# rf design

ideas for engineers

October 1986

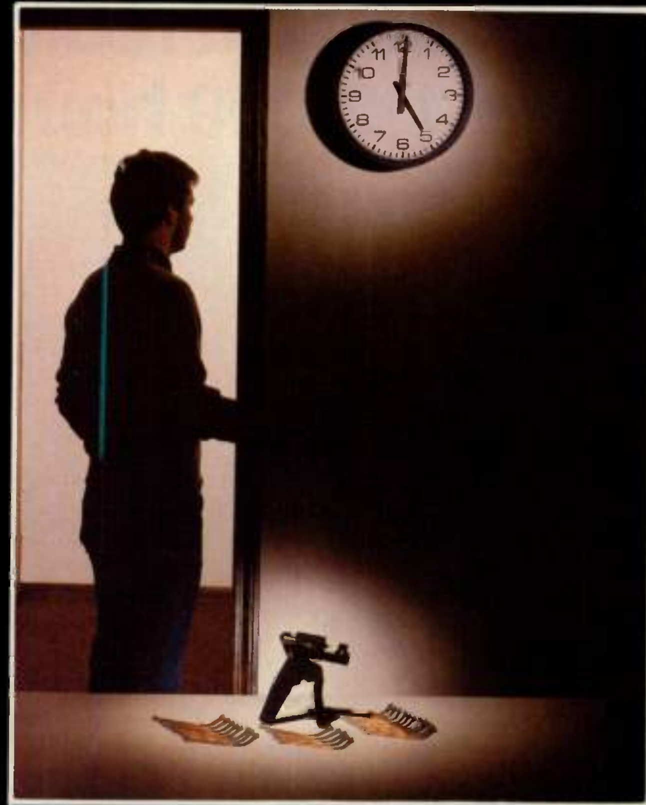
## Cascadable GaAs Amplifier Chips



## Special Report: How to Specify Coaxial Cable

## RF Expo East technical program

# IS TIME GETTING AWAY FROM YOU? LET OMNI SPECTRA GIVE IT BACK.



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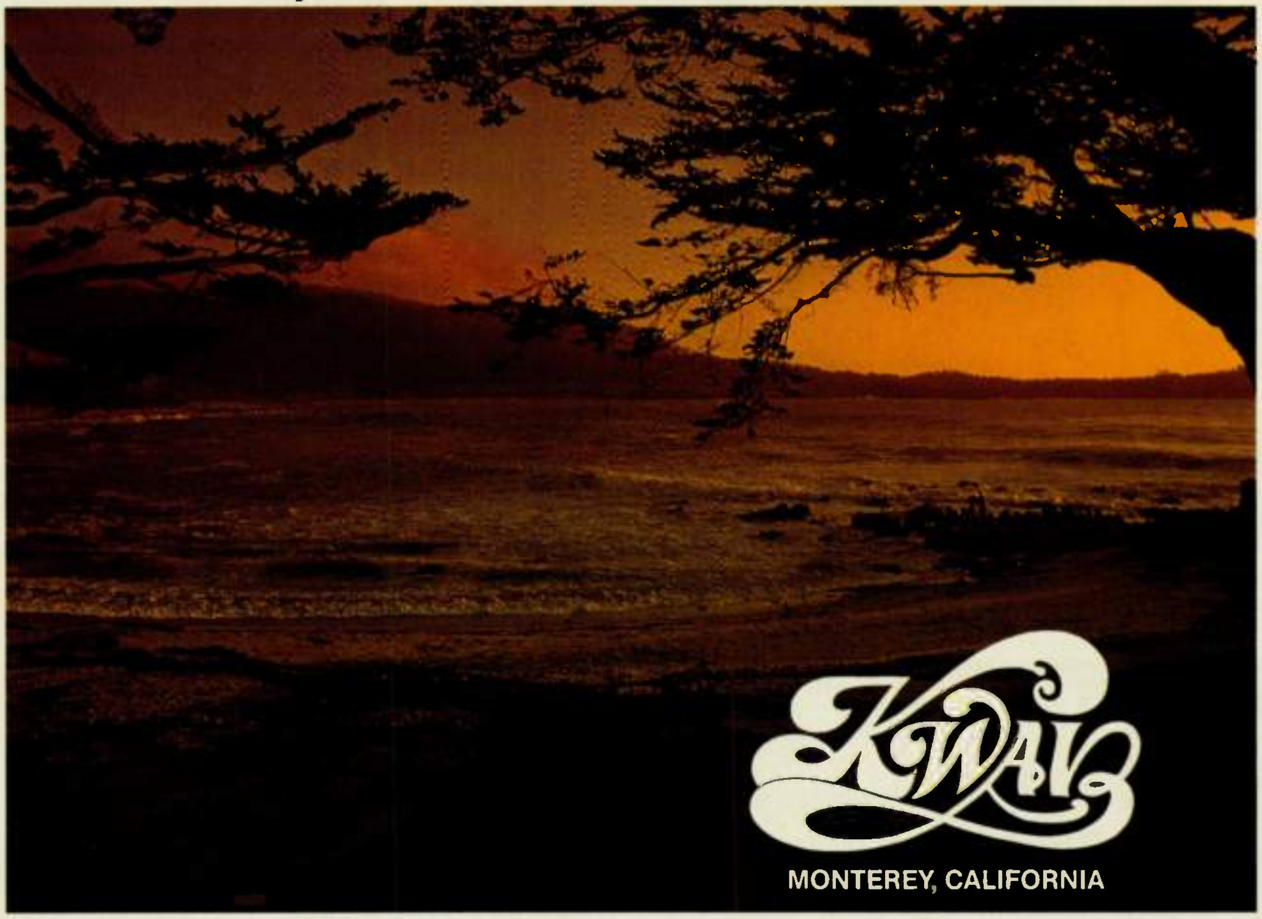


Ken Warren, Chief Engineer at KWAV reports that their 10 kW FM transmitter went on the air in November, 1972, equipped with EIMAC power tubes. The original tubes are still in operation after over 13 years of continuous duty!

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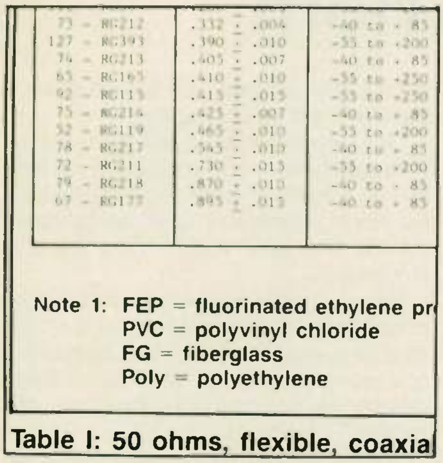
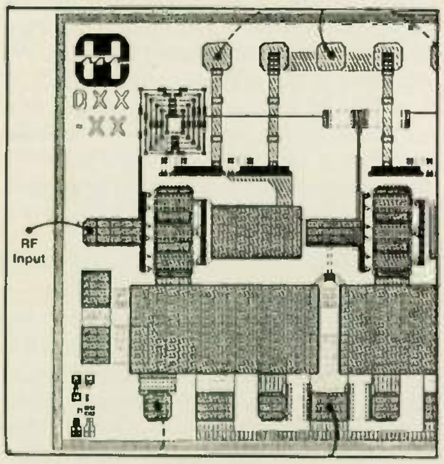
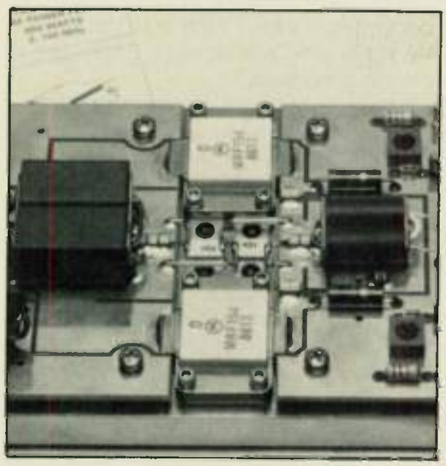
October 1986




*Page 24 — Special Report*




*Page 39 — GaAs ICs*



*Page 43 — High Power MOSFETs*

## Cover

Represented on this month's cover are new products from Harris Microwave Semiconductor — cascadable, monolithic GaAs linear amplifiers for 500 MHz to 5 GHz. The chip configuration of these gain blocks makes them usable with as little effort as attaching four bond wires.

## Features



## Departments



R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in August. October 1986, Volume 9, No. 10. Copyright 1986 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6530 S. Yosemite Street, Englewood, CO 80111 (303) 694-1522. Contents may not be reproduced in any form without written permission. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: 1 East First Street, Duluth, MN 55802, (218-723-9355). Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $22 per year in the United States; $29 per year in Canada and Mexico; $33 (surface mail) per year for foreign countries. Additional cost for first class mailing. Payment must be made in U.S. funds and accompany request. If available, single copies and back issues are $5.50 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 N. Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.
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## rf editorial

# A Toot of the Horn

*By James N. MacDonald*
*Editor*

It is unseemly to brag, but sometimes you just can't help it. We can't help pointing out the strides *RF Design* has made lately.

We have a reputation for bringing engineers useful design articles to help them do their job well. The current staff also has a goal to keep on top of the latest technological developments in RF and bring them to our readers' attention. The last four months of this year show that we are accomplishing that goal.

It starts with the August issue, in which we were the first to tell you about Sciteq's new modular frequency synthesizer. Here is a frequency synthesizer that uses SAW technology and can cover a wide RF frequency range with 500 MHz modules. No crystal, no cavity, no frequency multiplication, and only 10 watts, and you saw it first in *RF Design*.

This month we announce Harris Microwave Semiconductor's new cascadable GaAs amplifier chips illustrated so dramatically on the cover. Microwave frequency versions of this technology have been described in the latest issues of other publications, but we are the first with complete design information about the 500 MHz to 5 GHz version. These chips give designers the option to add gain by using cascadable 10 dB gain blocks with +/− 0.75 dB full band gain flatness.

Next month we will reveal a new instrument that represents a surprising new direction for a major company. We can't tell you who or what, yet, but we guarantee it will get your attention.

Our December issue will feature a different instrument with impressive capabilities by a much smaller company (in size, but not in reputation). It will be exhibited for the first time at RF Expo East, in November.

We can't help but be proud of this recognition of our importance as a magazine. You can be proud, too, because it is a recognition of the importance these companies assign to the engineers who read *RF Design*.

We want to call attention to another accomplishment because of its significance to the industry. In the August editorial we described a new public domain software library assembled by Gerald Harrison. We believed in his idea and were happy to support and encourage him, but we were surprised at the response that editorial generated. We gave him an INFO/CARD number and that number has generated far more inquiries than any other item in the magazine's history.

Last May we started a separate New Software section in the new products pages because of the number of announcements we were receiving and the interest our readers showed in circuit design programs. We knew you wanted such programs, but we didn't know you wanted them so much! Our recent reader survey, described in the September issue, told us three-fourths of you use a personal computer at work. With that information we knew why you were so interested in design programs.

Major software companies saw this need, too, and developed CAD software for PCs. We have reported on these programs in a Special Report and several news items, this year, as well as the New Software section. We will continue to try to keep you informed about all such design aids, from public domain programs for PCs to comprehensive CAD programs for mainframes. And we will continue to try to bring you the latest technological breakthroughs.

We won't keep bragging about it, but maybe you'll forgive us for blowing our own horn just once. After all, nobody else is going to tell you how wonderful we are.

James N. MacDonald


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INFO/CARD 5

## rf viewpoint

# The Silent RF Majority

*By Keith Aldrich*
*Publisher*

Last month we published the results of a reader profile survey which suggested in its essence that RF engineers are well-paid and quite proud of their work.

This conclusion is a distinct contrast to rumblings we hear on several sides that engineers in general, and RF and microwave engineers in particular, are discontent with their professions, both because they feel underpaid in constrast to other professionals and because their work is undervalued in their companies.

Our profile survey indicates that such rumblings are not truly an expression of the majority of RF engineers, but come from a disproportionately vocal minority.

I don't mean to be a shill for the establishment, but the facts of RF life revealed by the profile do seem to me to justify an attitude of pride on the part of RF engineers, rather than discontent. No respondents, for instance, reported a salary under $25,000 a year, while the median salary was over $45,000, even though the median age is less than 40.

These figures are not typical of all engineering, much less all workers. Some engineers in other fields do make less than $25,000, and, of course, many good engineers are not working now at all. Due to their scarcity, there is virtually no unemployment among RF engineers.

Money, of course, isn't everything. RF engineers probably feel that they are in one of the more exciting areas of current electronics technology, as indeed they are. The breakthrough in GaAs FET technology announced on this month's cover is just an example of the activity that is being generated by and because of their designs. The runaway success of our RF EXPOs — first on the West Coast, and next month for the first time in the East (November 10-12 in Boston) — is an indication of how eager RF engineers are to get together and advance the technology of which they are the custodians.

So, the long and short of it is, we believe our readers' report. We believe they feel the way they say they feel, and not the way some say they do or ought to feel. Granted, they may be in a rare spot determined more by the luck of the draw than by a Utopian system — but life is like that. Let's do all we can to spread the word about this fortunate niche, and to help those less fortunate. In the meantime, it's not irresponsible, I think, to make hay while the sun shines.

Keith Aldrich


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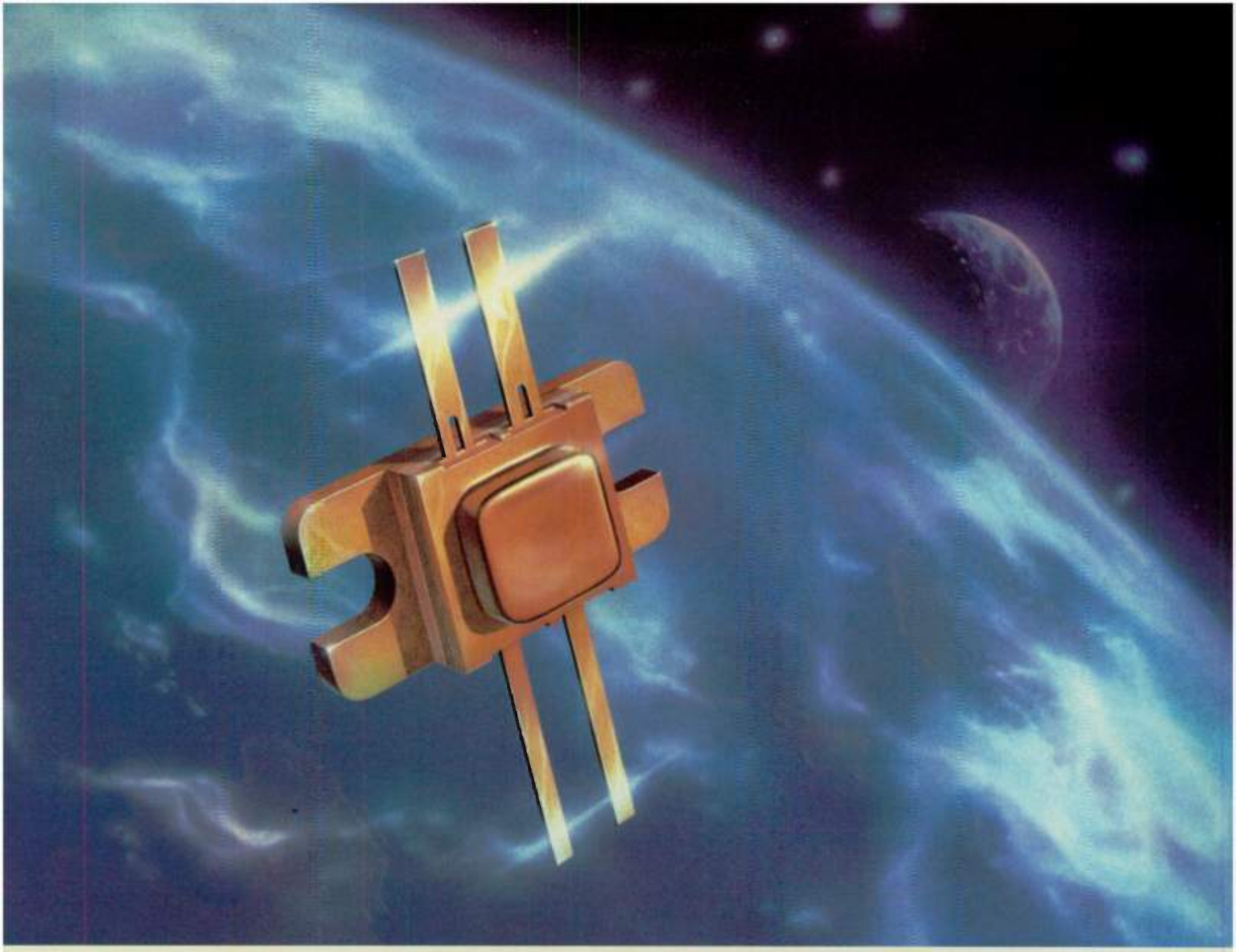

# PROOF THERE IS INTELLIGENCE IN SPACE.

The Strategic Defense Initiative. A deterrent concept so novel, there are years of research ahead before the best method of implementing it can be agreed upon. But there's one aspect that virtually every major SDI contractor has already agreed upon.

That the UHF pulsed power transistors used in their system evaluations will be from Thomson Components-Mostek Corporation.

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|---|---|---|---|---|---|---|---|---|
| SD1564 | Common emitter | 400-450 MHz | 400 Watts | 40 Vcc | 7.5dB | 1ms | 10% | Tstg = −65 - +200°C<br>$T_j$ = +200°C |
| SD1565 | Common base | 400-450 MHz | 500 Watts | 40 Vcc | 10.0dB | 250ns | 10% | Tstg = −65 - +200°C<br>$T_j$ = +200°C |

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INFO/CARD 7

### James J. Lev Authored That Article

Editor:

In your August editorial on the "Public Domain Library," an idea which deserves *every* praise, I think you may have unintentionally done me in *twice* again.

At the top of the right hand column is a reference to an article by "James E. Lev." I'm sure that's an early paper of mine and that it should say "James J. Lev." I wrote a piece with that title for *Electronics* magazine back in 1973. Also, further down, near the end, you've given credit to Kevin McClaning for "Synthesize and Analyze Microstrip Lines." Now, I'm sure Kevin has done a lot of good things, but this isn't one of them. It might be a coincidence, but *I* wrote a piece by the same exact title, and I've enclosed a copy for you. It was published in the January 1985 issue of *Microwaves & RF* magazine. I think it possible you've given credit to the wrong person for that paper.

Those two papers, and several others, have been well received by the RF and microwave community at large. Many of them are your readers. I've thoroughly enjoyed the writing and would encourage others to share their knowledge by submitting articles for publication.

These papers, and the belief that good design techniques would always be well received, prompted me to *start* Microwave Software! I've spent the last two years translating the best of my ideas into good low-cost software for the Apple and IBM PCs. Our pricing policy reflects a personal belief that a "back to basics" approach, and volume, are the key to low prices. I want good software to be within the reach of the average engineer, not just the large corporation that he/she might work for. I think I have the right idea. Sales so far this year are up 145 percent over all of 1985. There is an awakening realization "out there" that good software doesn't have to cost thousands of dollars.

It would be appreciated if you would check out the facts in this matter and correct any error, either on my part, or on yours.

James J. Lev
Microwave Software
P.O. Box 764
San Juan Capistrano, Calif. 92693

### Gerald Harrison's Reply

Editor:

With respect to Mr. Lev's comments, I did refer to him mistakenly as James E. in the catalog of disk #2. To clear up the Kevin McClaning credit line, Kevin wrote the BASIC program using the equations from James J. Lev's article and from the book "Physics" by Halliday and Resnick. This is on disk #4 (with Mr. Lev's proper middle initial). It gives credit to Mr. Lev for the article and to Mr. McClaning for the program.

Also note the program on "Low Impedance Double Tuned Circuits" was based on an article by Andrzei Przedpelski. Kevin laboriously converted the calculator program to BASIC.

The library is off to a good start, I hope we can motivate engineers to part with their hard work to keep it going. My hat is off to the Kevin McClanings and the Criss Trasks for their valuable contributions fo the engineering community.

Gerald S. Harrison
E.E. Public Domain Library
36 Irene Lane East
Plainview, N.Y., 11803





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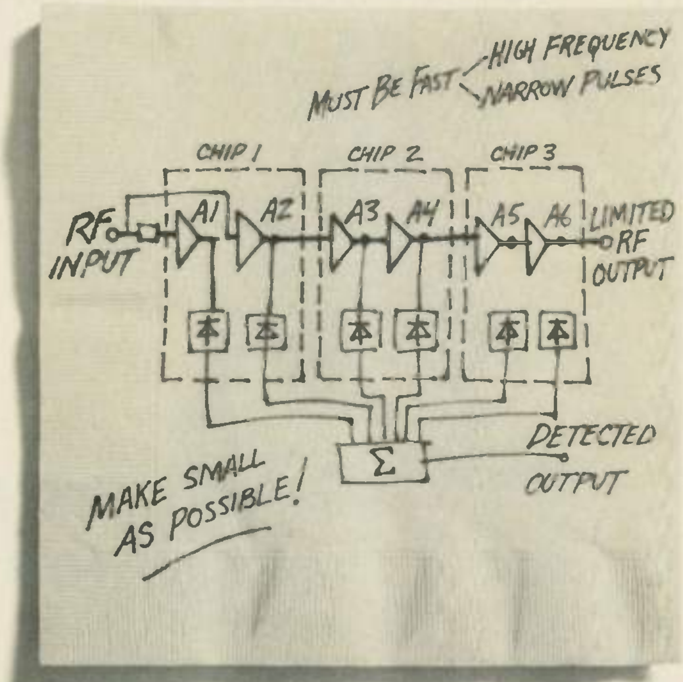


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INFO/CARD 15

### Termination Insensitive Mixer Patented by Adams-Russell, Anzac

Editor:

Your August 1986 issue of *RF Design* ran an article by Gary A. Breed, your technical editor. This article was entitled "Mixers: Making The Right Choice." In this article you described a device called a Termination Insensitive Mixer (TIM). Where did you get your information? In your references there was no mention of the "TIM" or its developer and patent holder.

Let me enlighten you. Adams-Russell Electronics, Anzac Division, holds the patent on the "Termination Insensitive Mixer (TIM)." Also TIM is a registered trademark of Adams-Russell Electronics Co., Inc.

Don't you agree that one should qualify their sources of information prior to running an article? To facilitate the qualification of your TIM article, I have attached a full brochure describing its operation and application. I would like to see your magazine publish this to clarify your article on the TIM.

Adams-Russell Electronics allocates much time and funding to research and development of new products, procedures and technology. Also, enclosed for your information is a technical article on "Loss Less or Coupler Feedback" technology, of which we again are the patent holder.

Other patents held by Adams-Russell Electronics, Anzac Division, are as follows:

- Transformer Feedback .................................... 3,891,934
- 180° Hybrids Technology ............... 3,311,850, 3,508,171, 3,325,587
- 90° Hybrids Technology .................................. 3,484,724
- N-Way Power Divider Technology .......................... 3,428,920
- Impedance Bridges ....................................... 3,492,569
- Coupler Technology ...................................... 3,426,298
- Coupler Feedback Amplifier .............................. 3,624,536
- Termination Insensitive Mixer (TIM) ..................... 4,224,532

Julian D. Parker, Manager, Component Marketing
Adams-Russell Electronics Co., Inc., Electronics & Instruments Group
Burlington, Massachusetts

### Is It Magnetostriction or Skin Effect?

Editor:

I read with interest the article by Mr. Colin Gyles on "Anomalous Behavior of Reed Relays" in September *RF Design*. I have noted the same response for relays with magnetic signal path conductors, but I do not feel that magnetostriction needs to be invoked to explain it. I believe that simple "skin effect" gives an adequate explanation for the phenomenon, especially since the "tail" appears to be of the classic error function shape associated with skin effect.

Brian V. Cake
Vice President
Advanced Development
LeCroy Corp.
Spring Valley, New York

### Equations and Flow Chart Might Be Enough

Editor:

Keats Pullen hit the nail squarely when he correctly identified the really important issue regarding programming (August 1986). Indeed, it is *not* the means whereby we are aided, but the *correctness* of the equations that counts.

Perhaps I might add an alternate suggestion to Mr. Pullen's question with regard to best form. Rather than offering a "program" at all, why not along with the proper — and correct — equations, also offer a flow chart. Being armed with an understanding of how the author thought through a solution would aid materially in writing the program, regardless of language.

Yes, why not poll your readership as Mr. Pullen suggests. I'm sure the task would be very worthwhile to authors and readers alike.

Ed Oxner
Siliconix
Santa Clara, California

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

# rf calendar

**October 7-9, 1986**
**Connector and Interconnection Technology Symposium**
Disneyland Hotel, Anaheim, California
Information: Kent R. Bumpas, Daniels Manufacturing Corp., 11360 Palm Dr., Suite "A," Desert Hot Springs, CA 92240; Tel: (619) 329-2947

**October 10-12, 1986**
**ISA/86**
Houston Astrohall, Houston, Texas
Information: Philip N. Meade, Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709; Tel: (919) 549-8411

**November 10-12, 1986**
**RF Expo East**
Boston Marriott Copley Square, Boston, Massachusetts
Information: Kathy Kriner, Convention Manager, Cardiff Publishing Co., 6530 So. Yosemite St., Englewood, CO 80111; Tel: (303) 694-1522 or (800) 525-9154

**November 18-21, 1986**
**Wescon/86 High Technology Electronics Exhibition and Convention**
Anaheim Convention Center, Anaheim, California
Information: J. Fossler, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; Tel: (312) 299-9311

**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

**February 11-13, 1987**
**RF Technology Expo 87**
Disneyland Hotel, Anaheim, California
Information: Kathy Kriner, Convention Manager, Cardiff Publishing Co. (see address above)

**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

**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)

# rf courses

**The George Washington University**

**Grounding, Bonding, Shielding and Transient Protection**
October 20-23, 1986, Orlando, Florida
December 8-11, 1986, Ottawa, Canada

**Radar Systems and Technology**
November 3-7, 1986, Washington, DC

**Wideband Communications Systems**
December 15-19, 1986, 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 Modern Radar**
November 3-7, 1986, Atlanta, Georgia

**Phased-Array Antennas: Theory, Design and Technology**
November 18-21, 1986, 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**
November 12-14, 1986, Baltimore, Maryland
December 15-17, 1986, Santa Clara, California

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

**University of Mississippi**

**Dielectric Resonators**
October 29-31, 1986, University, Mississippi

Information: Bruce Bellande, Dept. of Continuing Education, University of Mississippi, University, MS 38677; Tel: (601) 232-7282

**R & B Enterprises**
**TEMPEST — A Detailed Design Course**
October 6-10, 1986, Philadelphia, Pennsylvania

**Electromagnetic Pulse (EMP) Design and Test**
October 9-10, 1986, Washington, DC
October 27-28, 1986, Philadelphia, Pennsylvania

**Grounding, Bonding and Shielding**
October 27-28, 1986, Washington, DC
October 20-21, 1986, Philadelphia, Pennsylvania

**Understanding and Applying MIL-STD-461C**
October 16-17, 1986, Washington, DC
October 30-31, 1986, Philadelphia, Pennsylvania

**Printed Circuit Board and Wiring Design for EMI and ESD Control**
October 14-15, 1986, Philadelphia, Pennsylvania
October 20-21, 1986, Boston, Massachusetts

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

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Three models are available: basic, rivet-mount and double-faced adhesive-mount designs. The basic design consists of low-compression, adhesive-mounted strips. A generous radius profile provides for the greatest incident engagement angle with the lowest force. As with all Sticky Fingers® shielding strips, the self-adhesive tape makes mounting easy and secure.

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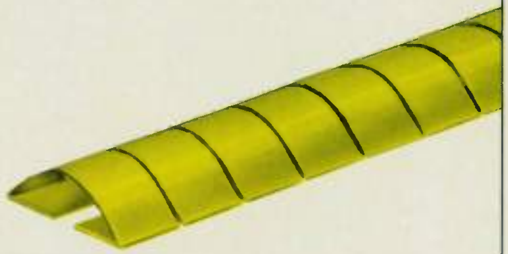
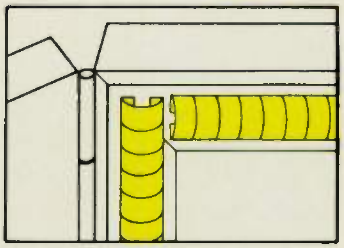
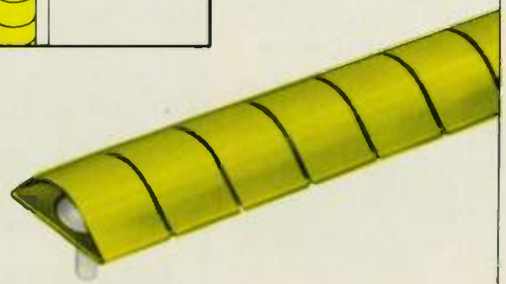
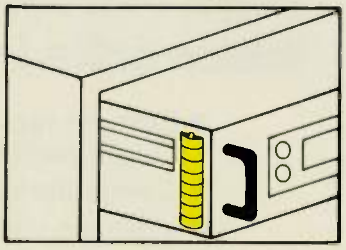
For complete information, including exact specifications, dimensional drawings, etc., on these and other Instrument Specialties shielding strips, use this publication's Reader Service Card. Or write to us directly at Dept. RFD-27.



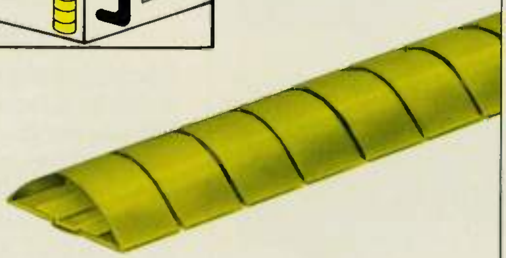


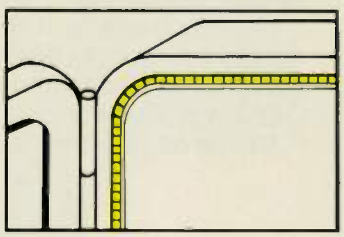
Adhesive-mounted strips for typical electronic enclosures.





Strips with integral mounting track* and nylon push rivets, for sliding drawer applications.





Strips with integral mounting track* and self-adhesive strip for fast field replacement.

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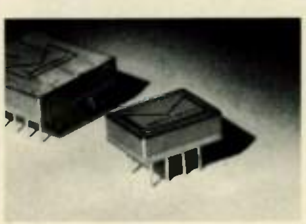
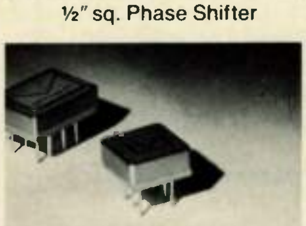

½″ sq. Phase Shifter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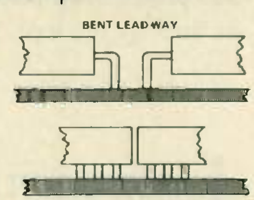


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INFO/CARD 18

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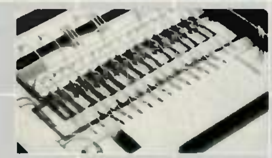
It is this dedication to building reliability into our products and services that has made us industry leaders. Let us show you how MSC can build longer life into your radar systems. *MSC: where the solution makes a difference.*



SEM photo of the MSC 0710-300

*Results of independent testing as reported in NRL Contract (N-00173-78C-0012) final report, published August 1981: that the MTF of MSC devices is significantly higher than other competitors' devices tested.

**CLASS C AMPLIFIER** (Pulse Conditions Per Table) **ELECTRICAL CHARACTERISTICS** (@ 25°C)

**L-BAND RADAR PULSED POWER TRANSISTORS**

| Model Number | Test Freq. (MHz) | $P_{OUT}$ Min. (W) | $P_{IN}$ (W) | Eff Min. (%) | $V_{CC}$ (V) | Pulse Width (usec) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|
| AM 1214-100 | 1235-1365 | 125 | 28 | 50 | 32 | 1000 | 10 |
| AM 1214-300 | 1235-1365 | 270 | 63 | 40 | 50 | 50 | 4 |
| AM 1416-100 | 1400-1600 | 90 | 15 | 40 | 45 | 10 | 10 |
| AM 1416-200 | 1400-1600 | 180 | 40 | 40 | 50 | 10 | 10 |
| AM 0610-200 | 650-1000 | 180 | 35 | 40 | 45 | 10 | 10 |
| AM 0710-300 | 750-950 | 270 | 30 | 40 | 50 | 10 | 10 |

**S-BAND RADAR PULSED POWER TRANSISTORS**

| Model Number | Test Freq. (MHz) | $P_{OUT}$ Min. (W) | $P_{IN}$ (W) | Eff Min. (%) | $V_{CC}$ (V) | Pulse Width (usec) | Duty Cycle (%) |
|---|---|---|---|---|---|---|---|
| AM 82731-12 | 2700-3100 | 12.5 | 3.0 | 32 | 40 | 100 | 10 |
| AM 82731-45 | 2700-3100 | 45.0 | 12.0 | 30 | 40 | 100 | 10 |
| AM 82931-55 | 2900-3100 | 55.0 | 14.0 | 30 | 42 | 50 | 10 |
| AM 83135-15 | 3100-3500 | 15.0 | 4.0 | 30 | 40 | 100 | 10 |
| AM 83135-30 | 3100-3500 | 30.0 | 8.5 | 30 | 40 | 100 | 10 |
| AM 83135-40 | 3100-3500 | 40.0 | 12.5 | 30 | 40 | 100 | 10 |

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# SYSTEM RELIABILITY

INFO/CARD 19

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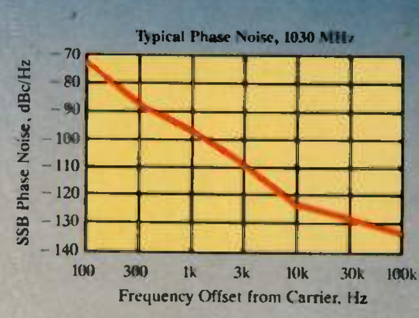


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INFO/CARD 20

# AMD to Open Quality and Design Centers in Japan

Advanced Micro Devices, Inc. will open a quality assurance test center in Japan in January, to be followed by a design center later in 1987. The two new facilities will share a location in the Tokyo area. In addition, AMD will open a sales and service office in Osaka next month to complement its existing office in Tokyo. The company plans to double the number of employees in Japan by the end of this year.

President and chief executive officer W.J. Sanders III said Japan is, or soon will be, the world's largest semiconductor market. He also noted that the recently concluded semicondutor trade agreement between the U.S. and Japan contemplates increased market opportunities in Japan for U.S. semiconductor manufacturers.

"Any company aspiring to be among the world leaders in integrated circuits must also have a major market position in Japan," Sanders said. "AMD is committed to being a world leader in integrated circuits, and we are committed to working very hard to serve the Japanese market, which is our top priority for investment in people."

Earlier, Sanders announced cost-reduction steps for the company. The semiconductor industry's recovery from its longest-ever recession stalled in June and the business environment appears flat for the near term, he said.

"At the national level the trade deficit remains sky-high and business investment is in decline. There are no meaningful signs of an increase in demand for semiconductors from the computer sector," he said.

As a result, Sanders said the company is implementing a number of cost-reduction steps in addition to those taken previously. Among them will be dismissal of all non-essential personnel who have been employed less than one year and are therefore not covered by the company's no-layoff policy. Approximately 200 such employees were to be terminated on August 15, and provided severance pay, other benefits and outplacement assistance. In addition, the company is withdrawing from the DRAM (dynamic random-access memory) marketplace, which accounted for less than 1 percent of the company sales but where spending on research and development and related projects was significant.

In order to provide the flexibility to respond to business conditions and to improve international competitiveness in the future, the company is discontinuing its no-layoff policy, Sanders said. However, he said no work force reduction involving employees with more than one year's service will be considered until mid-October, when results of the fiscal year are clearer. Any reduction, he said, will be based on individual performance.

"In short, our world has changed and to survive we too must change. As we strive to structure our organization to recover profitability by eliminating programs, projects and products, we may be unable to offer all AMDers equivalent employment.

"It is my sincere hope that a turnaround will develop and such measures will not be necessary," Sanders concluded.

# *Microwave Update 1986* Shows Amateur Radio Contributions

Technical seminars on amateur radio communications at microwave frequencies drew dozens of participants to Estes Park, Colo., on Labor Day weekend to exchange ideas on the design and construction of equipment for the L-, S-, C-, X- and K-bands. Don Hilliard, a National Bureau of Standards researcher, was the organizer of the conference. Although an "amateur" group, over half of the attendees were RF professionals employed by such firms as Texas Instruments, Martin Marietta, Westinghouse, Michigan Tech and San Jose State.

Topics presented included design techniques for low-cost MMIC amplifiers, a discussion of spectrally pure crystal oscillators, construction of a tetrode cavity amplifier for 1.3 GHz, and an interesting report on experiments with rainscatter propagation at 5.76 GHz. Other papers emphasized practical aspects of performance measurement, construction and modification of equipment. A description of the S-Band transponder included in the next amateur radio satellite was another presentation of note.

With recent allocation of new operating frequencies, the microwave spectrum represents the greatest technical challenge to amateur radio enthusiasts. Lack of commercial equipment makes it necessary to build or modify equipment, and the ingenuity of these technically advanced hams in finding low-cost solutions was clearly evident.

# Siemens Acquires Silicon Valley Facility

Siemens Components, Inc. has acquired a 98,000-square-foot wafer fabrication, R&D and office facility in Santa Clara, Calif., to headquarter its Semiconductor Group. The two-year-old, three-story facility includes an 11,000-square-foot, state-of-the-art clean room. Siemens will begin occupying the new building immediately.

Semiconductor Group senior vice president and general manager Robert E. (Ed) Caldwell said the new facility will house the consolidated activities of the Semiconductor Group of Siemens Components, Inc.

"This facility acquisition and move represent a significant extension of the Semiconductor Group's manufacturing presence in the United States," Caldwell said. "It is the first step in a multi-year program to add substantial new capabilities to Siemens Components in the field of power semiconductors, integrated circuits (ICs), and optoelectronics, with new domestic R&D and production capabilities to meet the requirements of our growing U.S. market."

# GigaBit Logic Trims Workforce

GigaBit Logic Inc., a manufacturer of high performance gallium arsenide integrated circuits, has announced the layoff of 33 people, 25 percent of the company's workforce.

John D. Heightley, president and CEO, stated, "A cutback is always difficult, especially when highly qualified people are affected. However, this action is required in order to bring operating expenses in line with expected sales levels. These reductions have been done in such a way that GigaBit Logic's leadership role in digital gallium arsenide integrated circuits will be preserved and our strategic investments for future revenues will be maintained. I expect our remaining workforce to be able to sustain GigaBit Logic's revenue growth rate of 100 percent per year."

GigaBit Logic Inc. markets a broad

range of digital GaAs integrated circuits marketed under the PicoLogic™ tradename and also provides foundry services to a variety of electronics companies.

## Lucas Industries to Acquire Weinschel

Weinschel Engineering has reached agreement with Lucas Industries Inc. for Lucas to acquire Weinschel in a merger transaction. The transaction is subject to formal approval by each company's board of directors and the shareholders of Weinschel, and certain other conditions. If the transaction is approved at the Weinschel shareholders meeting, Sept. 19, Lucas will pay $10,450,000 to the shareholders of Weinschel, or $17.0633 per share outstanding. Weinschel is a designer and producer of microwave components and test and calibration instruments. Upon completion of the transaction, Weinschel, which employs 259 persons, will become a subsidiary of Lucas Industries Inc.

A company spokesman said the intent is to keep the Weinschel operation running as it is and keep all key personnel in place. Weinschel will remain as a consultant to the company, but a general manager appointed by Lucas will take over the operation of the subsidiary.

Lucas Industries, Inc., headquartered in Troy, Mich., is a wholly-owned subsidiary of Lucas Industries PLC, an international aerospace, automotive and industrial systems and components group, based in the United Kingdom.

## Publication Reviews Surface Mount Reliability

A new Reliability Analysis Center publication, *Surface Mount Technology: A Reliable Review* (SOAR-5), discusses the status of surface mounting in the scope of today's manufacturing environment. The objective of SOAR-5 is to establish the character of surface mount technology (SMT) with regard to its reliability. The document contains investigations of SMT's impact on the manufacturer/user community both in terms of resources and cost.

The primary focus of the report is associated with the specific failure mechanisms of surface mount packages, solder joint connections and printed wiring boards. Evaluating each of these primary areas provides the basis for failure rate model development, a highlight of the publication. While most of the material presented is universally applicable to different device types and package styles, the emphasis is on surface mount packaging and reliability. SOAR-5 presents a dynamic evaluation of a potentially vital technology.

Order from and make check payable to Reliability Analysis Center, RADC/RAC, Griffiss AFB, NY 13441-5700. Cost is $56 per copy ($66 outside the U.S.).

## Motorola Accepts Perkin-Elmer's Lithography System

The AEBLE 150, the world's first direct-write-on-wafer electron beam lithography system cabable of submicron VLSI (Very Large Scale Integrated) circuit production, has been accepted by Motorola, Inc. from the Perkin-Elmer Corporation. Motorola will use the AEBLE 150 to fabricate very-high-speed, high-density, submicron integrated circuits for its research, government, and commercial leading-edge device technology.

The AEBLE 150 is the commercial derivative of an engineering prototype developed by Perkin-Elmer at its Electron Beam Technology Division in Hayward, Calif. That development program was conducted jointly with Hughes Aircraft Corporation Research Center of Malibu, Calif., under the sponsorship of the Department of the Army for the Department of Defense's VHSIC (Very High Speed Integrated Circuit) program.

The AEBLE 150 is a vector scan, variable-shaped electron beam lithography system capable of writing circuit patterns with features as small as 0.25 micron. Without using a mask, the AEBLE 150 writes directly on silicon wafers, and at production rates required for commercial manufacturing. The AEBLE 150 also can be used in mix and match applications with equipment such as Perkin-Elmer SRA-9535 steppers and Microlign 600 full field aligners.

Motorola's Semiconductor Products is a participant in the VHSIC Phase II 0.5 micron technology program, which involves establishing submicron chip fabrication capability in bipolar and CMOS technologies. The AEBLE system will be installed at Motorola's semiconductor facility in Mesa, Ariz.

The acceptance culminates nearly six years of development by Perkin-Elmer in partnership with Hughes, the U.S. government and VHSIC contractors such as Motorola and marks the successful completion of the production system qualified by rigorous testing.

## New Air Traffic Control System Warns of Hazards

The Republic of Korea has begun operating one of the world's most sophisticated air traffic control systems, which automatically alerts controllers when aircraft fly in converging paths, stray from airway boundaries or descend below a safe altitude. The new system, developed by Hughes Aircraft Company's Ground Systems Group, provides complete control of South Korean air space, including enroute and airport approach control of aircraft throughout the nation and over ocean areas to the south, east and west.

Radar data and flight processing functions are automated and combined in the system, enabling controllers to move air traffic safely and expeditiously. The system monitors data simultaneously from multiple overlapping radar networks, creating a tracking picture that is significantly more reliable than most current systems which provide data from only one or two radars.

## Norden Awards Contract to Sawtek

Sawtek Inc., Orlando, Fla., has been awarded a contract by Norden Systems Inc., a subsidiary of UTC. The development and initial hardware production contract in excess of $2 million for surface acoustic wave (SAW) pulse compression devices and expansion subsystems is the largest SAW contract ever awarded to any SAW manufacturer.

A substantially larger production contract may follow upon Norden's successful implementation of its program. Norden's Airborne Systems Group programs include several major military radar systems. Production potential on this program may exceed $7 million over the next five years, according to company sources.

According to Ian Brown, Sawtek's vice president of sales, Norden selected Sawtek to supply the SAW systems because of Sawtek's continued strong performance in the advancement of SAW technology and its capability to produce sophisticated and reliable SAW devices.

# RF POWER

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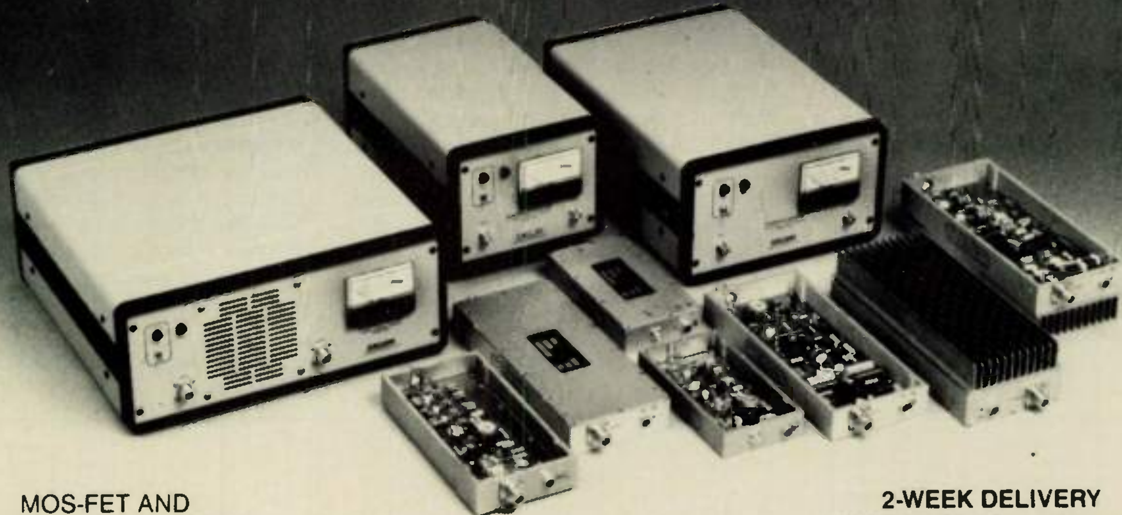

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INFO/CARD 36

# How to Specify Coaxial Cable

## A Practical Guide to Cable Selection for Commercial and Military Applications.

*By Allen Kushner*
*Times Fiber Communications, Inc.*

*RF designers must regularly specify coaxial cables for the interconnection of equipment. In this Special Report, the author covers the basics of cable specification for applications up to about 2 GHz, using the list of cables in MIL-C-17 as the starting point for both military and commercial applications. A three-part process for the RF engineer to follow includes: 1) determining the input and output requirements, plus the environmental and mechanical conditions; 2) if no unusual conditions exist, selecting a cable from the MIL-C-17 lists; and 3) consulting the applications engineering department of cable manufacturers listed on the QPL list for MIL-C-17.*

The task of selecting a coaxial cable for interconnecting equipment is difficult, not because the technology is unknown, but because there are many factors involved and the information has not been readily available. It is made more complicated by the fact that the coaxial cable industry, although 50 years old, is still changing. In addition, the product must fucntion over a broad frequency range. The RF designer is most concerned with the frequency range to 2 GHz, and discussion will be limited to coaxial cable characteristics over that frequency range.

There are mechanical, electrical and environmental requirements which apply to the output and input of the equipment to be interconnected. If the environment is reasonably controlled, a coaxial cable may be selected from a recommended list of cables from MIL-C-17, a military standard representing the most commonly available cables produced in economic lots.

Because there are more variables in cable selection than can be discussed here, it is recommended that the requirements be discussed with the application engineering group of a cable manufacturer who can help verify that you have selected the optimum cable from a performance, availability and cost viewpoint.

There are a number of requirements to be determined regarding the input and

| Part Number M17/xx | O.D. (in.) | Operating Temperature Range (°C) | Jacket[1] | Max Frequency (GHz) | Center Conductor | Shields[2] | Attenuation[3] Max. dB/100 ft | | | Power Max. Watts | | | VSWR Max. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | .4 | 1 GHz | 2 | .4 | 1 GHz | 2 | .4 | 1 GHz | 2 |
| 93 - RG178 | .071 ± .004 | -55 to +200 | FEP | 3 | Stranded | 1:SC | 33 | 52 | 76 | 115 | 68 | 45 | 1.18 | 1.25 | 1.36 |
| 113 - RG316 | .098 ± .004 | -55 to +200 | FEP | 3 | Stranded | 1:SC | 21 | 38 | 47 | 220 | 135 | 94 | 1.16 | 1.20 | 1.24 |
| 119 - RG174 | .110 ± .004 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 25 | 45 | -- | 26 | 17 | -- | 1.21 | 1.26 | --- |
| 152 - 00001 | .114 ± .004 | -55 to +200 | FEP | 12.4 | Stranded | 2:SC | 25 | 40 | 47 | 210 | 130 | 92 | 1.11 | 1.16 | 1.19 |
| 54 - RG122 | .160 ± .005 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 18 | 30 | -- | 62 | 35 | -- | 1.18 | 1.23 | --- |
| 111 - RG303 | .170 ± .005 | -55 to +200 | FEP | 3 | Solid | 1:SC | 8.6 | 15 | 21 | 1100 | 630 | 430 | 1.11 | 1.14 | --- |
| 28 - RG58 | .195 ± .004 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 17 | 28 | -- | 88 | 50 | -- | 1.12 | 1.15 | --- |
| 60 - RG142 | .195 ± .004 | -55 to +200 | FEP | 12.4 | Solid | 2:SC | 11.7 | 19 | 28 | 1100 | 650 | 420 | 1.15 | 1.18 | 1.23 |
| 128 - RG400 | .195 ± .004 | -55 to +200 | FEP | 12.4 | Stranded | 2:SC | 10.5 | 17 | 28 | 1100 | 620 | 420 | 1.14 | 1.18 | 1.22 |
| 84 - RG223 | .212 ± .004 | -40 to + 85 | PVC | 12.4 | Solid | 2:SC | 12 | 21 | 31 | 86 | 50 | 33 | 1.12 | 1.15 | 1.19 |
| 112 - RG304 | .280 ± .005 | -55 to +200 | FEP | 12.4 | Solid | 2:SC | 6.4 | 11 | 17 | 1450 | 870 | 550 | 1.12 | 1.15 | 1.18 |
| 73 - RG212 | .332 ± .004 | -40 to + 85 | PVC | 11 | Solid | 2:SC | 6.5 | 12 | 19 | 330 | 200 | 140 | 1.12 | 1.15 | 1.27 |
| 127 - RG393 | .390 ± .010 | -55 to +200 | FEP | 10 | Stranded | 2:SC | 5.0 | 8.8 | 14 | 820 | 280 | 130 | 1.13 | 1.16 | 1.19 |
| 74 - RG213 | .405 ± .007 | -40 to + 85 | PVC | 1 | Stranded | 1:BC | 4.8 | 9.0 | -- | 320 | 180 | --- | 1.10 | 1.12 | --- |
| 65 - RG165 | .410 ± .010 | -55 to +250 | FG | 3 | Stranded | 1:SC | 4.7 | 8.0 | 12 | 2700 | 1600 | 1050 | 1.10 | 1.14 | 1.22 |
| 92 - RG115 | .415 ± .015 | -55 to +250 | FG | 12.4 | Stranded | 2:SC | 5.7 | 9.8 | 17 | 2600 | 1500 | 1000 | 1.11 | 1.16 | 1.20 |
| 75 - RG214 | .425 ± .007 | -40 to + 85 | PVC | 11 | Stranded | 2:SC | 5.5 | 9.6 | 15 | 380 | 210 | 135 | 1.18 | 1.22 | 1.24 |
| 52 - RG119 | .465 ± .010 | -55 to +200 | FG | 3 | Solid | 2:BC | 4.4 | 7.2 | 11 | 2600 | 1500 | 1000 | 1.10 | 1.10 | 1.12 |
| 78 - RG217 | .545 ± .010 | -40 to + 85 | PVC | 3 | Solid | 2:BC | 3.7 | 7.0 | 10 | 470 | 250 | 160 | 1.44 | 1.44 | 1.44 |
| 72 - RG211 | .730 ± .015 | -55 to +200 | FG | 1 | Solid | 1:BC | 2.3 | 4.0 | -- | 10000 | 6000 | --- | 1.15 | 1.17 | --- |
| 79 - RG218 | .870 ± .010 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 2.8 | 5.0 | -- | 1200 | 600 | --- | 1.93 | 1.93 | --- |
| 67 - RG177 | .895 ± .015 | -40 to + 85 | PVC | 12.4 | Solid | 2:SC | 2.6 | 5.0 | 10 | 1600 | 780 | 450 | 1.93 | 1.93 | 1.93 |

Note 1: FEP = fluorinated ethylene propylene
PVC = polyvinyl chloride
FG = fiberglass
Poly = polyethylene

Note 2: 1:SC = 1 silverplated braid
2:BC = 2 bare copper braids
1:TC = 1 tin plated braid

Note 3: Attenuation at 20°C and power at 25°C and sea level

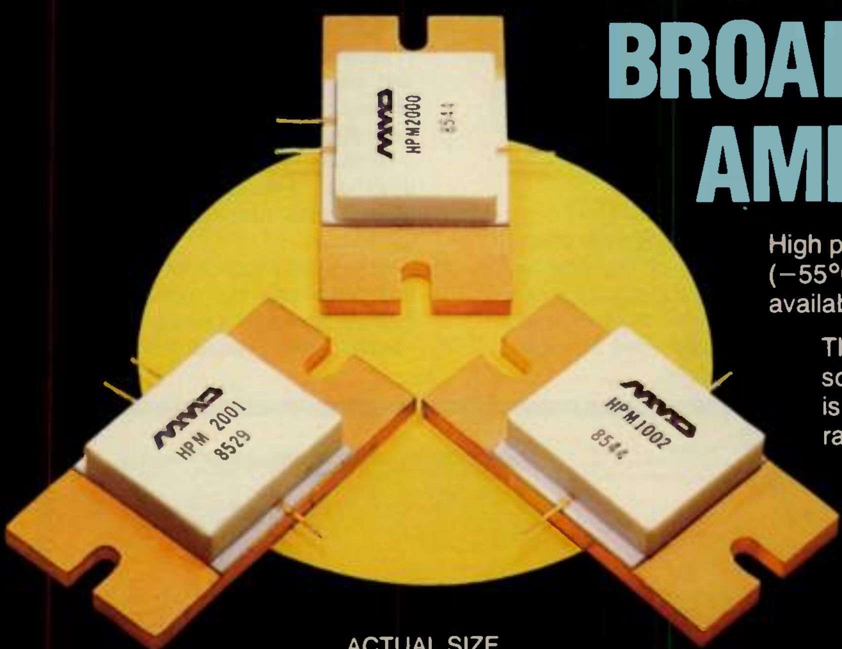
**Table I: 50 ohms, flexible, coaxial, swept**

# MMD™ 2.0 W POWER

## MODEL HPM-1002

# 20 MHz to 1 GHz

## ONE OF A SERIES OF BROADBAND AMPLIFIERS

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High power, broadband, low-noise performance (−55°C to +71°C) in a drop-in package is available from MMD today.

The HPM Series of hybrid amplifiers can solve your design problems when space is at a premium and high dynamic range a necessity.

Now available from stock, the HPM-501 (1W), HPM-2000 (+23dBm @ 1dB comp.), HPM-2001 (1W) and HPM-1002 (2W), offer you unparalleled design flexibility.

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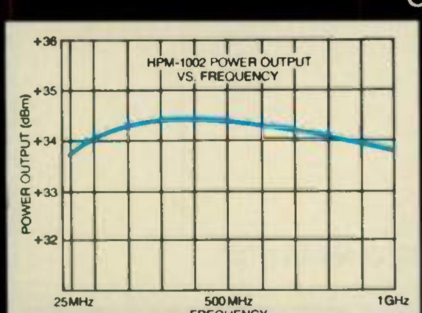
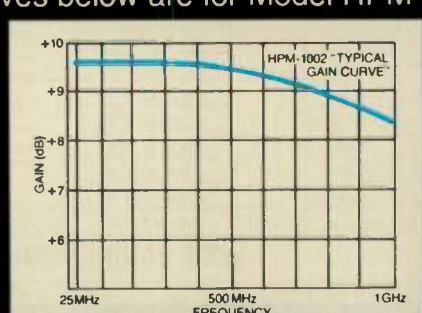
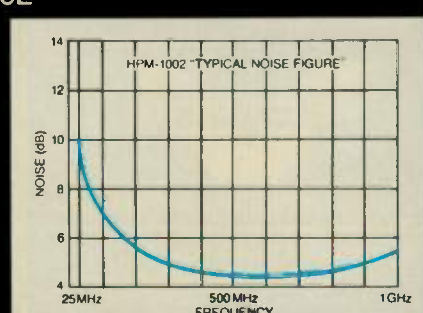
Curves below are for Model HPM-1002




Typical performance @+15V unless otherwise noted.


MMD
MICROWAVE MODULES & DEVICES, Inc

550 Ellis St., Mountain View, CA 94043 (415) 961-1473 Telex 508746


Literature — INFO/CARD 22, Demonstration — INFO/CARD 53.

| Part Number M17/xx | O.D. (in.) | Operating Temperature Range (°C) | Jacket | Max Frequency (GHz) | Center Conductor | Shields | Attenuation Max dB/100 ft. @ 0.4 GHz | Power Max. Watts @ 0.4 GHz |
|---|---|---|---|---|---|---|---|---|
| 169-00001 | .071 ± .004 | -55 to +200 | FEP | 3 | Stranded | 1:SC | 33 | 115 |
| 172-00001 | .098 ± .004 | -55 to +200 | FEP | 3 | Stranded | 1:SC | 21 | 220 |
| 173-00001 | .110 ± .004 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 25 | 26 |
| 157-00001 | .160 ± .005 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 18 | 62 |
| 170-00001 | .170 ± .005 | -55 to +200 | FEP | 3 | Solid | 1:SC | 8.6 | 1100 |
| 155-00001 | .195 ± .004 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 17 | 1100 |
| 158-00001 | .195 ± .004 | -55 to +200 | FEP | 12.4 | Solid | 2:SC | 12 | 1100 |
| 175-00001 | .195 ± .004 | -55 to +200 | FEP | 12.4 | Stranded | 2:SC | 11 | 1100 |
| 167-00001 | .212 ± .004 | -40 to + 85 | PVC | 12.4 | Solid | 2:SC | 12 | 86 |
| 171-00001 | .280 ± .005 | -55 to +200 | FEP | 12.4 | Solid | 2:SC | 6.4 | 1150 |
| 162-00001 | .332 ± .004 | -40 to + 85 | PVC | 11 | Solid | 2:SC | 6.5 | 230 |
| 174-00001 | .390 ± .010 | -55 to +200 | FEP | 10 | Stranded | 2:SC | 5.0 | 820 |
| 163-00001 | .405 ± .007 | -40 to + 85 | PVC | 1 | Stranded | 1:BC | 4.7 | 320 |
| 159-00001 | .410 ± .010 | -55 to +250 | FG | 3 | Stranded | 1:SC | 4.6 | 2700 |
| 168-00001 | .415 ± .015 | -55 to +250 | FG | 12.4 | Stranded | 2:SC | 5.2 | 2600 |
| 164-00001 | .425 ± .017 | -40 to + 85 | PVC | 11 | Stranded | 2:SC | 5.5 | 380 |
| 156-00001 | .465 ± .010 | -55 to +200 | FG | 3 | Solid | 2:BC | 4.5 | 2600 |
| 165-00001 | .545 ± .010 | -40 to + 85 | PVC | 3 | Solid | 2:BC | 3.8 | 470 |
| 161-00001 | .730 ± .015 | -55 to +200 | FG | 1 | Solid | 1:BC | 2.0 | 10000 |
| 166-00001 | .870 ± .010 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 2.8 | 1200 |
| 160-00001 | .895 ± .015 | -40 to + 85 | PVC | 12.4 | Solid | 2:SC | 2.7 | 1600 |

**Table II: 50 ohms, flexible, coaxial, non-swept**

output of the equipments to be interconnected:

a) What impedance? What VSWR can be tolerated?
b) Frequency range.
c) Maximum average power output.
d) Minimum output and input powers (allowable attenuation).
e) Estimate of RFI compatibility.
f) Temperature range.
g) Flexure-frequent or intermittent.

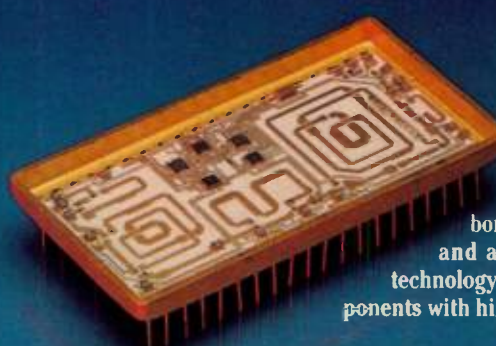
Once these requirements are identified, a cable can then be selected.

## Cable Selection from MIL-C-17

MIL-C-17 is the primary specification used by the Department of Defense to standardize cables most commonly used in military systems. Cables described in the specification are also used in most non-military applications because the specification has created a consistent product for which connectors to MIL-C-39012 are available. MIL-C-17 consists of the following parts:

a) Material Specification — detailing specific materials which can be used in cable construction including chemical analysis, strengths and thicknesses.
b) Individual Cable Specification Sheets — detailing dimensions, tolerances, electrical, mechanical and environmental tests, requirements and performance.
c) Detailed Test Procedures — ensuring that tests can be repeatably performed by manufacturers and users.
d) Qualification Procedures — stating

# DAICO HIGH RELIABILITY R.F. MIC STEP PHASE SHIFTERS



Daico step phase shifters combine thin-film microstrip circuitry, automated wire-bonding, computer aided testing, and advanced solid-state switch technology. The results are reliable components with high stability and accuracy.

The following typical characteristics define the range of specifications of parts already developed and delivered to a variety of customers:

| | |
|---|---|
| Frequency Range: | 200MHz to 2GHz ($f_0$ to be specified) |
| RF Power Handling: | Up to +20dBm |
| Insertion Loss: | 0.5 to 1dB Per Bit (depending upon frequency) |
| Insertion Loss Variation: | Compensated to within 0.5dB |
| Phase Steps: | 1 to 6 Bits |
| MSB Range: | 45° to 360° (depending on frequency, number of bits and package size) |
| Phase Accuracy: | ±2° |
| Control Configuration: | CMOS, TTL, ECL<br>Uncoded, Coded or Latched |
| Switching Speed: | 100 nanoseconds to 10 microseconds (depending on control configuration) |

If your system requires cost effective switches, step or voltage-controlled attenuators or step-phase shifters with:

- ☐ Fast switching speeds
- ☐ High isolation
- ☐ Low switching transients
- ☐ MIC DIP or Flatpack packaging
- ☐ Phase or attenuation compensation

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INFO/CARD 25

how a manufacturer may become able to be listed on the Qualified Products List.

e) Quality Conformance Testing — listing the tests and sampling procedures to which all finished lots of material must be subjected.

Cables may only be marked with the M17/xx-xxxx nomenclature if the product meets all specification requirements and is listed on the Qualified Products List. The Department of Defense has notified manufacturers that legal action may be taken if cables are marked by manufacturers who are not QPL, or do not meet the applicable specifications.

MIL-C-17 lists approximately 125 cables. From that list four tables have been prepared, including those coaxial cables which RF designers would most commonly use:

*Table I* lists those 50 ohm cables which have been made to a specified VSWR requirement. The swept requirements of those cables requires them to be manufactured under the tightest manufacturing controls and are recommended for most applications. Note that low temperature cables (−40° to 85°C) and high temperature cables (−55 to 200°C) are listed. High temperature cables may cost five times as much as the equivalent low temperature cable. Note that each cable has a maximum frequency range over which it can be used. Also note that the center conductors may be solid or stranded. Stranded conductors are recommended when the cables are frequently flexed. In addition, single or double shields are available. Double shields give approximately 30 dB more isolation than single shields.

*Table II* lists a series of 50 ohm cables which are not recommended for use over 400 MHz as there are no VSWR requirements for these cables. Where the electrical requirements are practically nonexistent, these cables may be used. They are less expensive than their swept counterparts and manufactured under less stringent controls.

*Table III* lists 75 ohm coaxial cables which are non-swept.

*Table IV* lists special application cables including other impedances, low noise cables and a triaxial cable with approximately 10 dB more isolation than double shielded cables.

### How to Select a Cable

Determine the characteristic impedance of the equipment being interconnected. In addition, determine whether there is a VSWR requirement and the applicable frequency range. MIL-C-17 includes a VSWR requirement for 50 ohm cables only, with typical values shown in Table I. The values shown are for at least 3 dB of cable. The actual value encountered will depend on the actual length of cable used. Non-swept 50 ohm cables are listed in Table II, non-swept 75 ohm cables are listed in Table III and special application cables in Table IV.

It will be noted in the tables that the operating temperature range of the cables is either −40°C to 85°C or −55°C to 200°C. The cable which best matches the ambient temperatures of use should be selected.

The larger the cable, the lower will be the attenuation and the greater the power handling capability. The cables rated to 200°C operating temperature will exhibit

| Part Number M17/xx | O.D. (in.) | Operating Temperature Range (°C) | Jacket | Max Frequency (GHz) | Center Conductor | Shields | Attenuation Max dB/100 ft. .4 | 1 GHz | 2 | Power Max. Watts .4 | 1 GHz | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 94 - RG179 | .100 ± .005 | -55 to +200 | FEP | 3 | Stranded | 1:SC | 21 | -- | -- | 420 | 260 | 180 |
| 110 - RG302 | .202 ± .005 | -55 to +200 | FEP | 3 | Solid | 1:SC | 8.0 | -- | -- | 1700 | 800 | 470 |
| 29 - RG59 | .242 ± .004 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 9.0 | 16 | -- | 130 | 74 | -- |
| 2 - RG6 | .332 ± .004 | -40 to + 85 | PVC | 3 | Solid | 1:BC/1:SC | 6.5 | -- | -- | 210 | 110 | 66 |
| 6 - RG11 | .405 ± .007 | -40 to + 85 | PVC | 1 | Stranded | 1:BC | 5.2 | 9.4 | -- | 285 | 150 | -- |
| 62 - RG144 | .410 ± .010 | -55 to +200 | FG | 3 | Stranded | 1:SC | 4.5 | -- | -- | 2200 | 1100 | 620 |
| 77 - RG216 | .425 ± .007 | -40 to + 85 | PVC | 3 | Stranded | 2:BC | 6.5 | -- | -- | 260 | 145 | 92 |
| 24 - RG34 | .630 ± .010 | -40 to + 85 | PVC | 1 | Stranded | 1:BC | 3.8 | -- | -- | 69 | 38 | -- |
| 64 - RG164 | .870 ± .010 | -40 to + 85 | PVC | 1 | Stranded | 1:BC | 2.8 | 6.0 | -- | 1200 | 550 | -- |

**Table III: 75 ohms, coaxial, flexible, non-swept**

a substantially higher power handling capability than their lower temperature versions. The cost of a cable increases approximately by the square of the diameter and the 200°C cables are approximately five times more expensive than their 85°C versions. Therefore, the smallest and lowest temperature cable to meet the attenuation and power requirements should be selected. The maximum average ratings of the cables are listed in the tables. Unless the peak power exceeds 4 kilowatts, the designer need not be concerned with the peak voltages applied.

Cables smaller than .160 inches will exhibit cable pull strengths of 35 pounds or less, requiring care during installation and operation. Therefore, unless space or weight is a factor, the smaller size cables should be avoided where possible.

If the cable will be flexed frequently, a stranded center conductor should be used, rather than a solid center conductor which exhibits lower loss. If there is a concern about RFI, then the double shielded cables should be used, offering a 30 dB improvement.

The largest portion of the coaxial cables sold today are standard cables purchased to MIL-C-17. However, there are a number of applications where additional characteristics are required, such as low attenuation, plenum, phase compensated, risetime compensated, radiating, EMP shielded, broadband video, waterproof, pressure tight, high strength, LAN and extra flexible. In such applications, cables are normally manufactured to customer specifications and can be delivered in 8 to 16 weeks depending on material availability. Many cable manufacturers offer application engineering assistance.

## Cable vs. Cable Assemblies

Cable assemblies with connectors installed are procured to a customer's specification normally when the electrical requirements are tight and the cable and connectors are exposed to mechanical and environmental extremes. It is difficult to establish discrete guidelines; however, the designer may wish to consider specifying a cable assembly when: the VSWR from .05 to 2 GHz must be less than 1.4; when phase tracking is required; or when the assembly is subjected to severe loads, vibration, corrosive liquids, moisture and temperature cycling. Many coaxial cables used in aircraft, missiles, RPVs and transportable ground equipment are purchased as a cable assembly from manufacturers who design special cable and connectors to meet rigid test requirements.

## Additional Information

A complete listing of all current cables listed in MIL-C-17, including pulse cables, balanced lines and semi-rigid cables, can be obtained by writing to Manager, Cable Sales, Times Fiber Communications, Inc., P.O. Box 384, Wallingford, CT 06492. Tel: (203) 265-8700.

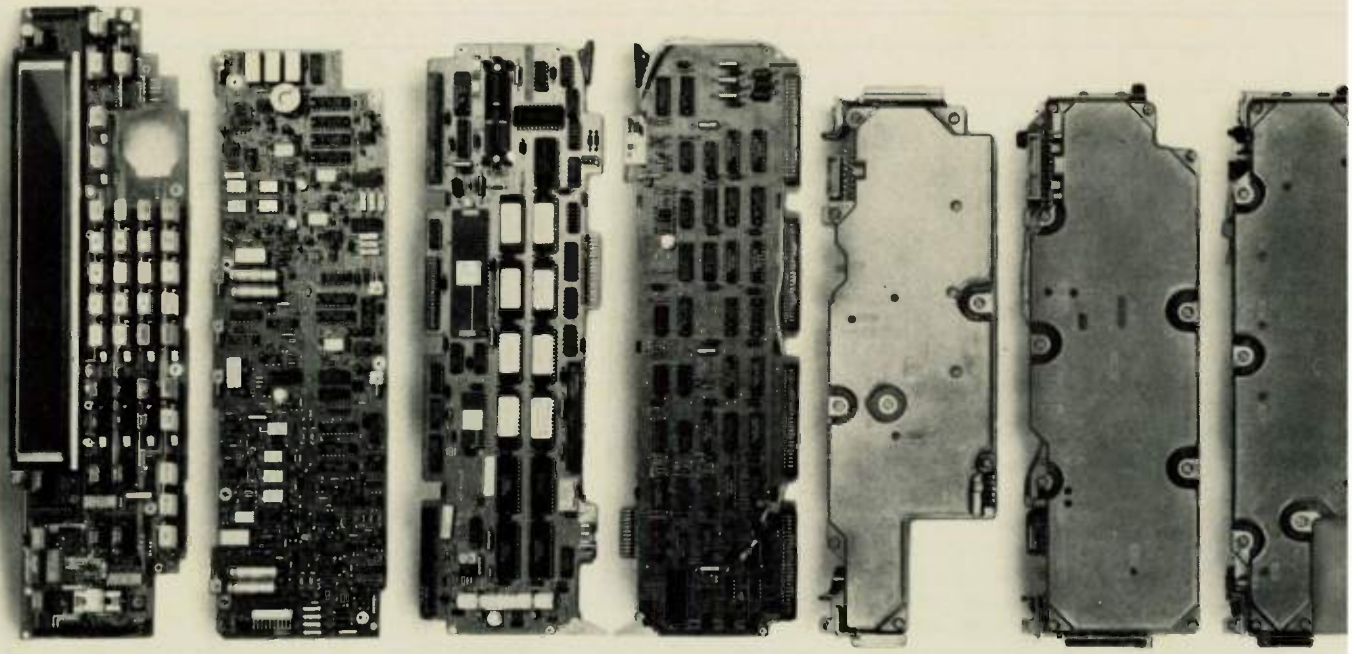
Copies of MIL-C-17, Supplement I, listing all available cables, and the individual Specification Sheets are available separately from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. rf

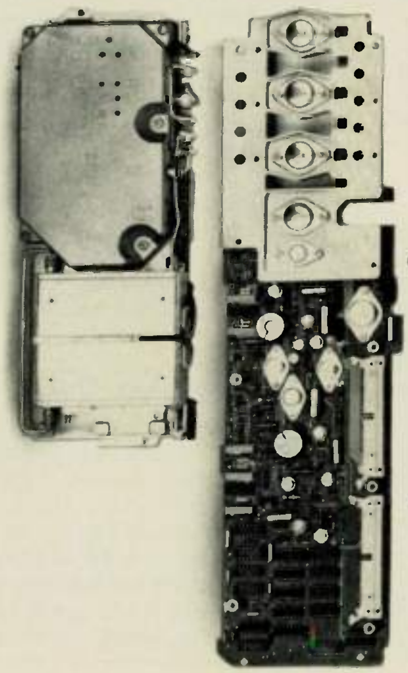

### About the Author

Allen Kushner has a Bachelors Degree in Mechanical Engineering from RPI and a Masters in Electrical Engineering from the University of Connecticut. He is Director of Microwave Engineering at Times Fiber Communications and has been involved in the design and manufacture of coaxial cables and assemblies since 1958.


| Part Number M17/xx | Application | Ohms | O.D. (in.) | Operating Temperature Range (°C) | Jacket | Max. Freq. (GHz) | Center Conductor | Shields | Attenuation Max dB/100 ft. .4 | 1 GHz | 2 | Power Max Watts .4 | 1 GHz | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 132 - RG404 | Low Noise | 50 ± 2 | .098 ± .004 | -55 to +200 | FEP | 1 | Stranded | 1:SC | 29 | -- | -- | -- | -- | -- |
| 131 - RG403 | Triaxial | 50 ± 2 | .116 ± .012 | -55 to +200 | FEP | 10 | Solid | 2:SC | 29 | 50 | 75 | 95 | 69 | 42 |
| 126 - RG391 | Low Noise | 72 ± 3 | .405 ± .010 | -40 to + 85 | PVC | 1 | Stranded | 1:TC | 15 | -- | -- | -- | -- | -- |
| 95 - RG180 | Low Cap | 95 ± 5 | .141 ± .004 | -55 to +200 | FEP | 3 | Solid | 1:SC | 17 | -- | -- | 370 | 230 | 160 |
| 97 - RG210 | Low Cap | 93 ± 5 | .242 ± .008 | -55 to +200 | FG | 3 | Solid | 1:SC | 8.0 | -- | -- | 1000 | 630 | 420 |
| 30 - RG62 | Low Cap | 93 ± 5 | .242 ± .007 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 8.0 | 13 | -- | 90 | 45 | -- |
| 90 - RG71 | Low Cap | 93 ± 5 | .245 ± .005 | -55 to + 80 | POLY | 1 | Solid | 2:TC | 8.0 | -- | -- | 135 | 77 | -- |
| 100 - RG133 | Low Cap | 95 ± 5 | .405 ± .010 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 5.7 | -- | -- | 63 | 31 | -- |
| 31 - RG63 | Low Cap | 125 ± 6 | .405 ± .010 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 5.5 | -- | -- | 330 | 200 | -- |
| 47 - RG114 | Low Cap | 185 ± 10 | .405 ± .010 | -40 to + 85 | PVC | 1 | Solid | 1:BC | 8.5 | -- | -- | 150 | 92 | -- |

**Table IV: Special applications, flexible, coaxial**





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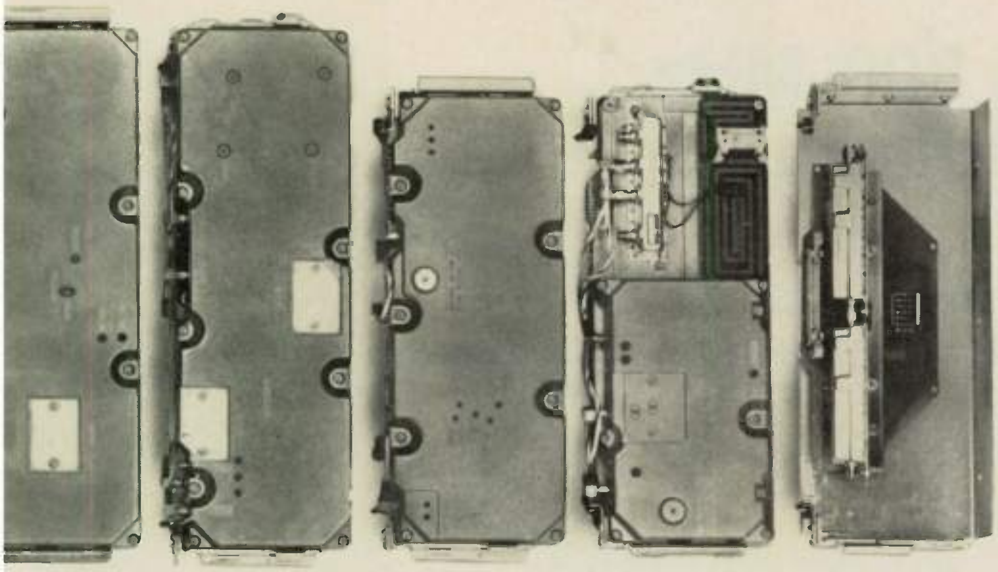

ıoment your measurements are less than erfect. (Not to worry. Actual warranty data ıtes a healthy 10,000 hours MTBF). Then, ush a few buttons; remove the faulty ıodule indicated on the display; and swap it with one from the kit. Recalibrate to original high-performance specs in seconds. Honest.

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# FCC Awards 800 MHz Reserve Spectrum

## *Managing "Natural Resources" of the Electromagnetic Spectrum is No Easy Task.*

*By George Dennis*
*Contributing Editor*

*In what one observer described as a "Herculean job" the FCC concluded years of speculation and months of indecision by doling out the bulk of reserve spectrum at 800 and 900 MHz. The FCC action — surprisingly decisive in light of extraordinary pressure from politicians, diplomats, and spectrum users — was a major victory for the opponents of a broad-based "flexible allocation" plan.*

There are no clear-cut winners and losers. No single group pleading for a chunk of the spectrum got precisely what it wanted; neither was any group completely denied access to the spectrum.

The commission combined several different proceedings and announced the following allocations:

- 10 MHz for private land mobile, including 5 MHz for trunked SMR, 2.5 MHz for business radio, and 2.5 MHz for industrial and land transportation users.
- 10 MHz for cellular, evenly split between wireline and non-wireline applicants.
- 6 MHz for future public safety use.
- 2 MHz for a "general purpose mobile radio service," a catchphrase implying an experimental flexible approach.
- 27 MHz in L-band (at 1500 and 1600 MHz) for mobile satellite service and aeronautical mobile satellite service users. users.
- 4 MHz to stay in reserve for future designation.

Most pleased with the results appeared to be representatives of private radio users.

"We are very happy," said NABER president Jay Kitchen. "It certainly has exceeded what we expected to get."

Kitchen voiced relief about the prevention of a large-scale flexible allocation plan. He praised the FCC for making hard choices, adding, "They came to understand that their job was to allocate, and they did it." In addition, he sang the praises of the Private Radio Bureau (PRB) for making land mobile's case to the commissioners.

PRB Chief Bob Foosaner conceded that the spectrum allocation battle had been a difficult one.

"There were real good potential uses for the spectrum. They players were substantial," he said. "It's the hardest thing I've dealt with in my 20 years."

Foosaner said that if all goes according to the plan, the new spectrum could be in use by land mobile sometime next year.

Industry and legal sources said they believe land mobile will greatly benefit from the new allocations.

"The additional channels are a welcome relief," said a representative of a national SMRS operator. However, the spokesman said that in major metropolitan areas, the relief may be short-lived. "It's probably not enough in those areas," he added. "They're going to scream that they still need more."

Two significant aspects of the allocation for SMRS are that it requires all users of the new spectrum to trunk their systems, and applicants will be awarded grants in blocks of 10 channels, rather than the current five.

Opinion from the cellular industry on its 10 MHz allocation was not as positive.

"I am disappointed that the commission did not allocate the full 12 MHz that we requested," said a downbeat Robert Maher, executive director of CTIA. Maher also said he was deeply concerned about the manner in which cellular's frequencies were allocated — in noncontiguous chunks of 1-2 MHz.

"This is not as though you're putting scoops of ice cream down," Maher said. "They've got us split in different sections." He said CTIA is commissioning engineering studies of the technical impact of the allocations.

Maher also said the new allocations, still subject to reconsideration petitions before the FCC, may not come in time for big city operators who may run out of current spectrum by the end of this year.

A Telocator spokeswoman was much more optimistic about the FCC's decision.

"We're really quite pleased with it," said Grace Smith, director of Telocator's cellular division. "We look at it in terms of the commission supporting our demonstration of need."

Both Smith and Maher voiced concern over the usefulness to cellular of the 2 MHz "general purpose" service, which the FCC placed at 901-902 MHz, and 940-941 MHz. Both said their associations will be examining that spectrum to see if it is technically feasible for use by cellular licensees.

Gaining least by this round of allocations was a number of mobile satellite applicants who had premised their applications on use of spectrum at 800 MHz, rather than L-band. The final FCC decision was delayed in part by pressure from the Canadians to allocate the lower frequencies for MSS, where Canada has designated its proposed mobile satellite service. The FCC handled the heat by saying that an MSS service that could be compatible with the Canadians was a frontrunner for future allocation of the 4 MHz that is presently being held in reserve.

Said one observer, "I think they did a good job in finessing it." rf

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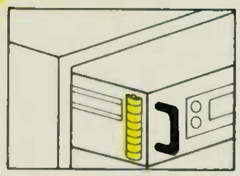
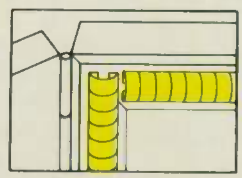
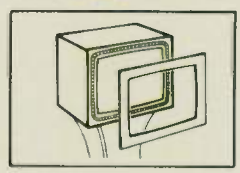
— as reported by Research Institute of America







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# RF EXPO EAST TECHNICAL SESSIONS

## Monday, Nov. 10, 1986 — 9:00 a.m. to 12:00 noon

**Session A-1: RF Analog ICs**
**Chair: B. Hoffman, Harris Microwave Semiconductor**

**9:00 Monolithic RF Amplifiers for Hybrid Applications**
**— J. Schappacher, Harris Microwave Semiconductor**
Describes two broadband GaAs ICs for flexible receiver/transmitter and signal processing applications. The amplifier chips provide general purpose gain from 500 MHz to 5 GHz. One is a fully integrated unit requiring no external circuitry other than bond wires. The other is identical except that bias supply decoupling capacitors are not on the chip.

**10:00 Broadband GaAs Monolithic Amplifiers and Their Applications**
**— T. Cummings, California Eastern Labs**
A discussion of the application of three new low cost broadband MMICs designed for medium power, low noise, and gain block use. Each is a cascadable, multi-octave, 50 ohm device, with typical bandwidths from 50 MHz to 3 GHz.

**11:00 Logarithmic Amplifiers**
**— D. Kleven and T. Munson, Plessey Semiconductor**
A radar with a maximum range of 32 miles can normally be expected to resolve the same target at one mile. This 32:1 range variation gives a 96 dB signal variation, and linear amplifiers with such dynamic range are not practical now. Logarithmic amplifiers compress the dynamic range, giving an output voltage proportional to the logarithm of the input. This paper describes when and why log amps are used.

**Session B-1: Power Amplifiers I**
**Chair: E. Niemec, Merrimac Industries**

**9:00 A Solid State HF Transmitter for Over-The-Horizon (OTH) Radar**
**— F. Agi, M/A-Com MPD and D. J. Hoft, M/A-Com, Inc.**
Modern OTH systems typically use transmitters with 200 kW (CW) or more power delivered to an array of 10-20 antenna radiators. This paper describes a solid state 20 kW CW amplifier for such an application.

**10:00 Development of a C-Band Power Module for the Morelos Mexican Satellite System**
**— A. Velazquez and A. Serrano, C.I.C.E.S.E. Research Center**
Design and characterization of 1, 3, and 5 watt power modules intended for use as transmission elements in RF sections of earth stations linked through the Morelos Mexican Satellite System.

**11:00 An HF Dynamic Range Amplifier Using Feedforward Techniques**
**— J. Yamas, Locus**
Describes how feedforward was successfully applied to a three decade bandwidth amplifier (100 kHz to 100 MHz) to achieve a second-order output intercept point greater than +110 dBm, a third-order output intercept point greater than +55 dBm, and a noise figure less than 7 dB.

**Session C-1: Oscillators I**
**Chair: D. Krautheimer, Narda Microwave**

**9:00 Choosing the Right Crystal and Oscillator for the Application**
**— B. Rose, Q-Tech**
Crystal oscillator requirements such as frequency stability, aging, noise and sensitivity to environment will determine the best choice of crystal characteristics and oscillator configuration. The crystal overtone mode will depend on the output frequency as well as noise, aging, pullability, etc. Design guidelines, charts and examples are presented.

**10:00 Construction Tips and Environment for Dielectric Resonator Circuits**
**— L. Carpenter, Pennsylvania State University**
The resonance cavity is discussed in terms of metallic enclosures and the meaning of a perfect magnetic boundary is described. The effect of a dielectric resonator on microstrip is described in terms of reflection coefficients and coupling coefficient. Describes a program disk for the IBM-PC to help the designer choose the appropriate dielectric resonator for an application.

**11:00 A Tactical Miniaturized Crystal Oscillator**
**— B. E. Lowell and T. S. Payne, Piezo Technology**
Describes a tactical miniaturized crystal oscillator (TMXO) with a power consumption of 21 mA at −55C and an overall size of 17 $cm^3$. The paper describes the most important aspects of design of the TMXO and related aspects of the ITMXO, an improved version under development.

**Session D-1: SAW Devices**
**Chair: C. Erikson, Andersen Laboratories**

**9:00 A High Performance SAW Filterbank Achieves 80 dB Rejection**
**— C. Lanzl, W. Ossman and R. Bernardo, Andersen Laboratories**
Performance specifications for a selectable bandwidth SAW filterbank used in a modern adaptive receiver system are presented, illustrating the precise bandwidth control and excellent rejection possible with SAW filters. Use of this filterbank along with a synthesized local oscillator will be discussed.

**10:00 Design Considerations for SAWR Oscillators**
**— K. Feldmann, Watkins-Johnson**
Discusses specifications for a SAWR device and the design parameters for incorporating the SAWR into an oscillator circuit. Two oscillator designs are described, with their advantages and disadvantages and the problems encountered in circuit design.

**11:00 A Linear FM Modulator**
**— J. Isell, Texas Instruments**
This system will generate a linear FM modulated pulse signal. It uses a 100 MHz clock and 200 MHz CW input to generate a 20 nS pulse of 200 MHz energy. The pulse is used to excite a SAW expander. The resulting signal is a continuous linear sweep of frequencies of 75 MHz bandwidth centered about 200 MHz.

## Monday, Nov. 10, 1986 — 1:30 p.m. to 4:30 p.m.

**Session E-2: RF Design Awards Contest Entries**
**Chair: G. Breed, RF Design Magazine**

**1:30 A Crystal Controlled Frequency and Amplitude Calibrator**
**— D. Baker, Tektronix**
The winner of the first RF Design contest describes and demonstrates his crystal controlled frequency and amplitude calibrator.

**2:30 A Thermally-Tuned VCO**
**— A. Helfrick, Dowty RFL Industries**
Describes an experimental oscillator using heated high temperature coefficient capacitors as the variable tuning elements, replacing varactors in pulsed or power oscillator applications.

**3:30 A Complex Impedance Meter**
**— C. Lodstrom, Dow Key Microwave**
A transmission line with four detectors placed at 1/8 wavelength intervals makes a useful narrowband impedance meter with an oscilloscope display approximating a Smith Chart representation.

**Session F-2: Computer Aided Design I**
**Chair: Al Pergande, Martin-Marietta Aerospace**

**1:30 Non-Linearity Effects in RF Circuits**
**— D. Leiss and L. Olsen, Besser Associates**
Illustrates how to derive a model and evaluate key non-linearities for an amplifier and a VCO using the commercially available non-linear CAD program, mwSPICE.

**2:30 Microwave Device Characterization Utilizing CAT Test Equipment and Computer-Aided Engineering Software Tools**
**— S. Hamilton, EEsof**
Describes RF and microwave device characterization using EEsof software tools and the HP 8753 network analyzer.

**3:30 Bipolar Parameter Extraction for Modeling Class C Amplifier Response**
**— P. Sanders and A. Wood, Motorola Semiconductor**
Linear models for RF circuit response based on intrinsic transistor parameters have only recently been used. Extraction of these parameters from I-V, C-V, and AC measurements is something of an art. A 12.5 volt, 870 MHz, 5 watt amplifier is modeled and parameter extraction optimization is discussed.

**Session G-2: RF Power Devices**
**Chair: S. Johnson, Motorola Semiconductor**

**1:30 Practical Wideband RF Power Transformers, Combiners and Splitters**
**— R. Blocksome, Rockwell International - Collins**
Describes the design and fabrication of transformers used in modern solid state HF power amplifiers, emphasizing bandwidths greater than four octaves at power levels over 100 watts and insertion losses of a few tenths of a dB.

**2:30 HF/VHF/UHF Power Static Induction Transistor Performance**
**— R. Regan, S. Butler, E. Bulat, A. Varallo and M. Abdollahian, GTE Labs**
(Abstract not available.)

**3:30 Efficiency of Envelope Tracking RF Power Amplifier Systems**
**— F. Raab, Green Mountain Radio Research**
Describes a technique for increasing the efficiency of a linear power amplifier by varying its supply voltage to track the envelope of the RF signal. Advantages of envelope tracking include simple circuitry and usability at any RF frequency, RF bandwidth, and signal bandwidth.

**Session H-2: Filter Design I**
**Chair: T. Leonard, M/A-Com Advanced Semiconductor Operations**

**1:30 High Power Filter Design Considerations**
**— D. Wainwright, Cir-Q-Tel**
Covers information designers often fail to furnish when specifying filters, such as harmonic content of transmitter power output relative to fundamental power, compatibility of specified connectors, available surface area for heat conduction and realistic VSWR.

**2:30 A Practical Approach to the Design of Voltage Tunable Lowpass and Bandpass Filters**
**— B. Long, Techtrol Cyclonetics**
Presents a method of designing voltage tunable lowpass and constant percentage bandwidth bandpass filters. Design example of a lowpass filter and a bandpass filter, both tunable over an octave range, is given.

**3:30 Microware — An Interactive Microwave Filter Design Program**
**— Michael K. Ferrand, Microlab/FXR**
The techniques of top down design of a software package are given. The emphasis on user interface results in an almost intuitive work environment. Two designs are given and compared with actual prototypes.

## Tuesday, Nov. 11, 1986 — 9:00 a.m. to 12:00 noon

**Session I-3: Frequency Synthesizers**
**Chair: B. Rose, Q-Tech**

**9:00 The Phase Lock Loop That Works — Almost**
**— M. Black, Texas Instruments**
Many phase-lock loops never fully meet the expectations of their designers. This paper examines some of the basic problems that keep a PLL from working correctly.

**10:00 Single Chip CMOS VHF Synthesized ICs**
**— P. Chadwick, Plessey Semiconductors**
The advent of new CMOS procedures has led to a new generation of frequency synthesizers in which the requirement for an extra device to act as a prescalar has disappeared. Very low power CMOS single chip VHF synthesizers are now available.

**11:00 Design and Analysis of 4th and 5th Order Indirect Synthesizer Loops**
**— J. W. Maben, Sanders Associates**
Implementations of indirect synthesizer designs using second or third order feedback loops contain additional filters that tend to invalidate the two or three pole assumptions in the mathematical model. The design technique described here includes five or more poles in the analysis.

**Session J-3: Mixer Design**
**Chair: D. Roth, Amplifier Research**

**9:00 A Commutation Double-Balanced Mixer**
**— E. Oxner, Siliconix**
Examines a new FET mixer with commutation that achieves high dynamic range without increased local oscillator drive. Third order intercept points upward of +39 dB input have been achieved with only +17 dBm of LO drive.

**10:00 The Schottky Diode Mixer**
**— J. Lepoff, Hewlett-Packard Microwave Semiconductor**
Discusses Schottky diode parameters — capacitance, resistance, and barrier voltage, and circuit parameters — DC bias and load resistance, as they relate to mixer efficiency.

**11:00 A New Double-Balanced Mixer of Very High Dynamic Range Improves System Performance**
**— A. Jaffer, Bertronics**
Describes a new configuration for a double balance mixer that reduces spurious respnonse and allows operation with fewer and lower IF frequencies.

**Session K-3: Digital Interfacing**
**Chair: H. Pfizenmayer, Motorola Semiconductor**

**9:00 Microprocessor Control Considerations for Modern RF Signal Generators**
**— T. Dudziak, Wavetek, Indiana**
Many features of modern microprocessors can be used to enhance the performance of RF signal generators. This paper discusses the overall microprocessor control architecture and other aspects of a new Wavetek signal generator.

**10:00 RF-Digital Interfacing — The Story of a Marriage**
**— R. W. Sproul, Lorch Electronics**
A description of RF-digital interfaces and the problems RF designers encounter when they try to use them.

**11:00 RF Design Evaluation Made Easier Through Automatic Control**
**— S. Mussman, Wavetek, Indiana**
The manufacturing environment offers an automated testing solution that can be applied to the engineering development laboratory, the IEEE 488 general purpose interface bus. This paper describes the capabilities of the GPIB and some criteria for selecting a GPIB instrument.

**Session L-3: Medical Applications of RF**
**Chair: T. Wilsey, Varian**

**9:00 A Low-Noise Preamplifier for NMR (10 - 200 MHz)**
**— O. Mueller, General Electric**
(Abstract not available)

**10:00 RF Design for a 0.4 Tesla Static Transverse Field MRI System**
**— G. Kirk, Resonex**
(Abstract not available)

**11:00 (No paper)**

## Tuesday, Nov. 11, 1986 — 1:30 p.m. to 4:30 p.m.

**Session M-4: Transistor Designs and Applications**
**Chair: H. Hench, Amperex**

**1:30 RF and Microwave Transistor Bias Considerations**
**— G. Franklin, Hewlett-Packard Microwave Semiconductor**
Advantages and disadvantages of some common bias circuits. Resistive, diode, and active bias circuits are compared for effectiveness in stabilizing the transistor bias point against DC parameter changes.

**2:30 Design Considerations for the Development of Internally Matched FETs**
**— M. Kumar and B. S. Hewitt, Microwave Semiconductor Corp.**
Describes design considerations for internally matched FETs with power levels of 10 watt up to X-band and 1 to 2 kW at Ku- and K-band, using single and multichip designs.

**3:30 State of the Art of Silicon High Power RF FETs**
**— R. Moss, Polycore RF Devices**
Describes the development of the FET and the characteristics of the Polyfet, marketed by Polycore.

**Session N-4: Oscillators II**
**Chair: S. Butler, GTE Laboratories**

**1:30 Maximizing Crystal Oscillator Frequency Stability**
**— B. Rose, Q-Tech**
The important parameter determining the frequency stability of a crystal and circuit combination is the slope and stability of phase versus frequency in the closed loop. The paper explores this topic using analysis, computer simulation, and breadboard results.

**2:30 Low Noise Oscillator Design**
**— A. Upham, Hewlett-Packard**
Explores the concept of phase noise mechanisms in oscillators and the design of low noise devices. The paper describes what determines spectral purity in oscillators.

**3:30 (No paper)**

**Session O-4: High and Low Power RF Switching**
**Chair: D. Wainwright, Cir-Q-Tel**

**1:30 High Reliability Electromechanical Switching**
**— G. Hoffman and H. C. Bell, Wavecom**
Recent developments and industry trends in electromechanical switching are presented. Maximum frequency of operation can be expected to reach 40 GHz soon, with connector performance being a critical factor. Future switch designs and capabilities will be discussed.

**2:30 How to Specify High Performance PIN Diode Switches**
**— R. Sicotte, American Microwave Corporation**
Discusses parameters needed to specify PIN diode switches. The six key parameters are type (SPST, SPDT, SP3T, etc.), frequency band, insertion loss, isolation, switching speed, and power handling. Five other specifications that may be necessary are driver type (TTL, ECL, CMOS, and driver delay), phase tracking, off-arm terminations, intercept point, and video transients.

**3:30 Theory and Application of PIN Diode Switching at Low and High RF Power**
**— J. F. White, M/A-Com**
Discusses the effect of holes, electrons, and mobility on microwave resistance. Limits of insertion loss and high power switching will be related to heat sinking, voltage breakdown, and cutoff frequency.

**Session P-4: Computer Aided Design II**
**Chair: A. Pergande, Martin-Marietta Aerospace**

**1:30 The Poor Man's Engineering Workstation, or Cheap CAD**
**— R. Kolbly, Lockheed-California**
Shows how to achieve sophisticated interactive RF and microwave design aid from a personal computer using software available in listing form from trade and professional journals and other public domain sources.

**2:30 Developing Non-Linear Oscillator Models Using Linear Design Tools**
**— U. L. Rohde, Communications Consulting Corporation**
As a transistor built around a Class C oscillator is driven into saturation the computation of efficiency and harmonics cannot be handled by linear programs. This paper presents an approach using a linear CAD tool with some computation of non-linearities.

**3:30 DESIGN: A Program for the Automated Synthesis of Broadband Matching Networks Between Complex Terminations**
**— S. E. Sussman-Fort, State University of New York, Stony Brook**
DESIGN performs an automated synthesis of precision, broadband, gain-sloped, lumped-element or distributed-parameter matching networks between complex sources and complex loads. The paper presents a review of earlier work on the real-frequency method and a discussion of recent modifications.

## Wednesday, Nov. 12, 1986 — 9:00 a.m. to 12:00 noon

**Session Q-5: Local Area Transmission Techniques**
**Chair: A. Victor, Motorola Portable Products**

**9:00 OOK, FSK, and PSK Modems Using an AM-FM Receiver IC**
**— J. GrosJean, Woodstock Engineering**
The Sprague ULN2241A and its derivatives are unique AM-FM receiver ICs in that the AM and FM IF section use the same stages. The IC can be used for a data receiver up to 100 MHz for OOK (AM) operation, FSK reception, or PSK reception with few external parts.

**10:00 A Thick Film Hybrid Transmitter for Cellular Radio**
**— P. Mikkola, Mobira Oy**
The design and performance of a thick film hybrid transmitter. Circuits were printed on alumina substrate using gold and resistor pastes. Chip transistors were bonded with conductive epoxy and gold wires directly to the substrate. The amplifier achieves 22 dB gain and 1.5 watt output power at 900 MHz.

**11:00 A Research Report on Coaxial Cable Leakage**
**— B. Shreve, Delta Electronics**
Coaxial cable exhibits leakage of electromagnetic energy from its shield at greater than negligible levels. This paper discusses research on such leakage at frequencies between 2 and 30 MHz. Several types of cable, the experimental and analytical methods, and numerical results are discussed.

**Session R-5: Receiver Performance**
**Chair: M. Levy, Racal-Dana Instruments**

**9:00 Phase Noise, Intermodulation, and Dynamic Range**
**— P. Chadwick, Plessey Semiconductors**
A discussion of these basic aspects of receiver design.

**10:00 A Low Noise Fiber Optics Receiver/Amplifier in VHF Range**
**— L. Burgyan, Signetics**
Describes a new monolithic, trans-resistance RF amplifier for fiber-optic receiver applications. Theory of operation, device characteristics, and application circuits, including non-fiber-optic applications, will be discussed.

**11:00 EW Applications of High Resolution Compressive Receivers**
**— M. M. Apter, Andersen Laboratories**
Describes such analog technologies as acousto-optics, charge-coupled devices, folded tape meander, linear and non-linear FM, IMCONs, and linear and non-linear FM SAW devices.

**Session S-5: Filter Design II**
**Chair: R. Wainwright, Cir-Q-Tel**

**9:00 Harmonic Filtering of a 500 MHz SAW Resonator Oscillator**
**— P. Snow, Tektronix**
Describes the design procedure for a 500 MHz SAW resonator oscillator using quarter wavelength distributed transmission lines in a simple, cost-effective shunt configuration.

**10:00 Bandpass and Band Reject Filters: 100 - 1000 MHz, the Search for Q**
**— R. V. Snyder, R.S. Microwave**
The frequency range between 100 and 1000 MHz poses special problems for the designer, requiring a compromise between size and Q. Much can be accomplished by combining lumped and distributed elements. This paper discusses lumped minimum phase bandpass filters with essentially symmetrical skirts, most of which require 'extra' low pass or high pass elements to increase the slope of one side of the stop band or must be overdesigned with the shortcomings of the less steep skirt in mind.

**11:00 Ultra Stable Tunable Bandpass Filters for Troposcatter and Satellite Applications**
**— K. Coleman, Coleman Microwave**
Describes tunable bandpass filters having digital readout accurate to +/− 0.02% of $f_0$ and temperature stability of +/− 10 ppm/°C for use in troposcatter and satellite bands.

**Session T-5: Solid State Control Devices**
**Chair: R. Sicotte, American Microwave Corporation**

**9:00 The PIN Diode — Uses and Limitations**
**— J. Lepoff, Hewlett-Packard Microwave Semiconductor**
Discusses modulation frequency limitations,, distortion, effect of voltage on capacitance, package limitations, frequency limitations due to diode capacitance and diode models.

**10:00 Everything You Wanted to Know About Tuning Diodes**
**— J. Howe, Motorola**
Describes a simplified theory of operation of tuning diodes, processing, and package manufacturing methods. Discussion of a manufacturer's data sheet will show how to use available curves.

**11:00 Direct Single-Sideband Modulation of Transmitter Output Switcher Stages**
**— F. G. Tinta, General Instrument Corporation**
Describes a technique for obtaining SSB pulse duration modulation without using intermediate DSB signals. Instantaneous voltage comparison of modulating and carrier waveforms generates timing signals which are applied to a system of master flip-flops driving switching output stages for power RF transmitters.

# Low Cost Monolithic GaAs ICs Boost System Performance

## *500 MHz - 5 GHz Chip-Level Amplifiers Are Universal "Building Blocks."*

*By Jerry Schappacher*
*Harris Microwave Semiconductor, Inc.*

*Monolithic Gallium Arsenide ICs for RF systems have held promise for many years, yet there has been only a modest list of products offering basic functions with relatively high costs. Using these basic components implied even higher costs due to the need for supporting external components and circuitry. This has been particularly true of early amplifier transistor products that required extensive bias circuitry or decoupling components. The real promise of integrated circuitry lies in reducing the number of components to minimize assembly costs and performance variations while improving reliability and overall system performance.*

GaAs technology has now reached the level of maturity where more complex functions can be integrated onto single analog or digital ICs. Foundry, design and test services are offered in abundance, but standard product offerings, addressing high volume "generic" applications, have been slow to emerge.

Now, Harris Microwave Semiconductor has introduced the first two products in a line of GaAs RF ICs for receiver/transmitter and signal processing applications. These are broadband amplifier chips covering 500 MHz to 5.0 GHz providing general purpose gain. The HMR-10503 is a fully integrated unit requiring no external circuitry other than bond wires to connect the RF input, RF output, +Vdd, and DC/Signal ground. The companion chip HMR-10502 is identical except that bias supply decoupling capacitors are not included on-chip. These parts offer the designer/integrator of RF systems a new option in system architecture and implementation at UHF frequencies and above. Tough cost-performance criteria can be met more easily through the use of complete IC gain blocks and the relaxed performance specifications for other system functions these amplifier ICs allow.

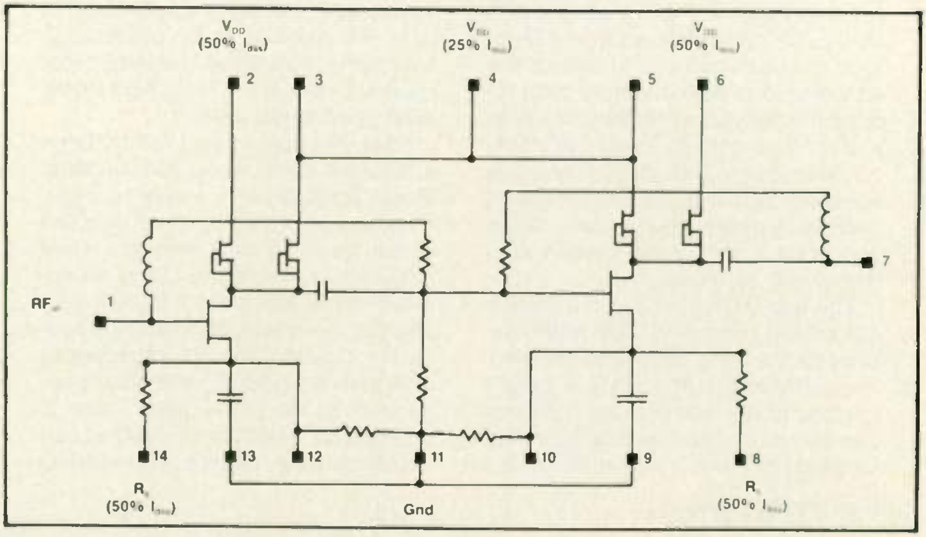



**Figure 1. HMR-10503 Schematic**

Fundamental in offering an effective GaAs IC is the basic quality of the fabrication processs. Harris Microwave Semiconductor uses the DIGI-1 process technology for both MMICs. Harris has been manufacturing GaAs ICs (digital) with this process for over three years. Process technology repeatability is the secret of the low cost and consistency achieved in these analog ICs, using one micron gate length, depletion mode technology with −2 volt pinchoff.

The circuitry is designed to exploit the

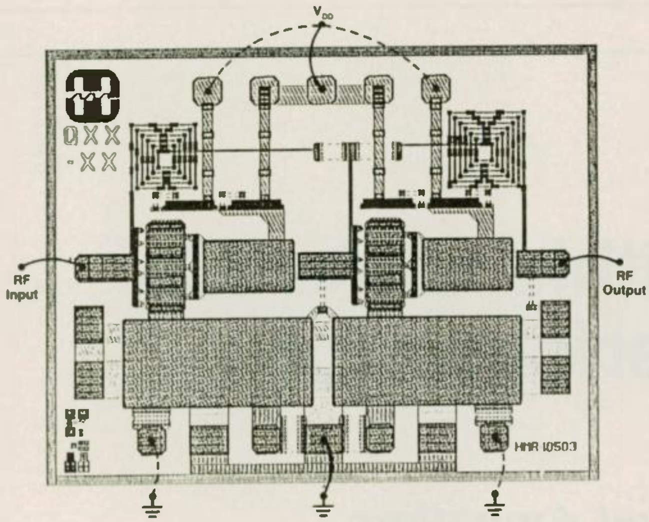



**Figure 2. Wire bond diagram for HMR-10503. Solid lines are 25% $I_{dss}$ connections ($V_{DD}$ = +8 V). Dashed lines are additional connections for 50% $I_{dss}$ ($V_{DD}$ = +10 V).**

performance characteristics of the process technology. The HMR-10503 schematic is shown in Figure 1. The heart of the IC is a 1 × 600 micron GaAs FET "cell." Two of these cells are isolated from each other by integral MIM capacitors. The source terminals of the RF transistors and self biasing, implanted resistors in series with the sources are decoupled by additional MIM capacitors of approximately 25 pF each. Drain bias on the active RF devices is provided by FETs operating as current sources. Each current source is shunted by an implanted resistor to minimize bias point sensitivity to process and temperature variations. Consistent, broadband RF performance is the result of series resistor-inductor shunt feedback to the RF transistor. The two stages have been designed as a system to minimize input/output VSWR, maximize gain, and maintain a controlled noise figure.

## Applications of Utility Gain Blocks

The diagram below describes an RF downconverter operating in the 500 MHz-5.0 GHz range. For this example, a double-conversion system is assumed, with a first IF of around 500 MHz. The system shows how distributed gain can be used to reduce the specifications (and therefore cost) required of subsystem elements such as mixer and filters. By using the HMR-10503 to restore gain after lossy circuit elements and to boost drive levels to less costly mixers, the dynamic range and noise figure of the system as a whole can be maintained.

The first HMR-10503 in the system follows the bandpass filter which defines the converter passband and eliminates the image frequency. A simple microstrip filter with perhaps 2 dB loss can be used. Another amplifier filter following the first mixer restores the system gain after the loss due to the mixer.

Another HMR-10503 is used after the bandpass filter and temperature-compensating variable attenuator. This device is used at its 50 percent $I_{dss}$ bias point to increase the third order intercept level at this fairly high signal level point in the system.

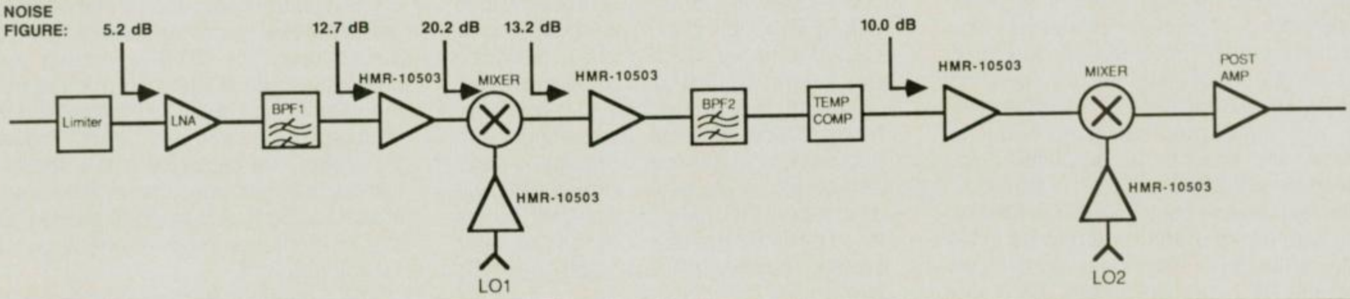
Note that both mixers are buffered at all three ports, where the amplifier blocks actually serve a dual purpose. First, as gain stages, they increase signal levels to overcome the mixer noise figure, boost the LO to an optimum level, and restore system gain after the mixer loss. Secondly, the consistent input and output impedances of the HMR-10503 provide proper termination to the mixer ports, which is required for best intermodulation performance. Both of these roles serve to reduce the performance requirements of the mixer itself, allowing a less costly device to be used.

The consistent impedance characteristics are an advantage at the other stages of the system as well. Filters and attenuators, as well as mixers, are all designed for operation at specific impedances. Predictable performance requires that stages prior to and following these devices be matched to that impedance.

With these high dynamic range, impedance matched amplifiers, each subsystem component can benefit from reduced specifications. Gain distribution throughout a system, using low cost system blocks, can yield significant cost savings in such complex and costly components as mixers and filters, while maintaining system noise figure and dynamic range.

STAGE SPECIFICATIONS

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GAIN | -0.5 | 18.0 | -2.0 | 12.0 | -7.0 | 12.0 | -5.0 | -6.0 | 13.0 | -7.0 | 12.0 | dB |
| N.F. | | 2.0 | - | 6.0 | - | 6.0 | - | - | 7.5 | - | 6.0 | dB |
| IP3 | | 17.0 | - | 17.0 | 17.0 | 20.0 | - | 40.0 | 22.5 | 17.0 | 27.0 | dBm |
| IP3 REFERENCED TO OUTPUT | | 39.0 | - | 29.0 | 29.0 | 27.0 | - | - | 27.5 | 22.0 | 27.0 | dBm |



Two bias point options are readily available to the systems designer. In addition to the standard 25 percent $I_{dss}$, either or both of the stages can be biased to 50 percent of the RF transistor $I_{dss}$ with additional wirebonds. Bonding diagrams for two of the four wiring options are shown in Figure 2.

## Wide Band Performance

Performance of a typical HMR-10502/HMR-10503 is shown in Figure 3. Operating frequency for the ICs is 500 MHz to 5.0 GHz with extended frequency operation possible with reduced performance. Power supply limits are from 6 volts to 15 volts, although typical applications call for +8.0 volts or +10.0 volts for $V_{dd}$.

A minimum of 10 dB gain is readily achieved at 8 volts and at the 25 percent $I_{dss}$ bias point, 12 dB is typical (configuration A). Gain flatness is ±.75 dB for the HMR-10502 over the complete 0.5 to 5.0 GHz frequency range with two 100 pF source decoupling capacitors, one on each source decoupling port. The HMR-10503 has the same ±.75 dB variation over a smaller 1.0 to 5.0 GHz bandwidth without optional source decoupling capacitors. Optional source decoupling capacitors of greater than 50 pF result in full band flatness for the HMR-10503. The VSWR of the input and output is always better than 2.0:1 and typically better than 1.7:1 across the specified frequency band when assembled using nominal lengths of 15 to 25 mils.

Noise figure for either unit at 25 percent $I_{dss}$ is typically 6 dB with a worst case of 7.0 dB. When biased at 10 volts and 50 percent $I_{dss}$ (configuration B), the noise figure is less than 10 dB, typically less than 8.0 dB. Figure 4 shows the typical noise figure at both bias conditions vs. frequency.

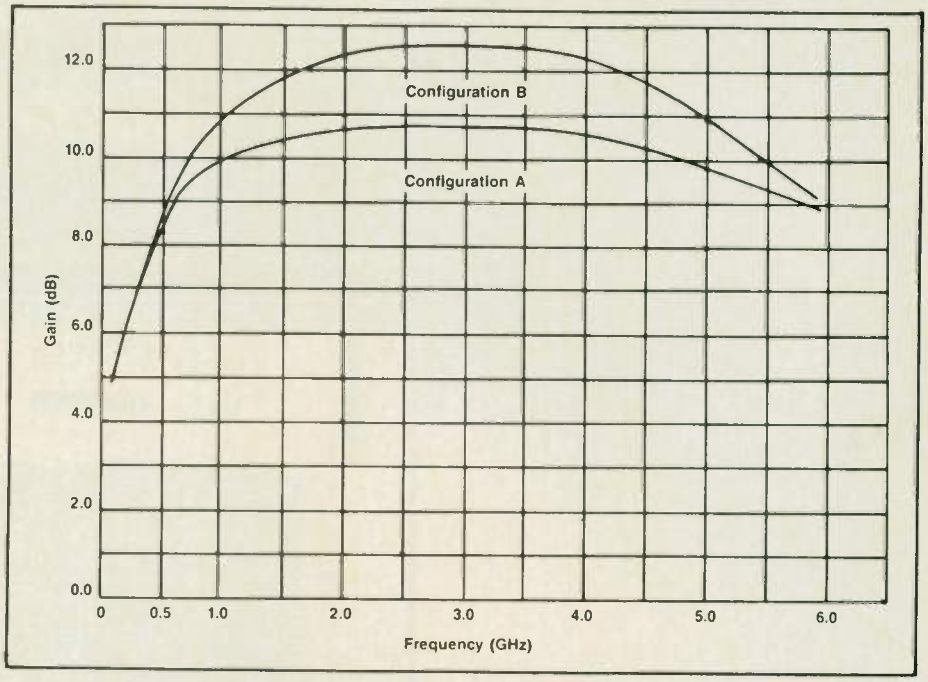



**Figure 3. Gain (S21) vs. frequency, configurations A and B. Bias for Conf. A: $D_{dd}$ = 8.0 V, $I_{dd}$ = 50 mA; Bias for Conf. B: $V_{dd}$ = 10.0 V, $I_{dd}$ = 100 mA.**

The third order intercept point (IP3) vs. frequency for both bias states is shown in Figure 5. The minimum of +18 dBm is at the high end of the frequency band at low bias. Typical third order intercept point at 50 percent bias is in excess of +20 dBm.

$I_{dss}$ variation is consistent unit to unit as well. Typical supply for the total amount is 50 mA plus or minus 10 mA at the low bias point. Supply voltage is user defined from 8 to 15 volts, depending on the specific power supply voltage availability, output power desired, and temperature range requirements. The gain, VSWR, and isolation are relatively independent of power supply voltage. Operation over wide temperature ranges results in a typical gain variation of 0.03 dB/°C and flatness is maintained across the temperature range.

The introduction of the HMR- series of RF IC products offers RF subsystem designers a unique opportunity for high performance at a lower cost. Key attributes offered by amplifier stages, distributed through a subsystem design, can now be inserted affordably into communication, EW and radar systems, supplying more function in a smaller package at lower cost. rf

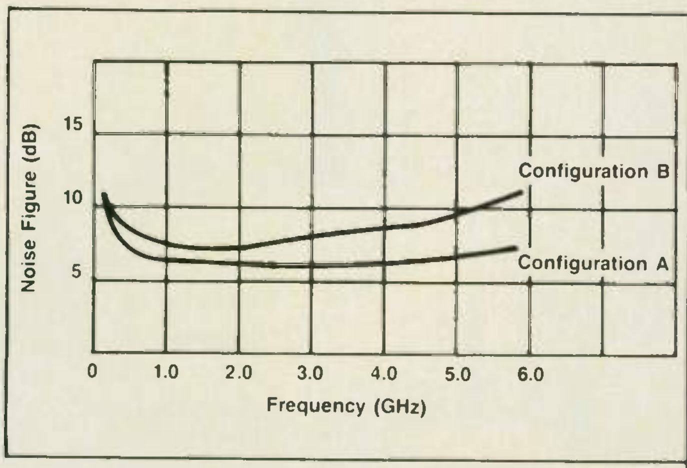



**Figure 4. Typical noise figure vs. frequency, configurations A and B.**

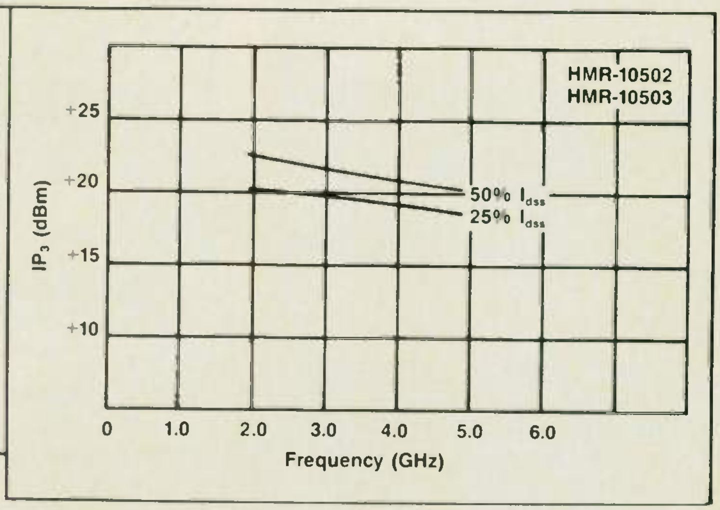
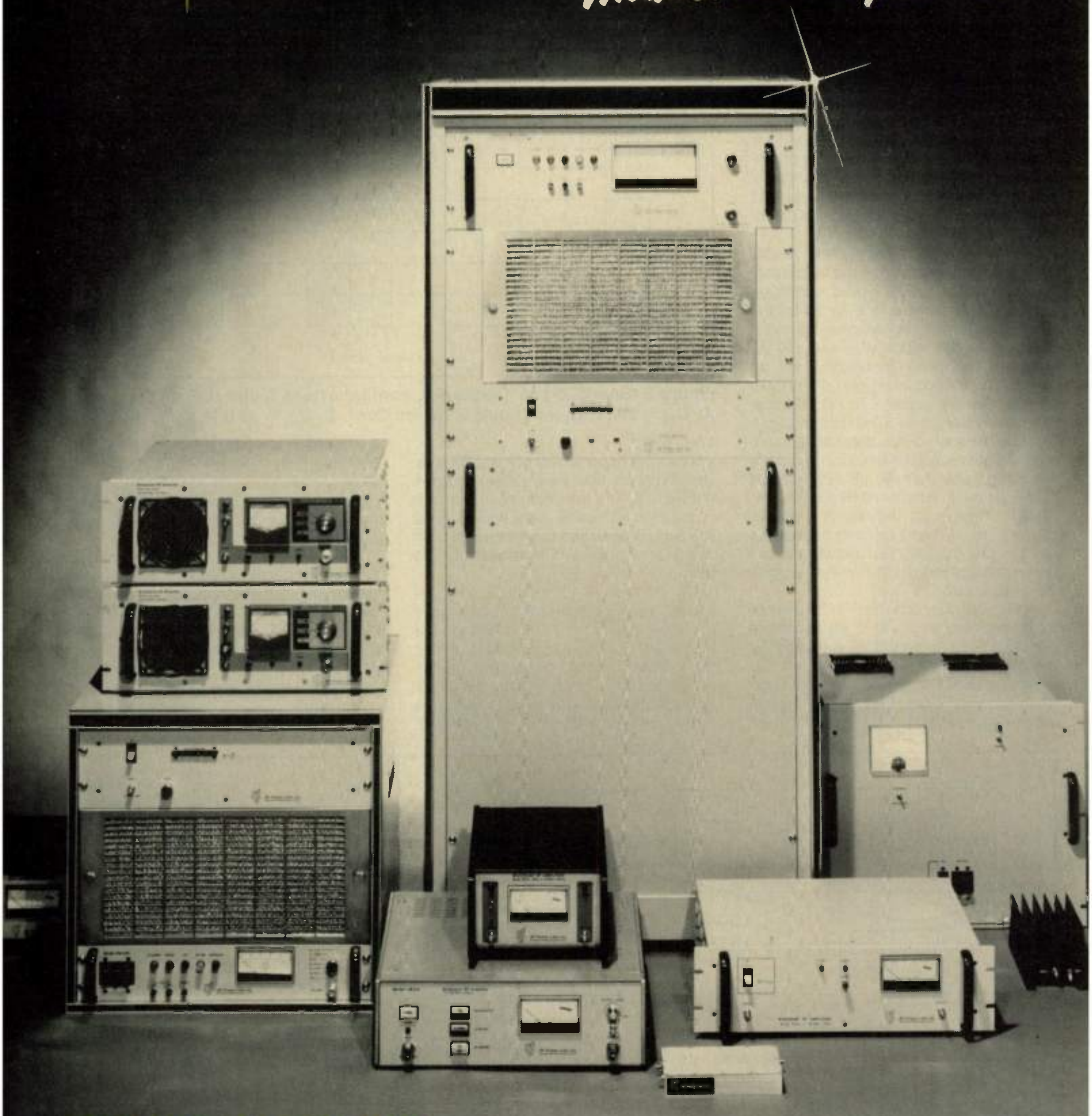



**Figure 5. Third order intercept point vs. frequency.**

# RF POWER LABS

*Wideband Amplifiers*



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# New MOSFETs Simplify High Power RF Amplifier Design

By H.O. Granberg
Motorola Semiconductor Products Inc.

*There are many applications for high power solid state RF amplifiers in the 1 to 120 MHz range. Past designs have consisted of a number of 200-300 watt modules combined to produce power outputs in the multikilowatt level. Power combiners and splitters are expensive and difficult to design for extremely wide bandwidths, and at low frequencies are bulky as well. It is always desirable to combine as few modules for a given power output as possible, although system cooling becomes more difficult with thermal energy concentrated in a smaller area. There is obviously a practical limit to the point where this philosophy is valid.*

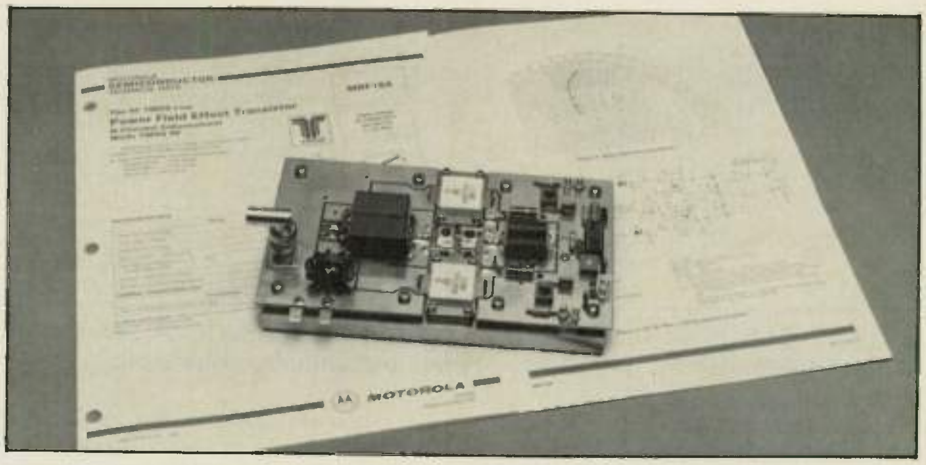



**Figure 1. One kilowatt 10-90 MHz amplifier. The two FETs, input and output boards are mounted to a copper plate, which is then attached to the main heat sink.**

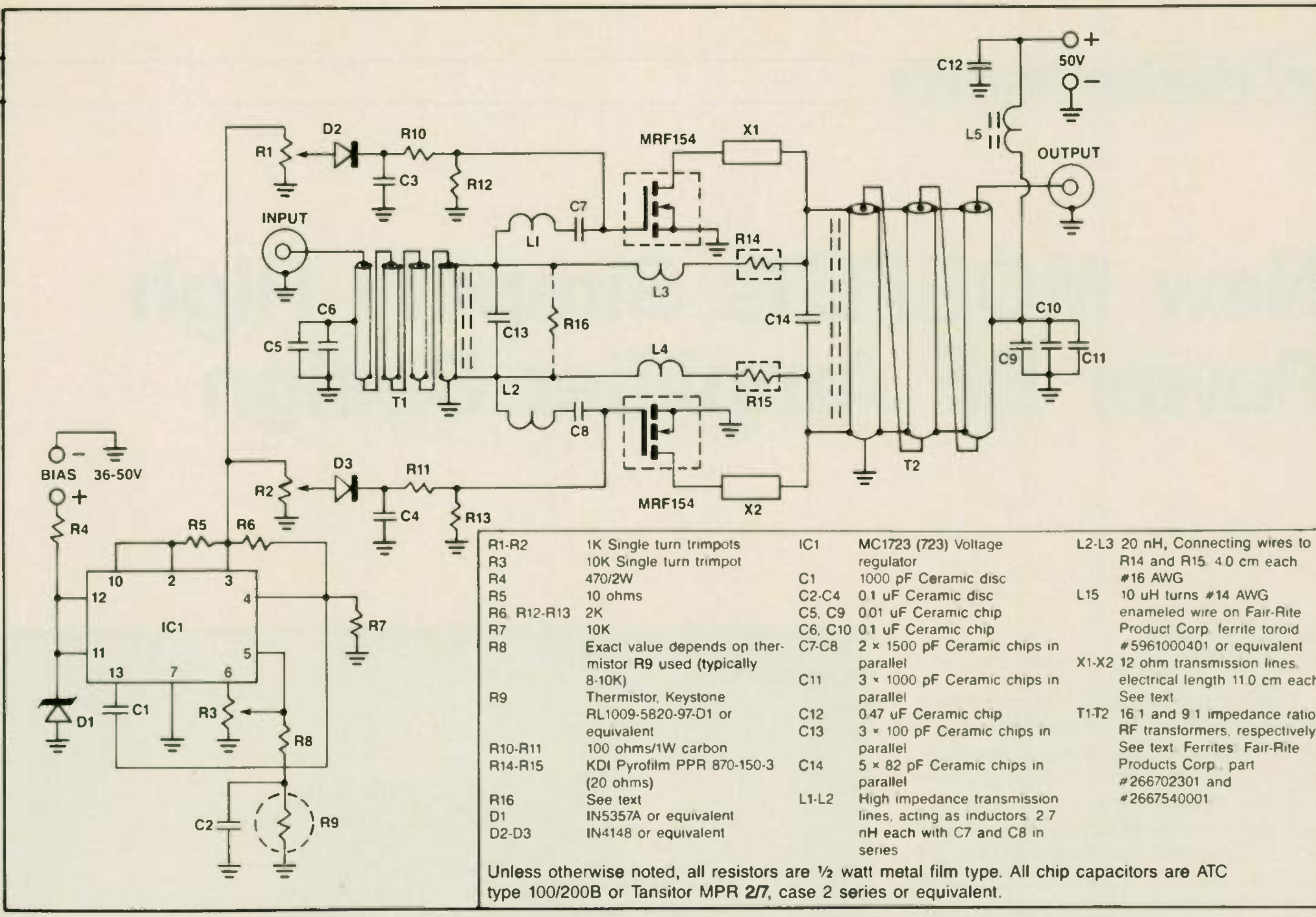
Motorola has recently introduced high power MOSFETs MRF153 and MRF154, which are rated for 300 watt and 600 watt power output, respectively. A 600 watt bipolar transistor (MRF430) is also in this family of RF power devices. The MRF154, which is the subject of this article, is usable up to 100 MHz with a power gain of 8-10 dB. Special design techniques result in a junction to ambient thermal resistance as low as 0.13°C/w. The transistor housing is designed for conduction cooling, and has 1.4 square inch flange surface area. A mounting surface of high conductivity material such as copper is recommended, since up to 900 watts of power may be dissipated in each device. The heat dissipator itself can be forced air or liquid cooled.

The 1 kW push-pull amplifier described here is designed to cover a frequency range of 10 to 90 MHz. Its applications include military communications, jammer, low channel TV, etc. Although the point of saturation is well over 1000 watts, the amplifier was tested for linearity at 800 watts. The available output transformer impedance ratios (9:1 or 16:1) are the limiting factor: the 16:1 impedance ratio would be optimum at around 1500 watts power output, but the 9:1 was chosen in order to achieve a better overall CW efficiency at the 1 kW level. In pulsed applications such as Nuclear Magnetic Resonance, linear operation is possible up to 1000 watts per device due to the low average dissipation and lowered thermal limits. In such case the output impedance matching can be modified accordingly.

## Circuit Description

In contrast to a single ended amplifier circuit, in a push-pull configuration only the device mutual inductance (source to source in this case) is critical, and must be as low as possible for good high frequency performance. The common mode inductance (from each source to ground) is less important, reducing the requirement for low inductance grounding between the input and the output circuits. Input and output sections of the circuit board can be split and grounded only through metal spacers to the heat sink. The source of the MRF154 is internally connected to the mounting flange, which is also grounded to the heat sink. This provides a good, low inductance path between the two sources. The arrangement (Figure 1) results in a convenient and compact mechanical layout and makes the unit easily serviceable, since each board can be removed separately.

In addition to the matching network, the input circuit board includes the FET bias regulator, making the bias current insensitive to supply voltage variations. With the component values shown in Figure 2, excursions of 30 to 50 volts result in less than 1 percent changes in the bias current. The regulator also provides a convenient point for connecting a thermistor for bias current temperature tracking purposes. The thermistor must be of NTC type, and can be thermally connected to one of the FETs or to any central location at the heat sink, depending on the ther-




| | |
|---|---|
| R1-R2 | 1K Single turn trimpots |
| R3 | 10K Single turn trimpot |
| R4 | 470/2W |
| R5 | 10 ohms |
| R6, R12-R13 | 2K |
| R7 | 10K |
| R8 | Exact value depends on thermistor R9 used (typically 8-10K) |
| R9 | Thermistor, Keystone RL1009-5820-97-D1 or equivalent |
| R10-R11 | 100 ohms/1W carbon |
| R14-R15 | KDI Pyrofilm PPR 870-150-3 (20 ohms) |
| R16 | See text |
| D1 | IN5357A or equivalent |
| D2-D3 | IN4148 or equivalent |
| IC1 | MC1723 (723) Voltage regulator |
| C1 | 1000 pF Ceramic disc |
| C2-C4 | 0.1 uF Ceramic disc |
| C5, C9 | 0.01 uF Ceramic chip |
| C6, C10 | 0.1 uF Ceramic chip |
| C7-C8 | 2 × 1500 pF Ceramic chips in parallel |
| C11 | 3 × 1000 pF Ceramic chips in parallel |
| C12 | 0.47 uF Ceramic chip |
| C13 | 3 × 100 pF Ceramic chips in parallel |
| C14 | 5 × 82 pF Ceramic chips in parallel |
| L1-L2 | High impedance transmission lines, acting as inductors 2.7 nH each with C7 and C8 in series |
| L2-L3 | 20 nH, Connecting wires to R14 and R15. 4.0 cm each #16 AWG |
| L15 | 10 uH turns #14 AWG enameled wire on Fair-Rite Product Corp. ferrite toroid #5961000401 or equivalent |
| X1-X2 | 12 ohm transmission lines, electrical length 11.0 cm each. See text |
| T1-T2 | 16:1 and 9:1 impedance ratio RF transformers, respectively. See text. Ferrites: Fair-Rite Products Corp., part #266702301 and #2667540001 |

Unless otherwise noted, all resistors are ½ watt metal film type. All chip capacitors are ATC type 100/200B or Tansitor MPR 2/7, case 2 series or equivalent.

**Figure 2. Schematic of the 1 kW FET amplifier. The MRF154 is supplied in matched pairs for $g_{FS}$ and gain. It is necessary to have gate bias voltages individually adjustable.**

mal time constant desired. The slope can be adjusted with R8, for which the exact value is determined by the FET $g_{FS}$. The value shown typically results in bias current tracking of less than 20 percent for 25° to 75°C. The bias can be turned completely off by grounding R8. However, this cannot be used for high speed switching of the amplifier due to the limiting time constant of the FET input capacitances and the bias voltage source path. Since the bias voltages are individually adjustable with R1 and R2 in addition to a common adjustment R3, the FET gate threshold voltages do not need to be matched. The power gain of an FET is mainly dictated by the $g_{FS}$ and not by the $V_g$(th).

The bias setting procedure is as follows: 1) adjust R1 and R2 to minimum; 2) adjust R3 for a voltage higher than the device $V_g$(th) at pin 3 of IC1. This should be typically 7-9 volts in order to place the R1 and R2 settings in the middle of the tuning range; 3) measure current at 50 volt supply point; 4) with power supply connected, advance R1 for desired current reading; 5) advance R2 until the current reading is doubled; 6) R1 and R2 need no adjustment after this, and the bias currents of both FETs can now be set with R3. During this operation (1-6) the input and output should be both terminated into 50 ohms with no RF drive applied.

On the output side of the circuit board design, the DC paths must be able to handle current levels of *50 amperes* and more, and the maximum RF currents are in the order of 15 amperes RMS at the low impedance points. The DC current would require almost $10^4$ mils$^2$ for the conductor cross sectional area in free air, but since the conductor will be heat sunk to the circuit board surface, a number about one fourth of this is adequate. Even then, circuit board material with at least 2 ounces of copper is required, and should be solder plated for added conductor thickness. In regards to the skin effect, a certain foil thickness is also necessary for the conductors carrying the RF currents. The skin depth at the high frequency end (90 MHz) is about 0.40 mils, and the foil thickness in the RF conducting paths should be at least five times that, or 2.0 mils, according to a rule of thumb. Since the skin depth varies as an inverse function of the frequency, it is really only meaningful at high frequencies, where the dimensional conditions can be met. It is then desirable to have a conductor with a large surface area and a thickness that meets the minimum requirement. Normally this will also be sufficient for low frequencies, where the conductor losses become nearly purely resistive.

### Input-Output Impedance Matching

Since the output impedance matching and transformer design are far more critical than the input side, they will be discussed first. According to (1) and (2) dips in transmission line transformer response will occur when the physical line length reaches ¼ wavelength, if the $Z_0$ differs from the optimum required value or if the terminating impedances are incorrect. These dips, which actually are changes in the transformer impedance characteristics, have been noticed with ⅛ and 1/16 wavelength increments as well. Their magnitude also strongly relates to the amount of leakage inductance present, which has the same effect as an incorrect line impedance. Standard practice is to keep the line lengths as short as possible to reduce the IR losses, preferably shorter than ⅛ wavelength at the highest operating frequency. Although operation between the incremental frequencies is possible, the bandwidth would be limited to less than one octave.

The effective line length varies with the transformer configuration. In a balanced

4:1 as shown in Figure 3B, the two lines are electrically in series, making the effective line length twice the actual. Cascading these for 16:1 impedance ratio further doubles the effective line length, making the total four times the length of one line. In a 9:1 impedance ratio transformer (Figure 3A) the two lines *a* and *b* are electrically in parallel, making the effective line length equal to the length of one line. However, since a balun is required for the balanced to unbalanced function, its length must be added to the total.

In high power solid state RF amplifiers it is desirable to eliminate the need for output DC blocking capacitors. Even if they are located at the 50 ohm points, they must be able to handle large RF currents (4.5A at 1 kW) and should be chip type to minimize the series inductance. This can be done either by replacing the typical autotransformer configuration with a design as in Figure 3C, or replacing the balun with a 1:1 isolating transformer (Figure 3Ad and 3Dh). A disadvantage with 3D is that an impractically low characteristic impedance may be required for line *h*, but its high frequency performance is excellent due to the equal delay unbalanced 9:1 section.

The design shown in Figure 3C is probably the most practical one for its simplicity and ease of manufacture. It lends itself to high impedance ratios such as 16:1 and up, which would be difficult to implement with other types. The impedance transformation is achieved by parallel connection of one conductor of the lines and series connection of the other. In principle it resembles the multifilar type transformers described in references (3) and (4), and must be considered a conventional (non-transmission line) transformer, although the low impedance line provides most of the coupling between the primary and secondary at high frequencies. The line impedance is not defined in the same manner as in transmission line transformers, and is not as critical. For increased coupling and low IR losses it can be lowered to a point where the resonance of the line capacitance and the leakage inductance falls outside the highest frequency of operation.

As discussed earlier, the high frequency limit of an RF transformer is set by the physical length of the line or the winding on the high impedance side. Considering the ⅛ wavelength rule, mentioned in several of the references, the maximum total line length at 90 MHz would be:

$$\frac{\lambda}{8} \times V_p = \frac{333}{8} \times 0.63 = 26.2 \text{ cm.}$$

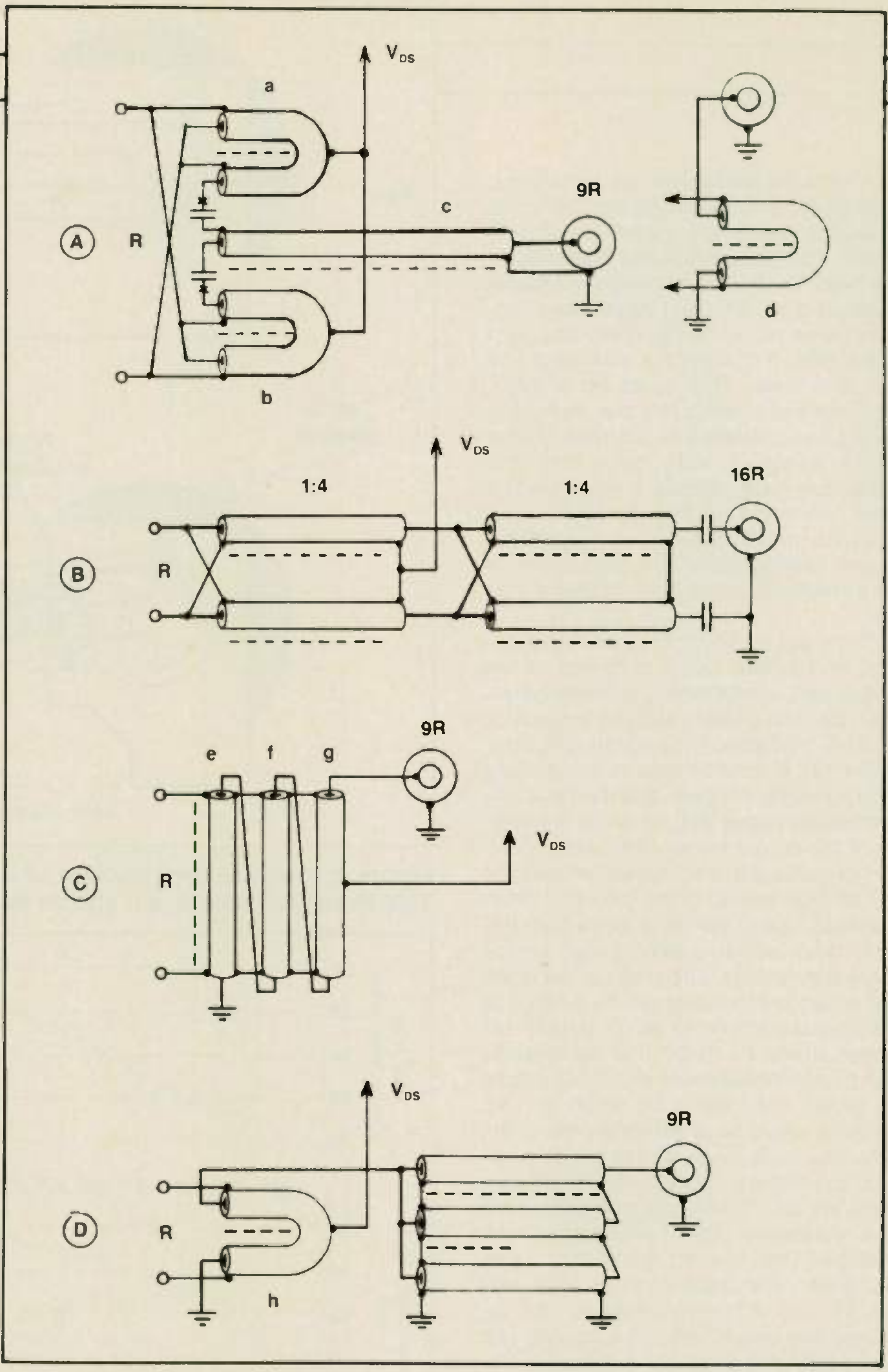



**Figure 3. Wideband RF transformer configurations for balanced to unbalanced impedance matching at high power levels. Coaxial transmission lines are most convenient for compact physical designs.**

Where: $V_p$ = velocity factor (0.63 for low impedance TFE co-axial cable).

Figure 4 shows the amplifier frequency versus power gain characteristics, *A* with a 9:1 transmission line output transformer, and *C* with a transformer shown in Figure 3C. Both were designed to have equal line or winding lengths of 16 ohm TFE insulated coax cable (Type CXN 1848 W.L. Gore Co.), except for the added 50 ohm balun in *A*. The balun and the higher leakage inductance resulting from the interconnections and the blocking capacitors in *A* possibly cause the slight roll-off at the high end. The type *C* transformer was also tried with 50 ohm coax line, which resulted in a 0.8 dB gain reduction across the band, plus an additional 0.3 dB at the high end compared to the unit made with 16 ohm cable. This indicates that the IR losses in the cable with a smaller center conductor are dominant over the line impedance.

Both transformer types reached temperatures of 80°C in a five minute CW test at the full power output, although type *A* had twice the ferrite cross sectional area. This leads us to determine that the ferrite dielectric losses are a problem in high power and high frequency applications such as this. Lower permeability material could be a solution, but larger cross sectional area would be required, making it more difficult to meet the maximum line length criteria. This could be a major problem and limiting factor in designing wide band amplifiers of this type, unless ferrite materials with lower dielectric losses can be developed. It would also be worth investigating how powdered iron material would behave in broadband power transformers, although suitable core shapes have not been available thus far.

The input transformer used in this design is of similar type and design as the output unit, except having a smaller physical size. The primary winding is made of 25 ohm miniature coax cable (Microdot 260-4118). It must be able to handle less than 100 watts of power, and its losses only affect the power gain, whereas the quality of the output transformer determines the overall system efficiency as well.

The high values of the gate and drain capacitances of the FETs make both the input and output matching difficult for large bandwidths. The effect of the drain capacitance can especially be noticed at frequencies above 50 to 60 MHz in reduced efficiency. Part of this capacitance can be compensated for with small values of series inductance or stripline. The stripline would be of extremely low characteristic impedance, and probably practical only in the output where high RF currents are also involved. Using calculated and measured drain parameters to be matched into the 9:1 transformer and computer optimization, values as shown for X1 and X2 were obtained. As an etched line on a 62 mil G10 substrate, the line width is 0.7 inches. In practice the lines had to be folded into a form of U, but this allows part of the line to be conveniently shorted for adjustment purposes. The effect of the output lines can be noticed in increased efficiency at 90 MHz (6% to 8%), but at a cost of reduced power gain by approximately 0.5 dB.

Similarly, using the data sheet numbers converted to parallel form, indicated values for input lines L1 and L2 were obtained. They are high impedance etched lines on similar G10 substrate. They act as inductors and their values are also adjustable by shorting part of the line or by moving the input transformer connection points. The values of L1 and L2 will finally depend on the amount of negative feedback necessary for the desired gain slope. Although not adapted to this design, a dummy resistor (R16) can be used to make the input look more resistive and improve the input VSWR. A suitable amount of L in series with it, combined with negative feedback, is a common technique in applications requiring extremely large bandwidths.

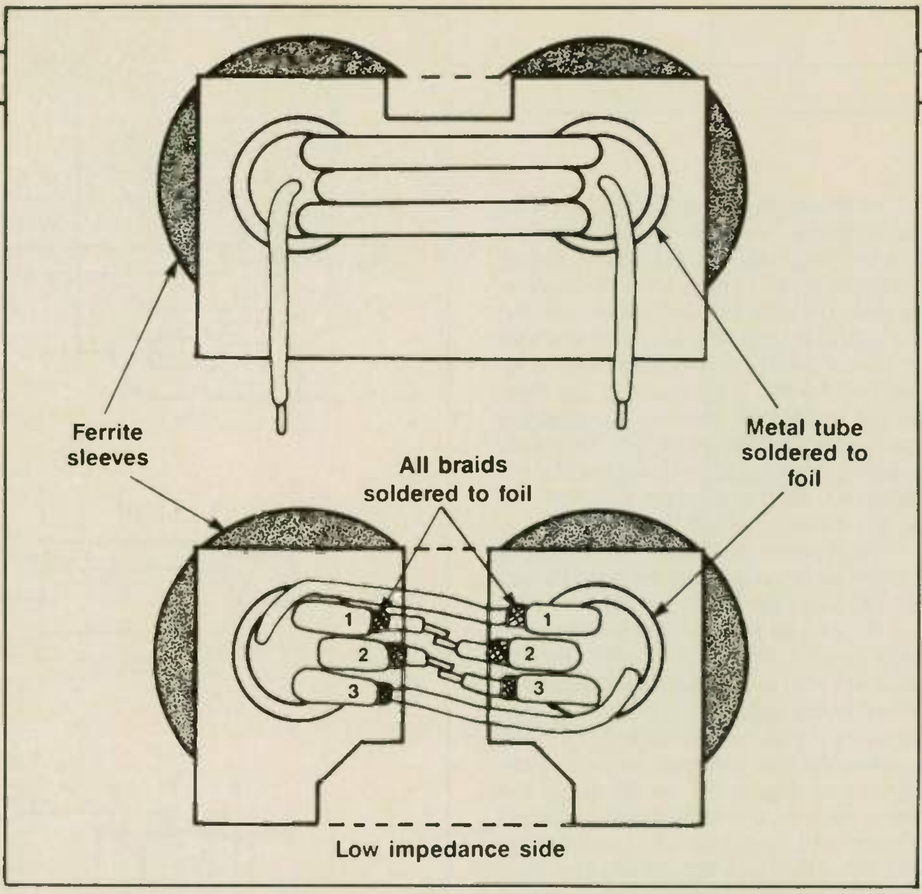



**Figure 4. Physical construction of RF transformers used in the amplifier. The electrical details are shown in Figure 3C.**

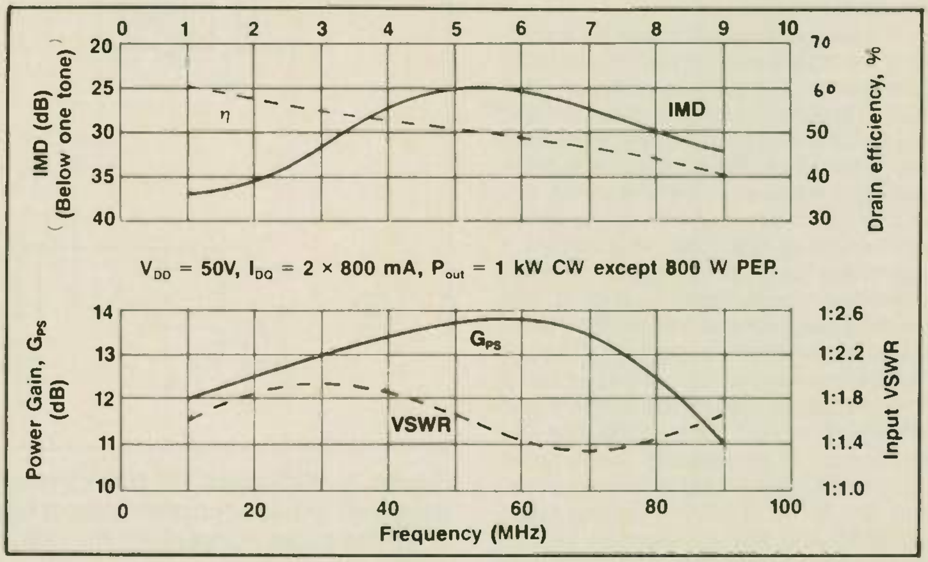



**Figure 5. 1 kW, 10-90 MHz amplifier typical performance. The numbers may vary slightly depending on the exact device parameters within specified limits.**

## Gain Leveling with Negative Feedback

The negative feedback term usually refers to a condition where part of the output power (voltage) is fed back to the input out of phase. Out of phase generally means 180° phase difference, although in practical systems the voltage fed back usually lags the input voltage due to delays in the circuitry. Any inductance in the feedback path causes a delay and a phase error, but seldom has effects large enough to cause instability. Sometimes an amount of inductance is intentionally included in the feedback circuit in order to prevent the feedback from affecting the high end. In most circuit configurations the phase shift is close to 180° between the input and the output, in which case the feedback is easy to implement. Otherwise a phase reversing component, such as a transformer must be employed.

Here the series inductances L3 and L4 are limited to their minimum values of 20-25 nH by the physical distance between the input and the output, although they can be controlled to a degree by varying the conductor diameter. Their reactances are about 8 ohms at the mid-band, where lower values would result in increased feedback and a flatter gain response than shown in Figure 5. It must be noted that the reactances at 10 MHz may be also significant, and should be deducted from the values of $R_{fb}$ to be calculated.

In addition to gain reduction, negative feedback lowers the effective input impedance. Ideally the amount of feedback voltage should be inversely proportional to the frequency in such amplitude that the gain would be reduced just the correct amount at all frequencies below the high end. This is not possible with simple feedback networks consisting only of L and R. Even with more sophisticated networks the feedback voltage source should be adjustable in some manner. Such a system is described in (6), but due to the high frequencies and higher power level involved it would be difficult to implement in this design. Here the feedback voltage is derived directly from the FET drains, which will limit the optimization of the system in this respect.

The MRF 154 data sheet shows a power gain of 22 dB for the device at 10 MHz, and a one to four difference in the gate input impedance from 10 to 90 MHz, or 12 ohms and 3 ohms composite parallel, respectively, from gate to gate. The 22 dB can be considered typical, and can vary as much as 3 dB at 30 MHz. However, the devices are supplied in matched pairs for operation in push-pull systems. The 22 dB translates to a power input of 6.5 watts for

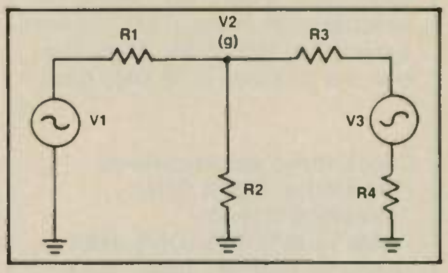



**Figure 6. A simplified model of the negative feedback network can be used to figure the loop parameters with sufficient accuracy.**

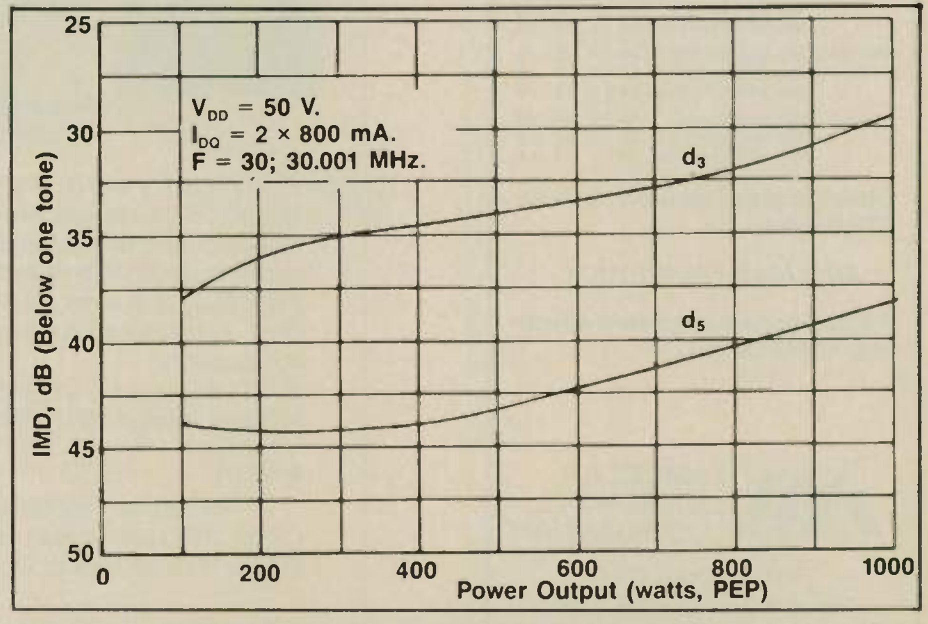



**Figure 7. Intermodulation distortion versus power output of 1 kW amplifier. Output impedance matching is optimum only at 800 watts with the transformer impedance ratio employed.**

two devices at 1 kW output. Assuming a 10 dB gain reduction, the power input then would be 65 watts. Since the device power gain is not affected by the feedback and part of the input power is cancelled by the feedback voltage, the difference power must be dissipated somewhere. Most of this occurs in the feedback resistors, which also control the amount of feedback.

A 16:1 impedance ratio input transformer was selected with an idea in mind that the feedback would bring the low frequency gate to gate impedance down to the 90 MHz value (3 ohms). Because of the reasons discussed ahead, the gain slope cannot be controlled, and since no loss of gain in the high end can be afforded the feedback is limited to an amount that results in a low VSWR at 10 MHz. The computer analysis of the input matching mentioned earlier assumed a constant 3 ohm impedance, but this will deviate considerably at the mid-band. A computer program with all these variables would be very complex, and since the system could not be totally optimized anyway it was decided to discard the effort at this point.

Since an FET is a voltage-controlled device, the feedback loop can be modeled

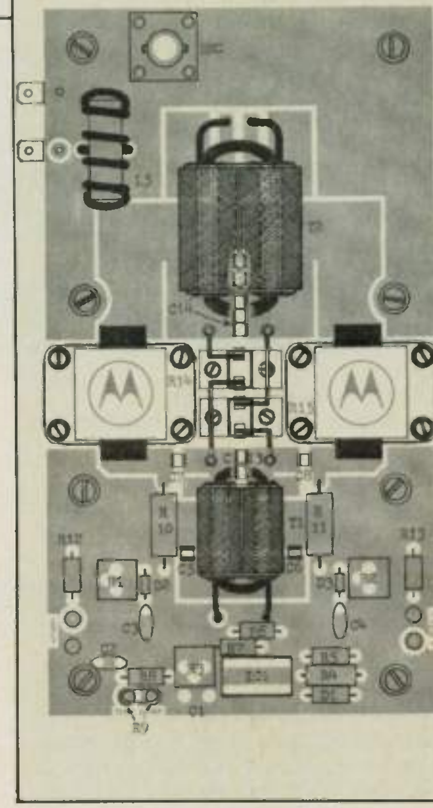


**Figure 8a. Component layout.**

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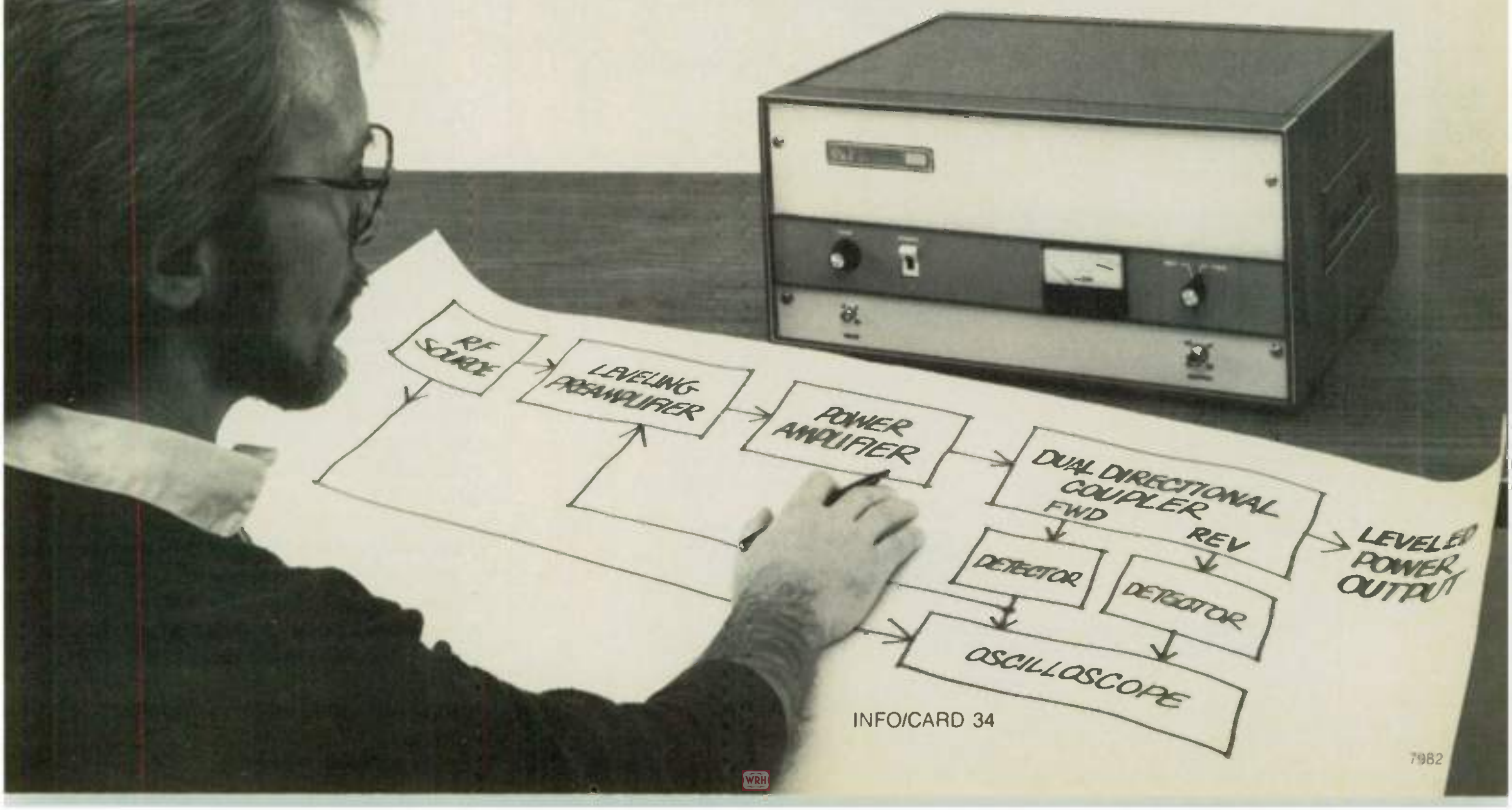


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at low frequencies or DC as shown in Figure 6, where:

R1 = Transformer source impedance
R2 = FET gate to gate impedance
R3 = Feedback resistor. (Divided into two equal values in the amplifier.)
V1 = input voltage
V2 = FET gate to gate voltage
V3 = Drain to drain output voltage across R4

For a given level of power output, the values of R1, V2 and V3 will remain virtually unchanged regardless of the amount of feedback.

It is assumed for simplification, that the value of R2 will be reduced by the feedback from 12 ohms to equal R1. Then:



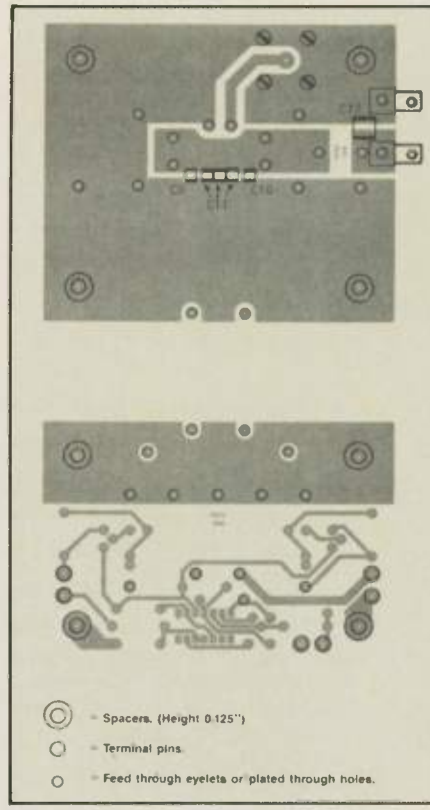


**Figure 8(b). Underside of p.c. board.**

R1, R2 = 3.12 ohms.
V1 = 14.23 volts (−10 dB)
V2 = 4.5 volts (22 dB)
V3 = −74.2 volts (R4 = 5.5 ohms)

$$R3 = \frac{(V2 + V3)}{\left(\frac{V1 - V2}{R1}\right) - \left(\frac{V2}{R2}\right)} - R4 =$$

$$\frac{(4.5 + 74.2)}{\left(\frac{14.23 - 4.5}{3.12}\right) - \left(\frac{4.5}{3.12}\right)} - 5.5 =$$

$$\frac{78.7}{1.70} - 5.5 = 40.8 \text{ ohms}$$

or 20.4 ohms each.

The feedback resistors then must be able to dissipate 65-6.5 watts plus any excess power resulting from the non-optimum voltage source. In this case the dissipation is 78.7 × 1.70 = 133.8 watts, or 66.9 watts per resistor. It is obvious that they must be of a type with a provision for heat sinking, and with low parasitic inductance (8).

## Design and Construction Summary

The amplifier performance, shown in Figures 5 and 7 can be affected by circuit parameters such as type of components, their values and exact locations. In this

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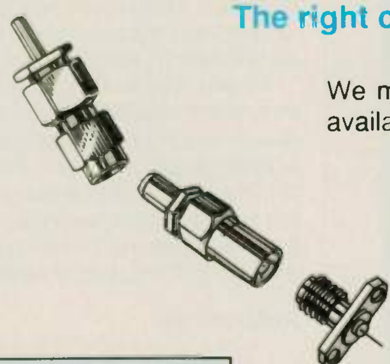

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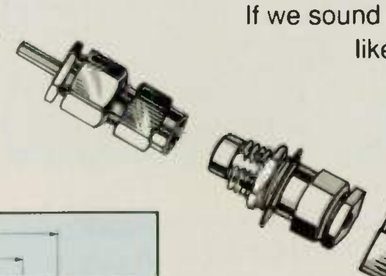

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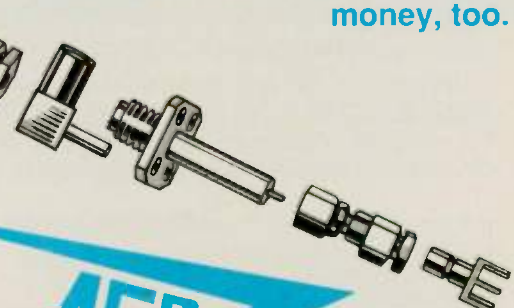

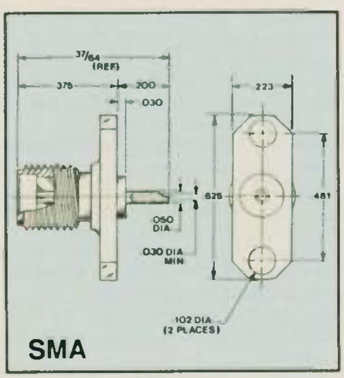

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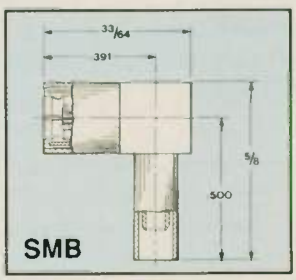

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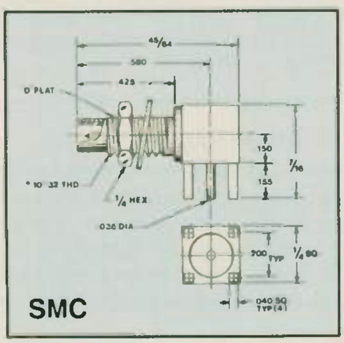

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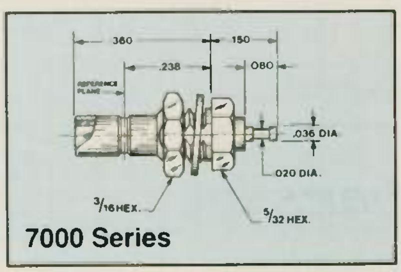

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respect, it can be compared to a low power UHF design if the impedance levels are scaled down with frequency. Although the layout resembles that of a typical 2 to 30 MHz amplifier, considerable differences in the construction techniques are essential to ensure proper operation, especially at the high frequencies.

Due to the high gate capacitance ($C_{iss}$) of the devices, the input matching is critical for good broadband performance. The values of L1 and L2, as well as the physical locations of T1 and C13, have a dominant effect in the input VSWR. The above is also true concerning the output matching, where these variables affect the power gain, efficiency, saturated power, and the IM distortion. Special attention must be paid to the location and quality of C14, which is essential to the amplifier operation above 50 MHz. Once all these criteria have been established, duplication of the system should not be a problem, although it is not possible to give physical details with sufficient accuracy in an article of this proportion to guarantee the exact results without minor adjustments.

The RF currents associated with the high power level and low impedances also introduce new problems to the designer in the form of passive components. The weakest link probably is the capacitors, which in certain locations must be composed of several paralleled smaller values in order to achieve the current carrying capability required and reduce the series inductance. Other limitations associated with the passive components have been discussed earlier. One of these is the circuit board itself, where the DC currents and the skin effect place a minimum limit to the foil thickness.

The low impedance levels are not new to a solid state power designer, but their association with a kW power level in a single amplifier is unique at these frequencies. This places new requirements on all passive components and presents challenges in thermal design.

Finally, it must be pointed out that the component values given or the mechanical design may not be exactly optimum for the specific goals described. The intent was to make the circuit board layout, including the output section, as universal as possible to allow its use for designs with other devices and frequency ranges. rf

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### About the Author


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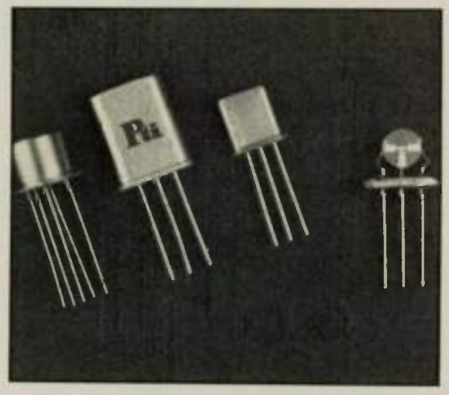
# PTI Unveils New Products, Fabrication Techniques



PTI's new crystal filters and resonators for VHF and UHF.

Piezo Technology, Inc. has made its third new product announcement in a month with the introduction of the XO1092 voltage-controlled oven-controlled crystal oscillator (VCOCXO). This unit offers stability of $\pm 2 \times 10^{-7}$, three minute warm-up, less than 1 watt power consumption and low phase jitter. Output on standard models is CMOS compatible, with a frequency range of 5 to 25 MHz. Trim range is available to compensate for 10-year aging. In 10-piece quantity, the XO1092 is priced at $200.

The XO1092 follows recent introductions of the XO1041 miniature TCXO, packaged in a 1.4 × .35 × .75 inch housing; and the XO1028 precision ovenized crystal oscillator, featuring high stability and low aging rate.

In addition to new products, PTI has developed techniques for the fabrication of AT and SC cut resonators with fundamental frequencies as high as 1.6 GHz. Under U.S. Government agency sponsorship, these techniques have been used to manufacture monolithic and discrete resonator VHF crystal filters at fundamental frequencies up to 250 MHz. The advantage of resonators and filters at higher frequencies is the simplification of designs by eliminating some or all frequency multiplication and conversion stages.

The VHF/UHF process involves refining crystalline quartz by electrodiffusion ("sweeping") to improve purity. Lapped and polished wafers are selectively etched in the central region to produce membranes, with a thickness of 1.6 micrometers for a 1 GHz device. The process leaves a strong ring of quartz at the outer edge of the etched area, providing uniform support for military-required shock and vibration environments.

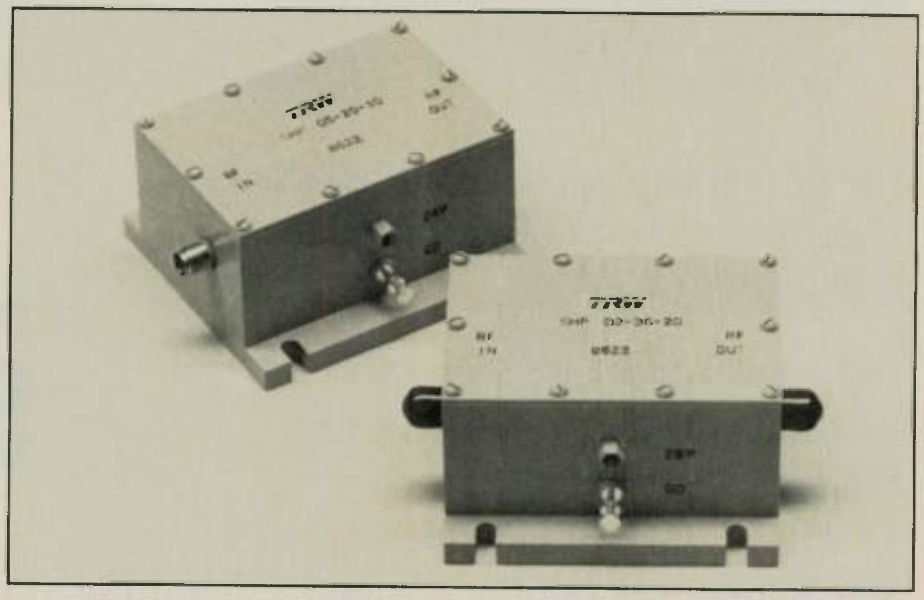
Commercial offerings include resonators up to 250 MHz in both AT and SC cuts, plus AT cut monolithic crystal filters up to 150 MHz. **Piezo Technology, Inc., Orlando, Fla. INFO/CARD #151.**

## TRW Introduces Broadband, Linear Amplifier Modules

TRW RF Devices Division has introduced packaged versions of their well-known broadband amplifier hybrids. The amplifiers are enclosed in a 5.2 cu. in. machined aluminum housing with hermetic input and output connectors and an RFI gasket.

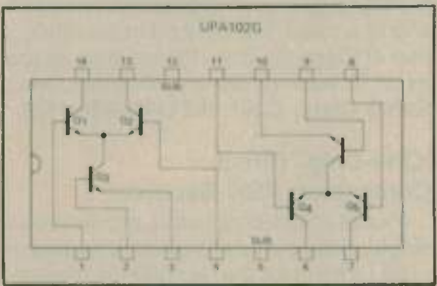
A TRW spokesman noted that demand for complete "building block" function modules is growing among RF system designers, and TRW's existing line of hybrids are perfectly suited for assembly into low cost connectorized modules. The company is also proceeding with new hybrid products to extend the frequency and power ranges now available. Although well known to CATV equipment makers, the hybrid amplifier line is suitable for many medium power broadband amplifier applications. This new method of packaging should make them more useful as RF system components. Pricing is $250-$275 for 1-9 quantities and $200-$220 for 10-99 units. **TRW RF Devices Division, Lawndale, Calif. Please circle INFO/CARD #146.**

| Model | Bandwidth | Gain | Power Output |
|---|---|---|---|
| SHP02-36-20 | 1-200 MHz | 36 dB | 2W |
| SHP05-20-10 | 30-500 MHz | 20 dB | 1W |
| SHP10-15-08 | 10-1000 MHz | 15 dB | 800 mW |
| SHP05-34-04 | 30-450 MHz | 34 dB | 400 mW |



**Microwave Transistor Arrays Are User Configurable**

New high frequency transistor arrays from NEC are now available through California Eastern Labs. These new microwave logic devices contain silicon transistor arrays which can be configured by the user to provide a variety of functions ranging from double balanced mixer to high speed logic gates. Four arrays are available: UPA101 contains six 9 GHz transistors configured as an active double balanced mixer or doubler; UPA102 contains two pairs of 9 GHz transistors configured differentially with a common bias transistor for each pair; UPA103 — contains one pair of 9 GHz transistors in dif-






INFO/CARD 39

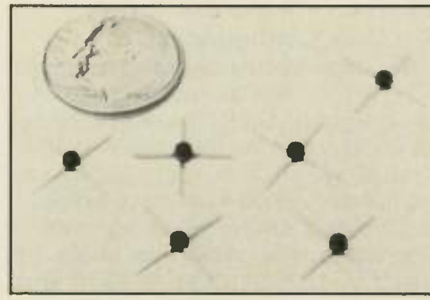


INFO/CARD 40

ferential and three individual 9 GHz transistors; UPA104 contains one 9 GHz transistor in parallel to a differential pair and two individual 9 GHz transistors for OR, NOR, or exclusive NOR gates. Options are a 14-pin ceramic package with superior thermal dissipation, and a 14-pin (8-pin for UPA101) mini-flat pack. **California Eastern Laboratories, Santa Clara, Calif. INFO/CARD #176.**

### Transistors Have High Performance, Low Cost Packages

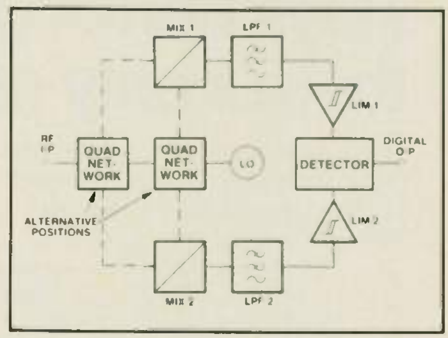
Avantek has introduced three of its high performance NPN silicon bipolar transistors in low-cost 85 mil plastic packages, designed for use in low noise, wideband amplifier and oscillator applications operating over VHF, UHF and microwave frequencies. At 2000 MHz models AT-41485/–42085 and –60585 feature op-



timum noise figures from 1.7 to 1.9 dB with associated gains at $NF_0$ from 11.5 to 13.5 dB and power output at 1 dB gain compression from +15 to +20.5 dBm. Excellent uniformities in performance are produced by the ion implantation and self-alignment techniques used in the fabrication of these devices. Prices start as low as $1.15 each (1,000 qty.) **Avantek, Inc., Santa Clara, Calif. INFO/CARD #175.**

### 'One-Chip' Direct Conversion FSK Receiver

Plessey Semiconductors announces a single chip low-power direct conversion radio receiver for the reception of frequency shift keyed (FSK) transmissions, providing a low-cost solution for both tone only and data paging systems operating up to 200 MHz. Designated the SL6637, the device can be used as a complete radio receiver offering a typical sensitivity of




200 nV, and a power consumption of just 4 mW. The IC also includes control circuitry for a single cell battery operation if required. The SL667 features a patented four phase detector and a 260 microwatt "power down" capability. Applications include hand-held signal receivers and ultrasonic direction indicators. **Plessey Semiconductors, Irvine, Calif. INFO/CARD #174.**

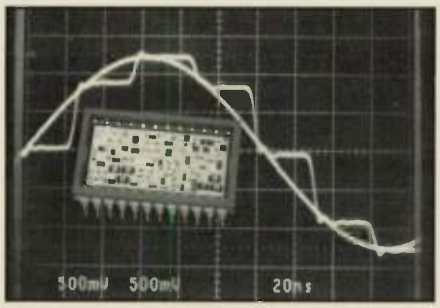
### Sample Offered of Formable D.C. Laminate

A free 8" × 9" sample of BEND/flex® formable laminate clad on both sides with one-ounce copper is available from Rogers Corporation. The material is an ideal alternative to using two or more rigid circuit boards connected with electronic connectors. It can also be used in place of non-dynamic flexible circuits. The material's unique physical characteristics enable it to be processed by standard rigid board techniques. Once processed, BEND/flex boards can be stuffed manually or with automatic insertion equipment.

Available in 15-mil, 20-mil and 30-mil thickness, the material offers electrical and mechanical properties which fall between those for flexible and rigid dielectric materials. **PORON & Composites Division, Rogers Corporation, Rogers, Conn. INFO/CARD #173.**

### Ultra-Fast Track and Hold Improves A/D Systems

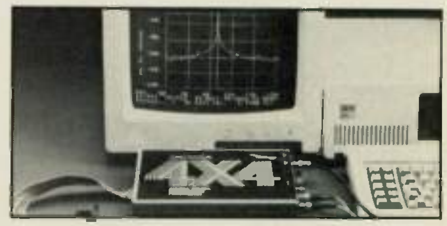
A new ultra high-speed track and hold amplifier, the CLC940 Flash-Track™, provides flash A/D designers the ability to improve A/D system performance. Key specifications which differentiate the CLC940 from other track and hold amplifiers include: hold-to-track acquisition time of 10 ns (to 1.0 percent); track-to-hold setting time of 12 ns (to 1 mV); aperture jitter of 1 ps (1.3 ps max.); −3 dB bandwidth (small signal) at 150 MHz; and slew rate of 470 V/us. The CLC940 is packaged in a 24-pin DIP and is available in both a commercial/industrial version (−25°C to




+85°C) and a high-rel/military version (−55°C to +125°C). The 100-piece price of the commercial/industrial version is $196. **Comlinear Corporation, Fort Collins, Colo. INFO/CARD #172.**

### PC Peripheral is Signal Processing Spectrum Analyzer

Rapid Systems has announced the R360, a 250 kHz spectrum analyzer and digital signal processing peripheral for



IBM PC, XT, ATs and compatibles. The R360 features the TI TM32010 and offers four channel, real time spectrum analysis. The price is $2699. Also available is a less expensive data acquisition module version for $1499 (R340). **Rapid Systems Inc., Seattle, Wash. INFO/CARD #171.**

### CAE Software Program Provides Network Synthesis, Independent Analysis and Optimization

Designers of amplifiers, subsystems, filters, and MMICs now have greater control over network synthesis with EEsof's latest release of E-Syn™, Version 1.10, a CAE program which produces filter, multiplexer, and impedance-matching networks. E-Syn 1.10 writes a circuit file that is ready to run in Touchstone™, EEsof's program for the design, analysis and optimization of RF/microwave circuits, without modification. In addition, the new release features automatic Touchstone-like network analysis, transformation of lumped elements to distributed elements, and optimization of element values to exact goals. Analysis and optimization are completely independent of the synthesis; two separate gradient optimizers ensure convergence, and the user has complete control over setting lumped and distributed element constraints for the optimization.

E-Syn runs on an IBM PC-AT, PC-XT and Hewlett-Packard Vectra or compatible personal computers with 640K memory, 10 Mbyte hard disk drive, 360 Kbyte floppy, and a math coprocessor. The program retails for $5,000, with quantity discounts available, and delivery is immediate. **EEsof, Inc., Westlake Village, Calif. INFO/CARD #144.**

### Computer Simulation Design Tools Used For TRW Devices

TRW will sell a series of computer simulation design tools for use with its family of VHSIC devices. The tools allow engineers to insert TRW's advanced VHSIC technology into electronic systems during the design stage and test its effect without having to build test hardware or purchase VHSIC devices before their impact on a system is known. Designed to operate in a computer-aided design environment, the simulation tools are part of TRW's response to its VHSIC customer's direction to spread VHSIC technology to key Department of Defense programs. **TRW Inc., Redondo Beach, Calif. Please circle INFO/CARD #143.**

### CAE Synthesis Software Analyzes Transmission Lines

Four programs cover the synthesis and

analysis of transmission lines used by the RF and microwave community. This initial release includes: SLINE (single-strip stripline), MLINE (single-strip microstrip), WGLINE (rectangular waveguide), and WRDLINE (double and single ridge waveguide). Each CAE program is user-friendly and includes default values for each input parameter, so the non-expert can operate the software while learning about the transmission line and its response profile versus frequency. Parameter values calculated by the programs include the following features: dimensional synthesis from impedance, impedance synthesis from dimensions, transmission-line losses (conductor and dielectric loss), sensitivity analysis, electrical response versus frequency, and higher-order mode cut-off frequency. **Microwave Software Applications Inc., Norcross, Ga. Please circle INFO/CARD #142.**

### IBM PC Circuit Design Software Aids Monte Carlo Analysis

PRE-SPICE, combined with IS-SPICE and Intu-Scope, is the most comprehensive SPICE-based CAE program available for the PC. Features added in PRE-SPICE include syntax extensions to the U.C. Berkeley SPICE for including libraries, passing parameters to subcircuits and evaluating tolerance parameters for a Monte Carlo analysis. Included is a screen editor with help menus, a library of 25 parts and a Monte Carlo analysis driver. The program is compatible with any version of SPICE that conforms to the Berkeley syntax, a feature especially useful for running very large simulations on a mainframe.

Intu-Scope works like a Tektronix digital oscilloscope. It acquires waveforms from the IS-SPICE ASCII output file, performs auto scaling with manual adjustments available, makes cursor relative measurements, and performs vector waveform operations that include integration, differentiation and Fourier Transforms.

IS-SPICE is the circuit simulation program, adapted for the PC from the U.C. Berkeley SPICE version 2G.6. The simulation program performs AC, DC and Transient analysis on circuits with up to 300 nodes. Features include temperature sweeps, noise analysis, transfer functions and sensitivity analysis. Models are built in for bipolar junction transistors, JFETs, MOSFETs, diodes and passive devices. Transient analysis includes circuit nonlinearities. PRE-SPICE sells for $125.00, IS-SPICE for $95.00 and Intu-Scope is $175.00. All three together are $395. **Intusoft, San Pedro, Calif. Please circle INFO/CARD #141.**





INFO/CARD 47

# rf literature

## Articles Teach Digital Control of RF Components

Lorch Electronics Corp. has announced a volume of nine technical articles of interest to all who work with digitally controlled RF components. Written by Robert W. Sproul, director of engineering at Lorch, the articles have the following titles:

Bridge the Gap from RF to I/O without Falling in the Cracks;
Interfacing RF Components with TTL Logic Control;
Trouble-Free Interfacing of TTL and RF Components;
Good RF Design Techniques Aid High-Speed TTL Control;
Decode the Numbers Game Before Tackling Digital RF;
Ubiquitous UART Speeds Digital-RF Interfacing;
IEEE-488 Versatility Keeps Networks in Check;
Unravel the Riddle of Switch-Matrix Designs;
The Working Man's Phase Shift Primer.

The first seven articles were published as a cohesive primer on the art of digitally controlling RF components, a discipline that spans the disparate worlds of RF and Digital. Reprints of these articles are free. **Lorch Electronics Corp., Englewood, N.J. INFO/CARD #156.**

## NBS Publishes Calibration Services Guide

The Commerce Department's National Bureau of Standards (NBS) has published a new "users guide" listing calibration services, special test services, and measurement assurance programs (MAPs) available from the bureau. The calibrations and special tests include NBS services that check, adjust, or characterize instruments, devices, and sets of standards. The MAPs are quality control programs for calibrating a customer's entire measurement system. The guide includes, among other areas, ionizing radiation and electromagnetics (including DC, AC, RF, and microwave). The guide explains fees, types of services, measurement criteria, reports of test results, references to NBS in advertisements, traceability of calibrations, and shipment of equipment. A fee schedule for the calibration services is published every six months as a supplement. **National Bureau of Standards, Gaithersburg, Md. INFO/CARD #155.**

### Siliconix Short Form Catalog

The new Short Form Catalog from Siliconix provides product information in a format that allows rapid device selection. This concise product guide includes the company's lines of discrete transistors, small-signal FETs, analog switches, analog multiplexers, data acquisition ICs, power converters and drivers, gate arrays, and power ICs. Key specifications and package options are listed for each Siliconix part number. **Siliconix, Inc., Santa Clara, Calif. INFO/CARD #154.**

### Capabilities Brochure Describes Microwave Circuit Boards

A six-page brochure describing its capabilities in the fabrications of precision PTFE-based microwave circuit boards is available from the Soladyne Division of Rogers Corporation. Entitled "Innovators in Precision PTFE-Based Microwave Circuit Boards Fabrication," the brochure describes Soladyne's fabrication capabilities, as well as processing innovations accomplished by the Rogers division, including a unique optical inspection technique which assures accurate front-to-back registration to ±0.001". Also discussed is the division's patented process for making plated-through holes to aluminum, and its ability to plate through and around PTFE-based substrates. **Rogers Corporation, Soladyne Division, San Diego, Calif. INFO/CARD #153.**

### New Book Teaches PASCAL for Electronic Applications

Howard W. Sams. & Co. has recently published *PASCAL for Electronics and Communications,* a practical guide to learning how to write programs in Standard PASCAL. A particularly careful treatment is given to the use of arrays and files in view of the difficulties it is possible to encounter. The efficient use of the structural and procedural facilities of the language is stressed at all stages. Author Richard Meadows is head of the Department of Electronics and Physics, The Polytechnic of North London, U.K. He holds a BSc, an MS, and a Ph.D. The book retails for $12.95. **Howard W. Sams & Co., Indianapolis, Ind. Please circle INFO/CARD #152.**

### EMI Shielding Design Guide

A complete reference source that provides design engineers with state-of-the-art information for dealing with the demands of EMI shielding problems is available from TECKNIT. The 75-page publication, entitled "EMI Shielding Design Guide," systematically addresses the design criteria involved in the area of EMI shielding. The guide is organized into ten sections, each covering a specific topic, ranging from "Metal Shielding Barriers" to "Shielding Performance Testing and procurement." A glossary and a comprehensive bibliography are provided to assist those readers wishing to delve deeper into specific areas of study. **TECKNIT, Cranford, N.J. INFO/CARD #150.**

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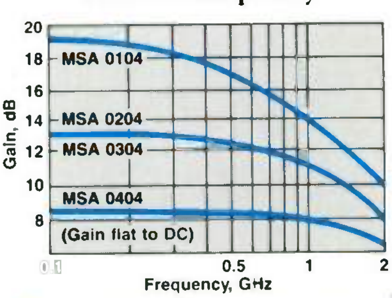


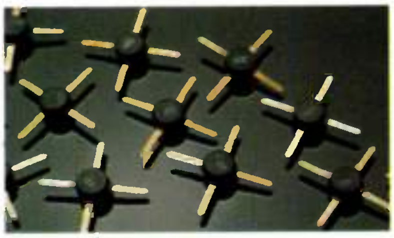

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