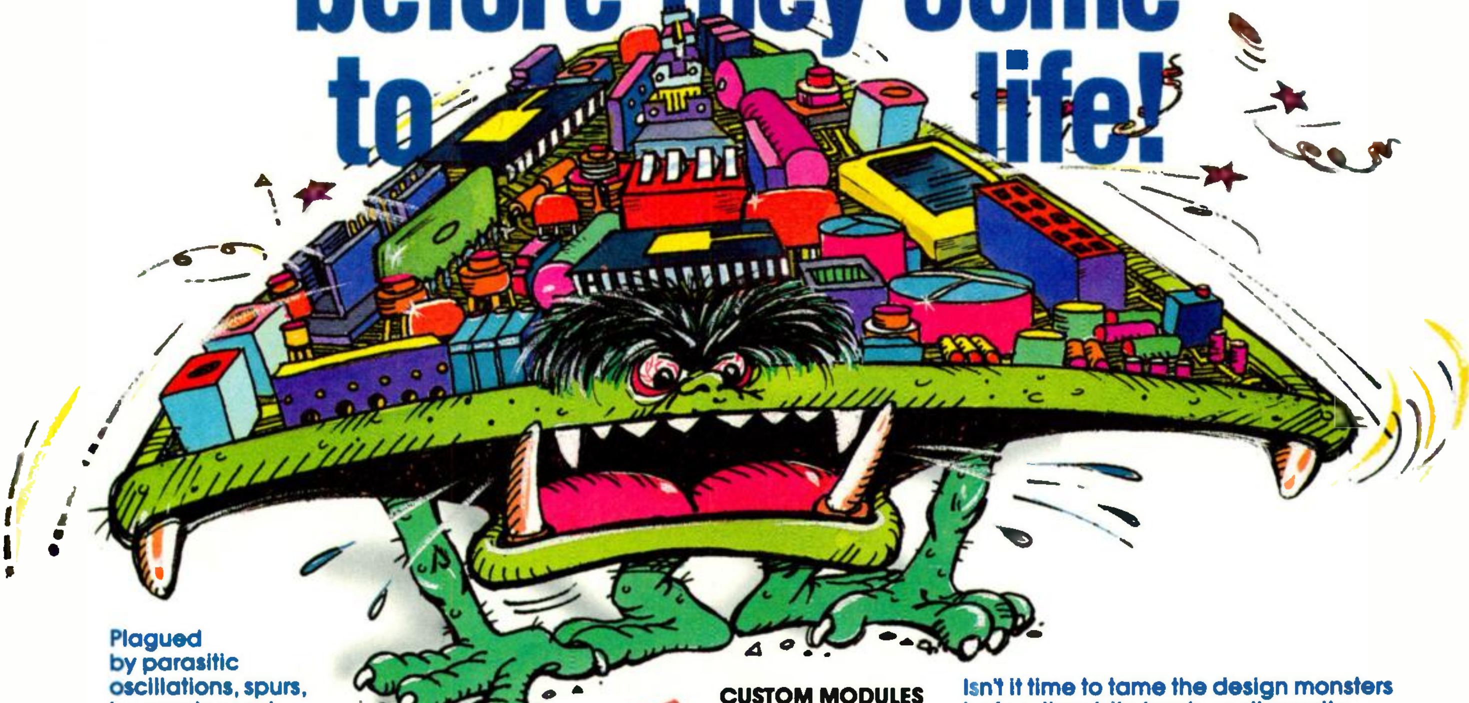
9. Extent and nature of circulation	Average No. copies each issue during preceding 12 months	Actual No. copies of issue published nearest to filing date.
A. Total No. Copies (Net Press Run)	35,512	36,253
B. Paid and/or requested circulation		
1. Sales through dealers and carriers, street vendors and counter sales	None	None
2. Mail subscription (Paid and/or requested)	32,536	34,422
C. Total paid and/or requested circulation (Sum of 10B1 and 10B2)	32,536	34,422
D. Free distribution by mail, carrier or other means (samples, complimentary and other free copies	1,805	1,178
E. Total distribution (Sum of C and D)	34,341	35,600
F. Copies not distributed		
1. Office use, left over, unaccounted, spoiled after printing	1,171	653
2. Return from News Agents	None	None
G. TOTAL (Sum of E, F1 and 2 — should equal net press run shown in A)	35,512	36,253

11. I certify that the statments made by me above are correct and complete.
(Signed) Keith Aldrich, Publisher

Advertiser's Index

Toko coils and filters attack RF design problems before they come to life!

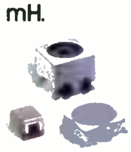


Plagued by parasitic oscillations, spurs, harmonics and feedback? The problem may not be your design, but the coils and filters you selected. Toko is the world's largest manufacturer of quality small coils and filters, with a selection so large, you're sure to find the right components to neutralize your rf design problems.

SUBMINIATURE ADJUSTABLE AND FIXED

Toko has what you need, so you won't need to compromise... subminiature adjustable coils and transformers, molded coils, radial fixed coils and fixed coils with axial leads. Toko high-Q coils are engineered in sizes from 5mm to 15mm, and inductance ranges from .02 μH to 500 mH.

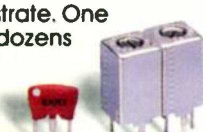
CHIP AND ADJUSTABLE SMD



Need to reduce the size of your products or automate production? Toko solves these problems with a wide range of surface mountable coils and LC, ceramic and helical filters in fixed and adjustable configurations. Packaged for automatic insertion and available for reflow or solder dipping.

CUSTOM MODULES

Toko hybrid modules are a great way to simplify design and production tasks. With short lead time, Toko can develop compact custom modules utilizing a variety of components, surface mounted on a ceramic substrate. One module replaces dozens of components.



FILTERS

For i-f or tuned rf circuitry. Toko filters simplify attenuation of out-of-band signals, while cleanly passing your desired signal. Ultra-miniature ceramic and LC filters at popular i-f frequencies fit tight spaces and tight budgets. With frequencies up to 1.2 GHz Toko helical filters are the right choice for communications transceivers.

ACTIVE FILTERS

If you're advancing the state-of-the-art in digital audio or PCM products you'll appreciate Toko active filters. Especially designed for small size and low distortion, they're also very cost-effective.

Isn't it time to tame the design monsters before they bite back...call or write Toko today for a free coil and filter catalog or a quote on your needs. No matter what Toko coils and filters you choose, you can be assured of exceptionally high quality control at economical prices.

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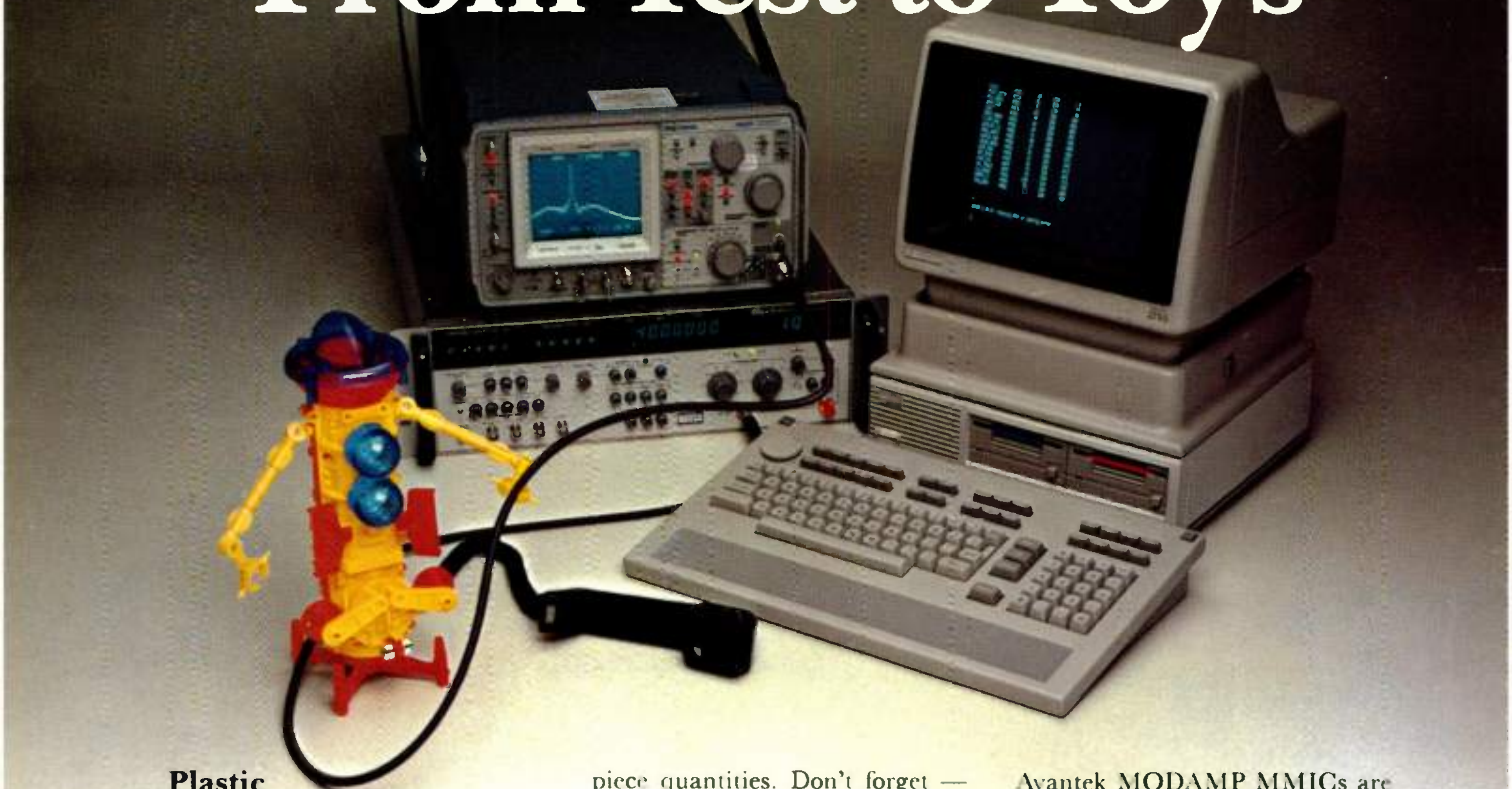
From Test to Toys



Plastic MMIC gain blocks. Avantek 4-Pac amplifiers. $1.80 each*.

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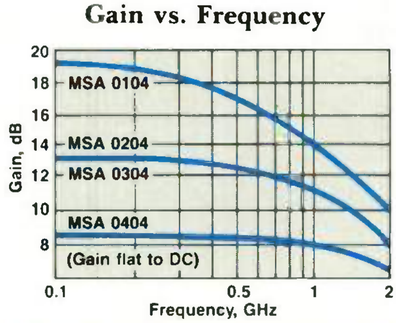
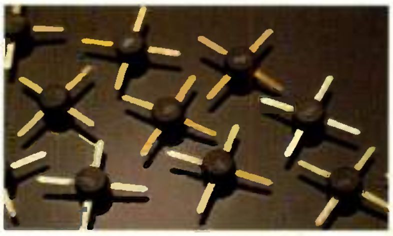
Gain vs. Frequency





*price in 10,000 piece quantities.

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