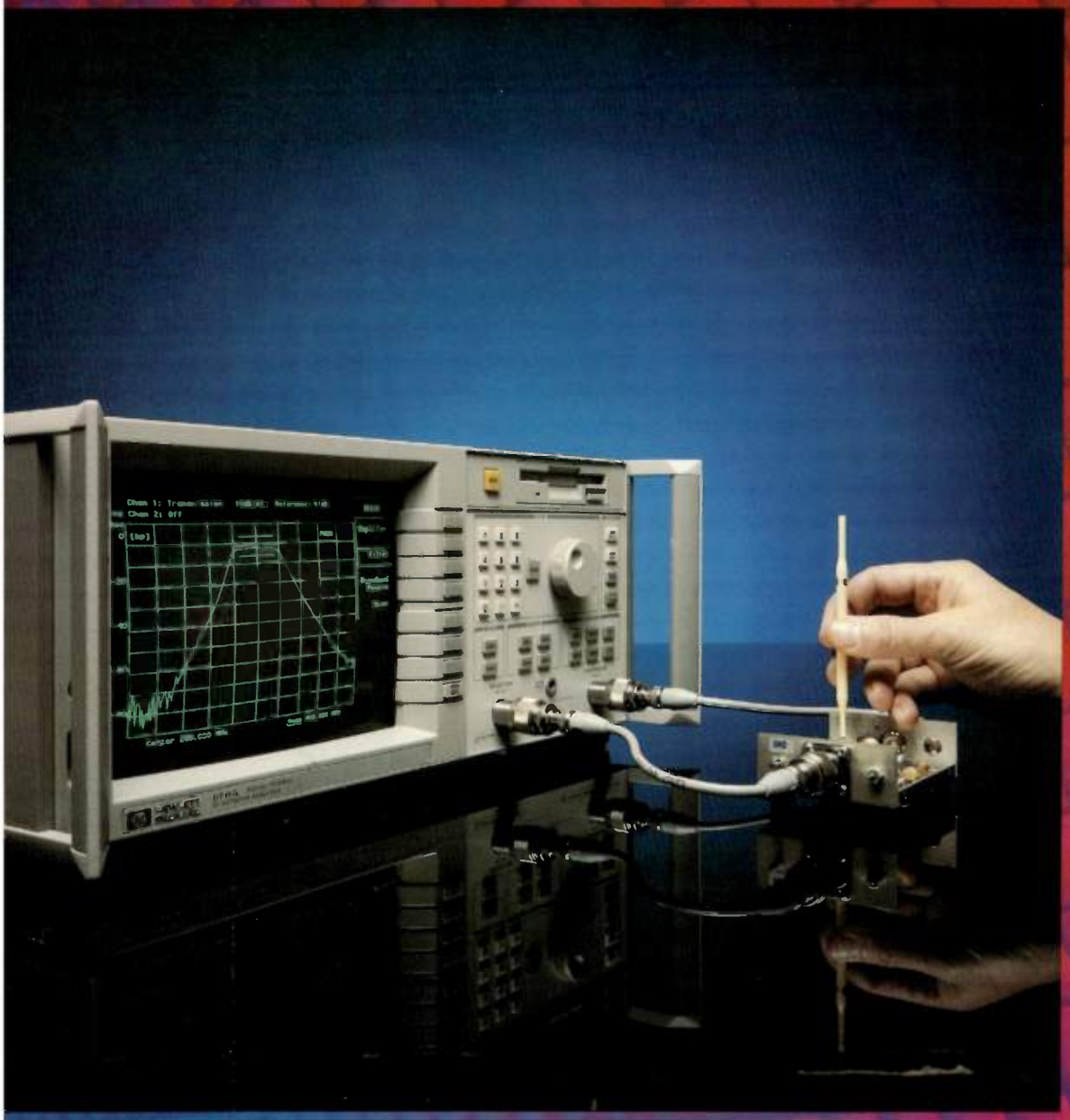
RFdesign

engineering principles and practices

August 1991



Cover Story
New Low-Cost Network Analyzer

Featured Technology
Analytical Techniques

EMC Corner
Analyzing Lightning Effects

How Many Times Do You Build Your Product?

Now EEsof Has the Answer to Faster Time-to-Market for Microwave and RF Product Design...

THE SOLUTION? EEsof SOFTWARE! With today's emphasis on commercial applications, faster time-to-market is critical to insure profit. But the cut 'n try design of microwave and RF circuits can wipe out those profits before manufacturing begins. And component tolerance and aging, process variation, and temperature effects can kill a product after it's gone to manufacturing. Not much to keep the boss happy...

VERSION 3.0

EEsof's Design-for-Manufacturing software brings advanced CAE/CAD technology to high-frequency analog engineers and lets you optimize designs under realistic manufacturing conditions. Even difficult nonlinear designs—amplifiers, mixers, and oscillators—become straightforward. EEsof's system and circuit simulation programs, including Touchstone,® OmniSys,® *jOMEGA*,™ and Libra,® let you simulate and *optimize manufacturing yield* while accounting for component statistical variations.

Send today for your free copy of EEsof's "Solutions in Design for Manufacturing," and let us show you how to eliminate prototype rework and get your product through manufacturing faster. Call us at (800) 624-8999, ext. 155. Or if you prefer, contact us by FAX at (818) 889-4159. In Europe, call (49) 8105-24005 or FAX (49) 8105-24000.

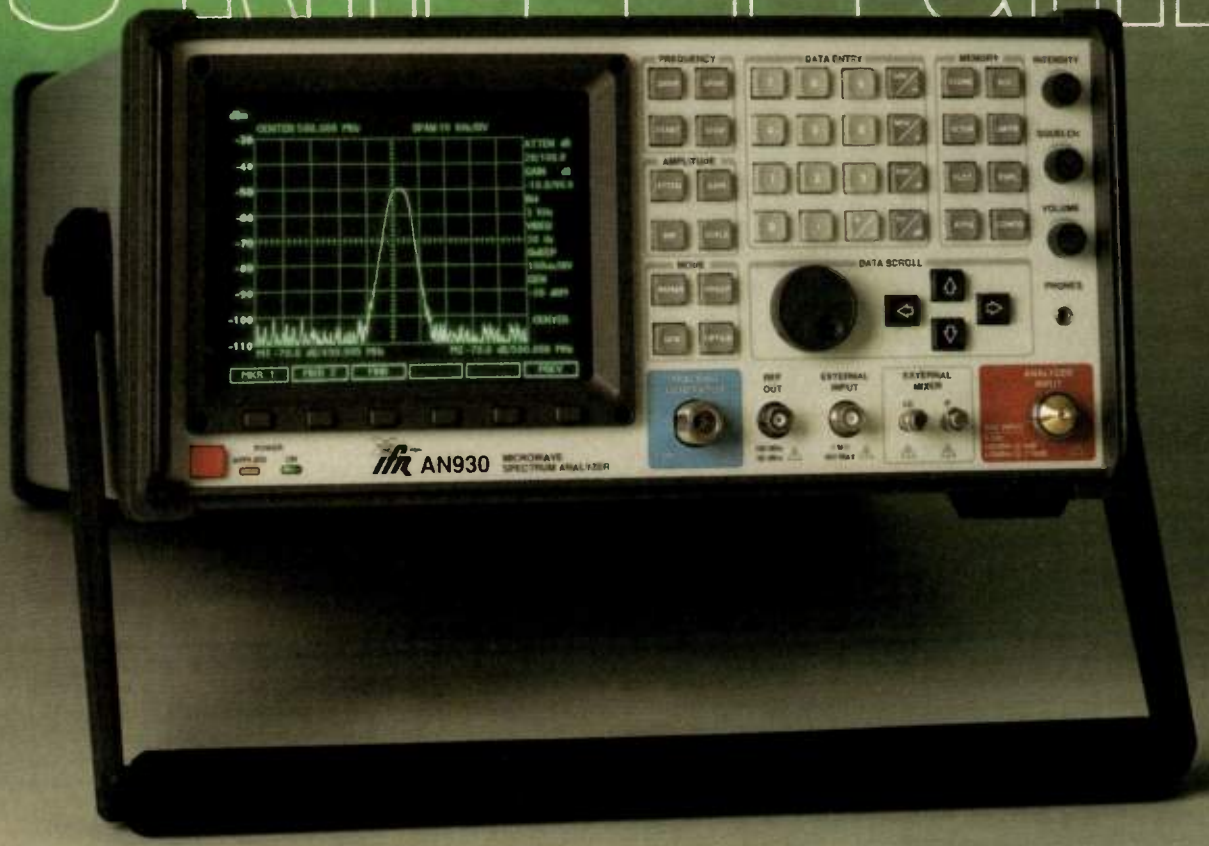
Breaking the Barriers...

EEsof®

INFO/CARD 1

Performance and value beyond anything in its class...

9 kHz-22 GHz



AN930 MICROWAVE SPECTRUM ANALYZER

At last, a high performance microwave spectrum analyzer that's truly portable and affordable.

Featuring low-order, preselected mixing and a highly stable synthesized RF system, the AN930 provides superior amplitude and frequency measurement performance over its entire 9 kHz to 22 GHz frequency range. Support for external mixers extends the AN930 measurement range beyond 22 GHz. A high impedance input permits measurement of baseband signals to 0 Hz and 40 volts peak amplitude.

Logical front panel controls on the AN930 reduce most measurements to a few simple steps. A powerful microprocessor provides advanced tools to simplify the solution of many complex measurements. The large, easy-to-read, 7-inch display speeds viewing and interpretation of measurements.

STANDARD FEATURES INCLUDE:
+30 dBm to −120 dBm measurement range, 300 Hz to 25 MHz analog resolution bandwidth, 3 Hz to 100 Hz digital resolution bandwidth, built-in 1 Hz resolution frequency counter, high speed time-domain sweep with pretrigger and delayed trigger, sensitive AM/FM receiver, RS-232 and IEEE-488 interfaces, and operation from DC power.

OPTIONAL FEATURES INCLUDE:
Rechargeable battery pack, built-in 2.9 GHz tracking generator, internal memory expansion (up to 99 traces and control setups plus 64 kbyte user-definable macro storage memory), 200 Hz to 1 MHz supplemental resolution bandwidth filters including EMI bandwidth filters, quasi-peak detector, and 0.02 ppm high stability time base.

For more information or a demonstration, contact your local IFR distributor or representative, or call IFR directly at 316/522-4981.

CRAFTED WITH PRIDE IN U.S.A.

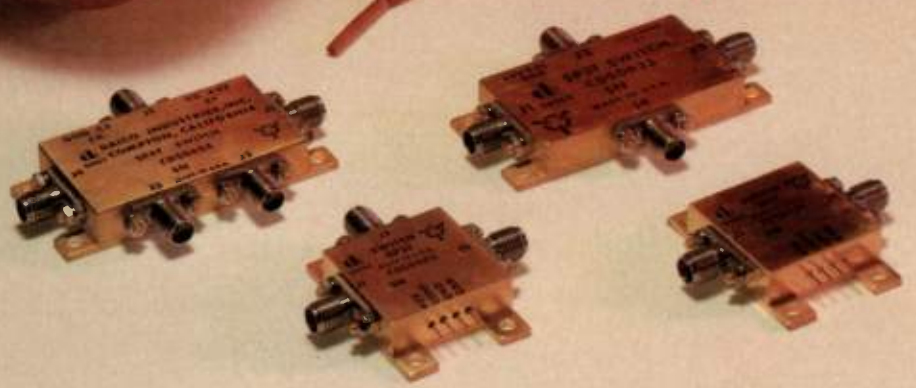
ifr

IFR SYSTEMS, INC.
10200 West York Street / Wichita, Kansas 67215-8935 U.S.A.
Phone 316/522-4981 / TWX 910-741-6952 / FAX 316/524-2623

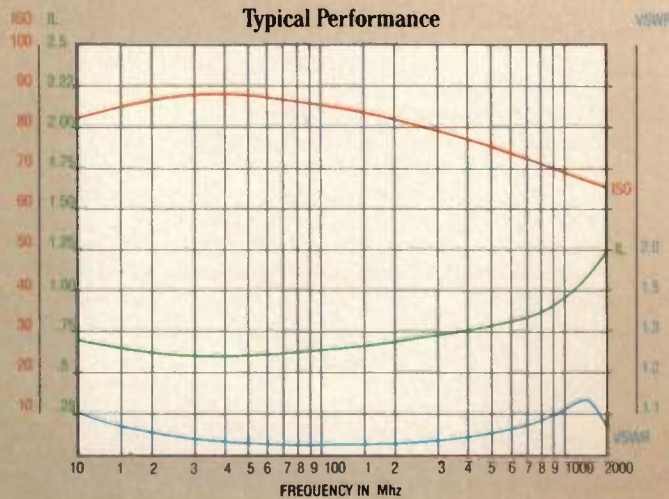
INFO/CARD 2

DAICO MIL-TOUGH

Miniature Connectorized Switches



Typical Performance



Typical Characteristics

Frequency:	20 - 2000MHz		Insertion Loss:	0.9dB	20 - 1000MHz
Isolation:	75dB	20 - 500MHz		1.3dB	1000 - 2000MHz
	70dB	500 - 1000MHz	DC Power:	12mA at +5VDC	
	60dB	1000 - 2000MHz			

DAICO miniature connectorized switches are hermetically sealed packages designed to survive the toughest military environments. Removable SMA connectors make for quick field replacement.

These switches have high isolation while maintaining low insertion loss, low DC current, and broad bandwidth.

When your applications demand MIL-TOUGH switches and attenuators, call Daico Technical Information for a prompt, realistic response.

DAICO INDUSTRIES, INC.

2135 East Del Amo Boulevard, Compton, CA 90220
Telephone 213/603-0143 • FAX 213/631-8076

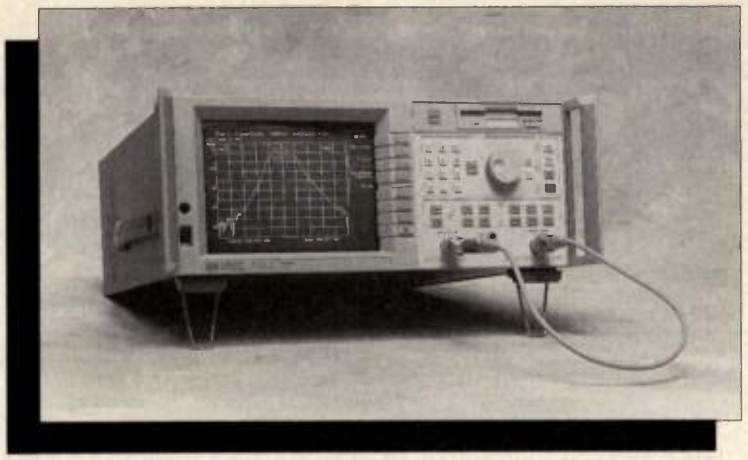
INFO/CARD 3

RF design

contents

August 1991

featured technology



cover story

emc corner

design awards

design awards

departments

R.F. DESIGN (ISSN: 0163-321X USPS: 453-490) is published monthly plus one extra issue in September. August 1991. Vol. 14, No. 8. Copyright 1991 by Cardiff Publishing Company, a subsidiary of Argus Press Holdings, Inc., 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111 (303) 220-0600. 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: *RF Design*, 5615 W. Cermak Rd., Cicero, IL 60650. Domestic subscriptions are sent free to qualified individuals responsible for the design and development of communications equipment. Other subscriptions are: $38 per year in the United States; $48 per year in Canada and Mexico; $51 (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 $5.00 each (in the U.S.). This publication is available on microfilm/fiche from University Microfilms International, 300 Zeeb Road, Ann Arbor, MI 48106 USA (313) 761-4700.

SUBSCRIPTION INQUIRIES: (312) 762-2193.

POSTMASTER & SUBSCRIBERS: Please send address changes to R.F. Design, 5615 W. Cermak Rd., Cicero, IL 60650.

Education and RF Engineering

By Gary A. Breed
Editor

Let me add some opinions to the information contained in this issue's education report (our Industry Insight column on page 28).

First, it's a shame that high school and college students get so little information on careers. Oh, they get lots of propaganda; lots of carefully selected data on a few major career areas, including engineering. What they miss is an accurate representation of some of specific areas of emphasis. "Engineering" is usually presented as covering everything from designing bridges to building the space station. Any detail in E.E. will focus on supercomputers, microprocessor chips. Maybe lasers or fiber optics will be thrown in for visual appeal.

Another unfortunate factor is the lack of hobbies that stimulate youngsters. Much of their life is structured — sandlot baseball has been replaced with T-ball and Little League, the swimming hole is now the local YMCA or recreation center, and curiosity about science and technology is supposed to be fulfilled in an "exploratory classroom" setting. Ham radio, working on cars, or filling your parents' garage with smoke no longer serve to encourage prospective electrical, mechanical and chemical engineers.

So, many new engineering students enter college with no goal at all for a job after graduation. As a result, they can't plan their college curriculum; a frustration for department advisors who try to guide them through a standard program of some sort. From this system, we get engineers who don't really know why they want to be engineers!

Why should we care? After all, some very vocal engineering groups claim that there are too many unemployed engineers already. If you examine the newspapers or engineering magazines, you will find only a modest number of jobs advertised for RF engineers. Yet, 90 percent of the companies I have talked to in the past few years have said that they really need certain types of expertise and would hire a good RF engineer if he walked in the door. This invisible job market is a bad sign —while it is evidence that there are lots of RF jobs to be had, it shows that the industry has almost given up on finding all the RF help it needs!

RF engineering needs a better "selling job" to students and educators at all levels. We should remind them that the fastest growing areas of all electronics right now are personal communications, data communications, and high speed digital applications. The first of these is all RF, the second is partly RF, and the third can benefit greatly from engineers with RF expertise.

Let's all try to remind our children's schools, our alma mater, and anyone else who cares to listen, that RF is a fascinating and in-demand area of engineering.

NOISE/COM

"NOISE IS OUR ONLY BUSINESS"

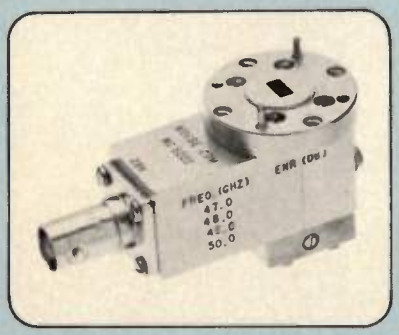
Broad Band Noise Sources

For Space, Military and Commercial Applications

DC-50 GHz

Broad Band Precision, Calibrated Waveguide

WR-22,-28,-42



TYPICAL STANDARD MODELS	
NC 5100 Series	up to 50 GHz 15.5 dB ENR, noise figure meter compatible
NC 5200 Series	up to 50 GHz 21-25 dB ENR, high noise output
NC 5300 Series	up to 50 GHz 21-25 dB ENR, high noise output

For More Information And Quick Response Call:

GARY SIMONYAN at 201-261-8797

Broad Band Instruments

115V or 230V Standard
Bench Type or Rack Mounted

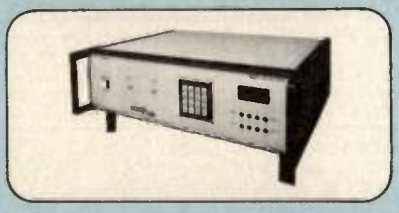
MANUALLY CONTROLLED
+ 10 dBM Output

TYPICAL STANDARD MODELS	
NC 6101	up to 20 kHz
NC 6107	up to 100 MHz
NC 6108	up to 500 MHz
NC 6109	up to 1 GHz
NC 6110	up to 1.5 GHz
NC 6111	up to 2 GHz
NC 6218	up to 18 GHz

Other standard models available
MOST ARE IN STOCK

PROGRAMMABLE

IEEE-488 (GPIB), MATE (CIIL)
RS232, etc. + 10 dBM Output



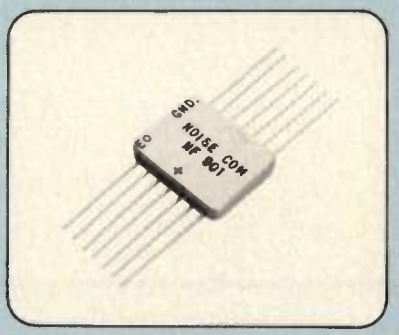
TYPICAL STANDARD MODELS	
NC 7101	up to 20 kHz
NC 7107	up to 100 MHz
NC 7108	up to 500 MHz
NC 7109	up to 1 GHz
NC 7110	up to 1.5 GHz
NC 7111	up to 2 GHz
NC 7218	up to 18 GHz

OPTIONAL: Remote variable filters, signal input combiner, 75 ohms output, marker input.
Other standard models available
MOST ARE IN STOCK

Custom & Hi Rel Products

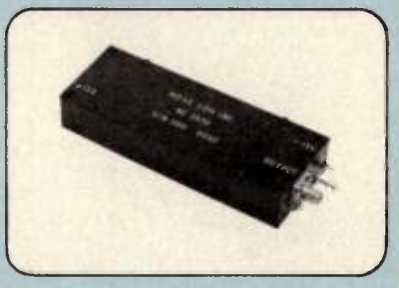
HYBRID FOR SPACE QUALIFIED AMPLIFIED MODULES

10 Hz to 10 MHz, 7 GHz, 9 GHz, 14 GHz etc. Small size and weight



DC COUPLED AMPLIFIED MODULES

- 1 volt output into 50 ohms
- DC-100 kHz
- Low offset voltage
- Compact
- DC-4 MHz



NOISE/COM

"NOISE IS OUR ONLY BUSINESS"

NOISE COM, INC.
E. 49 Midland Ave.
Paramus, NJ 07652

PHONE (201) 261-8797
FAX (201) 261-8339
TWX 910-380-8198

INFO/CARD 5

RF design

a Cardiff publication Established 1978

Main Office:
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111 • (303) 220-0600
Fax: (303) 773-9716

Publisher
Kathryn Walsh

Editor
Gary A. Breed

Associate Editor
Liane Pomfret

Consulting Editor
Andy Przedpelski

Associate Sales Manager
Bill Pettit

Account Executive
Maryanne Averill
Main Office

Account Executive
Cindy Wieland
Main Office

Editorial Review Board
Alex Burwasser
Doug DeMaw
Dave Krautheimer
James W. Mize, Jr.
Robert J. Zavrel, Jr.
Ed Oxner
Andy Przedpelski
Jeff Schoenwald
Raymond Sicotte

Advertising Services
Tisha Boberschmidt Hill

Secretary
Theresa Maier

Convention Manager
Kristin Hohn

Registration Coordinator
Dawn Keith

Exhibits Coordinator
Barb Binge

Trade Show Account Executive
LeAnn Nowacki

Associate Production Managers
Matt Park
Maurice Lydick

Artists
Kim Austin
Joyce Fields
Brad Fuller
Paul Rivera
Sheri Ryder

Composition
Mike C. Moore
Marcie Tichenor

Creative Director
Bob Stewart

Published by

CARDIFF PUBLISHING COMPANY, INC.

BPA

President
Robert A. Searle

Vice President — Production
Cherryl Greenman

Vice President — Convention Management
Kathy Kriner

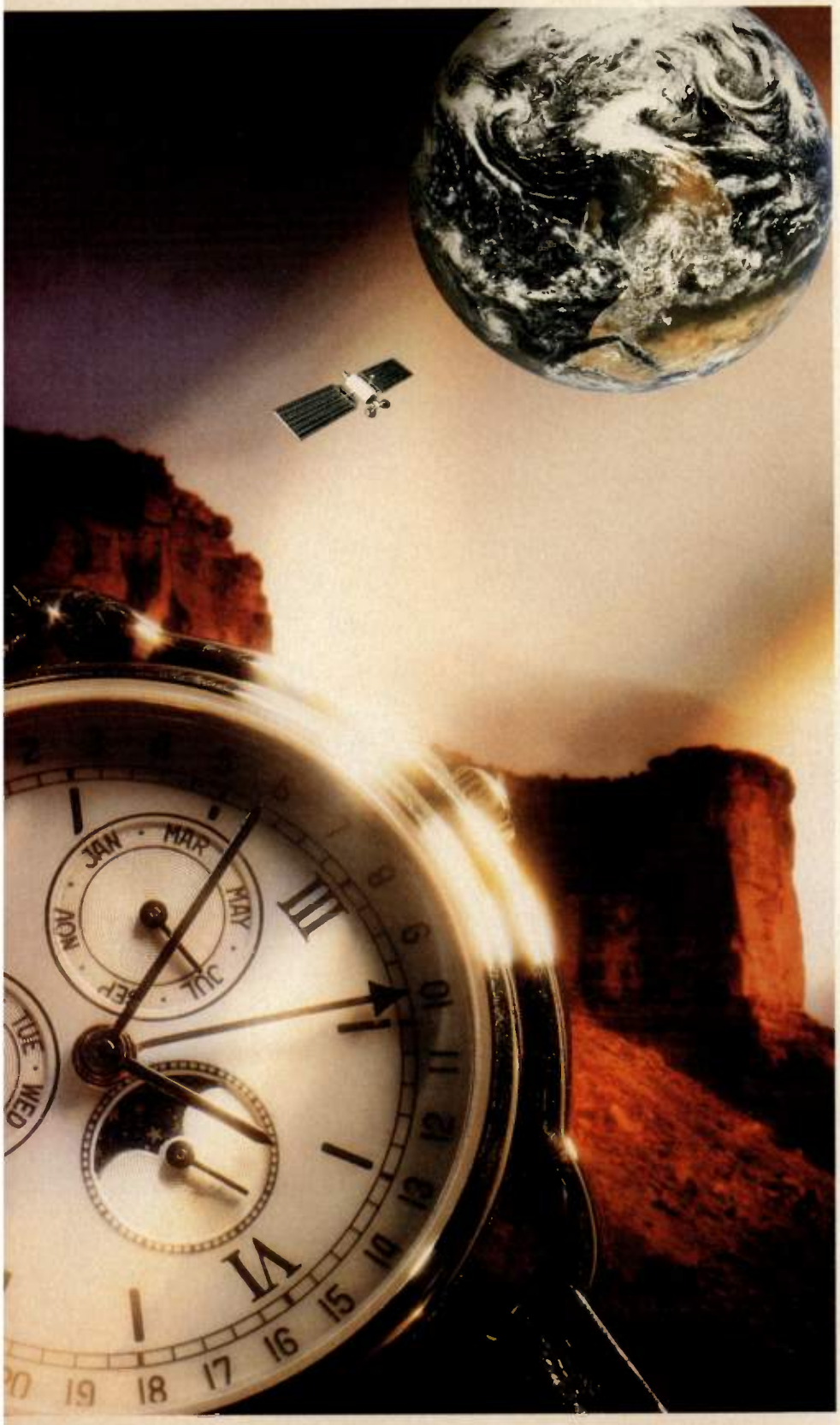
Treasurer
Jennifer Burger

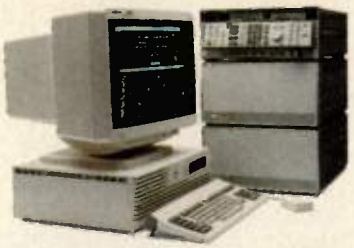
Circulation Director
Patricia Shapiro

Credit Manager
Patti McManness

Please address subscription inquiries to:
RF Design
P.O. Box 1077, Skokie, IL 60076-9931
Postmaster: send form 3579
to the above address.

For those who dream of suspending time in the rush to the communications market.





HP helps speed up design cycles by verifying models with real-life signals.

In communication systems labs today, the focus is on improving time-to-market. Comdisco CAE software tools help by creating complex signals to verify models at the design simulation stage. Now, HP's 11755A takes verification a crucial step further, by linking CAE modeling with real-life test equipment to quickly and accurately test brassboards after simulation.

The HP 11755A RF simulator WorkSystem driver provides the link between Comdisco and the HP Vector Arbitrary Waveform Synthesizer. It lets you use real-world signals (10 to 3000 MHz with precision impairments) in the lab to test designs at the earliest possible stage. You get the test results you need to uncover deficiencies and modify designs fast. To speed up design iterations, just download your software signal formats and link testing with CAE software.

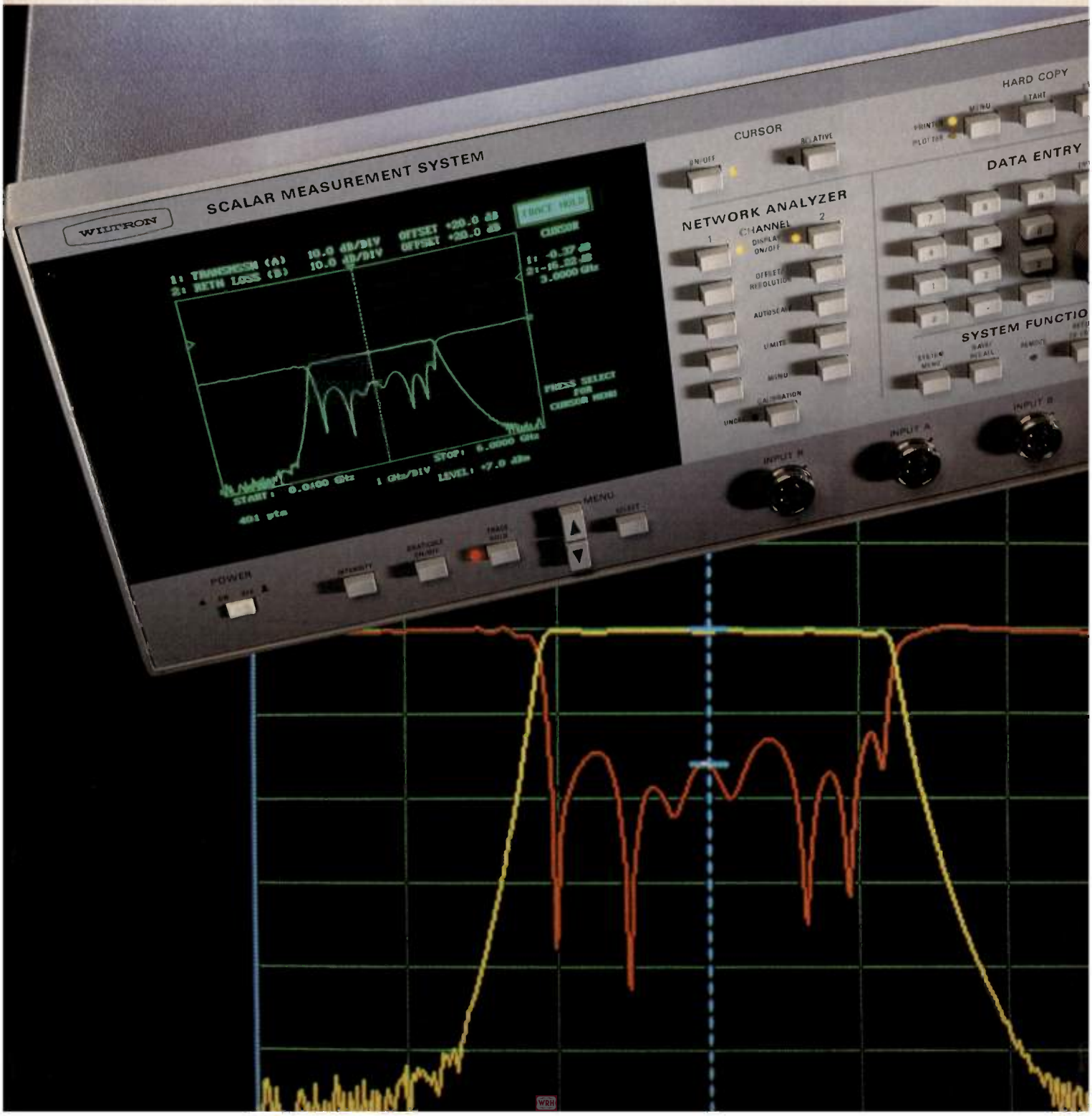
So, if you've ever wished you could suspend time in your communications systems design cycle, call **1-800-452-4844.** Ask for **Ext. 2410,** and we'll send you a brochure explaining how the HP 11755A can help make your dream come true.

There is a better way.

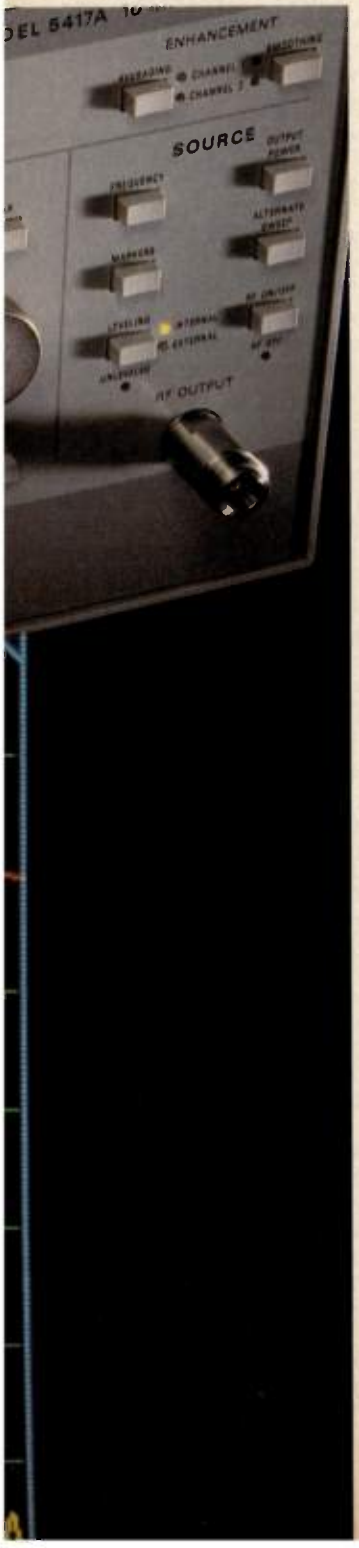
HEWLETT PACKARD

INFO/CARD 8

The Scalar Analyzer Your Savings

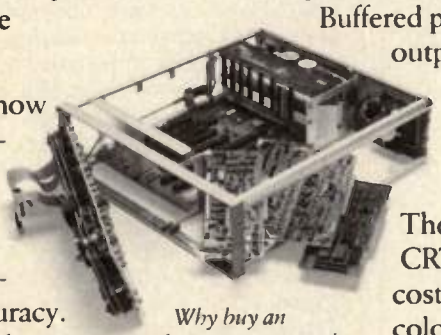


with Built-in Source: Are Obvious.



There's no costly hardware duplication. No second front panel to learn. And no compatibility issues to worry about. Just what you need to get the job done.

You'll discover how fast, easy and cost-effective scalar testing can be. The proprietary source has synthesized sweeper accuracy. Yet the cost is less than an ordinary scalar analyzer and sweep generator combination!



Why buy an extra frame, power supply, keyboard, display, logic, and more?

Frequency Coverage To Meet Your Needs.

Six models are available for applications in direct broadcast and satellite communications, terrestrial communications, military radar and many others: 10 MHz to 8.4 GHz, 2 to 8.4 GHz, 8 to 12.4 GHz, 10 to 16 GHz, 12.4 to 20 GHz, and 17 to 26.5 GHz.

Performance Is Not Compromised.

The analyzer gives you 71 dB dynamic range. Powerful marker and cursor features reduce operator errors. Smoothing and averaging improve dynamic range. Trace memory and custom X-axis labeling show results in your terms. Buffered printer and plotter outputs speed report generation.

Color VGA Output Saves, Too.

The crisp monochrome CRT minimizes system cost and size. A built-in color VGA output provides large screen capability at minimal cost.

Optional Capabilities To Meet Any Need.

The GPIB interface allows automated testing. External leveling provides flat power when external amplifiers are used to drive transmitters into compression. Reference channel maintains calibration as power is varied.

Request a Wiltron 5400A data sheet today. Power and value make it the obvious choice.

Contact: Wiltron Company, 490 Jarvis Drive, Morgan Hill, CA 95037 USA. Or call (408) 778-2000.

WILTRON

INFO/CARD 9

RF letters

Letters should be addressed to: Editor, *RF Design*, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111.

A "BASIC" for Engineers

Editor:

I still think that the old HP-80-series computer with the built-in BASIC and graphics was one of the best systems for an engineer who had to do occasional programming to support his work. But, it was slow! For some time now, computer programmers were trying to talk me into getting an "IBM-compatible." However, I was not going to give up the convenience of having a "built-in" pi, both logs (how can you do dBs without logs to the base 10!) and other conveniences I was used to. Nevertheless, the higher available speed of the compatible was enticing. So, I kept on looking for a good scientific BASIC.

One day somebody told me about a BASIC for engineers very similar to HP's: the HTBASIC from TransEra in Provo, UT. The obliging people at TransEra sent me a demo disk. It looked good! But, at about $800 for a 386 computer, it was more than I wanted to pay for occasional use. I think that if I did more programming, I would seriously consider it.

One night after dinner, a friend of mine, having heard my complaint, took me to his computer and showed me a BASIC that seemed to do what I wanted. But, it was running on a Mac. I called the True BASIC people in West Lebanon, NH and was advised that, yes, TrueBASIC is available for compatibles and Amiga, as well as the Mac. For about $100 I could have one. The program was developed by Kemeny and Kurtz [*the authors of Dartmouth BASIC*] and, therefore, should be good. I was quite pleasantly surprised by its performance. Not only did it have pi and logs (natural and to the base 2 and 10), but also other useful features.

It differs from HP's by not telling you the errors as you enter the lines, but when you try to run it. It also allows you to store a faulty program for debugging at a later time without using ! or REM. It also has more features than the old HP. For instance, DO FORMAT will format your program so that it looks good and is easier to read. All FOR ... NEXT are indented, remarks are lined-up, etc. While the core TrueBASIC is quite satisfactory for most applications, I like the ease of programming using complex numbers instead of doing it the "long way." For about $80 I got the "Mathematician's Toolkit." It allows high precision arithmetic, complex number arithmetic, high precision and complex matrix operations and formula evaluation. It is loaded together with TrueBASIC and provides all of these additional functions. I thought I had it made!

But, when I tried to plot some functions, while the curves could be easily drawn with the basic TrueBASIC, they did not have the refinements of the HP built-in graphics. For another $80 I got the "Scientific Graphics." It is also loaded together with TrueBASIC and provides many graphics possibilities: linear axis, log (one or both), color, titles, dotted, dashed grids and/or curves, points etc. It will also do curve fitting. While this sounds complex, it actually is not. The program scales the axes to fit the data and locates the titles where it thinks they should be. However, if you want to, most of these can be customized. The only thing it will not do is 3-D. That is another $80 ("3-D Graphics Toolkit").

The nice feature of their approach is the low initial cost and possibility of customizing the software, at a future time, to meet your specific needs. In addition to the above mentioned enhancements, many others are available. The people at True BASIC are very helpful in explaining some of the features of the different programs to make your selections easier. The three above mentioned programs are all I need at the present time. But should I need others, I know they are available (for about $80 each).

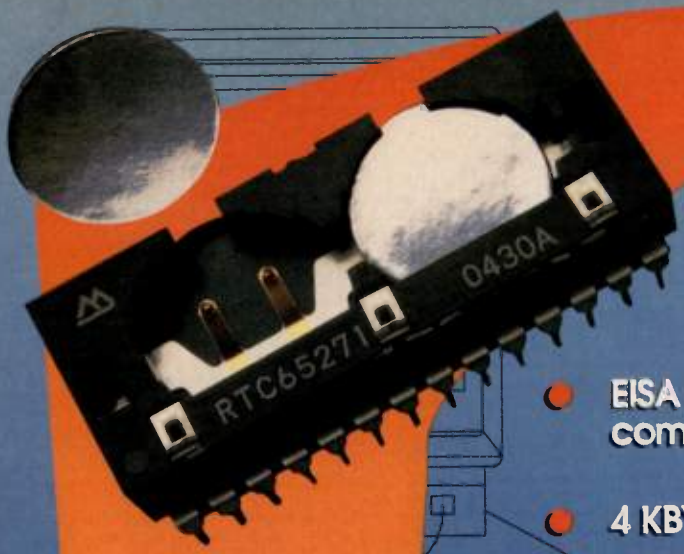
Nothing is perfect, however. Some of the manuals are not as clear as HP's. But, the people at True BASIC are always glad to help out. If you do a lot of programming you may also want to investigate the TransEra HTBASIC. It may suit your needs better, but at a higher cost. To me, they both beat the "standard" BASICs.

By the way, I am also using DR-DOS, rather than MS-DOS. I think that it is more useful.

Andrzej Przedpelski
A.R.F. Products

Directional Couplers Correction

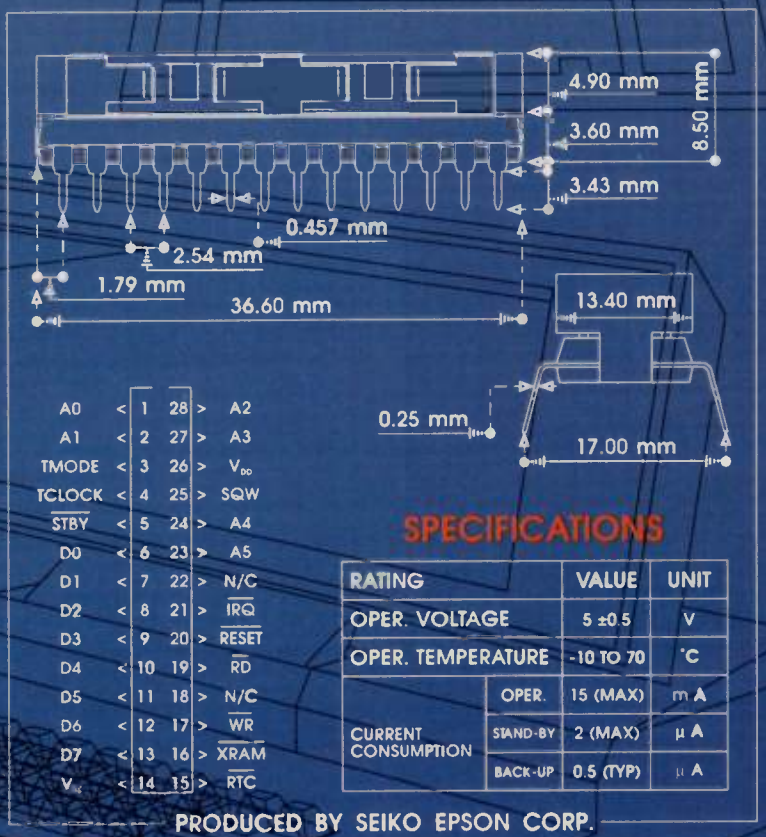
In Mark Mc Whorter's article, "Broadband RF Transformer Directional Couplers," July, 1991, there is an incorrectly labeled equation. Equation 7, page 54, should be identified as Isolated Port Current and not Coupled Port Current.



EPSON
PRESENTS ANOTHER
LEADING TECHNOLOGY
PRODUCT:

PC COMPATIBLE REAL TIME CLOCKS

- EISA BUS COMPATIBLE (µC and AT/XT compatible available soon)
- 4 KBYTES OF SRAM MEMORY
- CRYSTAL AND OSCILLATION CIRCUIT BUILT IN
- COMPARTMENT FOR 2 REPLACEABLE BATTERIES
- BASIC MOTOROLA RTC FUNCTION COMPATIBLE



A0	<	1	28	> A2
A1	<	2	27	> A3
TMODE	<	3	26	> V_{DD}
TCLOCK	<	4	25	> SQW
$\overline{STBY}$	<	5	24	> A4
D0	<	6	23	> A5
D1	<	7	22	> N/C
D2	<	8	21	> $\overline{IRQ}$
D3	<	9	20	> $\overline{RESET}$
D4	<	10	19	> $\overline{RD}$
D5	<	11	18	> N/C
D6	<	12	17	> $\overline{WR}$
D7	<	13	16	> $\overline{XRAM}$
V_{SS}	<	14	15	> $\overline{RTC}$

SPECIFICATIONS

RATING		VALUE	UNIT
OPER. VOLTAGE		5 ±0.5	V
OPER. TEMPERATURE		-10 TO 70	°C
CURRENT CONSUMPTION	OPER.	15 (MAX)	m A
	STAND-BY	2 (MAX)	µ A
	BACK-UP	0.5 (TYP)	µ A

PRODUCED BY SEIKO EPSON CORP.

EPSON®

EPSON AMERICA, INC.
COMPONENT SALES DEPARTMENT
TEL: 213.787.6300
FAX: 213.782.5320

INFO/CARD 11

WRH

RF calendar

August

13-15 **IEEE 1991 International Symposium on Electromagnetic Compatiblity**
Cherry Hill, NJ
Information: IEEE International Sympsium on EMC, PO Box 609, Lincroft, NJ 07738. Tel: (201) 386-2378.

18-21 **The 3rd International Symposium on Recent Advances in Microwave Technology**
Reno, Nevada
Information: Banmali Rawat, Chairman, Technical Program Committee, Electrical Engineering and Computer Science Department, University of Reno, Nevada, Reno, NV 89557-0030. Tel: (702) 784-6927. Fax: (702) 784-1300.

25-29 **Surface Mount International**
San Jose, California
Information: Surface Mount International, 1050 Commonwealth Ave., Boston, MA 02215 or Miller Freeman Exhibitions, Tel: (800) 223-7126 or (617) 232-3976.

September

2-5 **Sixth International Conference on Digital Processing of Signals in Communications**
Loughborough, United Kingdom
Information: Secretariat, Conference Services, IEE, Savoy Place, London WC2R OBL, United Kingdom. Tel: 071 240 1871 ext. 222.

5-10 **12th IMEKO World Congress**
China International Conference Center, Beijing, China
Information: Mr. Shi Shangping, IMCI '91 Office, China International Conference Center for Science and Technology, P.O. Box 300, Beijing 100086, China. Tel: (86) (1) 8313335.

9-10 **1991 IEEE Bipolar Circuits and Technology Meeting**
Marriott Hotel, Minneapolis, MN
Information: Janice Jopke, Conference Coordination Services, 6611 Countryside Drive, Eden Prairie, MN 55346. Tel: (612) 934-5082.

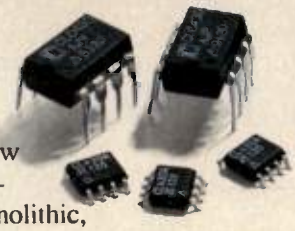
9-12 **21st European Microwave Conference**
The International Congress Centre, Stuttgart, Germany
Information: Microwave Exhibitions and Publishers Ltd., 90 Calverley Road, Tunbridge Wells, Kent TN1 2UN, United Kingdom. Tel: (44) 0 892 544027. Fax (44) 0 892 541023.

11-14 **Radio '91**
Moscone Convention Center, San Francisco, CA
Information: Radio 1991 Convention Registration, 1771 N Street, NW, Washington, DC 20036-2891. Tel: (800) 342 -2460. Fax: (202) 775-2146.

15-19 **1991 Electronics Packaging Conference**
Sheraton Harbor Island Hotel, San Diego, CA
Information: International Electronics Packaging Society, 114 N. Hale Street, Wheaton, IL 60187-5113. Tel: (708) 260-1044. Fax: (708) 260-0867.

Because you're thinking fast...

Now, the price and performance you want in 15V video op amps.



Here's great news for designers of 15V systems. Comlinear now offers its technology in monolithic, 15V video op amps. And, at a very attractive price.

Better video specs... lower price.

Immediately available, and priced at just $2.54* in 1000s, the new 55MHZ CLC430 offers a lower-cost alternative for professional video applications. What's more, it delivers differential gain/phase of 0.02%/0.04°, plus superior multiple-load performance to meet the demanding standards of composite video... reliably and consistently.

It gives designers of high-speed signal processing systems a fast 2000V/us slew rate and 35ns settling time to 0.05%. Plus a high-speed disable/enable feature, making it ideal for video switching and multiplexing applications. All in an industry-standard DIP pinout, or a space saving 8-pin SOIC package.

So take advantage of the latest in Comlinear's growing family of video products. Call today for details.

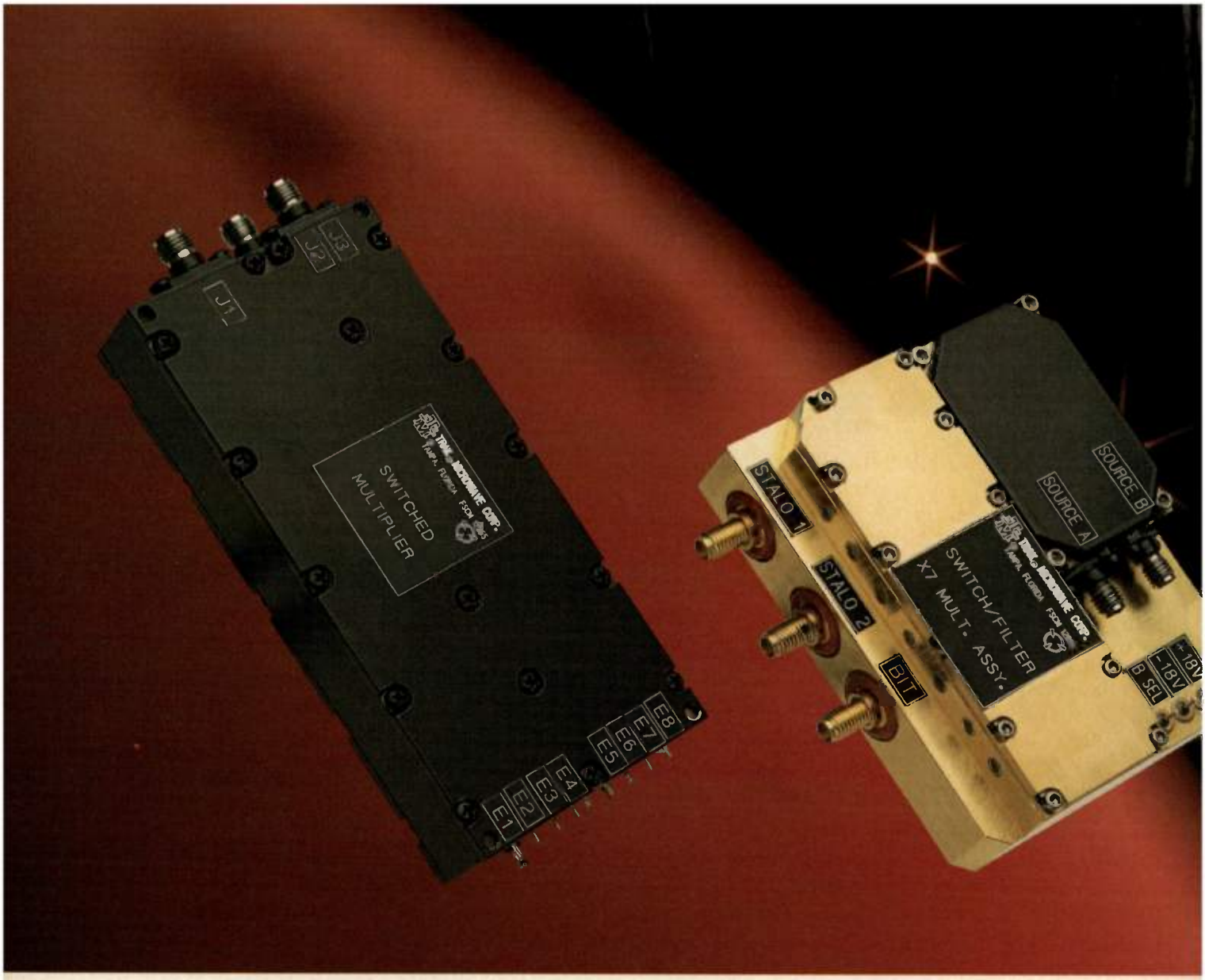
*U.S. price only

INFO/CARD 13

Comlinear Corporation

Solutions with speed

4800 Wheaton Drive
Fort Collins, CO 80525
(303) 226-0500
1-800-776-0500 (USA)



YOUR BEST SWITCH COULD BE MADE BY PICKING UP THE TELEPHONE

NOW'S THE TIME TO CONSIDER OTHER SOURCES.

The defense industry is regrouping. Marginal players are being shaken out. And the house you worked with last week may not be there tomorrow. Good reasons to consider switching to a steady, reliable supplier.

TRAK IS A RELIABLE, 30-YEAR VETERAN

We're a vertically-integrated, full-service, DoD supplier. We design and build our own microwave/RF products — from individual components to complete subsystems. And we deliver them on spec, on time, and on budget.

CONSIDER SWITCHING TO TRAK PRODUCTS

Like our switched filter banks, offering unusually high performance in a small package. Or our switched multipliers, featuring rugged microstrip circuitry in a small, low-weight envelope. And if you don't find what you want in our catalogs, call us anyway — we've got products in mind we haven't built yet, just waiting for someone like you to need them.

BUT WHATEVER YOU'RE WORKING ON, BE SURE OF YOUR SUPPLIER. THAT'S WHY IN TIMES LIKE THESE, IT'S TIME TO THINK TRAK.

Call or write for our Free Components Catalogs. See EEM or MPDD for other TRAK military products.

TRAK MICROWAVE
CORPORATION
Microwave Sales
4726 Eisenhower Blvd.
Tampa, Florida 33634-6391
Phone: (813) 884-1411
TLX: 52-827
FAX: 813-886-2794

TRAK MICROWAVE LTD.
Microwave Sales
3/4 Lindsay Court
Dundee, Scotland DD2ITY
Phone: (44) 382-561509
TLX: (851) 76266
FAX: (44) 382-562643

TRAK MICROWAVE CORPORATION

THINK TRAK

TOTAL QUALITY LEADERSHIP

INFO/CARD 14

RF courses

Designing for Surge and Transient Immunity in Electronic and Computer Systems
September 9-12, 1991, Madison, WI
Technical Cellular
September 16-19, 1991, Madison, WI
Information: University of Wisconsin — Madison, Francis P. Drake. Tel: (608) 262-2061. Fax: (608) 263-3160.

Electromagnetic Interference: Characteristics and Control
August 20-22, 1991, Boston, MA
Information: University of Wisconsin — Milwaukee, NonCredit Registration. Tel: (414) 227-3200. Fax: (414) 227-3119.

Advanced Communications Systems Using Digital Signal Processing
August 19-23, 1991, Los Angeles, CA
Analog MOS Integrated Circuits
September 16-20, 1991, Los Angeles, CA
Airborne and Spaceborne Radars: Surveillance, Tracking, and Imaging
September 16-20, 1991, Los Angeles, CA
Information: UCLA Short Course Program Office. Tel: (213) 825-3344. Fax: (213) 206-2815.

Modern Electronic Defense
August 21-23, 1991, Atlanta, GA
Information: Education Extension, Georgia Institute of Technology. Tel: (404) 894-2547.

Digital Cellular Telephony for Mobile Applications
August 26-30, 1991, Washington, DC
Introduction to Radar ECM and ECCM Systems
September 4-6, 1991, Washington, DC
Microwave Radio Systems
September 4-6, 1991, Washington, DC
Antennas: Radiation and Scattering
September 5-6, 1991, Washington, DC
Modern Receiver Design
September 9-13, 1991, Washington, DC
Broadband Communication Systems
September 16-20, 1991, Washington, DC
Information: The George Washington University, Continuing Engineering Education, Merril A. Ferber. Tel: (202) 994-8522 or (800) 424-9773.

Fiber Optic Communications
October 7-9, 1991, Tempe, AZ
Information: Center for Professional Development, Arizona State University. Tel: (602) 965-1740.

Switched Mode Power Supplies
September 11-13, 1991, Edinburgh, United Kingdom
Information: Eumos, Ltd., Edith Field. Tel: (44) 031 650 3473. Fax: (44) 031 662 4061.

Electromagnetic Compatibility
September 15-20, 1991, Canterbury, United Kingdom
Microwave Measurements
September 22-27, 1991, Canterbury, United Kingdom
Information: The Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, UK.

Seminar in EMI Software (EMCAD1)
August 21-22, 1991, Mariposa, CA

Advanced HIRF Seminar for Commercial Flight Applications
September 24-26, 1991, Mariposa, CA
Design Seminar: Principles of EMC
November 5-7, 1991, Mariposa, CA
Information: CKC Laboratories, Registrar. Tel: (209) 966-5240. Fax: (209) 742-6133.

Digital Signal Processing Workshop
September 11-13, 1991, Norwood, MA
October 15-17, 1991, Campbell, CA
Information: Analog Devices, Maria Butler. Tel: (617) 461-3672.

Fiber Optical Communication Technology and Systems
August 26-30, 1991, Switzerland
Modern Digital Modulation Techniques
October 14-18, 1991, Spain
Broadband Telecommunications
October 14-18, 1991, Spain
Information: CEI-Europe/Elsevier, Mrs. Tina Persson, Box 910, S-612 01 Finspong, Sweden. Tel: +46 (0) 122-17570. Fax: +46 (0) 122-14347.

Electromagnetic Propagation
August 20-22, 1991, Syracuse, NY
Adaptive ECCM Signal Processing for Radar and Sonar
September 10-12, 1991, Syracuse, NY
ELINT Analysis
September 10-12, 1991, Syracuse, NY
ELINT Interception
September 17-19, 1991, Syracuse, NY
ELINT/EW Applications of Digital Signal Processing
September 17-19, 1991, Syracuse, NY
Integrated EW
September 24-25, 1991, Syracuse, NY
ELINT/EW Data Bases
September 24-26, 1991, Syracuse, NY
Radar Vulnerability to Jamming
October 1-2, 1991, Syracuse, NY
Information: Research Associates of Syracuse. Tel: (315) 455-7157.

Designing for EMC
August 22-23, 1991, New York, NY
September 24-25, 1991, Washington, DC
Basic Network Measurements Using the 8510B Network Analyzer
September 10-12, 1991, Boston, MA
September 17-19, 1991, Atlanta, GA
September 30-October 2, 1991, Los Angeles, CA
Microwave Fundamentals
September 16-19, 1991, Los Angeles, CA
Information: Hewlett-Packard Company. Tel: (714) 999-6700.

DSP Without Tears
September 3-5, 1991, Ft. Lauderdale, FL
Information: Right Brain Technologies. Tel: (404) 420-3834. Fax: (404) 967-1672.

Practical EMI Fixes
September 16-20, 1991, San Diego, CA
EMC Design and Test
September 23-27, 1991, Las Vegas, NV
Information: Interference Control Technologies, Registrar. Tel: (703) 347-0030.

NEW from KALMUS...

Model 710FC

- ★ 10 Watts Output
- ★ 1-1000 MHz Broadband
- ★ 40 dB Gain
- ★ 10 dB Gain Adjust
- ★ Only 16 Pounds
- ★ MOS-FET Efficiency
- ★ 19" Rack Adapters Included

UP TO

200W/1000MHz LINEAR RF AMPLIFIER SYSTEMS

MODEL	POWER OUT	FREQUENCY RANGE	GAIN	SIZE (CM)	WEIGHT	AC LINE	U.S. PRICE $
700LC	1.5W CW	.003-1000 MHz	33dB	25x28x13	3.3kg	100-240V	$ 1,695
704FC	4W CW	.5-1000 MHz	33dB	23x18x09	2.8kg	100-240V	$ 2,195
706FC	6W CW	.5-1000 MHz	36dB	25x28x13	3.3kg	100-240V	$ 3,195
410LC	10W CW	.006-400 MHz	43dB	30x35x13	4.5kg	100-240V	$ 4,600
710FC	10W CW	1-1000 MHz	40dB	30x35x13	7.3kg	100-240V	$ 6,695
727LC	10W CW	.006-1000 MHz	43dB	48x46x13	8.5kg	100-240V	$ 7,750
711FC	15W CW	400-1000 MHz	40dB	30x35x13	5.5kg	100-240V	$ 3,620
720FC	25W CW	400-1000 MHz	40dB	48x46x13	8.6kg	100-240V	$ 5,995
712FC	25W CW	200-1000 MHz	40dB	48x46x13	8.8kg	100-240V	$ 7,350
737LC	25W CW	.01-1000 MHz	45dB	48x46x13	10.5kg	100-240V	$ 9,995
747LC	50W CW	.01-1000 MHz	47dB	48x46x26	26.5kg	100-240V	$22,500
707FC	50W CW	450-1000 MHz	47dB	48x46x13	13.0kg	100-240V	$ 9,995
709FC	100W CW	500-1000 MHz	48dB	44x48x18	22.5kg	100-240V	$19,990
722FC	200W CW	500-1000 MHz	50dB	44x18x31	41.5kg	100-240V	$31,900

Note: Models 727LC, 737LC and 747LC consist of two bands with one common input and output connector, switched with coaxial transfer relay, manually, or by remote. Switching speed 5 milliseconds.

MODEL 704FC

MODEL 707FC

21820 87TH SE
WOODINVILLE, WA 98072

KALMUS
Engineering International, Ltd., U.S.A.

(206) 485-9000
FAX: (206) 486-9657

INFO/CARD 15

EM Compatibility Superchamber

The National Institute of Standards and Technology has developed a new type of test chamber for evaluating the electromagnetic compatibility of a wide range of products. The new chamber combines the features of two systems commonly used for this type of test — a transverse electromagnetic cell and a reverberating chamber. This combination provides a test capability over the 10 kHz to 40 GHz frequency range. This method will also provide great cost savings in performing these measurements. The first chamber has been developed for the U.S. Army and measures 1.3 by 2.4 by 3.9 meters. While this chamber will be used for testing Army electronic equipment, the concept has direct application to commercial products. *Measurement and Evaluation of a TEM/Reverberating Chamber* (TN1342) summarizes results and is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Order by stock no. 003-003-030355-4 for $5.50 prepaid.

Electric Field Strengths to be Compared — The International Bureau of Weights and Measures has asked NIST to be the pilot laboratory for an international intercomparison of electric field strengths at frequencies between 300 MHz and 10 GHz. Such a comparison is needed to show consistency among national standards laboratories, which will be particularly important next year when the 12-nation European Economic Community will require imports to meet standards for electromagnetic compatibility. In addition to the United States and nations of the EC, other countries participating include Japan, Korea, Taiwan, Switzerland, Poland, Austria, the U.S.S.R. and Australia. NIST will supply each country with electric field sensors, which will be tested at a minimum of four frequencies.

Recession Slows Research Growth — A recent annual survey from *Inside R&D* indicates that research and development spending for 1990 increased just 6.3 percent as opposed to 8.7 percent for 1989. These figures are taken from the Top 100 spenders on research and development among United States corporations. But according to the report, spending more on research pays off. For the Top 100 research spenders, 1990 sales were up 9.2 percent and profits were down only 4.4 percent, while for the whole Fortune 500, 1990 sales were up only 6.4 percent and profits were down 11.7 percent. More companies are looking at universities, government labs, other companies, and abroad for the technologies they need rather than insisting on doing it all in their own labs. Emphasis is on research projects with a quick payoff and longer term projects are being put on the back burner.

Revised Schedule for HDTV — A revised calendar has been released for testing the six advanced television transmission systems under consideration by the FCC Advisory Committee and scheduled for laboratory testing at the

New from Narda

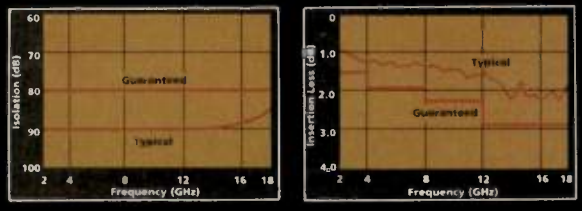
Highest performing PIN switches on the market.

The new Narda line of Super-Slim™ PIN switches is setting new industry standards for performance.

High isolation models, for example, deliver 80 dB plus low insertion loss over the 2-18 GHz range. Guaranteed.

What's more they do it from -54C to +95C. Also guaranteed.

Take an example – the SPDT Model SS123DHS-80. With a speed of 15 nsec, it delivers the following performance:



Another example is our transfer switch, Model XSS323DHS. It operates in 35 nsec and provides a minimum of 60 dB isolation.

The product line includes reflective, absorptive and transfer models.

All models are only 0.25" thick and have removable connectors for drop in applications.

The Super-Slim switches are ideal for demanding applications like EW, simulation and instrumentation.

Guaranteed delivery.
Guaranteed performance.

All Slim-Line switches are available off the shelf or on a guaranteed delivery schedule. Like all Narda Microwave devices, each is tested individually to guaranteed specs.

For more information, call or write Loral Microwave-Narda, 435 Moreland Road, Hauppauge, New York 11788.
Tel: (516) 231-1700. Fax: (516) 231-1711.

Visa and MasterCard accepted.

VISA MasterCard

LORAL
Microwave-Narda

INFO/CARD 17

Advanced Television Test Center. This calendar replaces the one released earlier this year in light of the recent advent of several "all-digital" systems, and the resulting changes in test plans and the completion of testing facilities.

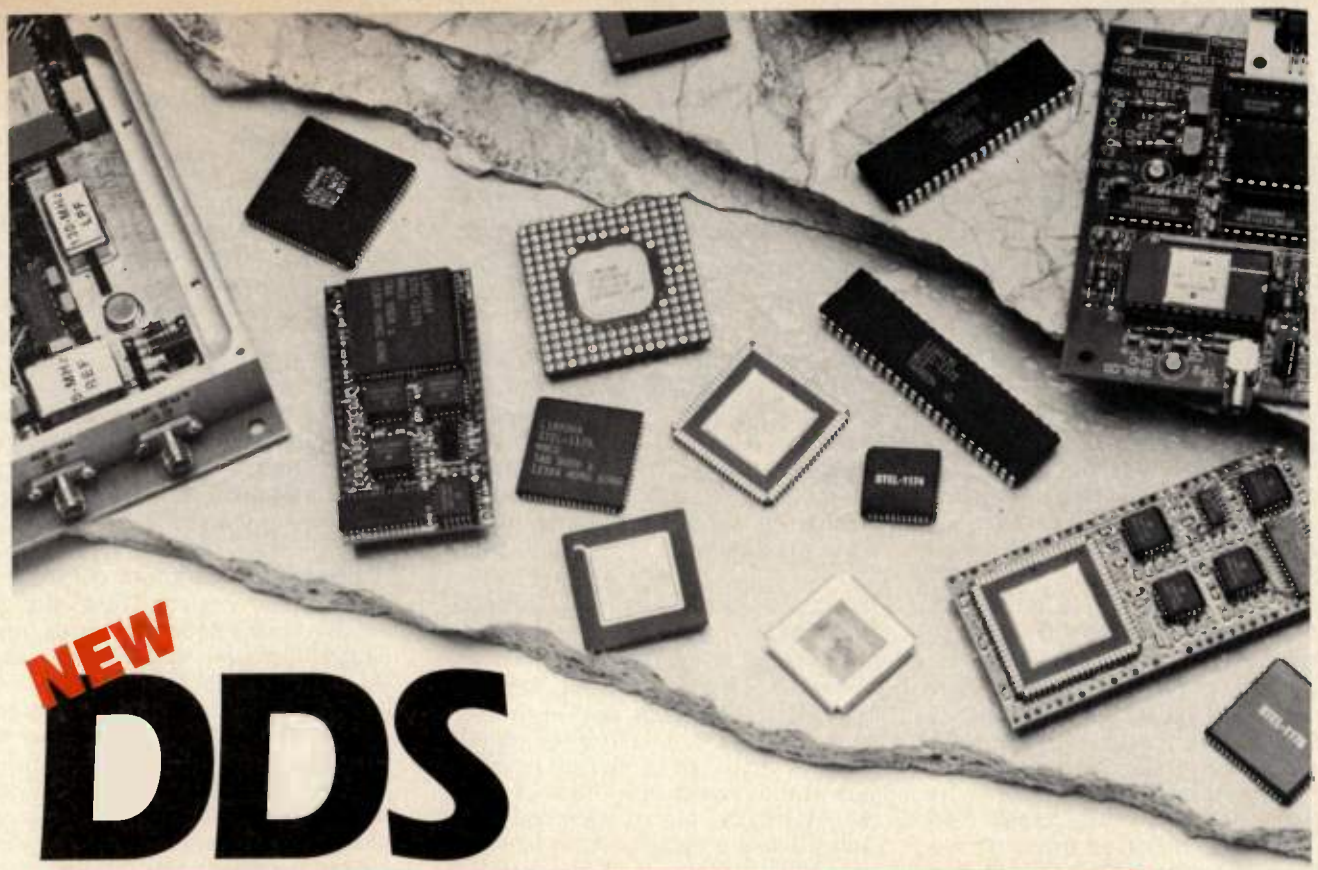
Software Grant to University of Illinois — EEsof recently announced a software grant to the University of Illinois at Urbana-Champaign in support of the University's educational programs for microwave and high-frequency circuit design. The company is providing 25 copies each of Academy® and Libra® software for the design and optimization of microwave linear and nonlinear circuits. The software will be used in support of such courses as: Microwave High-Frequency Circuit Design Using S-Parameters, Radio Communication Circuits, Microwave Devices and Circuits and Monolithic Microwave and Millimeter Wave Integrated Circuit Design.

EMC '92 Call for Papers — The Institution of Electrical Engineers (IEE) has issued a call for papers for the Eighth International Conference on Electromagnetic Compatibility, to be held in Edinburgh, Scotland, September 21-24, 1992. Papers are invited on all aspects of EMC, including but not limited to: case studies, equipment protection, shielding, instrumentation and measurement, EMP, and spectrum use and management. The deadline is September 13, 1991 and a one page synopsis may be sent to EMC '92, Conference Services, The IEE, Savoy Place, London, WC2R 0BL, United Kingdom. Tel: (44) 071-240-1871 ext. 222.

Superconducting Integrated Circuit — Researchers at Conductus, Inc. have successfully demonstrated the world's first integrated circuit containing active devices made from high-temperature superconductors. The circuit, a SQUID (Superconducting QUantum Interference Devices) magnetometer, contains seven layers of material which makes it the most complex circuit ever fabricated from high-temperature superconductors and demonstrates all the elements and techniques necessary to build even more complex ICs. The SQUID magnetometer circuit contains two main components, a SQUID sensor and a flux transformer integrated on the same chip.

Jerrold to Supply Olympics — Jerrold Communications has signed an agreement to furnish cable and distribution equipment for the 1992 summer Olympics in Barcelona, Spain. The company will install and maintain approximately 27 headends and distribution equipment during the course of the Games with on-site field support personnel. There will be a variety of event sites, including the Olympic Stadium, as part of an all-digital transmission system.

ARX Receives Multiple Contracts — The Comstron Division of Aeroflex Laboratories, an ARX Company has received over $4.3 million in awards from General Electric and Martin Marietta to produce synthesizers for the U.S. Navy's Consolidated Automated Support System (CASS). CASS is a



NEW DDS

PRODUCTS FOR DIRECT DIGITAL SYNTHESIS

Stanford Telecom . . .
continues to lead the way in providing the highest performance at the lowest cost.

These are but a few of the many outstanding products and prices available today and offered by Stanford Telecom for frequency synthesis and digital communications. For the highest performance and most cost effective solutions in integrated digital communications products, Stanford Telecom continues to stand out as the industry leader.

Call today to discuss how Stanford Telecom might become a member of your team.

STANFORD TELECOM®

ASIC Custom Products Group

2421 Mission College Boulevard
Santa Clara, California 95054-1298
Tel: (408) 980-5684 Fax: (408) 727-1482

MONOLITHIC NCOS

STEL-1172B	50 MHz, 32-bit, Quadrature
STEL-1173	50 MHz, 48-bit, High Resolution
STEL-1174	50 MHz, 16-bit, Low Cost
STEL-1175	60 MHz, 32-bit, Phase Modulated
STEL-1175/80	80 MHz, 32-bit, Phase Modulated NEW
STEL-1176	80 MHz, BCD/Decimal, High Speed CMOS
STEL-1177	60 MHz, 32-bit, full PM, FM, & Quadrature
STEL-1178	50 MHz, Dual NCO NEW
STEL-1179	25 MHz, Serial Input PM NCO, $5 in commercial quantities NEW
STEL-2172	300 MHz, ECL, 32-bit
STEL-2173	1 GHZ, GaAs, 32-bit, BPSK, QPSK

BOARD-LEVEL DDS

STEL-1272	based on 1172B, 0-20 MHz
STEL-1273	based on 1173, 0-20 MHz
STEL-1275	based on 1175, 0-25 MHz
STEL-1375A	miniature assembly based on 1175 MIL Spec version now available NEW
STEL-1376	miniature assembly based on 1176
STEL-1377	miniature assembly based on 1177 MIL Spec version now available NEW
STEL-1378	miniature assembly based on 1178 NEW
STEL-1277	based on 1177, 0-25 MHz
STEL-2272	based on 2172, 0-130 MHz
STEL-2273	based on 2173, 0-400 MHz
STEL-2373	based on 2173, 0-400 MHz - miniature hybrid NEW

CHASSIS-LEVEL DDS

STEL-9272	300 MHz Synthesizer based on 2172
STEL-9273	1 GHz Synthesizer based on 2173
STEL-9275	Synthesizer with 1 GHz internal clock NEW

multipurpose family of automated test equipment which is intended to support fleet aircraft electronics.

Architectural Shielding Agreement — Divisions of Monsanto Company and International Paper recently signed an agreement for the production and marketing of a new electromagnetic shielding material for architectural applications. The agreement calls for Monsanto to apply its patented process for Flectron metallized materials to metallize a variety of IP's nonwoven fabrics in Veratec's line of Saf N' Shielded products.

Dazix and AT&T Sign Joint Technology Agreement — Dazix has announced that it has signed a sole license agreement with AT&T Microelectronics to develop and market electronic design synthesis tools. Under the terms of the agreement Dazix will have the exclusive rights worldwide to sell, market and support the design synthesis tools developed by Bell Labs and the two companies will jointly develop high-level design synthesis tools for use in the future technologies.

Grumman Teams with Royal Ordnance PLC — Grumman Corporation has signed a memorandum of understanding with the Royal Ordnance PLC of the United Kingdom, Electronics and Precision Systems Division. The companies will pursue the Vehicular Intercommunication System production program for the U.S. Army's Communications Electronics Command. Terms of the agreement were not disclosed.

Motorola Wins Venezuela Cellular Network — Motorola's Radio-Telephone Systems Group has been selected by Telcel Celular of Caracas, Venezuela as the supplier of a countrywide cellular network. The AMPS 800 MHz system will be operational later this year in the metropolitan areas of Caracas, Maracaibo, Maracay and Valencia. Telcel Celular's initial order to Motorola for cellular infrastructure equipment is approximately $20 million.

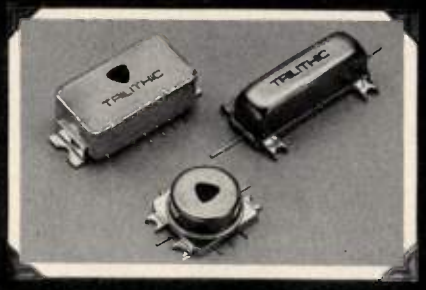
Teklogix and Dallas Systems Form Business Alliance — Teklogix, Inc. and Dallas Systems recently announced the formation of a strategic business alliance. The alliance will combine Teklogix's RF/DC terminal systems with Dallas Systems' distribution management software. Dallas Systems has specifically designed a system, the Distribution Center On-Board Terminal Application, to be used with Teklogix's line of RF products.

Licensing Agreement Signed — Texas Instruments and TranSwitch Corporation have signed a licensing agreement. Under terms of the agreement, TI will manufacture and market TranSwitch's line of VLSI circuits designed for operating in the DS3 and Synchronous Optical Network telecommunications environments. TI will manufacture certain TranSwitch VLSI components designed for switching, transmission and cross-connect applications and will

Trilithic Family Album

From our industry leading surface mount filters to our time-proven rotary and fixed pad attenuators, Trilithic is your source for a complete family of RF and microwave components. Our strict quality assurance standards apply to all product lines, whether your application is for high reliability military or field-tough commercial items. In addition, Trilithic's high stock volume ensures competitive pricing and availability, so call us toll-free at 800-344-2412, and get acquainted with our family.

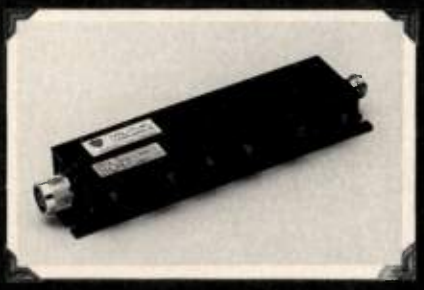
Miniature filters



Surface mount filters

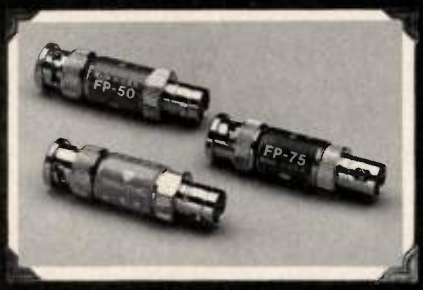
Tubular filters

Waveguide filters



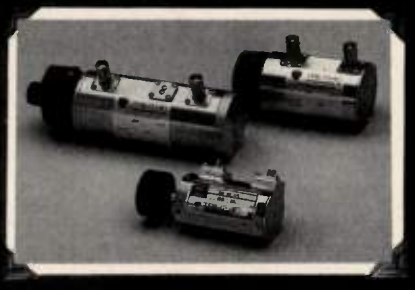
Cavity filters

Tunable filters

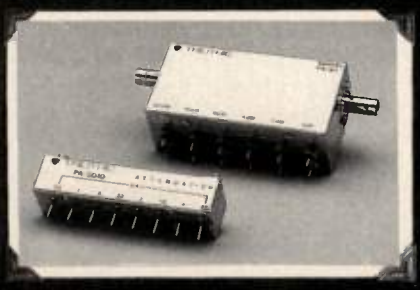


Coaxial attenuators

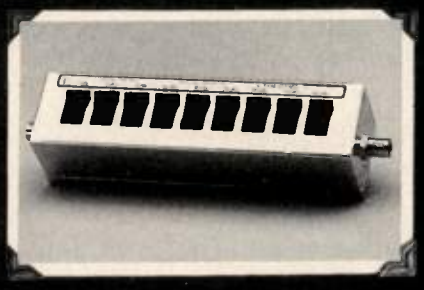
Pushbutton attenuators



Rotary step attenuators



Programmable step attenuators



Switch attenuators

Microwave coaxial attenuators

TRILITHIC

9202 East 33rd Street • Indianapolis, IN 46236
Phone: 317-895-3600 1-800-344-2412 FAX: 317-895-3613

be licensed to market specific TranSwitch products worldwide.

AEL Wins Production Contract — AEL Defense Corporation has been awarded a $1.7 million production contract by Raytheon Electromagnetic Systems Division. The contract calls for AEL's Microwave/Hybrid Division to produce Limiter/Switch/Filter, SPST and SPDT components for use in Raytheon's ALQ-184 (V) ECM pod. This is the third follow-on production option exercised by Raytheon.

Lucas Aerospace to Acquire Tracor Aviation —Lucas Aerospace announced that it has successfully obtained approval to acquire the operating assets of Tracor Aviation for a cash consideration of approximately $27 million. Tracor Aviation is a U.S. based company specializing in aircraft modification and maintenance services.

Maury Acquires Eaton Noise Line — Maury Microwave recently announced the acquisition of Eaton Corporation, Electronic Instrument Division's line of Noise Measurement Products. The acquisition includes all design information, inventory, and production equipment. Maury will be able to provide its customers with a comprehensive line of noise measurement products. Terms of the deal were not disclosed.

CAL Corp Buys Telemus Assets — CAL Corporation has purchased the assets of Telemus Electronic Systems Inc. Telemus' assets include work in process on several contracts, patents, custom designs, intellectual property, test and production equipment. The acquired technology will be used by CAL in the development of new product offerings which are projected to generate revenue somewhere between $3 and $10 million over the next twelve months. CAL Corporation also recently changed the name of their European subsidiary from Caltronic Systems Limited to CAL Systems Limited.

In-Flight Phone and Qualcomm Sign Contract — Qualcomm recently announced the signing of a contract with In-Flight Phone Corporation to provide OmniTRACS® satellite messaging units on aircraft outfitted with In-Flight's Phone and Information Centers. The contract supports the installation of the satellite communications system on airplanes as part of larger system designed to allow air-to-ground messaging capabilities from each seat in an aircraft.

Global Communications Opportunities — US West and DDI Corporation of Japan have announced the signing of an agreement to jointly pursue global communications opportunities, including the provision of roaming service for their cellular telephone customers traveling to Japan and the United States. The cellular telephones operated by US West and DDI are currently technologically incompatible. Under the new roaming agreement, DDI customers planning to visit the United States will pick up a US West Cellular telephone at a DDI office before departing Japan. The same process will apply to US West Cellular customers traveling to Japan.

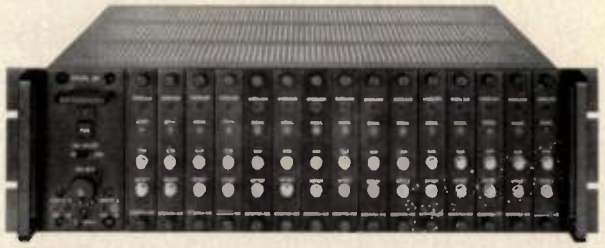
Specialized RF Products to Match Your Requirements

Apcom offers an extensive line of rf products designed to provide excellent performance characteristics at a competitive price. All products are designed for TEMPEST applications and may be easily customized for different operating frequencies and bandwidths.

Tunable frequency converters cover the range from 10 kHz to 10 MHz in 100 Hz increments. The input and output frequencies, plus the bandwidth, are entered with the front panel keypad or IEEE bus and are shown on separate digital displays. Additional features include image rejection mixers, automatic and manual gain control, and group delay compensation. Two converters may be operated in a master/slave mode; multiple converters may be controlled from a central point through the IEEE-488 bus.

IF to tape frequency converters feature push-button selection of four input and seven output frequencies, plus IEEE-488 control. Additional features include input and output level monitoring, selectable input attenuation, and manual or automatic gain control. Different units in the series cover many different frequencies. Additionally, a complete series of tape to IF converters are available.

Modular receivers provide a cost effective solution for extended term monitoring. Up to eight receivers plug into a standard 8¾ inch shelf. Covering the range of 20 to 520 MHz in 1 kHz increments, each receiver may be set for AM or narrow band FM detection. The common control module provides complete receiver control through IEEE-488, RS-422, or other bus protocols.



Analog and Digital distribution amplifiers provide multiple outputs from a single input. Different analog units cover the range from dc to the VHF band and feature adjustable input and output levels, signal detectors and loss of signal alarms. Digital units operate with data rates up to 10 Mbps with balanced or unbalanced inputs and outputs. Any combination of analog and digital amplifers may be plugged into the 15 slot enclosure.

Please contact Apcom at (301) 948-5900 for additional information on all of our different products and services. You will receive a copy of our current rf products catalog.

APCOM
INCORPORATED

APCOM INC.
8-4 Metropolitan Court
Gaithersburg, Maryland 20878
Phone: (301) 948-5900
FAX: (301) 948-1631

INFO/CARD 23

Engineering Education: Where Do They Learn About RF?

By Gary A. Breed
Editor

Where do engineers learn about RF? "Most RF engineers learn it on their own," states Dr. David Hertling, an EE Professor at Georgia Tech. This view is shared by a majority of engineering managers, who hire new graduates by choosing the brightest students they can find, hopefully with enough basic skills to develop into an RF engineer.

According to a GM/Hughes department head, they use a combination of short courses, in-house training seminars and mentorship, and it still takes six months to a year for young engineers to become productive. At this point, there is the risk that these newly-competent RF engineers decide that RF isn't as interesting as was once thought. Or, with a year's experience, they may discover that there are plenty of RF jobs available and change companies.

RF at Colleges and Universities

Despite the above comments, there are a number of programs in place at several colleges and universities that support the development of RF and microwave engineering skills. Dr. Tim Healy's program at Santa Clara University is well-supported by industry, particularly Hewlett-Packard Co., and has a good number of students, particularly graduate students from nearby "Silicon Valley" companies. At the other end of the country, the University of Massachusetts and Southeastern Massachusetts University have programs of note.

In the South, Georgia Tech has had the advantage of considerable research in applied technology at the Georgia Tech Research Institute. This has spilled over to the Electrical Engineering department, where Professors David Hertling and Robert Feeney have established an undergraduate sequence of RF courses. The University of Central Florida has a program which has been developed in part through research grants from the Electronic Industries Association (EIA) Piezoelectric Devices Group. This EIA group also supports work at Northern Illinois University, as well.

Short courses like those presented at RF Expos fill an educational need created by a lack of undergraduate RF courses.

Industry Support

All of the universities with significant RF/microwave engineering programs have support from the industry. In addition to those mentioned above, EEsof, Inc. has established a program or grants and purchase assistance to help make software tools available to over 200 universities. Johns Hopkins, Santa Clara, Penn State, West Point and Nevada-Reno are among the universities using modern design software to aid in teaching microwave techniques.

Direct grants are also an important part of engineering program development. EEsof recently provided an extensive software grant to the University of Illinois, providing 25 copies of their RF/microwave software suite. The New Jersey Institute of Technology has expanded their RF and microwave laboratory over the past few years with excellent support from a regional RF and microwave industry association. This group of New Jersey high-tech firms provided a complete RF/microwave laboratory, with a combination of new and used test equipment. Financial support for improved facilities has been excellent, as well.

There are many local or regional support programs, as well, such as Hewlett-Packard's support of Santa Clara University. Some are not nationally publicized, like E.F. Johnson's support of a small E.E. program at Mankato State University. Others are just getting underway, including Dr. Ted Rappaport's Mobile and Portable Radio Research Group at Virginia Tech. This program has gathered support from firms in cellular radio, factory communications, wireless data communications, and other areas of current development activity.

All of this activity gives the appearance of excellent resources for RF education, but the situation is not as good as it seems, for three reasons: First, many of the best programs are strongly microwave oriented, with a somewhat specialized approach. Next, most are based on research rather than practical design. This is not a criticism, but recognition that research is a primary role of the university in American education. Finally, most good programs are geared to graduate education, as might be expected for research programs.

What About the Undergraduate?

An engineer wishing to pursue an advanced degree with a specialty in some area of radio frequency technology, especially microwaves, has a choice of excellent university programs. This is excellent news for many RF companies who wish to encourage their best engineers to continue their academic development. However, the situation is not so rosy for the undergraduate who will receive a BSEE and enter the workplace without further study.

Because RF is a combination of circuit theory, electromagnetics and communications theory, it requires a special effort to put it into the engineering currculum. Although most of the pieces are in place at every engineering school, few schools offer classes in RF that bring those pieces together in an understandable manner. One such program is in place at Georgia Tech. There, a sequence of four or five courses takes

students from an introduction to RF through amplifiers, oscillators, transmitters and receivers. Unfortunately, this may be the only school to offer such a specific RF track.

For engineering students lucky enough to have stumbled into the right school, there may be one or two professors with a personal interest in RF who can guide a student through the standard EE program, making sure that RF basics are covered through laboratory projects and independent study. Professors like Douglas Miron at South Dakota State University, Richard Campbell at Michigan Tech, Darko Kajfez at the University of Mississippi, Carl Erikson at Messiah College, or Brian Huggins at Bradley University can help interested students select undergraduate classes that include the right combination of topics to build an understanding of RF.

Student Motivation and Career Goals

As has always been the case, many students enter engineering school without a clue as to what specialities are available, and what technologies are emerging that will need expertise at the time they graduate. This basic lack of understanding has become worse in the past ten years. Even six or seven years ago when engineering enrollments were at their peak, educators were aware that their students, while the best ever in scholastic terms, had no clear career direction in mind when they entered college.

Colleges and universities are now seeing a drop in engineering enrollments. Dr. Robert Caverly at Southeastern Massachusetts University thinks part of the cause is the intense media attention given to the sad state of American technology. It is not hard for students to assume that greater technological success in the Far East and Europe will hurt their career opportunities four years form now.

But, there is a clear, and very large information gap between students, educators and industry. Many areas of technology, including RF, are extremely active in this country, and have many unfilled career opportunities for bright young engineers. Environmental science, materials technology, and optics are other strong areas. Software engineering, the melding of technical and computer skills, may be the fastest growing technical job market. And certainly, the growth in RF applications and RF-like high speed digital circuits offers opportunities for ambitous and energetic new practitioners.

If RF companies want to get the skills they need in engineers, and if colleges want to give their EE students the best opportunities after graduation, these two groups must do a better job of communicating. Fortunately, there are a few places where this communication is happening. They can serve as examples for the rest of the industry. ***RF***

For reprints of this article, contact Cardiff Publishing Company at (303) 220-0600. Ask for the Circulation Department.

TOKO & **PENSTOCK**

A Product for Every Application

Don't Get Held-Up on Your Design with Lead Time. Immediate Delivery from Penstock's Inventory.

SATELLITE COMMUNICATIONS
RF Filters & Duplexers: LC, Helical, Dielectric.
IF Filters: LC, Helical, Ceramic, Saw, Coils, Matching Transformers & Baluns, Power Line Chokes, Voltage Regulators, DC/DC Converters, Varactor Diodes, Ceramic Resonators.

COMPUTER & NETWORKING SYSTEMS
Video Filters, Delay Lines, Pulse Transformers, Impedance Filters, Power Supplies, DC/DC Converters, Varactor Diodes.

VIDEO & AUDIO SYSTEMS
Low Pass & Band Pass Filters, Anti-Aliasing Filters, Audio Filters, Precision High Definition Video Filters, Oscillator Coils, Ceramic Resonators, Noise Filters/Chokes.

MEDICAL EQUIPMENT IMAGE/PROCESSOR
HDTV Filters, Coils & Filters, Diodes, Pulse Transformers, Delay Lines, Switches, Power Supplies, Noise Filters/Chokes.

DATA SYSTEMS
RF Filters & Duplexers: LC, Helical, Dielectric.
IF Filters: LC, Helical, Ceramic, Saw, Coils, Matching Transformers & Baluns, Power Line Chokes, Voltage Regulators, DC/DC Converters, Varactor Diodes, Ceramic Resonators.

Coil Prototyping/Sample Kits—Priced from $59.00
Order Today.

- **CHIP INDUCTORS**
  1210 Package, Type 32 CS. SPK-32CS-1990
- **SMD VARIABLE COILS**
  5 mm Size. Type 5 CD, 5 CE. SPK-5SMD-1990
- **5 mm VARIABLE COILS**
  5 mm Size. Types 5 K, 5 PH, 5 P. SPK-5MM-1990
- **7 mm VARIABLE COILS**
  7 mm Size. Types 7 KMM, 7 P, 7 PA. SPK-07-1987
- **10 mm VARIABLE COILS**
  10 mm Size. Types 10 K, 10 PA, 10 EZ. SPK-10-1987
- **MOLDED COILS**
  Types MC134, MC138, MC139, MC141. SPK-MC-1987
- **FIXED INDUCTORS/NOISE CHOKES**
  Type 8RSB Low Current/Low Profile. Type 8RBS High Current. SPK-8RBS-1991

Toko Is the World's Leader in Coils & Filter Products.
Penstock Is the World's Largest RF Microwave Distributor.

VISA/MasterCard Accepted • No Minimum Order

Offices Nationwide. **Phone: 1-800-PENSTOCK**

Please Note: CALL OR FAX TO ORDER KITS OR CATALOGS. **FAX: 1-408-730-4782**

By circling Bingo you will receive Penstock Product Selection Guide only.

INFO/CARD 25

ECM Effectiveness Analysis Using a Graphical Threat Footprint

By Marvin Kefer
AIL Systems, Inc.

In a countermeasure development program there is a need to evaluate and monitor, the system's ECM (Electronic Counter Measure) effectiveness for each threat in the environment. The objective of this paper is to present a graphical footprint, which is used to evaluate RF values used for ECM effectiveness, using a simple spread sheet approach. Additionally the parameter adjustability is explained, so that the designer can change the design for optimum performance.

The calculations of the threat detection area (Threat Footprint), and the ECM effectiveness within this footprint use the threat radar's parameters and the system's ECM parameters. These parameters determine the minimum and maximum ranges where the threat and the ECM are effective for each azimuth. The ranges are based on the radar range equation, slant range and a flat earth.

The threat footprint ECM effectiveness analysis procedure presents these results in a graph. The graph is similar to a radar display, with the ECM platform in the center, and with a threat radar and its effective ECM ranges plotted for each azimuth. See Figure 1. Note that the nose of the plane corresponds to the top center of Figure 1 and all points on the azimuth are referenced to the nose. The graphical analysis technique shows:

1. The Threat Footprint. The threat radar operational area (radial lines), which is bounded by the minimum and maximum ranges of the threat for 360 degrees of azimuth.
2. The ECM Footprint. An overlay on the same graph showing the ECM AREA bounds, where the ECM is effective.
3. The ECM Effectiveness Ratio. The percentage (81 percent) of the threat footprint area where the ECM is effective.

The range is the slant range, from the radar to the ECM radar range equation solutions.

Hardware/Software Requirements for the Calculations

The graphical analysis uses a spreadsheet program run on a personal computer. The spreadsheets used were Quattro (by Borland) or Lotus release 2.2. The associated software and hardware requirements are explained in Table 1.

Quattro is the recommended software choice, because it requires the least hardware, and uses the most advanced hardware features (extra RAM, Mouse and coprocessor) if they are available. Quattro provides the most user options, handles the very large file, annotates the graph, and squeezes the data to reduce storage space and decrease start up and save times.

Quattro or Lotus were selected because they are third generation computer language, which are easy to program, and save more than half the programming time because of the following features:

- Semi-automatic graphing capability
- Step by step column relationships which simplify calculations
- No in/output formatting required
- Each calculation step is visible for verification
- The program is user interactive, for example, change a variable and 10-20 seconds later the results are available (10 MHz AT with coprocessor)

The above memory was required because Lotus requires expanded memory (RAM) to run the software. Above memory converts the extended RAM (384 kb) beyond the DOS 640 Kilobyte limit, to expanded RAM which Lotus can use.

SPREADSHEET SOFTWARE	HARDWARE REQUIREMENTS	SUPPORT HARDWARE	SUPPORT SOFTWARE
QUATTRO PRO	IBM PC XT	HARD DISK 512 KB RAM MEMORY	NONE REQUIRED
	IBM PC AT	HARD DISK 512 KB RAM MEMORY	NONE REQUIRED
LOTUS 123 REL 2 01	IBM PC XT	HARD DISK 640 KB RAM MEMORY 384 KB EXTEND MEMORY	ABOVEMEM CONVERTS MEM FROM EXTEND TO EXPANDED MEMORY
	IBM PC AT	HARD DISK 640 KB RAM MEMORY 384 KB EXPAND MEMORY	NONE REQUIRED

QUATTRO PRO MADE BY BORLAND (SCOTTS VALLEY, CALIF)
LOTUS IS MADE BY LOTUS DEVELOPMENT CORP
ABOVEMEM IS MADE BY ABOVE SOFTWARE (SANTA ANA, CALIF)

Table 1. Minimum required hardware and software for running graphical ECM analysis.

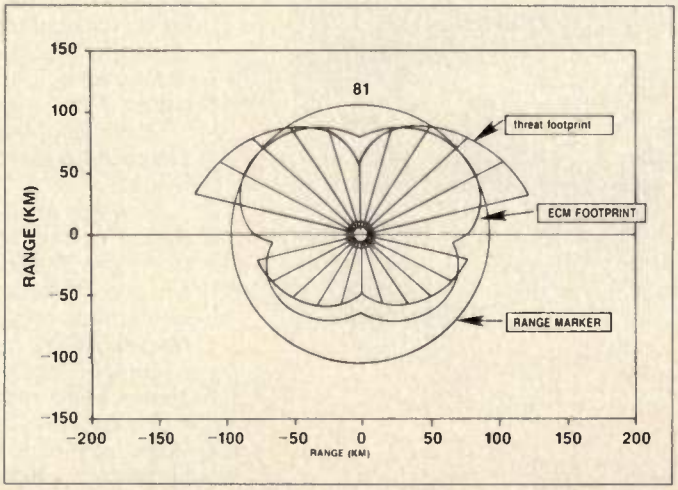


Figure 1. Graphical ECM effectiveness, threat footprint analysis.

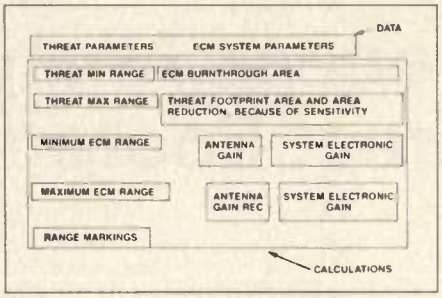


Figure 2. The spreadsheet template for graphical ECM effectiveness in a threat footprint.

Entering Threat and ECM Data

The Lotus spreadsheet uses a smart screen format. Data is entered by moving the cursor to the cell into which you want to enter the data, and typing in the data and pushing the enter key. In about 10 seconds (50 seconds without the coprocessor) the calculations based on the new data entry are completed. The recalculation mode which suppresses the calculations, until the recalculation key (F9) is pushed, is strongly recommended for multiple data entries.

The Calculation Template

The Lotus template for the spreadsheet is shown in Figure 2. The template shows where on the spreadsheet data is entered and where calculations are made.

The threat parameters and ECM parameters used in the program are shown in Figure 3.

Threat and ECM Parameter Definitions

The system parameters include the effects of cable loss, and frequency (when designated). The antennas include the effects of radome losses, and cable loss difference for different cable paths.

Minimum Threat Range — Range determined by the minimum missile range.

Forward and Aft Maximum Threat Range — This range is determined by the target Radar Cross Section (RCS), and the Radar's ranging ability based on its processing gain, and the Radar range equation parameters.

Threat Frequency — Operational frequency of the radar.

Threat Wavelength — A calculated value (speed of light/frequency) based on frequency expressed in meters.

Threat ERP (Effective Radiated Power) — Threat power x antenna gain

THREAT PARAMETERS

		RCS (M^2)
MIN THREAT RANGE	5 KM	
FWD MAX THREAT RNG	80 KM	10
AFT MAX THREAT RNG	50 KM	10
THREAT FREQUENCY	10 GHZ	
WAVELENGTH	0.030 METER	
THREAT ERP	1,000,000 KW	
ECM/THREAT FOOTPRINT	80.51 %	

ECM SYSTEM PARAMETERS

REC SENS	-28 dBm
SYS E.GAIN	61 dB
MAX POW	50 WATTS
J/S (MINIMUM)	3 dB
RNGE MARK	10 KM
RNGE MARK	100 KM

ANTENNA GAIN (PARABOLIC)

	GAIN (dB)	3dB BEAM (deg)	RT BORESIGHT (deg)	LFT BORESIGHT (deg)
REC FWD	4.5	45	45	315
REC AFT	2.5	45	135	225
XMT FWD	5	45	45	315
XTR AFT	3	45	135	225

Figure 3. Graphical ECM effectiveness in a threat footprint calculation.

in kilowatts.

ECM/Threat Footprint Ratio — The calculated value of the percentage of the threat area for which the ECM is effective.

Non-Operational Azimuths (Doppler Notch) — The Doppler notch is entered with zero operational range data when the ranges, where there is no Doppler, are set.

Receiver (ECM REC) Sensitivity (frequency sensitive) — The system sensitivity at the antenna port required for threat detection or successful countermeasure processing.

System Electronic Gain (frequency sensitive) — The system electronic gain, from the receive to the transmit antenna ports.

Transmitter (XMTR) Maximum Power (frequency sensitive) — The transmitter power measures at the transmitter antenna port.

J/S (Minimum) — The minimum ratio of Jam signal to the threat power signal, which bounces off the ECM platform's Skin, for successful countermeasure processing.

XMTR/REC Antenna Gain, Beamwidth, and Bore Site (frequency sensitive) —A matrix of the antenna parameters, for four 90 degree quadrants, for both the Receive and Transmit antenna systems are used in this example. The gains can be used to adjust receiver sensitivity and transmitter power for forward and aft line loss variations. In this example parabolic antenna patterns were used, but other pattern shapes can be programmed or manually specified. Modification of the number of antennas per quadrant and/ or the quadrant size is also a possible

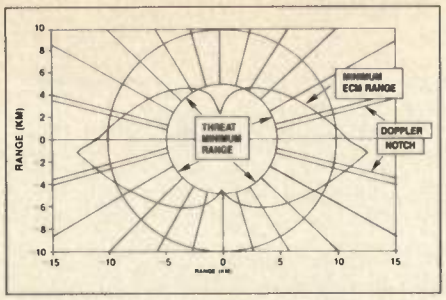


Figure 4. Minimum threat range less than minimum ECM range.

program adjustment.

Range Marks — Two range markers are provided to calibrate the graph's circular geometry.

Using the Software

In this example all of the threat and ECM parameters are inter-related, but notional.

Adjusting the Burnthrough Range

The minimum range of the ECM occurs when the threat ERP reflected from the ECM platform's skin (skin return) exceeds the ECM transmitter ERP and the minimum J/S requirement.

Figure 4 shows the minimum threat range (5 km) is less than the minimum ECM range, except within ±20 degrees about 0 degrees azimuth (which corresponds to the airplane nose), and at the tail. Notice that the burn through minimum range, for a 50 watt transmitter is less than 10 km reference circle, except near the aft Doppler notch region. 10 km may be user acceptable, if not, power can be added to reduce the burn through range below 5 km. Figure 5 shows the successful suppression of burnthrough below 5 km using 200 watts of transmitter power at the antenna ports.

Adjusting the Maximum Detection Range

The maximum range of the ECM system occurs when the system has enough receiver sensitivity to detect and analyze the threat signal. Additionally, the system requires enough gain to surpass the passive target gain, which amplifies the threat signal. Matching the antenna gain, bore site and shape to the required sensitivity and gain is also recommended.

Figure 6 shows that 81 percent of the threat footprint is covered with −28 dBm system sensitivity at the receiver antenna. Increasing the system gain to −31 dBm, Figure 7, provides 100 per-

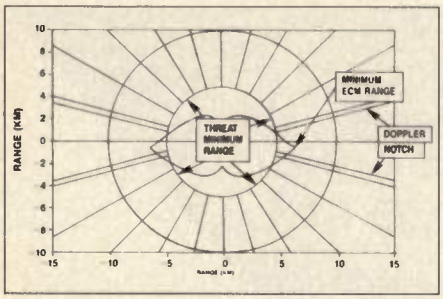


Figure 5. Suppression of burn-through below 5 km.

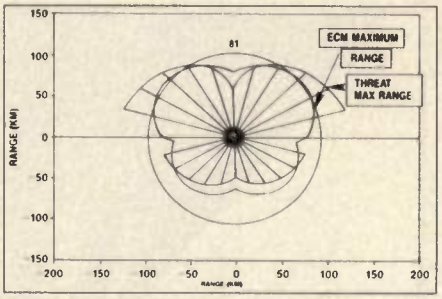


Figure 6. 81 percent coverage at the receiver antenna.

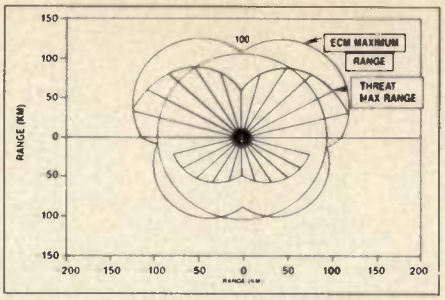


Figure 7. 100 percent ECM coverage.

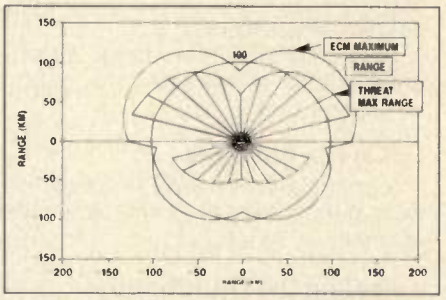


Figure 8. Matching the maximum ECM range to the threat footprint.

cent ECM coverage of the threat footprint. Matching the maximum ECM range to the threat footprint shape is accomplished by changing the forward receiver antenna bore sites to 60 and 300 degrees, as shown in Figure 8. This optional adjustment provides more uniform ECM margin.

The software simplifies hundreds of calculations by expressing them graphically and showing the percentage of the threat footprint where the ECM is effective. Figures 9 and 10 are samples of the calculations.

Minimum Threat Range

The threat minimum ranges (Figure 9, columns 1 to 4, center rows) are entered in a polar coordinate system. the Azimuth Angle (AA) is entered in the first column, and the corresponding threat Minimum Range (MR) in the second column. The transformation to X and Y coordinates is done in the third and fourth columns (X=MRxCOS(AA), and Y=MRxSIN(AA)). (Note that the trigonometric functions use radian angles. Preliminary operating instructions for Quattro/Lotus will occasionally be included as part of understanding the software). The minimum ranges for the other azimuths, which are incremented every five degrees, are not shown in Figure 9. They are entered using the Lotus copy feature.

Maximum Threat Range (Detection)

The maximum range (Figure 9, columns 1 to 4, bottom rows) is calculated from the free space radar range equation and is based on the threat parameters (Forward and aft maximum threat ranges based on RCS), and the aircraft RCS for each azimuth.

The maximum threat range is resolved using the radar range equation (from Skolnik's *Introduction to Radar Systems,* Second Edition, Chapter 1, equation 1.10), for free space.

$$R_{MAX} = \left(\frac{P_T A_E \Sigma}{4\pi\lambda^2 S_{MIN}} \right)^{1/4} \qquad (1)$$

Where (the dependent variables are):
R_{MAX} is the maximum range
P_T is the power transmitted
A_E is the effective antenna aperture
Σ is the receiver platform's cross section (RCS)
λ is the wavelength of the radar
S_{MIN} is the minimum signal received

The program could solve for R_{MAX} based on each dependent variable, but for a narrow band radar we assumed the

THREAT PARAMETERS

		RCS (M^2)
MIN THREAT RANGE	5 KM	
FWD MAX THREAT RNG	80 KM	10
AFT MAX THREAT RNG	50 KM	10
THREAT FREQUENCY	10 GHZ	
WAVELENGTH	0.030 METER	
THREAT ERP	1,000,000 KW	
ECM/THREAT FOOTPRINT	99.98 %	

ECM SYSTEM PARAMETERS

REC SENS	-31 dBm
SYS E GAIN	61 dB
MAX POW	200 WATTS
(J/S)	3 dB
RNGE MARK	10 KM
RNGE MARK	100 KM

ANTENNA GAIN (PARABOLIC)

	GAIN (dB)	3dB BEAM (deg)	RT BORESIGHT (deg)	LFT BORESIGHT (deg)
REC FWD	4.5	45	60	300
REC AFT	2.5	45	135	225
XMT FWD	5	45	45	315
XTR AFT	3	45	135	225

AZIMUTH (DEG)	THREAT MIN RANGE (KM)	THREAT MIN RANGE X VALUE (KM)	THREAT MIN RANGE Y VALUE (KM)	B THRU AREA RED. FOR RECM>Rthreat ALWAYS (KM)^2	B THRU AREA RED. FOR RECM>Rthreat FIRST VALUE (KM)^2	B THRU AREA RED. FOR RECM>Rthreat SECOND VALUE (KM)^2	ITER-SECTION XO	ITER-SECTION YO	SLOPE ECM	SLOPE THREAT	SLOPE THREAT INTERSECT ANGLE (RAD)	THREAT INTERSECT ANGLE denom
0	5	0.00	5.00	0.00	0.00	0.00	1.09	4.95	3.547	-0.044	1.340	4.4

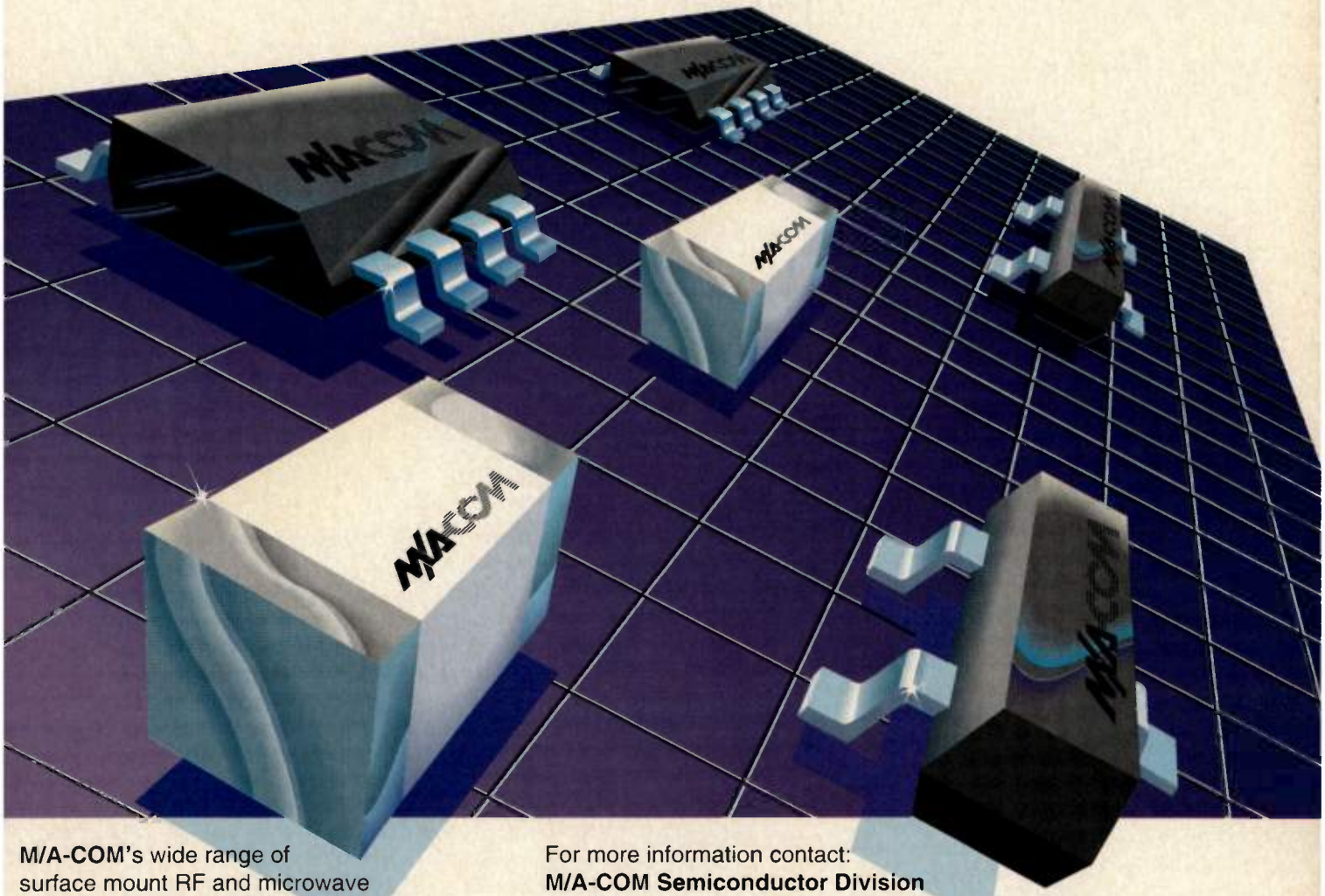
	THREAT MAX RANGE (KM)	THREAT MAX RANGE X VALUE (KM)	THREAT MAX RANGE Y VALUE (KM)	RCS (M^2)	THREAT SECTOR % AREA 99.98 (KM)^2	AREA RED. FOR RECM<Rthreat ALWAYS (KM)^2	AREA RED. FOR RECM<Rthreat FIRST VALUE (KM)^2	AREA RED. FOR RECM<Rthreat SECOND VALUE (KM)^2	ITER-SECTION XO	ITER-SECTION YO	SLOPE ECM	SLOPE THREAT	SLOPE THREAT INTERSECT ANGLE (RAD)
0	95.21	0.00	59.21	3	192.21	0.00	0.00	0.00	24.06	110.86	0.683	2.147	0.536

Figure 9. Graphical ECM effectiveness in a threat footprint calculation.

More Surface Mount Than Ever...

PINs...Schottkys...Varactors...Switches and More!

At M/A-COM, we are continually adding to our RF and microwave surface mount products... including a new line of surface mount varactors and our SMQ (square) packaged PIN diodes.



M/A-COM's wide range of surface mount RF and microwave products are suitable for military and commercial applications including military radios and cellular systems.
M/A-COM will meet your requirements with aggressive pricing, high volume availability and exacting quality standards.

For more information contact:
M/A-COM Semiconductor Division
Burlington Semiconductor Operations
43 South Avenue, Burlington, MA 01803
General information: **617-272-3000 X3808**
Applications assistance: Jerry Hiller X2625
Now Distributed by Richardson Electronics, LTD.
USA 1-800-348-5580 CANADA 1-800-387-2280

M/A-COM

INFO/CARD 29

range only depends on the RCS, or

$$\frac{R_{MAX}}{R_{MAX_{ref}}} = \left(\frac{\Sigma}{\Sigma_{ref}}\right)^{1/4} \quad (2)$$

where R_{MAXref} and Σ_{ref} are threat parameter forward and aft.

The equation for the maximum range uses (see Figure 9, top third of page columns 1 to 3) the reference values for range given RCS (column 3), and is calculated in the bottom third of the page in columns 1 to 5, for each azimuth dependent value.

Minimum ECM Range (Burnthrough)

The minimum ECM range (Figure 10 columns 1 to 4 top rows) is determined by the target RCS and the system power and gain. The system gain is the log sum of the antenna gains (receive and transmit) and the electronic gain.

When the threat is so near that the ECM ERP is overpowered by threat ERP burn through or minimum ECM range occurs. This happens because the system gain must exceed the target gain by the minimum J/S ratio, but as the range decreases the ECM system reaches saturation and the saturated gain is reduced. The equation for maximum ECM ERP's minimum range is resolved using Leroy Van Brunt's definitions of threat ERP, Path Loss and Target Gain from his *Applied ECM*, Volume 1 text, page 157.

(3)

Threat ERP = Effective Radiated Power

$$\text{Path Loss} = \frac{\lambda^2}{(4\pi\text{Range})^2} \quad (4)$$

contains the range variable

$$\text{Target Gain} = \frac{(4\pi\Sigma)}{\lambda^2} \quad (5)$$

Where Σ is the RCS of the ECM platform, and λ is the threat's wavelength.

The Maximum ECM ERP = Threat ERP × Path Loss × Target Gain × J/S (6)

Where MAX ECM ERP = MAX ECM POWER x ECM Antenna Gain and J/S = additional gain required for the ECM technique.

The ECM antenna gain ECM transmit is calculated using a parabolic equation based on the ECM system parameters or

MAX ECM ERP = THREAT ERP × PATH LOSS × TARGET GAIN × J/S_{MIN} (7)

MINIMUM ECM RANGE BURNTHROUGH

AZIMUTH (DEG)	RANGE (KM)	MIN RANGE X VALUE (KM)	MIN RANGE Y VALUE (KM)	RCS (M^2)
0	1.09	0.00	1.09	3

ANTENNA GAIN ECM REC (dBi)	ANTENNA GAIN ECM XMT (dBi)	REQ SYSTEM E.GAIN (dB)	BURN THRU RANGE (KM)
0.94	3.00	45.28	1.09

MAXIMUM ECM RANGE DETECTION

AZIMUTH (DEG)	RANGE (KM)	MAX RANGE X VALUE (KM)	MAX RANGE Y VALUE (KM)
0	94.44	0.00	94.44

RANGE MARKING

	RANGE X VALUE (KM)	RANGE Y VALUE (KM)
0	0.00	10.00

Figure 10. (a) minimum ECM range burnthrough, (b) maximum ECM range detection and, (c) range marking.

or solving for minimum range

$$\text{Range (km)} = \frac{\left[\dfrac{(\text{ERP}_{threat}\Sigma 10^{(J/S/10)})}{(4\pi P_{ECM} 10^{(G_E/10)})}\right]^{1/2}}{1000} \quad (8)$$

where,

P_{ECM} is the maximum ECM transmitter power

G_E is the ECM transmitter antenna gain (dB)

J/S_{MIN} is in dB.

Maximum ECM Range Detection

The maximum ECM range (Figure 10, columns 1 to 4, middle rows) is the furthest range where the ECM system can either detect or process the threat signal. In this example a free space detection range was used and the equation used to determine maximum range is explained below. The maximum range shrinks to the minimum range, when there is insufficient system gain, that is when the target gain and the J/S exceed the electronic and receive and transmit antenna gains.

The maximum ECM range is the range at which the threat is detected (using free space path loss), or can be processed, with a given minimum signal to noise ratio. The sensitivity requirement is derived by equating:

Threat ERP × Path Loss × Rec Ant Gain = Electronic Sensitivity (9)

where the electronic sensitivity is the threshold required for detection or processing. The solution for the Max Range R_{MAX} in the required units is:

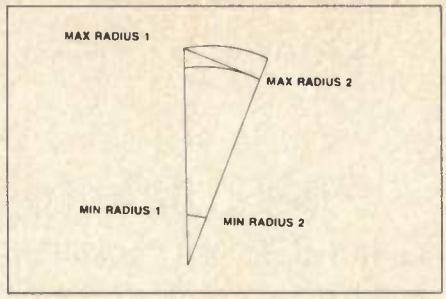


Figure 11. The sector area is based on the average of the two radii.

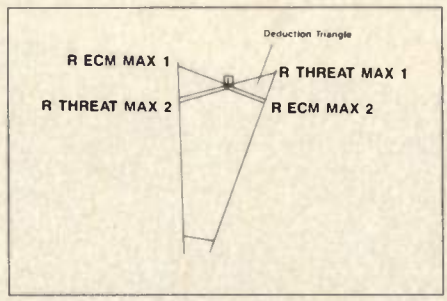


Figure 12. Calculating the relative ECM area compared to the threat area (footprint).

$$R_{MAX} = \quad (10)$$

$$\left(\frac{\lambda}{4\pi 1000}\right)\left(\frac{\text{ERP}_{THREAT}}{10^{\left(\frac{\text{ELECT SENS} - \text{ANT REC GAIN}}{10}\right)}}\right)^{1/2}$$

The ECM Receiver Antenna Gain is calculated using a parabolic equation based on the ECM antenna parameters (note other antenna shapes or actual antenna data can be alternatively programmed).

The required system electronic gain (REQ SYS E GAIN):

REQ SYS E GAIN = (11)

$$\frac{\text{TARGET GAIN}\left(\frac{J}{S_{MIN}}\right)}{(\text{REC ANT GAIN})(\text{XMTR ANT GAIN})}$$

or,

REQ SYS E GAIN (dBm) =

$$10\ \text{Log}\left(\frac{4\pi\Sigma}{\lambda^2}\right) + \frac{J}{S} - \text{REC ANT GAIN} - \text{XMTR ANT GAIN} \quad (12)$$

Range Markings

Range markings (Figure 10, columns 1 to 4, bottom rows) are provided as references range circle to calibrate the graph. Two are used, one for the

We can Electroplate PTFE

Any shape, any size - to your specs!

If you are looking for low loss tangent, low dielectric constant, very high volume resistivity, chemical inertness and insignificant water absorption, and you want it all at the same time, you can only find it in pure PTFE.

And if you are looking for electroplated PTFE you can only find it at Polyflon.

According to many authorities "nothing sticks to Teflon®"... it just can't be done. Actually, at Polyflon we've been doing it successfully for years. It has been proven in many diverse applications ranging from microwave communications to magnetic resonance imaging. The molecular bond between PTFE and the electrodeposied material is very strong, creating distinct advantages for products and components.

- Electroplated PTFE reduces corona: Without interfacial air entrapments, voids or inclusions, corona cannot easily be initiated.
- Electroplated PTFE reduces interfacial losses: especially at higher frequencies, because of the tight molecular bond and because the low loss tangent of PTFE at high frequencies is negligible.
- Electroplated PTFE improves mechanical connections: solder can be flowed directly onto the surfaces of electroplated PTFE to produce an integral, solderable surface.

There are many applications for electroplated PTFE, from the smallest capacitors to the largest imaging coils. It might be the solution to a problem that you are currently facing.

Call or write Polyflon to find out how our capabilities may solve a problem application and/or improve the performance of your product.

Teflon is a registered trademark of DuPont Company.

CRANE®

POLYFLON

Polyflon Company • 35 River Street • New Rochelle NY10801
Tel: (914) 636-7222 • FAX: (914) 633-3664
INFO/CARD 30

minimum required and the other for the maximum required ranges.

The threat area is calculated on a sector basis and the sector area is based on its average radius. There are 72 five degree sectors in 360 degrees of azimuth. The area of each sector is calculated, and the sum of the 72 sectors represents the threat area. Figure 11 is a drawing of a sector. The larger maximum radius 1 is extended to describe a circular sector and the smaller maximum radius 2 also describes a circular sector. Disregarding the minimum radii the sector area is the average of the maximum radius circular sectors. That is

MAX RAD SECTOR AVERAGE = (13)

$$\frac{\pi}{72 \times 2}\left[(\text{MAX RAD 1})^2 + (\text{MAX RAD 2})^2\right]$$

or the average maximum radius is

MAX RADIUS AVERAGE = (14)

$$\left[\frac{(\text{MAX RAD 1})^2 + (\text{MAX RAD 2})^2}{2}\right]^{1/2}$$

similarly the average minimum radius is

MIN RADIUS AVERAGE = (15)

$$\left[\frac{(\text{MIN RAD 1})^2 + (\text{MIN RAD 2})^2}{2}\right]^{1/2}$$

The total sector area is the average maximum radius sector area less the average minimum sector area.

TOTAL SECTOR AREA = (16)

$$\left(\frac{\pi}{72 \times 2}\right)\left[(\text{MAX RADIUS AVERAGE})^2 - (\text{MAX RADIUS AVERAGE})^2\right]$$

ECM Effectiveness Within the Threat Area (Ratio in Percentage)

The ECM effectiveness within the threat footprint is resolved by calculating the areas of the threat footprint not covered by the ECM. For example: if the ECM envelope contains the threat envelope then there is 100 percent coverage. If the ECM envelope is within the threat envelope then the threat envelope minus the ECM envelope area divided by the threat envelope area is percentage coverage. When the ECM radii is either larger of smaller than the threat radii within the sector, the ECM effective area is calculated by finding the threat footprint area, and subtracting the threat footprint area not covered by the ECM. There are three cases:

Case 1 — When the ECM area contains the threat area, Effective ECM area greater than threat area, reduction = 0 (no calculation necessary).

Case 2 — When the threat areas contains the ECM area. Effective ECM area less than threat area. Reduction = (threat area) — (effective ECM area)

Case 3 — When the threat area and ECM area bonds cross within a sector. Effective ECM area less than threat area, reduction = triangle (See Figure 12).

Figure 12 shows a typical ECM and threat sector footprint boundary crossing. Because R Threat Max 2 exceed R ECM Max 2, the triangle R threat max 2 to point 1 to point R ECM Max 2 is the difference between the threat and ECM areas. In Figure 9 the area reduction is calculated for the maximum range crossovers, in the center of the page the area reduction is calculated for the minimum range crossovers.

Case 1, when the ECM area contains the threat area, is shown in the bottom third rows, column 8. Case 2 is the adjacent column 9. Columns 10 and 11 calculate the area. Case 3, by calculating the intersection values (X0 and Y0) and the intersecting angle column 15.

Controlling the Graphics

The graphical outputs take advantage of the Quattro/Lotus preprogrammed graph functions. Setting the X and Y outputs in adjacent columns is the only requirement. Programming to lift the pen from the graph paper is accomplished by inserting a row of blanks between rows.

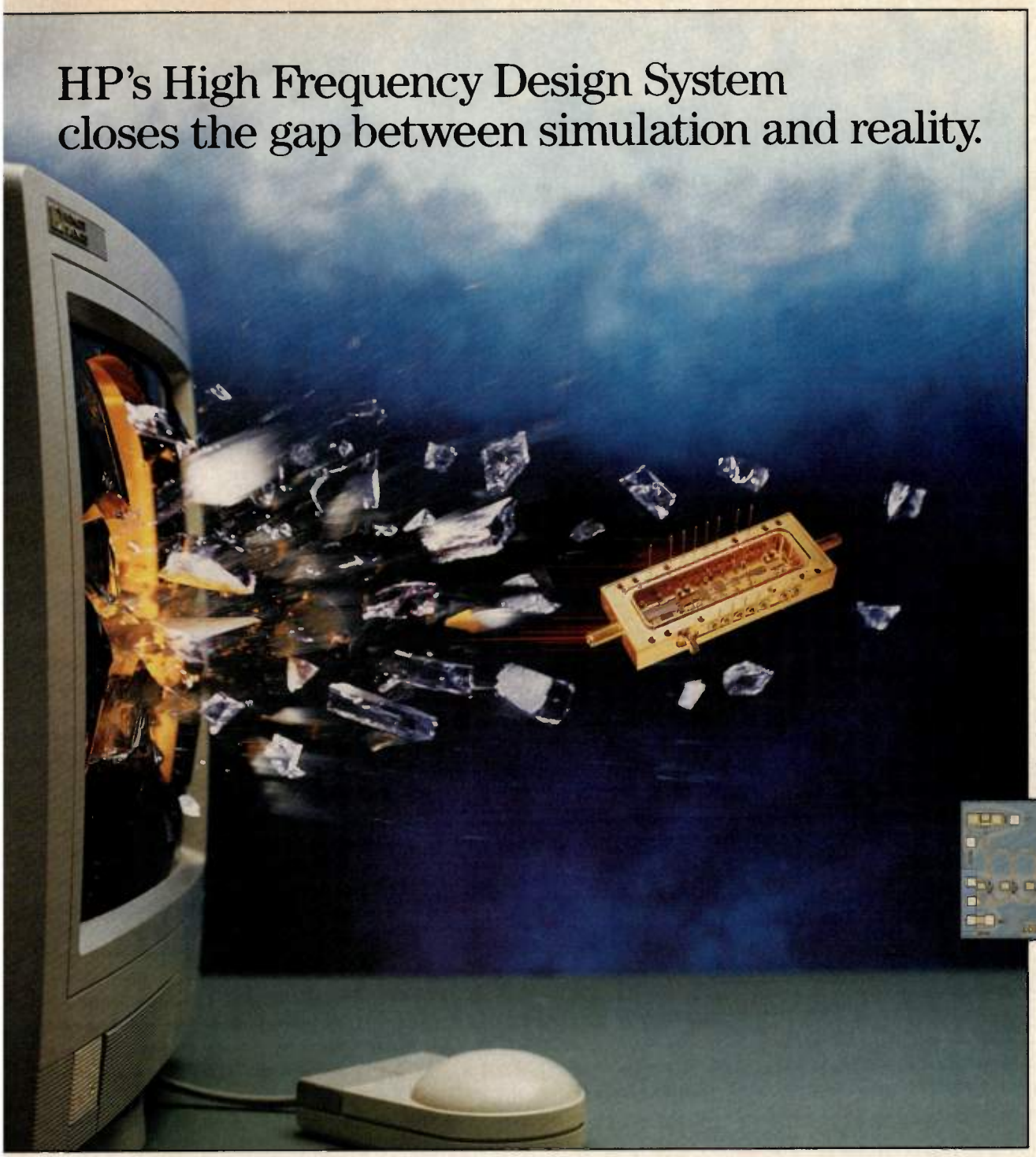
Adjusting the outputs for common scale dimensions for the X and Y axis, or circular symmetry, requires adjustment of the aspect ratio. To accomplish this the X and Y ranges are set manually with the X-axis maximum/minimum value approximately 1.4 times the Y-axis value.

Lotus templates for this analysis are available on disk from the RF Design Software Service. See page 71 for information. ***RF***

About the Author

Marvin Kefer is the Senior Staff System Engineer for AIL Systems Inc., Commack Rd., Deer Park, NY 11729. He is currently the B-1B System Engineering consultant for new business. His previous design experience includes active and passive component design and system integration from DC to X-band.

HP's High Frequency Design System closes the gap between simulation and reality.



This 0.5-50 GHz amplifier design, created on the HFDS, met specifications the first time it was tested.

HP's High Frequency Design System (HFDS) brings single-pass design solutions closer to reality. It predicts the performance of your designs using a non-linear simulator that gives you accurate results, even under high levels of compression. So, you can take advantage of the most powerful and sophisticated models and libraries available. Models tested against field simulation tools and verified with actual measurements.

You can also generate your own proprietary libraries with parameters extracted using HP instrumentation links. Enter equations for active devices. Or use S-parameters calculated for 3-D structures with HP's High Frequency Structure Simulator. And since it runs on HP, Apollo, and Sun, the HFDS fits nicely into the computing environment you already work in.

Bring your high-frequency simulations closer to reality. For more information, call your local sales office or circle the reader service number.

There is a better way.

HEWLETT PACKARD

INFO/CARD 32

Nobody in their right mind would use a pure silver dime to buy 10 cents worth of goods. . .

Pure Silver Dime
VALUE: 40 Cents

Copper Laminate Dime
VALUE: 10 Cents

Yet you may be doing about the same thing when you specify "Pure Silver" elastomer shielding materials!

Here's why!

For years, engineers and designers of EMI shielding systems have been forced to use expensive PURE SILVER filled conductive elastomers to achieve the required degree of shielding and meet high temperature service requirements. Today, reliable and cost-effective substitutes for these costly pure silver-filled materials are available from Parker Seal Group!

Parker's "Second Generation" of PARSHIELD silver plated/copper-filled elastomers offers outstanding electrical *and* physical properties—equalling pure silver-type materials, coupled with the ability to withstand long term, high heat environments without compression set degradation and loss of conductivity.

These PARSHIELD Ag/Cu materials are qualified to MIL-G-83528 specifications. In addition they meet the specifications for pure silver-filled materials. They are however, *significantly less expensive* than pure silver yet offer the same (and in some cases, SUPERIOR) performance.

For complete information on these Parker Ag/Cu conductive elastomers and the entire family of PARSHIELD MIL-G-83528 qualified conductive materials and shielding products, ask for Parker Brochure PSG2700, PARSHIELD CONDUCTIVE ELASTOMERS.

We will also be happy to send you copies of certified test reports and PARSHIELD samples to verify our claims of product superiority over traditional pure silver-filled conductive materials. Call or write:

PARKER SEAL GROUP
Conductive Elastomers Dept.
2360 Palumbo Drive
Lexington, KY 40509
(606) 269-2351

Parker Seals

INFO/CARD 33

New RF Network Analyzer Offers Speed, Accuracy, and Low Price

By Jim Curran
Hewlett-Packard Co.

Measurement speed, ease-of-use, and price are the most important criteria used in the selection of swept-frequency test systems for high-volume RF production applications. However, emerging RF communications equipment and consumer electronics have put more emphasis on test system performance, including high rejection of out-of-band signals, high Q filters, and reduced distortion over wider communications bandwidths. The latest RF network analyzer from Hewlett-Packard Company, the HP 8711A, maintains the simplicity required for production test, but adds the speed and performance necessary to maximize overall testing throughput.

The demand for commercial and consumer products containing RF components continues to grow rapidly. Commercial products in this category include cellular and mobile radios, pagers, and CATV distribution systems and receivers. Consumer products include televisions, video tape recorders and cordless phones. Manufacturers and their component suppliers are under competitive pressure to reduce costs without sacrificing quality.

Today, these components are tested with swept frequency response test systems, including scalar and vector network analyzers or spectrum analyzers with tracking generators. RF scalar analyzers are the most common choice in manufacturing because of their lower cost, fast measurement speed and simple operation. But as more demanding applications begin to crowd the RF spectrum, more narrowband, high-rejection components will have to be manufactured.

Hewlett-Packard's new HP 8711A is a fully integrated RF network analyzer designed for in-process test of RF components. This analyzer provides three to five times more speed, over 20 dB greater dynamic range, and several orders of magnitude increase in frequency resolution relative to comparably priced systems. It improves productivity with pass/fail limit testing, fast data storage to the built-in floppy disk drive, and automated testing without an external computer.

Figure 1. Fully integrated HP 8711A RF network analyzer.

An Overview of the HP 8711A

The HP 8711A is a low cost, 300 kHz to 1300 MHz network analyzer aimed at manufacturing test applications. It is a completely integrated test system with a fast, swept-synthesized source (50 millisecond full band sweep), and a dual broadband, frequency selective receiver with greater than 90 dB of dynamic range. Basic performance specifications are shown in Table 1. The built-in

Frequency range	300 kHz to 1300 MHz
Resolution	1 Hz
Dynamic range	>90 dB (narrowband)
	>66 dB (broadband, >10 MHz)
Sweep speed	50 ms/full band sweep
Output power	+16 dBm (<1000 MHz) +13 dBm (>1000 MHz)
Directivity	40 dB
Port match	20 dB
Measurements	Insertion loss, gain, power return loss, and SWR

Table 1. Specification summary.

```
IF THEN END INPUT DISP ASSIGN GOTO NOT FOR TO NEXT CLEAR
                                                    -----
 10    !=============================================
 20    ! This program measures the transmission and
 30    ! reflection characteristics of a bandpass filter
 40    !=============================================
 50    ASSIGN @Hp8711 TO 800

 60    ON KEY 0 LABEL "TRAN" CALL Transmission
 70    ON KEY 2 LABEL "REFL" CALL Reflection
 80    ON KEY 5 LABEL "SETUP" CALL Setup_diag
 90    ON KEY 7 LABEL "EXIT" GOTO End_prog
100    LOOP
110      DISP "WAITING FOR SELECTION"
120    END LOOP
130 End_prog: !
140    END
150    !=============================================
160    SUB Transmission
170 Transmission: !
180    OUTPUT @Hp8711;"CONF 'FILT:TRAN'"
190    OUTPUT @Hp8711;"DISP:ANN:FREQ1:MODE CSPAN"
200    OUTPUT @Hp8711;"SENS1:FREQ:CENT 175 MHZ"
```

Program Edit

Insert Line

Insert Char

Delete Line

Recall Line

Delete Char

Enter

Prior Menu

Figure 2. Create and execute IBASIC test programs on the HP 8711A.

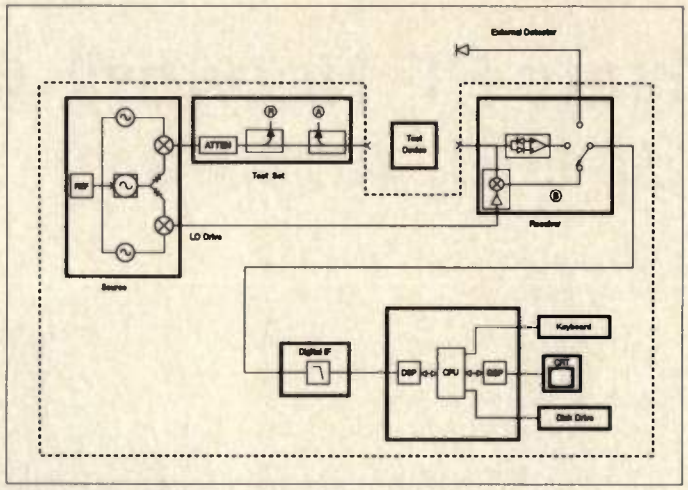


Figure 3. HP 8711A functional block diagram.

transmission/reflection test set, large 23 cm (9 inch) display, 3.5 inch floppy disk drive, and digital processor, make it a compact, easy-to-operate instrument (see Figure 1). Its unique receiver offers two important detection modes. First, the narrowband frequency-selective receiver provides high dynamic range for testing filters and switches. Broadband 'diode' detection measures mixers, frequency converters and amplifier output power. Built-in system frequency-response correction gives accurate results without a measurement calibration.

Productivity features which speed up RF component testing include eight on-screen frequency and amplitude markers, pass/fail limit testing, direct printer/

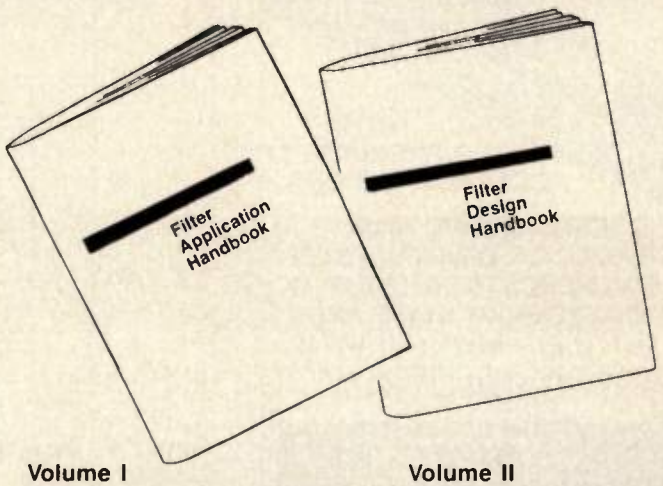
NO MORE CLIPPING, NO MORE COPYING, NO MORE SCAVENGING!

THE LIBRARY FOR BACK ISSUES!

ANNOUNCING...

RF DESIGNS' FILTER HANDBOOKS

Each handbook contains 80 compiled pages of our best (and most requested) articles on Filter Design, and Filter Applications. These Filter articles and tutorials come directly from the pages of *RF Design* magazine, and are written by experts from across the RF industry. Each Handbook is filled with articles that target every level of design experience and application...articles which will bring new engineers up to speed quickly on Filter basics...as well as articles that will teach experienced engineers how to maximize Filter performance at the most complex level.



Volume I
Filter Applications Handbook

Volume II
Filter Design Handbook

Use the handy coupon below, or simply call your order into our Circulation department @ 303/220-0600.

COUPON — COUPON

Yes, ship me (QTY) _____ sets of Filter Handbooks Volumes I, II, at $45.00 plus $5 postage.*

Yes, ship me (QTY) _____ Filter Applications Handbooks, Volume I, ONLY at $25.00 plus $3 postage.*

Yes, ship me (QTY) _____ Filter Design Handbooks, Volume II, ONLY at $25.00 plus $3 postage.*

*non U.S. orders please double shipping charges.

( ) Bill my company...signed PO enclosed. Amount_____

( ) Check enclosed...payable to *RF Design*. Amount _____

Bill my: ( ) MC ( ) Visa ( ) Amex exp. date _____

card # _____ signature _____

Ship to: Name _____ Company _____

Address_____ ms _____

City _____ State _____ Zip _____

Telephone _____

Mail order to: *RF Design*, Circulation Dept., 6300 S. Syracuse Way, #650, Englewood, CO 80111, or call 303/220-0600 TODAY!

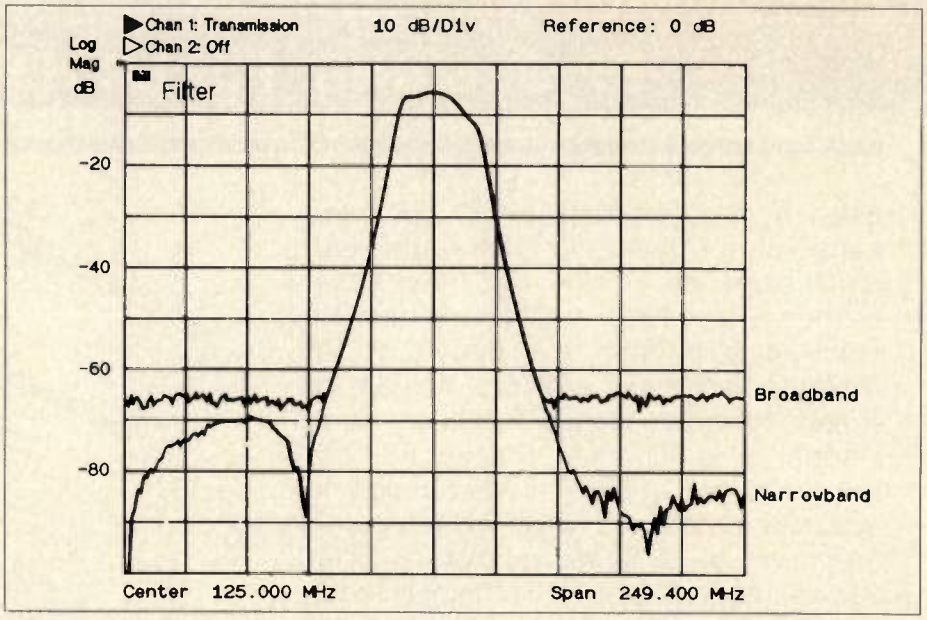


Figure 4. Dynamic range comparison for narrowband and broadband receiver modes.

plotter control, and multiple internal save/recall registers. The built-in 3.5 inch disk drive provides unlimited storage of instrument states and measurement data. Both HP BASIC and DOS formats are supported so that measurement data can be transported for use in PC-based application software.

Recent advances in CPU speed and processing power allow for internal execution of test programs. Hewlett-Packard's Instrument BASIC (IBASIC) is a full-featured instrument-control language that allows the creation, editing and execution of BASIC programs without an external computer. It also provides extensive data-processing capability, plus automatic recording of test results. Figure 2 shows an example IBASIC program listing as it is displayed on the instrument CRT. Programs can be created and edited using an external DIN keyboard, an external computer, or the front panel 'keystroke recording' mode. Keystroke recording simplifies programming by automatically generat-

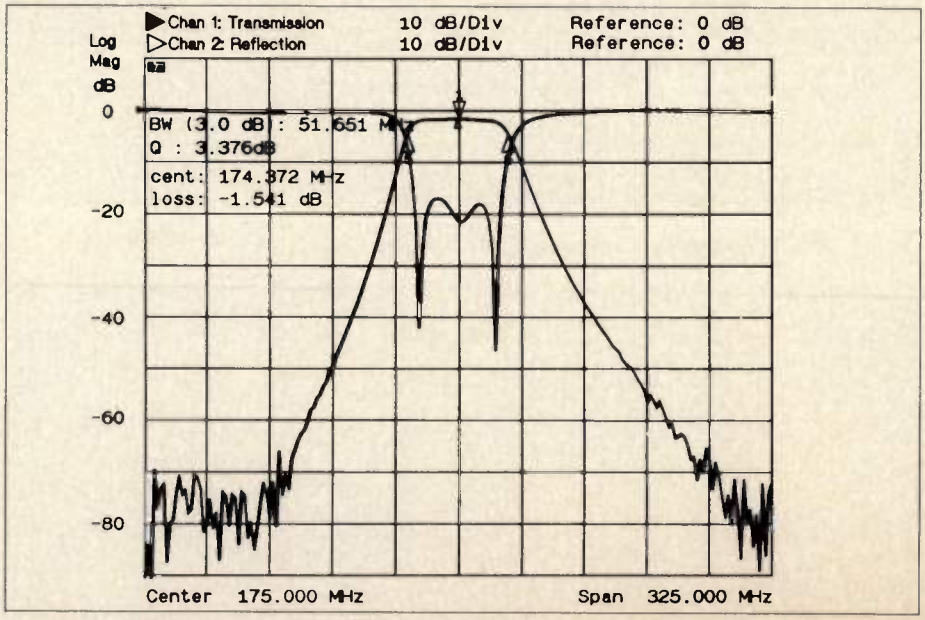


Figure 5. Measurement of filter bandwidth, center frequency, stopband rejection and return loss.

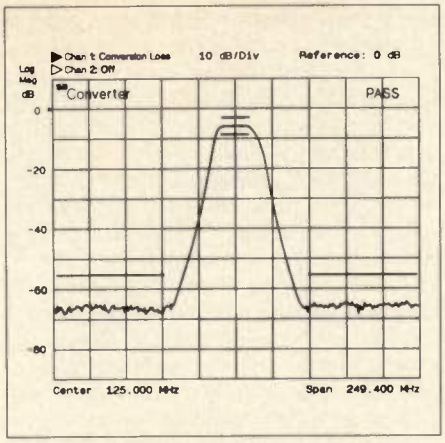


Figure 6. Frequency converter frequency response.

ing program statements as the corresponding front panel function keys are pressed.

The HP 8711A structure is shown in Figure 3, fully integrating all four key elements of a network analyzer system: source, signal separation, receiver and display/processor.

The cost of the RF source assembly is kept low and the sweep speed high through the use of PC board technology. Both the RF test signal and internal local oscillator (LO) are derived from a fractional-N synthesizer offset by two fixed oscillators. This enables a fast, full-band sweep. Output power is continuously adjustable from 0 to +16 dBm. The power level selected is the actual power delivered to the input of the component from the front panel test port. An internal (optional) 60 dB step attenuator follows the source assembly, providing low-level signals for testing amplifiers and sensitive receiver components.

A choice of signal separation methods is available. Reference and reflection channel couplers are internal, allowing for simultaneous transmission and reflection measurements between the front panel test ports. External bridges and detectors are not required. However, if the application demands remote testing, an external bridge or splitter and optional RF detectors can be used with the HP 8711A's two external RF detector inputs. These RF detectors can be located up to 20 meters away.

Unlike a scalar network analyzer, the directivity, source mismatch and frequency response of the internal reference and test channels can be improved through an error-correction technique. This technique, transparent to the user, uses the internal receiver to automatically improve the accuracy of reflection measurements.

The HP 8711A's dual receiver provides both a frequency-selective narrowband mode as well as a broadband diode detection mode, each with its advantages. Narrowband mode uses a tuned receiver that converts swept RF signals to a constant IF signal. This improves receiver sensitivity because the effective noise bandwidth is reduced, providing 90 dB of dynamic range for filter and switch isolation testing. Broadband mode accepts the full frequency spectrum of the input signal and makes measurements where the input and output signals are not the same frequency. An example of this is a measurement of mixer conversion loss. Either the internal or an external broadband diode detector can

be selected. The dynamic range of each of these methods is compared in Figure 4.

The three receiver channels measure reference, reflected and transmitted signals simultaneously. All three receiver channels provide an IF signal that is digitally processed. To maintain measurement speed even under 'calibrated' conditions, the system response is corrected in the IF processor, allowing the main CPU to handle I/O functions. The main CPU controls front panel functions, internal floppy disk, HP-IB, serial and parallel peripheral control outputs and is the host for editing and executing IBASIC programs.

Applications:

1. Filter Tuning. Filters are required to minimize signal distortion and crosstalk from adjacent channels in virtually every communications transmitter and receiver. Ideally, filters provide very high attenuation for unwanted signals with minimal in-channel signal distortion and attenuation. The sharpness, or Q-factor, of a filter is the ratio of the center frequency to the bandwidth. Channel spacing in CATV/TV applications is typically 6 MHz, and requires Q-factors of 8 to 10. On the other hand 30 kHz-wide voice channels in cellular telephone require front-end filters with Q-factors of over 1000.

Most filters require tuning for center frequency, passband flatness, stopband rejection and mismatch. Sweeper-based RF component test systems in use today require data-averaging techniques to increase dynamic range. This slows sweep speed and makes it difficult to tune the filter's swept-frequency response. Since these parameters are interdependent, some manufacturers find it necessary to add final test stations to re-check each specification and make final adjustments. In contrast, the HP 8711A lets you measure and display all these parameters simultaneously.

Figure 5 shows the measurement of a filter's transmission and reflection characteristics. Stopband rejection, 3 dB bandwidth and return loss are all displayed. On-screen markers provide high resolution while displaying the filter's passband and stopband response. Measurement accuracy, often a tradeoff with lower-cost RF test systems, is better than ±0.35 dB for insertion loss (0 to −20 dB), and ±2.5 dB for 60 dB stopband rejection. The filter's center frequency is accurate to 5 part per million, more than 100 times better than sweeper-based test systems.

2. Mixers and Frequency Converters. Frequency conversion is used in most RF communication systems to upconvert transmitted signals and downconvert received signals, using a mixer and local oscillator. Ideally, a mixer provides minimal distortion on a signal converted from the RF to the IF. This distortion is measured by comparing the amplitude response of the IF to the swept-RF stimulus. Mixers alone generally exhibit flat frequency response, but when integrated with IF filters, amplifiers and local oscillators, a frequency converter can exhibit a widely varying frequency response. LO's, whether internal or external, also affect the overall characteristics. Tuning LO frequency and power for optimal RF performance is required in most frequency converter applications.

The HP 8711A accurately characterizes a frequency converter's conversion loss and mismatch and provides broadband detection (internal or external), fast synthesized RF sweeps and power measurement capability. Figure 6 shows the conversion loss of a frequency converter, including test limits to assist in tuning.

3. Passive Components. Passive components such as cables, attenuators, isolators and switches require wide frequency coverage, high dynamic range and a maximum number of data points. The HP 8711A's 90 dB dynamic range receiver and 1601 point measurement display are also ideal for characterizing this class of devices.

Summary

This new network analyzer represents a significant step forward in providing fast and simple testing of high-volume RF components. The HP 8711A has a $13,500 U.S. list price with 16 weeks availability. Instrument BASIC with 2 megabytes of additional memory ($1,350), 60 dB step attenuator ($800) and 75 ohm test ports ($0) are optional. HP 86200A and 86201A 50 and 75 ohm external detectors ($600) and HP 86205A directional bridge ($1,300) are also available. For more information please circle Info/Card #250. ***RF***

About the Author

Jim Curran is Product Manager at Hewlett-Packard Company, Network Measurements Division. He can be reached at 1400 Fountaingrove Parkway, Santa Rosa, CA 95403, tel. (707) 577-1400.

OFF THE SHELF

RF AMPLIFIERS

MODEL NUMBER	POWER Watts	GAIN dB	SUPPLY Volts	PRICE
FREQUENCY RANGE 5 – 50 MHz				
RFP0550-100	100	44	50	$2,100.00
RFP0550-1000	1000	16	50	$5,040.00
FREQUENCY RANGE 50 – 100 MHz				
RFP0800-100P50	50	30	50	$1,485.00
RFP0800-100P100	100	30	50	$1,660.00
RFP0800-100P200	200	30	50	$2,200.00
RFP800-100	600	16	50	$2,424.00
FREQUENCY RANGE 1 – 100 MHz				
RFP01100-300	300	46	50	$3,150.00
FREQUENCY RANGE 76 – 108 MHz				
RFP0810-600	600	16	50	$1,780.00
FREQUENCY RANGE 75 – 150 MHz				
RFP0800-150P50	50	30	50	$1,485.00
RFP0800-150P100	100	30	50	$1,660.00
RFP0800-150P200	200	30	50	$2,200.00
RFP800-150	500	14	50	$2,424.00
FREQUENCY RANGE 100 – 200 MHz				
RFP0800-200P50	50	30	50	$1,660.00
RFP0800-200P100	100	30	50	$2,900.00
RFP800-200	400	13	50	$3,636.00
FREQUENCY RANGE 225 – 400 MHz				
RFP0204-4	4	20	28	$ 484.00
RFP0204-10	10	30	28	$ 685.00
RFP0204-25	25	30	28	$1,140.00
RFP0204-50	50	40	28	$1,695.00
RFP0204-100	100	40	28	$2,200.00
FREQUENCY RANGE 400 – 500 MHz				
RFP0405-4	4	20	28	$ 435.00
RFP0405-10	10	30	28	$ 616.00
RFP0405-25	25	30	28	$1,026.00
RFP0405-50	50	40	28	$1,525.50
RFP0405-100	100	40	28	$1,980.00
FREQUENCY RANGE 1 – 500 MHz				
RFP00105-4	4	20	28	$1,450.00
RFP00105-10	10	30	28	$2,300.00
RFP00105-25	25	30	28	$2,800.00
RFP00105-50	50	40	28	$3,752.00
RFP00105-100	100	40	28	$5,600.00
FREQUENCY RANGE 500 – 1000 MHz				
RFP0510-4	4	20	28	$2,610.00
RFP0510-10	10	30	40	$3,800.00
RFP0510-25	25	30	40	$4,900.00
RFP0510-50	50	40	40	$6,800.00
RFP0510-100	100	40	40	$9,800.00

☐ **YES You Can Have EXPRESS DELIVERY**

CUSTOM AMPLIFIER WORK SHEET

Output Power	+ ____ dBm or ____ watts
±	____ dBm or ____ watts
Frequency Range	_ MHz GHz to _ MHz GHZ
Input Power	____ dBm or ____ watts
or Gain	____ dB
Noise Figure	____ dB
Gain Flatness Partial Band	____ dB per ____ MHz
Gain Flatness Full Band	± ____ dB
Input/Output Load Impedance	____ ohms ____ ohms
Input VSWR/Output Load VSWR	____ ____
Load VSWR Protection	____ Yes ____ No
Amplification Class	__ A __ AB __ B __ C __ D
Amplification Mode	____ CW ____ Pulse
Pulse Width	__ mS __ microseconds
Duty Factor	____ % ____ CW
Operating Temperature Range	____ C to ____ C
Storage Temperature Range	____ C to ____ C
D.C. Power Supply Voltage	_____ volts (range)
D.C. Power Supply Current	_____ amps
Physical Dimensions	__ x __ x __ inches
Quantity Required/Potential	____ _____
Is NRE Available	____ Yes ____ No
Target Price	$_____
Target Delivery	_____
Other Notes:	_____

CALL (408) 778-9020

FOR YOUR CUSTOM WORKSHEET

OTHER PRODUCTS

- Power splitters and combiners
- Directional couplers
- Standard or custom microwave amplifiers
- Filters

R.F. SOLUTIONS INC.

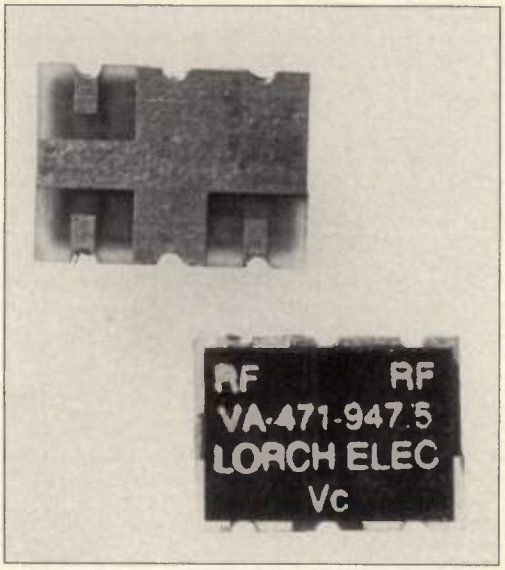
16055 Caputo Drive, Morgan Hill, CA 95037, Phone (408) 778-9020, FAX (408) 779-4832

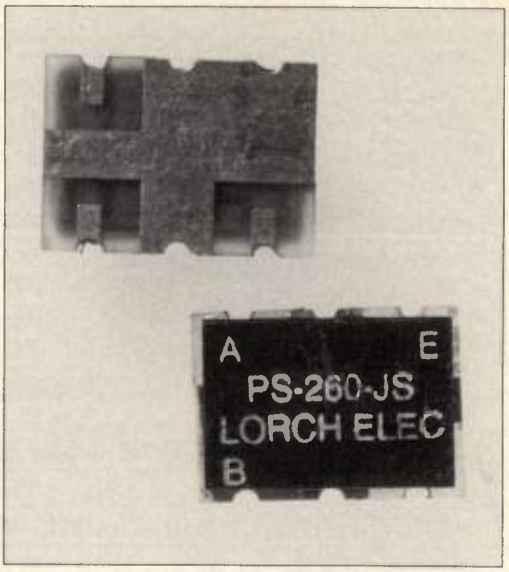
INFO/CARD 40

New SMT Transmission Components

Lorch Electronics introduces four new products in SMT packages. Voltage variable phase shifters are available in 10 percent bandwidths from 10-2000 MHz. The units feature up to 120 degrees shift with 0 to 30 volts control, with loss typically under 1 dB. SMT power splitters for 5-2000 MHz offer typical 0.2 dB amplitude balance and 1.5 dB phase balance. Mid-band isolation is better than 25 dB, and loss is 0.6 dB. Directional couplers for 5-2000 MHz are available with many different coupling values. Voltage controlled attenuators offer up to 25 dB attenuation under voltage control. 10 percent bandwidths are available over 10-2000 MHz.

Lorch Electronics
INFO/CARD #248





Swept Noise Figure Set

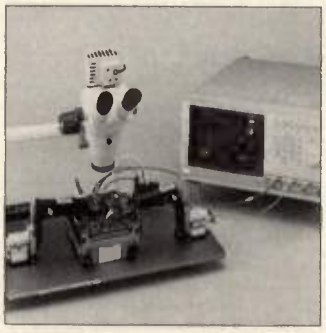
Two noise figure test sets have been introduced to operate with the Wavetek Microwave 8910 Sweeper and 8003 Scalar Analyzer. The system includes the new 21000 Series 18 and 26.5 GHz test sets and the 21200

Series noise sources. Swept noise figure measurements for TWT or solid state broadband amplifiers is possible, allowing real-time tuning for noise figure performance with a reduction in test time of up to 10 to 1. The system measures small signal gain, 1 dB compression point and VSWR directly, in addition to noise figure. The noise sources provide NIST traceable measurements. GPIB interfaces allow development of automated test stations. Complete measurement system prices start at $60,000, or individual system components can be purchased separately.

Wavetek Microwave, Inc
INFO/CARD #247

Module Test Station

Active modules and interconnecting devices can be tested in a new test station form Cascade Microtech. Circuits in packages, substrates, circuit boards, and other configurations can be tested using MTS-1000 system, which includes a stereo microscope and two probe holders. Up to eight probes can be mounted on the unit. Performance of the probes allows time and frequency domain measurements to be made from DC to 20 GHz with 10 picosecond resolution. User-configured power bus connection



allows custom setup. Mechanical design reduces vibration at frequencies as low as 60 Hz. This test station is intended to provide the benefits of a reliable, repeatable test system at an engineer's personal workbench. Prices are as low as $9,200.

Cascade Microtech
INFO/CARD #246

Low-Cost Spectrum Analyzer

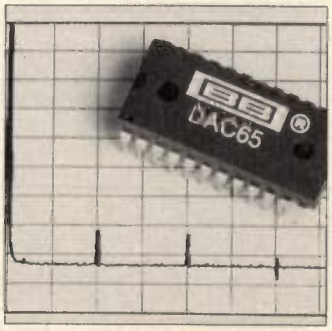
B+K Precision announces the Model 2610 spectrum analyzer, with 1 GHz frequency range, 70 dB dynamic range, input attenuator and various scan width and

resolution bandwidth selections. The analyzer weighs 20 lbs. and can be battery powered for field service applications. Input impedance is switchable between 50 and 75 ohms, and an internal reference of 100 MHz, 80 dBμV allows calibration anywhere. Targeted applications include MATV and CATV, cellular and other mobile radio systems, security systems and others in this frequency range. A selectable 1 MHz fixed bandwidth setting maintains this bandwidth at all scan width settings for convenient television and CATV measurements. Price of the Model 2610 is $2995.

B+K Precision
INFO/CARD #245

High-Speed DAC for DDS

A new 12-bit digital-to-analog converter from Burr-Brown is aimed at direct digital synthesis, local oscillator, arbitrary waveform generation, high resolution graphics, and other high-speed applications. Specifications include 35 ns settling, 1/4 bit LSB nonlinearity, −68 dBc distortion, and 70 dBc signal-to-noise ratio. Spurious-free dynamic range is specified at 70 dB. Data inputs are parallel, ECL compatible. The active DAC and internal reference are on-chip, with laser-trimmed resistor network and by-



pass capacitors included in the package. Output is ±1.25 V or ±6.25 mA, which can be increased using an internal precision resistor network and op amp. Power requirements are ±15 VDC. Price of the DAC65 is from $29.00 in 100s.

Burr-Brown Corp.
INFO/CARD #244

Switch:

1.) A change or shift from one thing to another. v 2.) K&L Microwave, Inc. n

QUALITY • HIGHER FREQUENCIES • SPEED • RELIABILITY • CUSTOM DESIGNS • LONG LIFE

K&L ... your definition of excellence in a switch!

K&L MICROWAVE INCORPORATED
A DOVER TECHNOLOGIES COMPANY

408 Coles Circle, Salisbury, Md. 21801 Phone: 301-749-2424 TWX: 710-864-9683 FAX: 301-749-5725

INFO/CARD 41

RF products *continued*

Mini-DDS Board

The DDS-3 from Sciteq Electronics is a complete DDS with DAC and filter. Constructed on a 1 × 1.5 inch SMT card, the synthesizer can operate up to 8 MHz (20 MHz clock), with 32-bit frequency control, under 500 ns switching speed, −60 dBc spurious level, parallel binary control bus, and 45 degree phase control. Price is $125 in 100s.
Sciteq Electronics, Inc.
INFO/CARD #243

UHF Power Amplifiers

Mitsubishi announces the M67787L high gain broadband amplifier and M67766A dual-mode cellular amplifier. The M67787L offers 6 watts power output with 10 mW input for 37.5 dB gain. Minimum efficiency is 35 percent over the 820-851 MHz band. The M67766A is designed for dual-mode digital and analog cellular application, with 7 watts output from 1 mW input. A control pin switches from Class AB linear to Class C operation.
Mitsubishi Electronics America, Inc.
INFO/CARD #242

Scalar Measurement System

Wiltron introduces the 5400A scalar analyzer family, with models covering 10 MHz to 8.4 GHz, 17-26.5 GHz, and four other ranges in between. Intuitive operation allows production test personnel to use the instrument with little training. The analyzer measures transmission, reflection, and power characteristics of devices through remote detectors and samplers. Dynamic range is more than 71 dB. Cursor and limit lines simplify PASS/FAIL testing. A synthesized microwave swept source provides excellent frequency accuracy. Built-in VGA color outputs can be used to drive a standard large-screen monitor, a printer interface allows hard copy output, and IEEE-488 bus control allows full programmability.
Wiltron
INFO/CARD #241

High Power Attenuator

New attenuator models from JFW are rated at 200 watts average and 5 kW peak with no external cooling requirements. Units in this series are specified to 1500 MHz, with attenuation from 0.5 through 50 dB. 50 ohm models or mismatch impedances are offered.

JFW Industries, Inc.
INFO/CARD #240

EMI Field Generators

Two field generating systems for RFI/EMI susceptibility testing within shielded rooms are announced by Amplifier Research. Operating over the 10 kHz to 1000 MHz range, System 20VP delivers a field intensity of 20 V/m, and System 50VP offers 50 V/m. Power amplifiers, field-generating antennas, leveling/control preamplifier, E-field monitoring system and interconnecting cables are included. Prices are $45,000 (20VP) and $79,000 (50VP).
Amplifier Research
INFO/CARD #239

Radio Modem

A 9600 bps radio modem, the T-MODEM 96 has been introduced by Dataradio. The modem is available for operation in the 403-430, 450-474, and 480-512 MHz bands, with 2 watts output power. Data connection is by a 9-pin RS-232 connector, and the antenna uses a BNC connector. Transmitter deviation is adjusted automatically for 1200, 2400, 4800 or 9600 bps.
Dataradio Corp.
INFO/CARD #238

High Pullability VCXO

Raltron Electronics announces the VC-7025, a VCXO with ±50 ppm control sensitivity, deliverable with up to ±70 ppm sensitivity. The unit is available in frequencies from 2 to 35 MHz, for applications in LANs, telephone networks and laboratory instruments. The price is $14.50 in 1000 quantities.
Raltron Electronics Corp.
INFO/CARD #237

Log Amplifier

A monolithic log amplifier covering 20-100 MHz has been introduced by RF Components. 70 dB instantaneous dynamic range, 800 mW power consumption, limited IF output, and 1 × 1.5 × .28 inch package size are pertinent specifications. The MCWL-3-9027 is priced at $495 (1-24 qty.).
RF Components, Inc.
INFO/CARD #236

RF Launchers

AMP offers RF launchers for matched transmission lines using SMA, SMC, 3.5 mm blindmate and 2.8 mm blindmate style connectors. Termination options include round pin, flat tab, slotted round pin, "nail head" or female contact. Flange and dielectric exposure options are available, as well. Pricing is $3 to $7 per piece (1000s).
AMP Incorporated
INFO/CARD #235

Wideband Synthesizer

The Model 902 from Zubiel RF Systems combines DDS and PLL technologies to provide 1 Hz frequency steps in the 150 MHz to 2.5 GHz range. Spurious outputs are below −85 dBc and phase noise is −75 dBc at 1 kHz. Octave tuning is available to 1.2 GHz with output power up to 100 mW. 500 MHz tuning is offered above 1.2 GHz.
Zubiel RF Systems, Inc.
INFO/CARD #234

Cellular Products

Power dividers, directional couplers and bandpass filters for cellular radio applications are now

offered by RLC Electronics. 2 to 32-way power dividers start at $35.00, couplers start at $95.00 and bandpass filters are priced from $75.00.
RLC Electronics, Inc.
INFO/CARD #233

High Speed CMOS Switches

New high speed CMOS switches from Quality Semiconductor offer 5 ohm on resistance and 250 ps propagation delay for video, RF and ATE systems. The 74QST3383 and 74QST3384 are bus switches with 10 TTL-compatible switch sections. Prices begin at $3.20 (1000s), depending on model and package.
Quality Semiconductor, Inc.
INFO/CARD #232

PLL Evaluation Boards

QUALCOMM announces two new PLL evaluation boards featuring the Q3036 synthesizer IC. The Q0410-1 provides frequencies from 900-1600 MHz with a maximum step size of 1.25 MHz. Q0410-2 is a semi-populated prototyping board, which requires user-added VCO, loop and reference-suppression filter, and has connectors for off-board VCOs and prescalers. Pricing is $895 and for $695 for the Q0410-1 and Q0410-2, respectively.
QUALCOMM, Inc.
INFO/CARD #231

Low Noise Transistor

A new low noise bipolar transistor, the B12V114 from Bipolarics, features less than 1.4 dB noise figure (typical) at 900 MHz, for applications in cellular radio and industrial data receivers. SOT-23, SOT-143 and Micro-X packages are offered, as well as 70-mil stripline and dice. Pricing for the SOT-23 packaged device is $.99 (1000s).
Bipolarics, Inc.
INFO/CARD #230

Higher Voltage Trimmers

Compression trimmer capacitors from Sprague-Goodman are now available in 2000 VDC working voltage (3000 VDC test). The Type 9 mica trimmers are available in eight ranges, from 10-48 through 250-480 pF. Prices start at $3.49 each in quantities of 100.
Sprague-Goodman Electronics
INFO/CARD #229

DSP Module

SFS Systems has introduced the DSPCHEEP module based on the Analog Devices 2105/2101 DSP processors. Two 2.5 MHz clocked 12 bit ADCs and two dual

RF products *continued*

12 bit multiplying DACs provide two analog channels. Operations manual, plus test and DSP software is included. Pricing is $99, plus options.
SFS Systems, Inc.
INFO/CARD #228

Digital Cellular Signal Generator

Hewlett-Packard announces the HP 8657D, a π/4 DQPSK signal generator. The new instrument adds the modulation needed for testing North American and Japanese cellular systems. The HP 8657D also provides analog AM, FM, PM and pulse modulation capabilities of the existing HP 8657A/B generators. The price is $22,500.
Hewlett-Packard Company
INFO/CARD #227

Wireless LAN

ProxNet is a Novell-compatible spread spectrum wireless network for new pen-based "notepad" computers. With a range up to 500 feet, the network allows convenient interconnection between computers and peripherals. Available only to OEMs, ProxNet is implemented in a miniaturized module which is integrated into the notepad assembly.
Proxim, Inc.
INFO/CARD #226

DBS Tuner IC

Anadigics announces a 950-1750 MHz DBS tuner IC for high volume applications. Low external parts count and an on-chip local oscillator are key features. The circuit features 8 dB noise figure and 9 DB conversion gain with a single 5 VDC supply, in an SMT package. Pricing is less than $2.50 for monthly usage of 50,000 units.
Anadigics, Inc.
INFO/CARD #225

UHF Power Transistor

The BLV98CE is an NPN transistor intended for common-emit-

ter, class AB operation in 850-960 MHz radio transmitters. Using a 24 VDC supply, the transistor delivers 15 watts with greater than 7.5 dB power gain. All leads of the six-lead package are isolated from the flange. In 1000s, pricing is $35.50.
Philips Components
INFO/CARD #224

Sharp Cutoff Filters

Faraday Technology "Step" Filters are sharp cutoff lowpass filters for video applications such as separating video from multiple audio subcarriers, stereo sound or multi-lingual transmissions. Group delay equalization is maintained over 93 percent of the passband.
RF Technology, Inc.
INFO/CARD #223

200-500 MHz Oscillators

Hybrid ECL oscillators covering 200-500 MHz are offered by Vectron Laboratories. 100K logic is employed to 400 MHz, with ECLiPS logic used from 400.1 to 500 MHz. Standard stability is ±25 ppm over 0-70C; ±5 ppm over 0-50C and wider temperature operation are available options.
Vectron Laboratories, Inc.
INFO/CARD #222

Nanosecond Delay Line

Accurate time delays can be inserted and measured with resolution of 2 ps over a zero to five

nanosecond range. Constant 50 ohm impedance is maintained over the entire range. The frequency range is from DC to over 5 GHz. Price of the instrument is $4400.
Bishop Instruments
INFO/CARD #221

Matrix Switches

Watkins-Johnson announces a series of Matrix Switch Distribution Systems using reed relay, FET or PIN technology, depending on the frequency range of the application: audio, video, HF, VHF, UHF or marrow band IF. Standard units come in 6x6, 8x8 and up to 30x40 configurations.
Watkins-Johnson Company
INFO/CARD #220

Baseband Modem

Operating in the 2-15 MHz range, the Motorola MHW11005 modem operates at a 5 Mbps data rate using frequency shift keying. Applications include factory communications using the Manufacturing Automation Protocol (MAP). Connection to the coaxial transmission cable is via F-connector. The price is $250 for 500 quantities.
Motorola, Inc.
INFO/CARD #219

Low Noise Synthesizer

Microsource introduces the MTS-2000 family of LO/exciter sources for applications requiring very low phase noise (−115 dBc/Hz at 10 kHz) and low spurious emission of −85 dBc. Tuning is offered over bandwidths greater than 1 GHz from 2-26.5 GHz. Resolution is as low as 1 Hz.
Microsource, Inc.
INFO/CARD #218

Flexible Cables

Gore-Tex now has a flexible alternative to 0.085 inch semi-rigid cable assemblies. With expanded PTFE insulation, the new cables are 40 percent lighter than semi-rigid cables. Custom interfaces have been engineered to maintain highest performance when using these cables.
W.L. Gore & Associates, Inc.
INFO/CARD #217

1P5T Switch

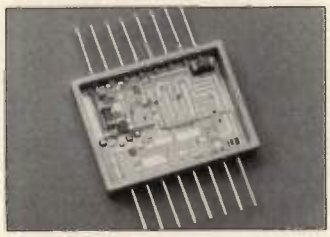
Model 3516-K20 is a new switch operating over the 2-18 GHz range with 50 dB minimum isolation and 3 dB maximum insertion loss. The standard unit is supplied with removable SMA connectors. $1400 is the unit quantity price.
Robinson Laboratories
INFO/CARD #216

Low Noise OCXO

The 250 series ovenized oscillator features the following performance in a 5 MHz unit: −100 dBc at 1 Hz to −160 dBc at 10 kHz phase noise, stabilities from $\pm 1 \times 10^{-7}$ to 1×10^{-9} over −30 to +70C. Sine or CMOS outputs are available. Price of the unit is $160 to $500 (in 50 qty.), depending on options.
Genwave Corp.
INFO/CARD #215

Low-GHz Range VCO

Radian Technology announces the model 2365 VCO, operating from 1.93-4.07 GHz, with modulation bandwidth greater than 7 MHz and a temperature range of −35 to +75C. The unit is packaged in a 1.0 × .75 × .13 inch hybrid module, and is available



as a space-qualified component.
Radian Technology, Inc.
INFO/CARD #214

ANSI C95.1 Field Meter

Model HI-3012 from Holaday Industries is a broadband field strength meter with two new probes to sense both electric and magnetic fields at the proposed ANSI C95.1 levels. The probes allow measurements from as low as 0.05 mW/cm^2, to higher that 250 mW/cm^2.
Holaday Industries, Inc.
INFO/CARD #213

Long Pulse Transistor

Motorola has expanded its line of long pulse power transistors with the MRF10120, which will deliver 120 watts peak power using a 36 volt supply. Typical peak power input is less than 15 watts over the 960-1215 MHz band. Applications include military location/information systems and commercial Mode S transmitters. The device is supplied in a hermetic metal-ceramic package. Price of the MRF10120 is $193.00 in 25-99 quantities.
Motorola Semiconductor Products Sector
INFO/CARD #212

A Technique to Determine the Effect of a Lightning Strike to a Shielded Cable

By Mike Frisoni
Contributing Editor

In the application of shielded cables for the transmission of power or data, protection from lightning induced transients must be taken into consideration to maintain the reliability of the overall transmission system. Lightning current flowing on the braided shield of a cable will induce a current on the inner conductors of the cable. This induced current will propagate along the inner conductors and can cause upset, failure and damage to the interfacing electronics. This article will present a technique to calculate the induced voltage and current on an inner conductor of a shielded cable using a finite difference expansion of the Telegrapher's Equations.

The waveform of a lightning return stroke typically has a maximum amplitude of 15 to 50 kA, but discharges with peak currents exceeding 100,000 ampheres are not uncommon. The rise time of the waveform usually ranges between 1 and 10 μsec (1, 2). Figure 1 gives an example of a lightning waveform where the peak amplitude is 50 kA and the rise time is 2 μsec. The rising edge of the waveform is modelled with a sine squared function, the decay is represented by an exponential function, and the derivatives are matched at t = 2 μsec.

Telegrapher's Equations

The voltages and currents induced on a transmission line can be determined using the Telegrapher's

$$\frac{\partial}{\partial x} V(x,t) + L(x) \frac{\partial}{\partial t} I(x,t) + R(x)I(x,t) = Vs(x,t) \quad (1)$$

$$\frac{\partial}{\partial x} I(x,t) + C(x) \frac{\partial}{\partial t} V(x,t) + G(x,t)V(x,t) = Js(x,t) \quad (2)$$

where V(x,t) are the transmission line voltages (Volts), I(x,t) are the currents (Amps), C(x) is the capacitance (F/m), L(x) is the inductance (H/m), R(x) is the resistance (Ohms/m), G(x,t) is the conductance (mhos/m), Vs(x,t) represents the distributed voltage sources (Volts/m), and Js(x,t) represents the distributed current sources (Amps/m). The Telegrapher's Equations are a TEM mode solution, and it is assumed that the line losses are small and the distance between the transmission line and the ground plane are much smaller than the wavelength of the highest significant frequency.

The point centered finite difference expansion of equations 1 and 2 are:

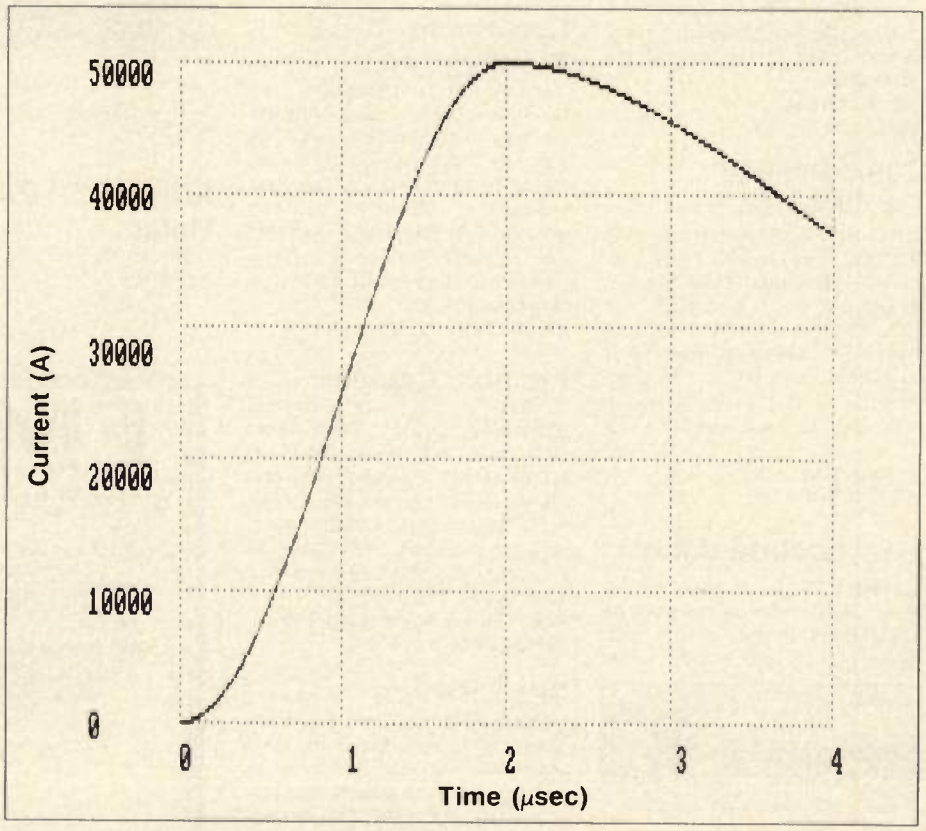


Figure 1. Lightning current waveform.

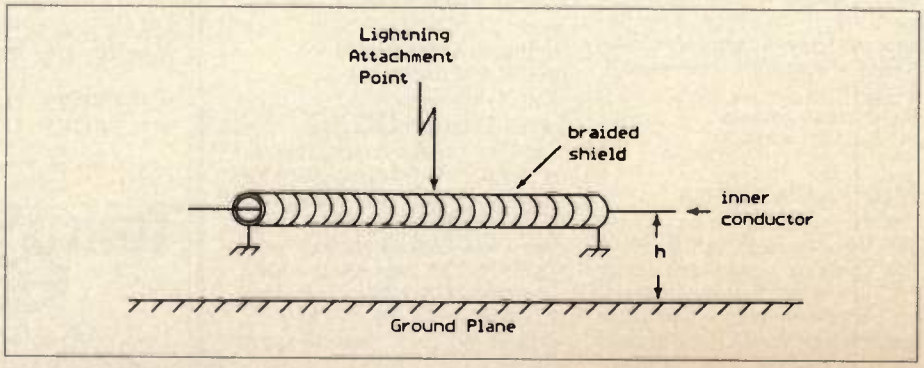


Figure 2a. Physical representation of cable with braided shield and inner conductor.

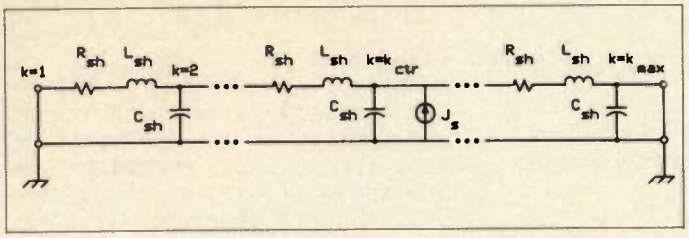


Figure 2b. Circuit equivalent for braided shield.

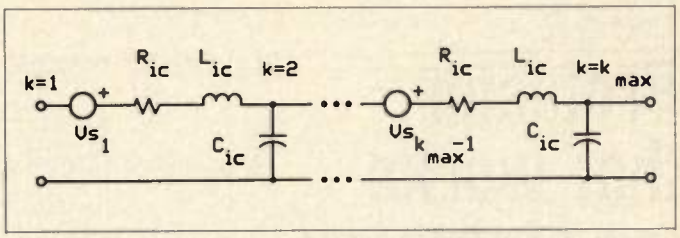


Figure 2c. Circuit equivalent for inner conductor.

$$I_k^{n+1} = \left(\frac{L}{\Delta t} + \frac{R}{2}\right)^{-1}\left\{\left(\frac{L}{\Delta t} - \frac{R}{2}\right)I_k^n - \frac{V_{k+1}^n - V_k^n}{\Delta x} + Vs_k^{n+1}\right\} \quad (3)$$

for $k=1,2,\ldots,k_{max}-1$, (4)

$$V_k^{n+1} = V_k^n - \frac{\Delta t}{C\Delta x}\left(I_k^{n+1} - I_{k-1}^{n+1}\right) + \frac{\Delta t}{C} Js_k^n$$

for $k=2,3,\ldots,k_{max}1$, and
$n=0,1,2,\ldots,n_{max}$.

In the above equations, k is the spacial step index, n is the time step index, Δx is the position increment, and Δt is the time increment. To maintain numerical stability, Δx should satisfy $\Delta x \leq \lambda_{min} / 5$ where λ_{min} is the shortest wavelength of the excitation, and Δt must satisfy the criteria $\Delta t \leq \Delta x / 2v$ where v is the velocity of propagation in the medium. Once the termination conditions have been defined, these equations can be used to solve for all the currents and voltages of a transmission line system.

Example

To illustrate the use of these equations, the following example is presented. Figure 2a shows a 30 meter long shielded cable located 4 meters above a ground plane. The shield is tied to ground at each end. The lightning strike attachment point is at the center of the cable. All the parameters of this example problem are given in Table 1.

For the braided shield, the equivalent

h = cable height = 4 m
L = cable length = 30 m
Δ x = 2.5 m
Δ t = 1 nsec
k_{max} = 13

a = inner conductor OD = 0.25 in.
b = shield ID = 0.50 in.
c = shield OD = 0.53 in.

C_{sh} = 9 pF/m
L_{sh} = 75 nH/m
R_{sh} = .200 Ohm/m

C_{ic} = 160 pF/m
L_{ic} = 400 nH/m
R_{ic} = 0

Table 1. Transmission Line Parameters

circuit is shown in Figure 2b. The shunt capacitances of the circuit can be determined from the capacitance equation for a cylinder over a ground plane (3).

$$C_{sh} = \frac{2\pi\varepsilon_o}{\ln\left(\frac{2h}{b}\right)} \text{ (F/m)} \quad (5)$$

The resistive and inductive components of the shield are arbitrarily chosen to be 0.200 Ohms/m and 75 nH/m, respectively. For a detailed examination of the parameters and electrical characteristics of braided shields, refer to Reference (4). In Figure 2b, the current source J_s represents the "injected" current due to a lightning strike to the center of the cable. The Js waveform is shown in Figure 1. Since the cable shield is grounded at each end, the termination conditions are $V_{sh}(k=1) = 0$ and $V_{sh}(k=k_{max}) = 0$. The currents and the voltages along the "braided shield" transmission line are calculated using equations 3 and 4. The current on the shield is then used to determine the distributed voltage sources which drive the inner conductor. Equations 3 and 4, along with the inner conductor circuit parameters, are then applied to solve for the voltages and currents of the inner conductor.

The equivalent circuit for the inner conductor is shown in Figure 2c. The capacitance and inductance are defined as

$$C_{ic} = \frac{2\pi\varepsilon_o\varepsilon_r}{\ln\left(\frac{b}{a}\right)} \text{ (F/m)} \quad (6)$$

$$L_{ic} = \frac{\mu_o}{2\pi}\ln\left(\frac{b}{a}\right) \text{ (H/m)} \quad (7)$$

where E_r = 2 (dielectric constant of an insulating jacket on the inner conductor). The shield and inner conductor diameters given in Table 1 were arbitrarily chosen. R_{ic} is assumed to be negligible. The distributed voltage sources which drive the inner conductor are determined from

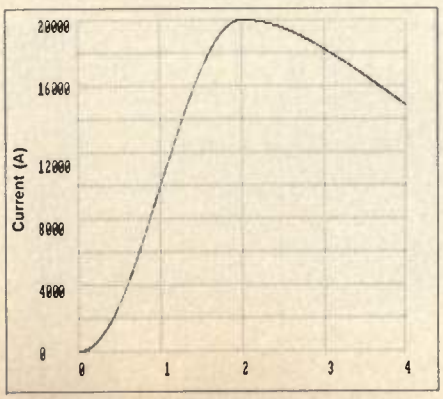


Figure 3. Current on braided shield.

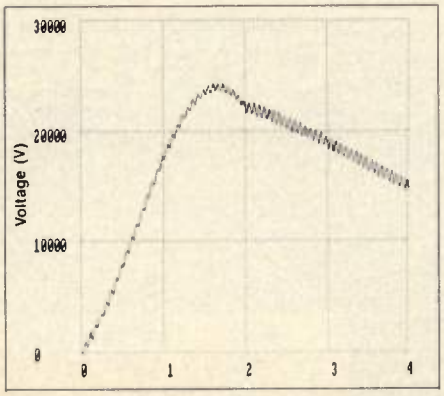


Figure 4. Open circuit voltage of inner conductor.

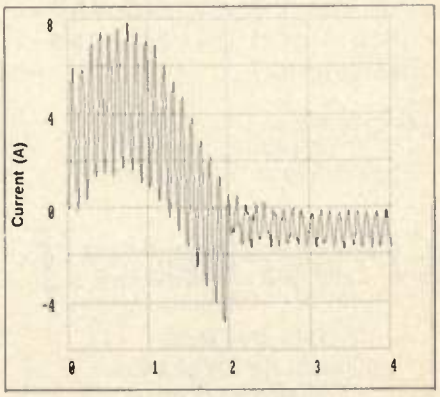


Figure 5. Short circuit current an inner conductor.

$$Vs(x,t) = R_{sh}I_{sh}(x,t) + L_{sh}\left(\frac{d}{dt}\right)I_{sh}(x,t) \quad (8)$$

which in finite difference form becomes

$$Vs_k^{n+1} = R_{sh}I_{sh_k}^{n+1} + L_{sh}\frac{I_{sh_k}^{n+1} - I_{sh_k}^{n}}{\Delta t} \quad (9)$$

In this example problem, simple termination conditions are applied to determine the short circuit current and open circuit voltage of the "inner conductor" transmission line. The short circuit current is calculated by forcing $V_{ic}(k = 1) = 0$ and $V_{ic}(k = k_{max}) = 0$, where $I_{ic}(k = 1)$ and $I_{ic}(k = k_{max} - 1)$ give the short circuit current. For the open circuit case, the termination conditions become

$$V_1^{n+1} = V_1^n - \frac{\Delta t}{C_{ic}\Delta x}I_1^{n+1} \quad (10)$$

$$V_{k_{max}}^{n+1} = V_{k_{max}} + \frac{\Delta t}{C_{ic}\Delta x}I_{k_{max}-1}^{n+1} \quad (11)$$

These boundary termination conditions will basically yield a worst case scenario. To implement resistive or reactive type terminations, a more elaborate formulization must be applied. This will not be covered in this example.

The results of this example are presented in Figures 3 through 5 and were obtained by applying the above equations in a Fortran program. The current on the shield I_{sh} at $k = k_{max} - 1$ is shown in Figure 3. Figure 4 shows the inner conductor open circuit voltage at $k = k_{max}$, and the inner conductor short circuit current at $k = k_{max} - 1$ is presented in Figure 5 and is proportional to the derivative of the open circuit voltage.

Conclusion

The technique presented in this article can be applied to other similar cable configurations. In the application of these equations, it is important that the user obtains accurate circuit parameters (R, L, C), since the results are highly dependent on these parameters. The results of this type of analysis should be used to gain an insight on the magnitude of the lightning threat — to determine worst case conditions.

The technique can be improved by incorporating resistive and reactive termination conditions. Also, the model can obtain greater stability and self consistency by taking into account the negative coupling of the inner conductor current to the outer shield current. ***RF***

References

1. Uman, Martin A., *The Lightning Discharge*, Academic Press, Inc., 1987.
2. Viemeister, Peter E., *The Lightning Book*, The MIT Press, 1972.
3. Hayt, William H., Jr., *Engineering Electromagnetics*, McGraw-Hill Company, 1981.
4. Vance, Edward F., *Coupling to Shielded Cables*, SRI International, Wiley-Interscience Publication, John Wiley and Sons, 1978.

About the Author

Mike Frisoni is Technical Editor of *EMC Test & Design* and a Contributing Editor to *RF Design*. He has a BSEE from Tri-State University plus a MSEE and Degree of Electrical Engineering from the University of Utah, and extensive experience in the modeling of electrical discharges. He can be reached at Cardiff Publishing Company, (303) 220-0600.

Quality Antennas and Sensors NOW and for the FUTURE

The one company to meet all your requirements.

ELECTRO-METRICS

All Electro-Metrics antennas are individually calibrated in accordance with MIL-STD-45662 and traceable to the National Institute of Standard and Technology (formerly NBS). Calibration standards used include ARP-958, ANSI C63.5, IEEE-302 as appropriate to the type of antenna and its intended use.

100 Church Street ● Amsterdam, New York 12010 ● TEL: 518/843-2600 FAX: 518/843-2812 TWX: 710-446-4798

VHF Active Bandpass Filters

By Eugene E. Mayle
R.L. Drake Company

A bandpass filter often determines the noise bandwidth of a communication system. A desired goal would be to obtain a narrow bandwidth (< 0.1 percent), high selectivity filter at a high center frequency (>100 MHz) where demodulation could occur with a high amount of image or undesired signal rejection (i.e. a single conversion receiver). No doubt when room temperature superconductors are discovered these specifications will become routine. Until that time, positive feedback can provide a reasonable approximation.

An active filter requires positive feedback from an active device. This feedback will add noise and distortion. To minimize these drawbacks a JFET was chosen as the active device. The superiority of the JFET over the bipolar device in low phase noise VHF oscillators has been shown in the literature. The active bandpass filter is nothing more than an oscillator with positive feedback reduced below the threshold of sustained oscillation.

The schematic of the active bandpass filter is shown in Figure 1. Noting that JFET parasitic capacitances may be modulated with bias voltage changes and that forward transconductance can vary with temperature, a heuristic analysis of the model follows. Coupling capacitor C_c provides step-up and step-down transformation to and from the tank L_t and C_t for the source and load resistance. C_c should be of high Q and chosen to realize reasonable values in the tank. A starting tank Q of 50 should provide good performance. The JFET (represented with parasitics C_{gd} and C_{gs}), bias resistor R_b, source capacitor C_s, and feedback capacitor C_f, generates a negative conductance in shunt with the tank that is adjustable via C_f. C_f also varies the net tank capacitance. G_t represents the tank's starting loss conductance. C_b is an RF short bypassing the supply voltage fed through L_{rfc}.

Photo of completed VHF active bandpass filter.

Figure 2 is the simplified schematic of the active bandpass filter. Henceforth, this circuit will be referred to as the basic cell. The active device is replaced by a variable negative conductance whose adjustment also tunes the tank capacitance. To illustrate the basic cell's flexibility, two cell responses representing Qs of 500 and 2000 were generated with feedback adjustment and are shown in Figure 3. C_c was fixed at 0.75 pF and L_t was fixed at approximately 20 nH. Unlike crystals, spurious responses are absent. Caution is advised at the higher Q as unloading may result in sustained oscillation.

Calculated responses for the respective Qs can be made by:

(1)

$$A_v = \frac{1}{Q\left[\left(\frac{1}{Q}\right)^2 + \left(\frac{f}{f_o} - \frac{f_o}{f}\right)^2\right]^{.5}}$$

and

$$P = ATN\left[Q\left(\frac{f_o - f}{f_o}\right)\right] \qquad (2)$$

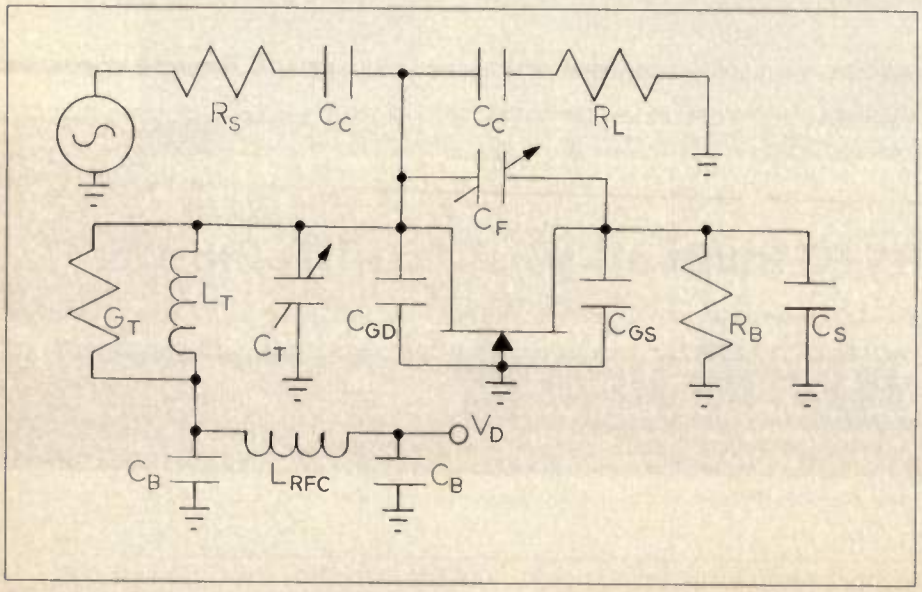


Figure 1. Active bandpass schematic

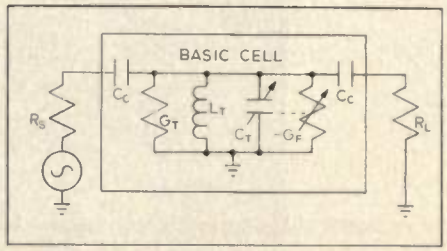


Figure 2. Basic cell simplified schematic

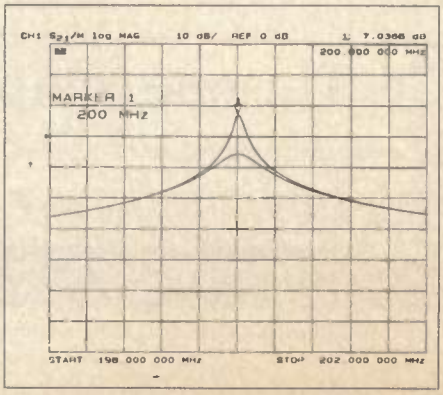


Figure 3. Basic cell responses, Q = 500, 2000.

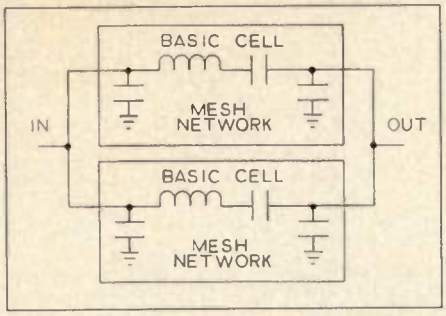


Figure 4. Elliptic cell/cell configuration.

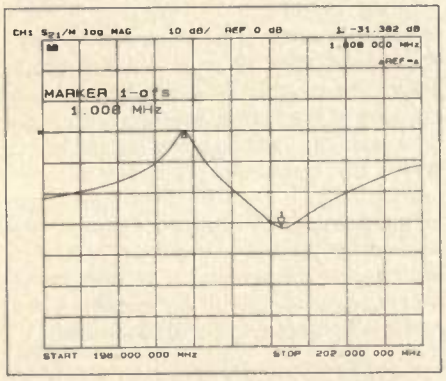


Figure 5a. Elliptic cell/cell high side notch with equal coupling.

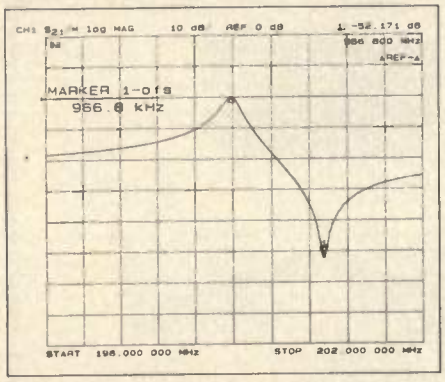


Figure 5b. Elliptic cell/cell high side notch with 4-to-1 coupling.

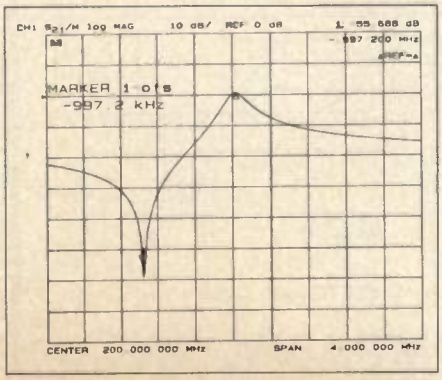


Figure 5c. Note notch on opposite skirt.

Equations 1 and 2 are derived from a parallel resonant circuit driven either by a Thevenin or Norton source. A_v is the voltage amplitude across the reactive elements. Q is evaluated at resonance as the ratio of the source resistance to the magnitude of either reactance. The amplitude in decibels is found by 20 LOG A_v. Insertion loss or gain is possible through the basic cell so the response should be referenced to the peak. Note that both responses converge to 6 dB/octave rolloff. P is the phase of the response.

Basic cells can be cascaded into higher order filter responses. Where very narrow bandwidths are desired, capacitive T-pads are recommended to reduce coupling. It should be remembered that coupling does not contribute to the amount of discrimination obtained, and therefore does not change the order of the polynomial. Shielding can isolate the basic cells between the shunt sections of the T-pads.

Elliptic Techniques

To generate high selectivity filters with a minimum number of cells requires an elliptic type response. This can be simulated by placing notches on the skirts. Figure 4 illustrates a double cell configuration that provides a skirt notch. The basic cell is implemented as a nodal network which best suits the active topology. The dual to the nodal is the mesh network which lends itself to analysis of the notch more concisely than the nodal; therefore, Figure 4 includes the mesh dual network within the basic cell block.

The basic cell provides flexibility in tailoring the notch response. Through the use of two trimmer capacitors, the center and depth can be adjusted. A notch will occur wherever the transverse basic cells' response becomes parallel resonant resulting in a large impedance to the summing node. The dominant response is the higher Q cell. Figure 5a represents a poor notch response that is the compromise one must make when the coupling of the transverse cells are kept equal. The notch depth is shallow and the flyback response is close to the passband. Figure 5b records a much improved response that can be obtained when the coupling ratio of the transverse cells is about 4 to 1. The resonance of the heavier coupled response can be tuned far enough away from the dominant response to be easily suppressed by cascaded cells. Figure 5c records a notch on the opposite skirt.

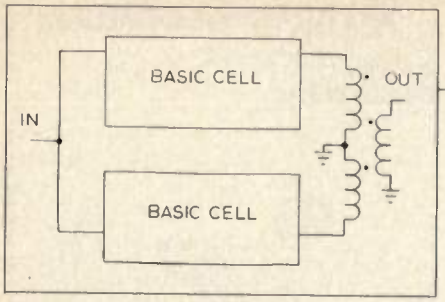


Figure 6. Differential cell/cell configuration.

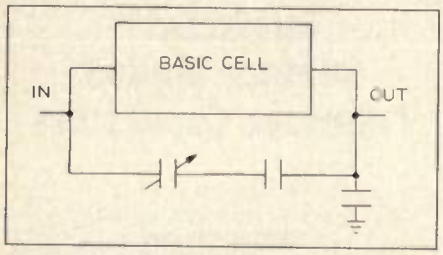


Figure 7. Elliptic cell/pad configuration.

Through phase inversion the subordinate response can be shifted opposite the notch while maintaining close-in performance. This inversion can be accomplished by inserting a differential transformer as shown in Figure 6. The transformer adds about 2 dB insertion loss. For best performance, windings should be symmetrical. Many unusual responses can be obtained and experimentation is encouraged.

A second technique for generating a skirt notch is illustrated in Figure 7. Only one basic cell in parallel with a capacitive pad is required. This has the advantage of reduced complexity but sets the ultimate rejection equal to the attenuation of the pad. The capacitive pad should probably have no less than about 22 to 24 dB of attenuation giving ultimates of 66 to 72 dB for three cascaded pads. The higher the Q of the pad, the deeper the notch in the skirt. The shunt element of the pad would be the shunt capacitor of the T-pad for cascaded cells. In the figures to follow, the load resistance of the measuring equipment comprised the shunt element of the pad.

Figure 8 illustrates the physics of how the elliptic cell/pad technique works. The capacitive pad, if of high Q, produces nearly −90 degrees phase shift

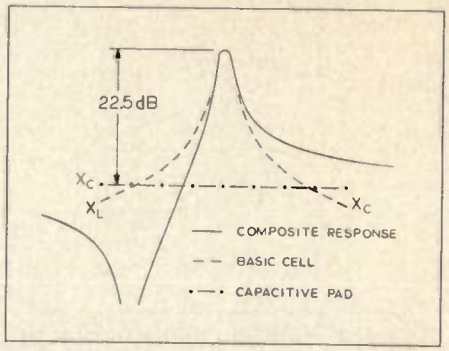


Figure 8. Elliptic cell/pad physics.

at the summing node with an amplitude down some 22.5 dB relative to the tank's peak. The basic cell is inductive on the low side of resonance and is of very high Q producing +90 degrees phase shift. Where the responses cross, the transfer function has a pole or maximum point of attenuation. Therefore, Figure 7 inherently produces a low side notch as recorded in Figure 9a. The composite response asymptotically approaches the pad level on either side of resonance.

To produce a high side notch, the phase of one of the responses must be inverted. An inductive pad may reduce the Q of the pad; if so, a differential transformer should be employed at the summing node of Figure 7. Figure 9b records a high side notch response using this technique. Transformer imperfections are probably the cause of the reduction in notch depth. The elliptic cell/pad technique is capable of producing higher Q responses than the elliptic cell/cell technique.

Coupling

The reader is referred to Reference 5, *Handbook of Filter Synthesis*, chapters 6, 8 and 9 for more detail. Coupling K between cells should roughly equal the decrement (i.e. 1/Q) of the cell tanks. With a tank Q of 1000, K = 0.001. Given a nominal tank capacitance C_t of 33 pF, C_c becomes 0.033 pF. This value can be less than board parasitics and therefore is not realizable as a single coupling capacitor. The solution is a capacitive T-pad.

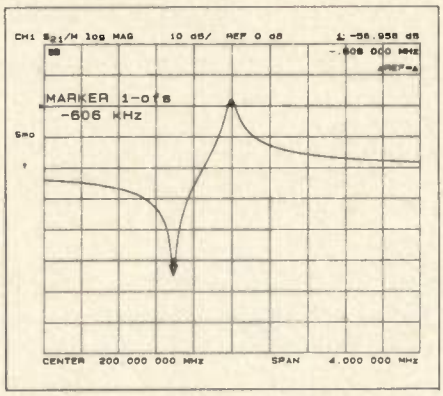


Figure 9a. Elliptic cell/pad low side notch.

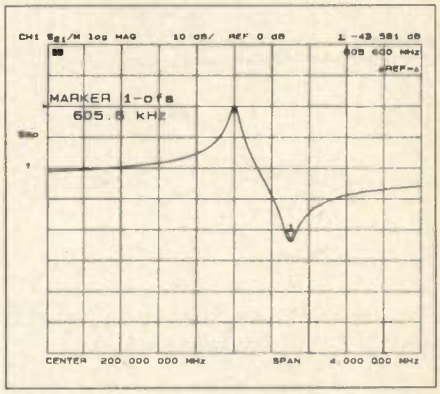


Figure 9b. Elliptic cell/pad high side notch.

For convenience the author used axial leaded components with minimum lead length. The pad took the form of two series capacitors spanning about an inch followed by a shunt capacitor to ground (<1/4 inch) followed by two series capacitors. It should be pointed out that the series capacitors comprise coupling capacitor C_c which is part of the basic cell. Therefore, only the shunt capacitor need be selected to satisfy the coupling in most cases. In the following responses the shunt capacitors were kept identical where multiple pads were required as passband characteristics are easily tailored via tank Qs and center frequencies. A shield around cascaded cells is required for optimum perform-

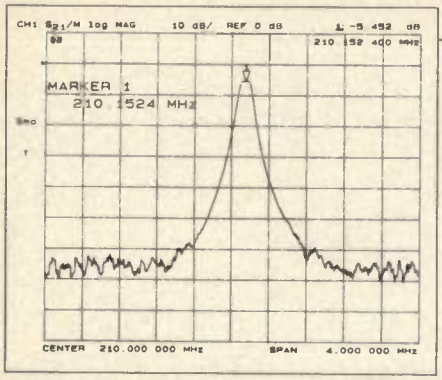


Figure 10a. 3 cell cascade (3 basic cells) T-pad coupling = 0.01.

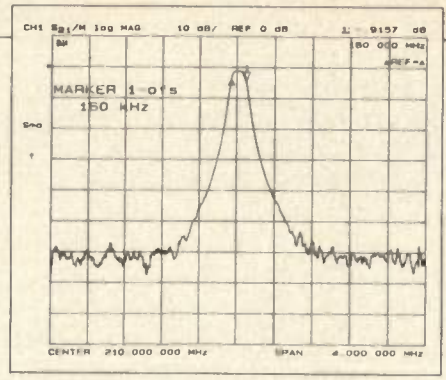


Figure 10b. 3 cell cascade (3 basic cells) T-pad coupling = 0.02.

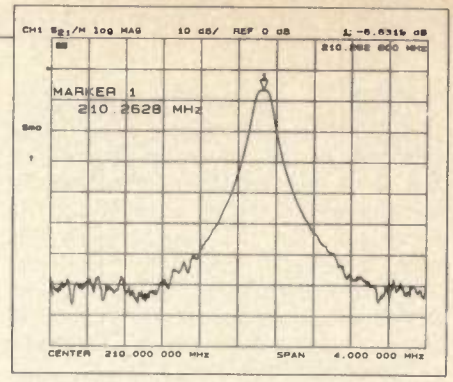


Figure 10c. 3 cell cascade (3 basic cells) T-pad coupling = 0.02.

ance. Tops may be left open for tuning access if the cavities are narrow.

Cascaded Responses

The responses of three cascaded basic cells are presented in Figures 10a through 10c. Basic cell coupling capacitors C_c were fixed at 0.75 pF. Filter 10a used 68 pF shunt capacitors while filters 10b and 10c used 33 pF capacitors. The passband of 10a was tweaked slightly narrower than 10b and 10c. The response of 10b obtained an insertion loss of less than 2 dB with a 3 dB bandwidth of about 160 kHz. The selectivity of 10b is also slightly better than 10a or 10c indicating higher Q responses in the outer resonators (i.e. Chebyshev response). 10b was operated at 14.5 V supply which resulted in a 1 dB input compression point of 18 dBm. 10a and 10c were operated at 18 V supply with compression points closer to −15 dBm. While these compression points may seem limiting at first, the output of a mixer is usually no more than this level.

Figures 11a through 11c record responses of cascading one basic cell with two elliptic cell/pads. The differential transformer was used to obtain the high side notch in all three cases. Though the responses violate the <0.1 percent bandwidth constraint proposed, they provide further insight into parameter versus performance interaction. Cell coupling capacitor C_c was increased to 1.5 pF to keep insertion loss under 10 dB.

The filter in Figure 11a used 22 pF shunt capacitors to obtain a 3 dB bandwidth of 600 kHz with 1.2 dB passband ripple and 6.5 dB insertion loss. The filter in Figure 11b used 33 pF shunt capacitors to obtain a 3 dB bandwidth of 440 kHz with 1.6 dB passband ripple and 1 dB insertion loss. The filter in Figure 11c required a fixed 1.5 pF capacitor to be added in the feedback of two of the cells before the final symmetrical response could be obtained. Using 68 pF shunt capacitors resulted in a 3 dB bandwidth of 320 kHz with 1.7 dB passband ripple and 7.5 dB insertion loss. In all three responses one or both notches were trimmed with a 1—3 pF trimmer capacitor paralleled across a fixed capacitor of 1.5 pF or 2.7 pF.

Comparing the responses of Figures 11 and 10 we see that for the same number of cells, the elliptic responses can achieve twice the selectivity of the monotonic responses. The selectivity of elliptic filter 11b compressed by a larger span in Figure 12a can be seen to be equal to or better than a commercial FM ceramic filter recorded in Figure 12b. In addition, the wider bandwidth filters requiring less positive feedback have proportionally higher compression points. Filter 11c's 1 dB input compression point was about −5 dBm at 15 V supply.

The basic cell possesses a gain constant associated with JFET parasitics. This constant is reduced by maximizing C_t. Filters 10 through 11 typically shifted ±50 kHz for a ±1V change in supply voltage about 15 V with little passband distortion. Large variations will affect cell Q resulting in gross distortions. Temperature dependent transconductance changes can also several affect cell Q and should be characterized for individual responses.

The optimum active filter given a desired bandwidth will have minimum noise figure, minimum insertion loss, and maximum 1 dB compression point which results in maximizing the dynamic range. Dynamic range is given by

$$DR = P(1dB) - P(o,mds) \qquad (3)$$

where P(1dB) is the output 1 dB compression point and P(o,mds) is the output minimum detectable signal power given by

$$P(o,mds) = k_{TB} + M + B + F + G \qquad (4)$$

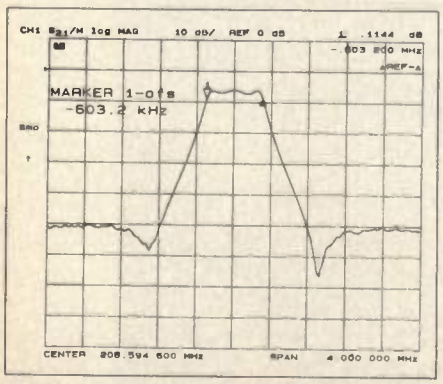


Figure 11a. 3 cell cascade (C/P, B-C, C/P) T-pad coupling = 0.07.

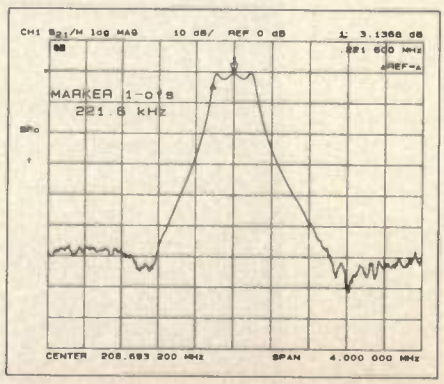


Figure 11b. 3 cell cascade (C/P, B-C, C/P) T-pad coupling = 0.05.

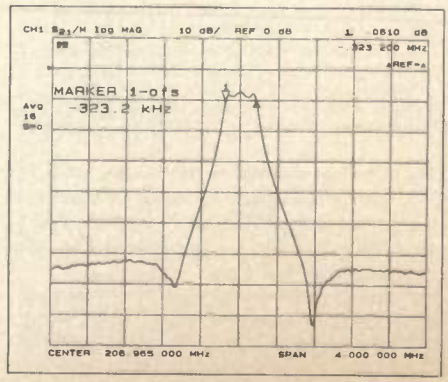
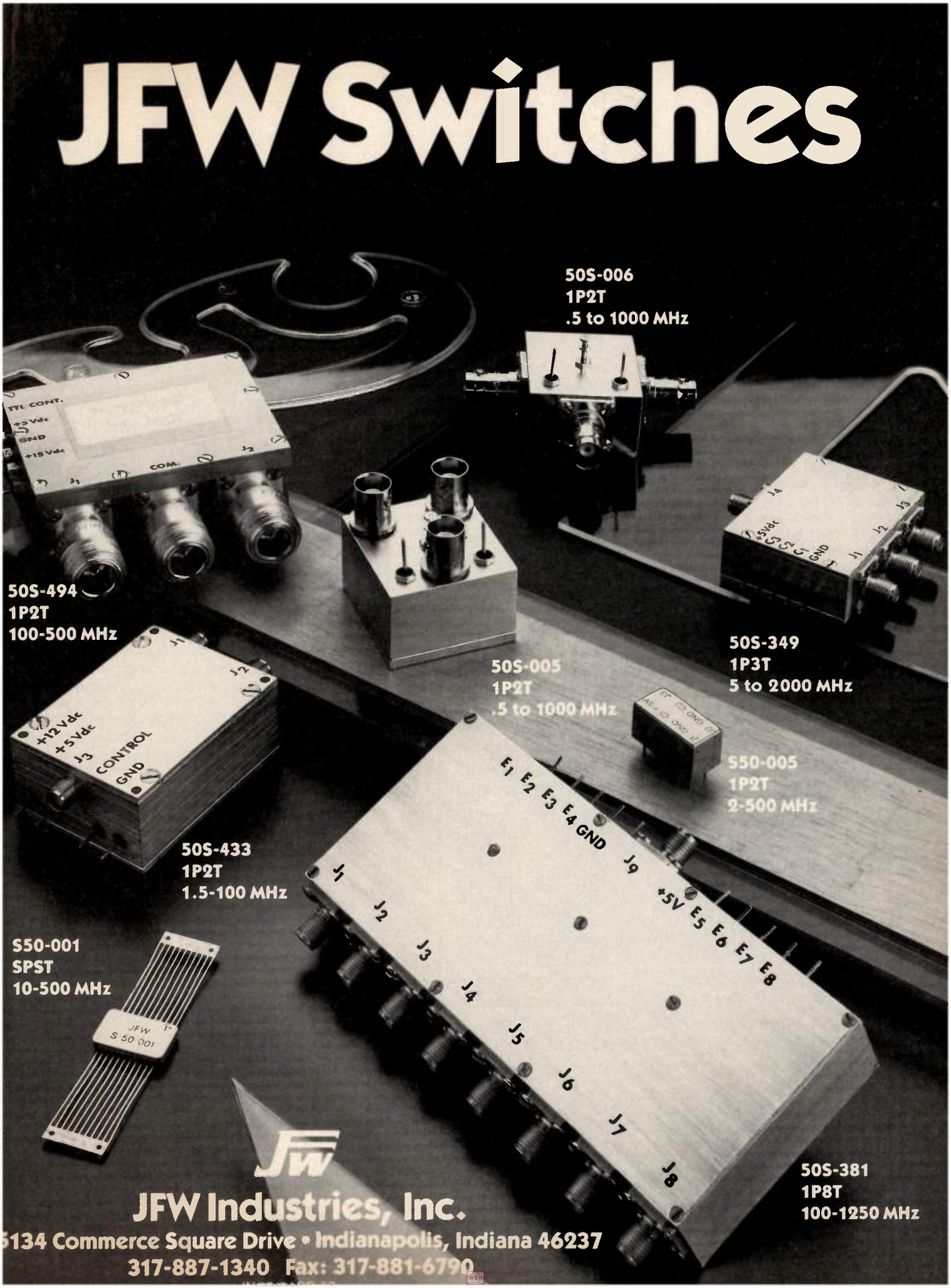


Figure 11c. 3 cell cascade (C/P, B-C, C/P) T-pad coupling = 0.02.

JFW Switches



JFW Industries, Inc.

5134 Commerce Square Drive • Indianapolis, Indiana 46237

317-887-1340 Fax: 317-881-6790

Where k_{TB} = −17dBm/Hz is the thermal noise at 300 degrees Kelvin

M = 3dB is the minimum detectable signal power above the thermal noise power.

B = 10 × log(bandwidth in Hz)

F = noise figure of the active device in dB

G = power gain or loss in dB through the filter

Because the noise figure contribution of positive feedback is not known, an example calculation would be illustrative only. A minimum dynamic range of 70 dB has been observed for filter 10b using a signal generator and spectrum analyzer. In amplitude modulated systems, dynamic range would be based upon the maximum two-tone input level that would produce the minimum detectable signal power intermodulation products not the 1 dB compression point.

Alignment and Tune-Up

Alignment and tune-up may be accomplished using a tracking generator and a spectrum analyzer. A network analyzer would make tuning even easier. The first step is to establish the tuning ranges of the tanks. The author's C_t is typically >90 percent fixed and <10 variable. L_t took the form of a partial loop to the drain comprised of the lead of a bypass capacitor. The quickest method to establish the tuning range is to increase C_t so that the cell oscillates and then vary C_t. If oscillation cannot be established, then C_s and/or C_f must be adjusted. If the oscillation range does not cover the desired center frequency (f_o) with some margin, then C_t or L_t must be adjusted. With more than three cells cascaded, oscillations may require an external pick-up loop to sense. Before injecting the FM signal, all oscillations should be stifled near f_o. This is accomplished by tuning down in frequency with C_t and up in frequency with C_f. This should leave a peaked response near f_o when the tracking generator is connected to the filter.

Tune-up is both iterative and systematic. Device to device parasitics, tank to tank non-uniformity, and trimmer variance may require compensation. Cell Qs are increased by tuning down in frequency with C_f or up in frequency with C_t. Passband tilt, sag, or bowing can be flattened by Q adjustment. In elliptic responses the notch position on the skirt will affect passband Q. Bandwidth is reduced by reducing the coupling while insertion loss is reduced by increasing the coupling. If both must be accomplished simultaneously, then C_t must be absorbed into C_c while the shunt capacitor is increased.

Finally a few comments about the basic circuit of Figure 1. In the responses presented, C_s was not required. R_b set at 200 Ohms, and in parallel with the common gate input impedance is considered a stabilizing element and therefore is not "opened" with an RF choke as might be done in an oscillator. The J310 was used as the active device drawing less than 10 mA with R_b = 200 Ohms. Negative coefficient capacitors may provide temperature compensation for passband characteristics.

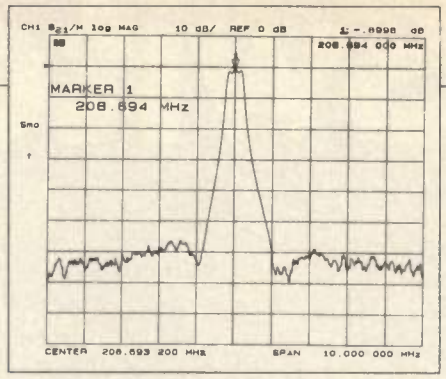


Figure 12a. 3 cell cascade (Figure 11b) wide dispersion.

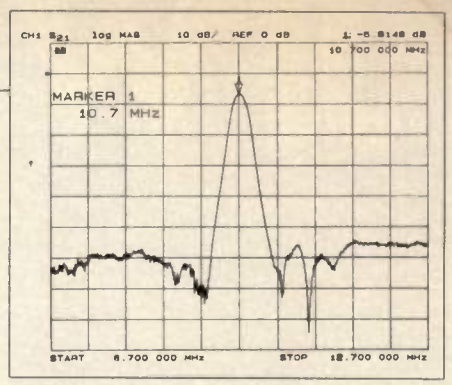


Figure 12b. 10.7 MHz ceramic filter response.

Active Notch

As a final demonstration of the versatility of the basic cell an active notch response is presented in Figure 13. The theory of operation is similar to that presented in Figure 8. Referring back to Figure 7 the capacitive pad is replaced with a series resonant tank with a Q of 10 to 20 (for 200 MHz a fixed 2.7 pF and ferrite-slug tuned .23 uH was used). The component values of the series resonant tank establishes the

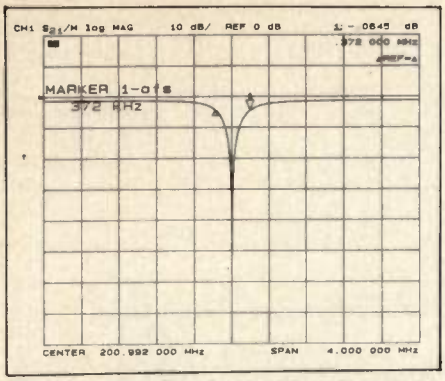


Figure 13. Basic cell/series-tank active notch.

passband insertion loss or reference line to which the peak of the basic cell response must be adjusted. C_c (0.75 pF) of the basic cell determines the Q of the notch. The resonances coincide and are 180 degrees out of phase which produces the notch at the summing node. Nearly 50 dB of rejection was obtained.

Conclusion

VHF active bandpass design techniques have been presented. Capable of narrow bandwidths (< 0.1 percent), low insertion loss, absence of spurious responses, elliptic sensitivity, and general versatility such as electronic switching, the active bandpass could prove invaluable in the prototype stage of product design. While limitations due to noise, distortion, and temperature in active devices are inherent, it is believed they will not be insurmountable to the resourceful designer. ***RF***

About the Author

Eugene Mayle received his BSEE from General Motors Institute and his MSEE from the University of Dayton. He is currently a senior design engineer with R.L. Drake Company where he has worked on projects such as TVRO systems, cable TV modulators, switching power supplies, and an IF board for a shortwave receiver. He is currently involved in designing a UHF remote control for satellite receivers. His spare time is spent remodeling his house or working on some electronic project. He can be reached at 713 Forest Grove Avenue, Dayton, Ohio 45406. Tel: (513) 866-2421.

References

1. "An Introduction to FETs," Siliconix Inc., application note AN73-7, July 1983.
2. "Audio-Frequency Noise Characteristics of Junction FETs," Siliconix Inc., application note AN74-4, July 1983.
3. Ed Oxner, "High Performance FETs in Low-Noise VHF Oscillators," Siliconix Inc., design idea DI73-2, July 1983.
4. A. Dekker, "Universal Voltage Controlled Oscillator with Low Phase Noise," *Electronic and Wireless World,* July 1987, pp. 707-709.
5. Anatol I. Zverev, *Handbook of Filter Synthesis,* John Wiley and Sons, Inc., New York, 1967.
6. Samuel Y. Liao, *Microwave Circuit Analysis and Amplifier Design,* Prentice-Hall Inc., New Jersey, 1987, p. 251.

Microwave Transmission Line Calculator

By Dan Swanson
Watkins-Johnson

This program earned its author Second Prize in the 1991 RF Design Awards Contest, a filter design package from DGS Associates. The inclusion of essential transmission line calculations, and special attention to the user interface are features of note. Menus lead the program user through the various calculation options and parameter selection.

A transmission line calculator was chosen for this project because it is a very general tool that can be used by all RF and microwave engineers. This program, called MWTLC, was written for the IBM PC using Microsoft Quick C. The software will compute electrical parameters from physical dimensions or synthesize physical dimensions from electrical parameters. Results can be printed and there are help screens to aid the user. The operation of the program should be quite clear to anyone who has used a spreadsheet. The program operates in EGA color graphics mode (VGA cards also support this mode) which seems to be a good compromise for most technical users. Support for other graphics modes might be possible in the future. A message to the user is provided if the proper graphics mode is not supported or if the printer can not be found. Only two files are required, MWTLC.EXE is the executable and MWTLC.LBR is a library of interface screens.

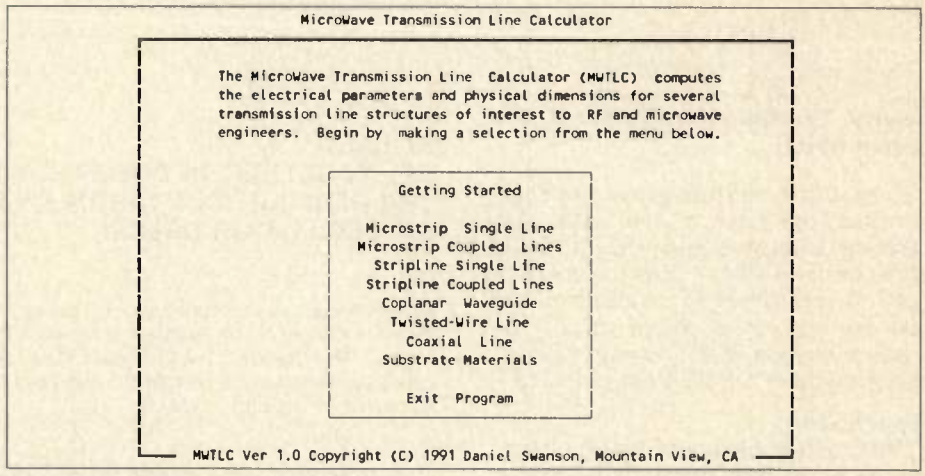


Figure 1. Main menu screen.

User Interface

A large amount of effort went into the user interface. About 80 percent of the code is user interface while only 20 percent is devoted to actual computation. This effort is justified when MWTLC is compared to "glass teletype" programs where input is one line at a time with no chance to go back and make a change. However, an RF or microwave engineer should not spend his or her time writing low level user interface routines. The initial menu screen is shown in Figure 1

Luckily, there are many third party software packages that support the type of advanced interface used here. In this case Hi-Screen Professional was used. Hi-Screen supports all the modern programming languages either through a TSR or a linkable object module. The user interface can operate in either text or graphics mode. In text mode all graphics adapters are automatically detected and supported. Graphics mode support is a little more difficult due to the limitations of the Microsoft graphics library. The initial menu screen in MWTLC runs in text mode, the rest of the screens run in graphics mode. The library of screens is loaded into memory so the program will run fast, even from a floppy disk.

Simple screen drawings are possible in text mode using box drawing characters but in graphics mode, more complex drawings can be presented to the user. Another utility called Drawbridge

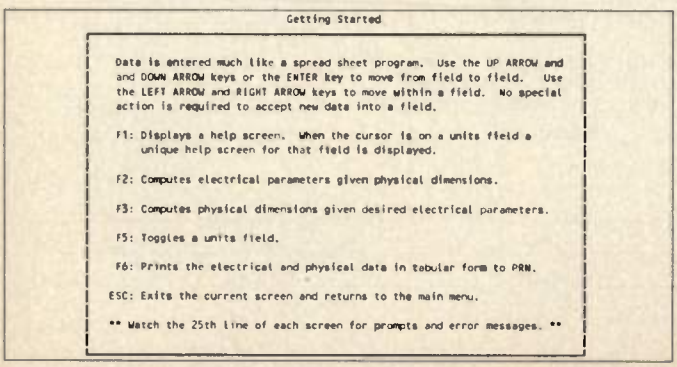


Figure 2. "Getting Started" screen, with basic operating instructions.

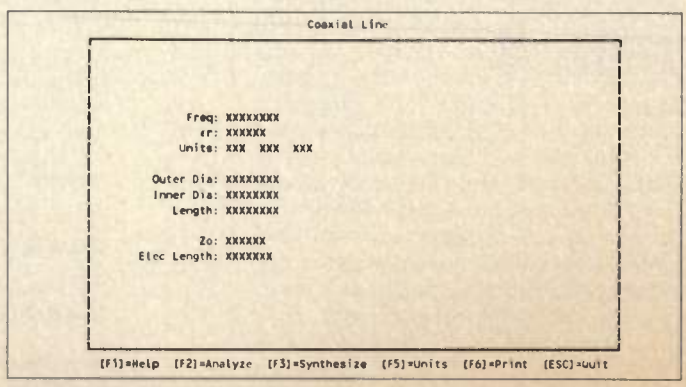


Figure 3. Computation screen for coaxial lines.

for the transmission line drawings. Drawbridge is a vector and object based drawing package that turns the finished drawing into graphics library calls in a C source code file. Drawbridge should not be confused with "paint" programs that turn bitmapped images into PCX files. Both Hi-Screen and Drawbridge allow finished applications to be distributed without royalties.

The references used for the transmission line calculations are in the help screens for each module. These references should help the interested engineer explore the limitations of the design equations. Every effort was made to use technically accurate sources. In general, only the basic calculations are provided without a lot of "corrections" for thickness, cover height, etc. In many cases, these so called corrections actually limit the useful range of the design equations. Thickness correction for coplanar waveguide was requested by a beta tester. It might be appropriate to also include thickness correction in the stripline computations.

Error trapping for negative values is done by the interface library. Trapping math errors during the actual computation is much more difficult. Reasonable input data should not cause any problems with the software. As is the case with virtually any program, extreme values of input data may cause it to crash. Any comments or suggestions from the readers on how error trapping could be improved would be greatly appreciated.

The current frequency and units for frequency, length and angle are variables that are common to all the modules. All the other input variables for each module have unique names. When the program starts, all these variables are initialized to default values. If the user leaves a module and comes back to the same module without ending the program, the last input data values used are retained. A future upgrade to MWTLC might include saving the default data to disk.

Operation requires only that the operator follow instructions given on the menus. The introductory screen is shown in Figure 1, the main menu for MWTLC. Figure 2 is the "Getting Started" screen, which can be selected from the main menu to review basic operating instructions. Figure 3 is the computation screen for coaxial cables. Known parameters are entered where "XXXX" is shown, and when the <F2> key is pressed, the spreadsheet-style computation updates all the parameters based on the changes entered. Also on-screen, but not shown on this printout is a simple cross-section diagram which helps the operator visualize the various parameters and dimensions.

Summary

Transmission lines are integral to RF (and other high frequency, high speed circuits). This program computes key transmission line parameters for microstrip and stripline (both single and coupled lines), coplanar waveguide, twisted wire line and coaxial cable. Its extensive menu and library of substrate materials simplifies the operator's task in using the program. The program requires an EGA/VGA compatible monitor.

This program is available on disk, including additional documentation, from the RF Design Software Service. See the ad on page 71 for ordering information. ***RF***

About the Author

Dan Swanson is a Staff Scientist in the Subsystems Division of Watkins-Johnson Company, 3333 Hillview Avenue, Stanford Research Park, Palo Alto, CA 94304-1204, tel. (415) 493-4141. He received his BSEE from the University of Illinois and an MSEE from the University of Michigan. In addition to RF and microwave CAD, he has a special interest in microstrip filters and holds a patent in this area. He has also done amplifier, YIG oscillator and DRO design, and recently completed a challenging pulsed VCO project.

ANNOUNCING THE FOURTH ADDITION TO THE RF DESIGN HAND-
BOOK SERIES...

ANNOUNCING...

RF DESIGNS' POWER AMPLIFIER HANDBOOK

The Power Amplifier Handbook contains 80 pages of our best and most helpful articles, on power amplifier design and application. Compiled and bound, these articles come directly from the pages of *RF Design* magazine, and are written by noted authorities on power amplifier technology.

These practical articles will bring new engineers up to speed on the principals behind power amplification technology, and the advanced technology articles and application notes will help even the most experienced engineers improve system performance.

Order a copy for yourself, your friends, and your library today. Supplies are limited.

INTERESTED IN OUR OSCILLATOR HANDBOOK, OUR FILTER APPLICATION HANDBOOK, OUR FILTER DESIGN HANDBOOK, AND THE NEW POWER AMPLIFIER HANDBOOK? ORDER A COMPLETE SET OF ALL 4 HANDBOOKS (AN $84.95 VALUE) FOR $69.95 PLUS $5 SHIPPING, WHILE SUPPLIES LAST!

— — — — — — — — — — — — — COUPON — — — — — — — — — — — — — COUPON — — — — — — — — — — — —

Yes, ship me all (QTY) _____ sets of the 4 different Handbooks, at $69.00 per set, plus $5* postage, per set.

Yes, ship me (QTY) _____ sets of the Power Amplifier Handbook, at $24.95 per handbook, plus $3* total postage.

*non U.S. orders, please double shipping charges.

( ) Bill my company...signed PO enclosed. $ _____ amount

( ) Check enclosed...payable to *RF Design*. $ _____ amount

( ) MC ( ) Visa ( ) Amex exp. date _____

Card # _____ signature _____

Ship to: Name _____ Company _____

Address _____ ms _____

City _____ State _____ Zip _____

Telephone _____

Mail order to: *RF Design*, Circulation Dept., 6300 S. Syracuse Way, #650, Englewood, CO 80111, or call 303/220-0600 TODAY!

Reliable Markets for Switches and Relays

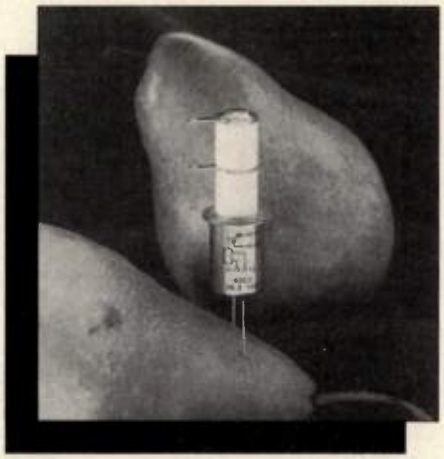
By Liane G. Pomfret
Associate Editor

Electromechanical switches and relays are well established, reliable components. While in some instances, solid state devices have replaced them, there are some applications to which electromechanical devices are better suited. Automatic test and communications equipment are two such areas. There are pros and cons for using electromechanical switches and relays and they must be weighed carefully.

On the positive side, electromechanical switches and relays can be used in high power, high frequency applications and over a very broad frequency range. Because they are mechanical rather than solid state, they also offer failsafe operation. In addition, their low contact resistance makes them virtually invisible to RF signals. However, electromechanical devices can be large and bulky and require significantly more power to operate than a similar solid state switch. Lifetime can be a consideration depending on the application and power requirements involved as well as the type of device. Switching time is also slower, but, depending on the switching application, this may not be a problem.

The largest markets for switches and relays are automatic test and communications equipment. In the automatic test equipment area, electromechanical devices are virtually the only choice. For example, field test equipment is often subject to surges, spikes and transient voltages which can destroy a solid state device. In many cases, manufacturers have found that it is better to replace the solid state device with an electromechanical one. Then, instead of being returned for repair every month, the test equipment can stay in the field longer.

Electromechanical switches and relays, in particular switch matrices, are seeing a large amount of use in VXIbus equipment. Bryan Thompson, Product Marketing Engineer at Hewlett Packard notes that, "we definitely see big growth opportunities for these products [switch matrices]. They complement all VXI products and give the customer an entire test system in VXI, so they don't have to go to other systems." Matrices



are also gaining interest for other types of automatic test equipment. "We can make fairly large matrices, an 8 by 8 matrix switch, that is GPIB controlled," notes Bruce Malcolm, President of Trilithic. This capability is what he calls a "technical tour de force" for his company.

Communications equipment has also been a strong area for switches and relays. While many radio systems have gone to solid state switching, there are applications where this is not possible because of power or frequency demands. Jim Lanum, Product Marketing Manager at Kilovac comments "The relays we manufacture are generally in high power, low frequency radio couplers and antennas." These are areas where solid state devices are almost completely unsuitable and therefore have not seen much competition from the solid state industry. John Beigel, Director of Marketing and Sales for Coto Wabash notes that people are "extending system capability with our relays, especially for automatic test equipment, where the reed relay offers faster clock speeds, very smooth impedance characteristics and very few signal discontinuities."

Relays have seen some interesting changes as well. For Coto Wabash this has meant a change in their markets. John Beigel notes, "our surface mount relay was introduced in 1983-84 and people began designing it into RF applications as well as replacing pin diodes, which are expensive." He also notes that, "RF design people don't always think of us for relays, but they are an excellent alternative." The changes are occurring in other parts of the relay business as well. Jim Lanum noted that despite the general downward trend of the military market, "the smaller subcontractors' business is picking up," which means more business for them.

Despite a few comments that business is booming, the consensus among manufacturers of both products is that the market is flat but stable. They don't seem to be overly concerned by this and most are looking down the road for an improvement in the market. Bruce Malcolm agrees that the market is slow but "expects to see a turnaround in 1992." Specialty products and niches have helped companies such as Coto Wabash, Kilovac and Hewlett Packard fare the slowdown somewhat better than others. Despite a flat market, there are some changes occurring. Customers are becoming more demanding in regards to cost, delivery and performance. In keeping with the recent trend, there has been a "resurgence in the emphasis on quality," according to Jack Dysart, Director of Marketing and Sales at Dow-Key Microwave. Total Quality Management (TQM) is nothing new, but it has become an important issue over the past few years. TQM has been easier to implement and maintain for manufacturers of electromechanical devices than for manufacturers of solid state devices.

There are advantages and disadvantages to every product and electromechanical switches and relays have their share. For manufacturers who are not overly concerned with speed, size and power considerations, but reqiure low loss or high performance, electromechanical devices offer an almost ideal solution at a lower price. ***RF***

What types of susceptibility testing does D.L.S. offer?

- **Radiated Electric Field**— a signal generator is used to create emissions similar to those from transmitters, CBs, and commercial radios. The signal is amplified and fed to an antenna where it is released into the air and picked up by your equipment. Testing is done from 10 KHz to 11.7 GHz to determine which, if any, frequencies cause your product to malfunction.
- **Conducted CW (Continuous Wave)**— test set-up is similar to that of radiated susceptibility except the energy is injected directly into the power or signal leads through a coupler. This simulates radio frequencies picked up on power and signal lines and brought into your equipment.
- **Conducted Transient**— a transient generator is used to inject various levels of voltage into the signal and power leads of your equipment. This test simulates the turning on and off of other equipment connected to the same power line as your product.
- **ESD (Electrostatic Discharge)**— ESD energy is injected into multiple points on your equipment from an ESD gun.
- **Voltage Variance (Surges and Sags)**— momentary high and low line voltages are sent to your equipment from a line voltage variation simulator, creating brown-outs and surges similar to those your equipment experiences from the power line.
- **Radiated Transient**— a transient generator is used to inject energy into external wires which have been wrapped around your equipment or bundled with your cables to simulate transients radiated from nearby equipment.
- **Radiated Magnetic**— current is injected into a loop antenna generating a magnetic field which is exposed to your equipment. The frequency is normally 50 or 60 Hz but can be varied. This test simulates high magnetic fields seen near motors, transformers, and other equipment using large amounts of power.

Radiated Electric Field Testing

Conducted Transient Testing

ESD Testing

Which tests apply to your product?

Test specifications are based upon specific product usage. Call D.L.S. today to discuss which specifications apply to your product, or to have us develop a specification that is unique for your particular needs. Current test specs available include:

EC 1992 requirements for Europe

MIL STD 461 A, B and C required for most military purchases

MDS 201-0004 for medical equipment (includes 25 pages of rationale showing how to modify these specs for non-medical purposes)

SAE, BELLCORE, and many others.

Why D.L.S.?

Just ask our customers—we're proud of our enviable track record of quick turn-around time, immediate results, and cost effective solutions.

Call D.L.S. to schedule a susceptibility test today. . . your company's reputation may depend on it.

DLS
ELECTRONIC SYSTEMS, INC.
10350 DEARLOVE ROAD
GLENVIEW, IL 60025
708 - 699 - 9060

Impedance Matching Design Tool

"Designing Impedance-Matching Networks with the HP 8751A" is a new application note from Hewlett-Packard describing the conjugate matching function of the HP 8751A network analyzer to design impedance-matching networks. This internal software automates the task of impedance matching that previously had to be done with external software packages or manually.
Hewlett-Packard
INFO/CARD #200

Circuit Analysis

DragonWave 2.0, a major update of the microwave circuit analysis and optimization software for the Macintosh computer, is now available. The software now has an enhanced S-parameter library interface and an expanded element library. In addition, DragonWave has moved completely to SANE floating point operations, can work in GHz, MHz or kHz, supports complex input/out terminations and more. Price is $1495.
Nedrud Data Systems
INFO/CARD #199

Active Filter Design

AFD-PLUS 3.0 is now available for immediate shipping. The software is a full-featured CAE active filter design program for the IBM PC and compatibles, with a menu-driven user interface. New features include: phase locked loop analysis, an automated macro recorder, a user definable file with extensive math functions and calculated pole/zero locations. User documentation has also been extensively revised and expanded.
RLM Research
INFO/CARD #198

Microwave Design System

Cadence Design Systems has produced a single design environment for microwave, analog and digital designs. Available as an option to the Analog Artist Design System, the Analog Artist Microwave Design System is comprised of a microwave simulation interface and microwave physical design system. The system includes interfaces to several industry standard microwave simulators.
Cadence Design Systems, Inc.
INFO/CARD #197

Interface Program

EEsof has announced Microwave ACCESS, a new program for the integration of EEsof's high-frequency analog and microwave simulators into third-party EDA frameworks. ACADEMY, OmniSys, Touchstone, Libra, and Microwave SPICE EDA design tools can now be accessed by framework systems using an advanced Inter-Process Control software technology.
EEsof, Inc.
INFO/CARD #196

RF Design Tools

Three software design tools are available for engineers from SW.I.F.T. Enterprises. ASP 3.0, a transistor amplifier design software, provides noise figure/gain optimization routines, as well as full design parameters and plotting routines. PLL3 1.2 calculates loop filter component values at desired phase margins and loop bw for active third order PLLs. PLL2 1.0 complements PLL3 with active and passive second order PLL design.
SW.I.F.T. Enterprises
INFO/CARD #195

RF literature

OCXO Data Sheet

Frequency Electronics has issued a two-page data sheet on their new OCXO, Model FE-2260A, a stable, oven-controlled miniature crystal oscillator without the normally long warm-up time. The data sheet contains full specifications, charts, diagrams and outlines.

Frequency Electronics, Inc.
INFO/CARD #190

Gasket Catalog

A new catalog features canted coil spring gaskets. The catalog details the advantages of this concept including assembly techniques, materials, compression forces, as well as charts comparing shielding effectiveness at frequencies up to 100 GHz with a standard spring series.

Bal Seal Engineering Company, Inc.
INFO/CARD #189

Market Data Book

The EIA's *1991 Electronic Market Data Book* is now available. The annual statistical encyclopedia includes coverage of consumer electronics, communications equipment, computers and industrial electronics, electronic components, government electronics, international trade, employment, and research and development. The annual is available for $175.

EIA Marketing Services Department
INFO/CARD #188

EMI/RFI Control Guide

A 64-page reference manual describing electromagnetic/radio frequency interference is available from Spraylat. The manual also provides detailed information and application instructions for the company's Wave Guard™ EMI/RFI architectural shielding paint.

Spraylat Corporation
INFO/CARD #187

OCXOs and Precision Resonators

A 12-page catalog contains specifications and mechanical drawings for low phase noise miniature ovenized oscillators. Specifications include frequency, phase noise, thermal stability, aging, short term stability and tuning ranges. Also included are electrical properties and outlines for precision resonators. Resonator properties include: cut, overtone, Q, aging/day and series resistance.

QK Genwave Corp.
INFO/CARD #186

RF literature *continued*

Network Analyzer Data Sheets

Two new data sheets are available from Wiltron describing two of their vector network analyzers. An 8-page data sheet describes the 360PS20A network analyzer with full-reversing, error-corrected S-parameter measurements in the 890 MHz to 20 GHz range. A 20 page data sheet describes the 360 Vector Network Analyzer which covers 10 MHz to 62.5 GHz in coax with a single test set.
Wiltron
INFO/CARD #185

New and Used Test Equipment

RAG Electronics has issued a catalog update of new and used electronic test equipment. The update features used equipment such as: oscilloscopes, spectrum analyzers, DMMs, power supplied, signal sources, environmental chambers, and more. Factory new test equipment is also included, featuring a full line of Tektronix oscilloscopes, Fluke DMMs and others.
RAG Electronics, Inc.
INFO/CARD #184

VLSI Product Selection

A Product Selection Guide featuring Qualcomm's ASIC line is available for the first time. The guide consists of technical product information of the 1.0 μ direct digital synthesizers, phase locked loop synthesizers and Viterbi codec devices. It also provides illustrations of each product family, product applications and ordering information.
Qualcomm VLSI Products Division
INFO/CARD #183

Passive Microwave Components

A 135 page catalog is now available that details Sage Laboratories' complete line of passive microwave products. The new literature relays electrical and mechanical parameters, as well as complete application notes, for standard and custom engineered components in the DC to 40 GHz range.
Sage Laboratories, Inc.
INFO/CARD #182

ASIC & Custom Products

The 6th edition of The ASIC & Custom Products Short Form Catalog is now available. The catalog provides a brief single page description of each product for quick reference to each of the devices in their frequency synthesis, forward error correction, coding and demodulation product families.
Stanford Telecom, ASIC & Custom Products Division
INFO/CARD #181

RF Shielding Catalog

"RF Shielding Selection: A Guide to Interference Control" provides detailed technical data on Instrument Specialties' line of beryllium copper shielding gaskets, electrostatic grounding products and ground and shielding contacts. The publication provides specifications and dimensional schematics.
Instrument Specialties Co., Inc.
INFO/CARD #180

Cable and Assemblies

Storm Products has released its new RF/Microwave Products Catalog. Some highlights of this catalog include: low loss flexible microwave cable assemblies, semi-rigid cable and assemblies, instrument cables, extra flexible cables, solder and delay lines.
Storm Products Advanced Technology Group
INFO/CARD #179

RF engineering opportunities

RF design

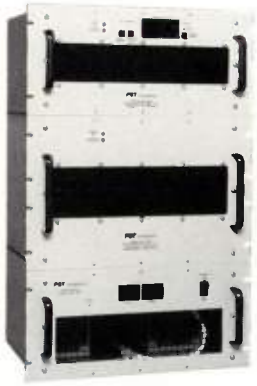
MARKETPLACE

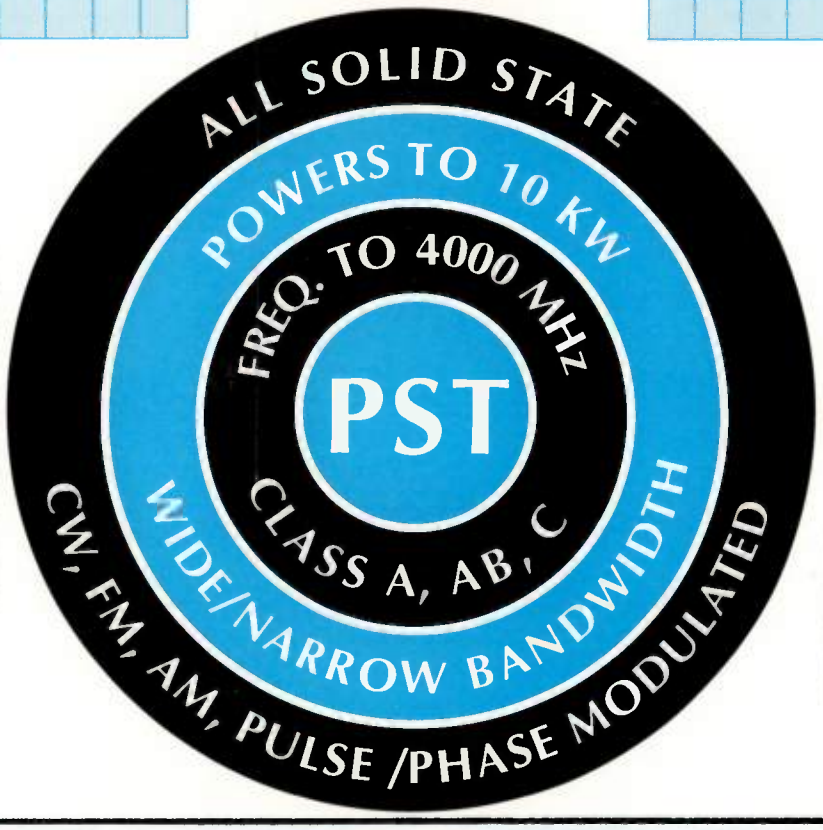
WHEN YOU ARE READY TO BUY-SELL-TRADE CALL *RF DESIGN* MARKETPLACE

Increase your REVENUES with ***RF Design Marketplace*** advertising! Over 40,000 prospects read and buy from this section each month. To reach this sophisticated, targeted market call today **(303) 220-0600.**

Advertising Index

POWER IS OUR FIRST NAME





If your aim is set on the state-of-the-art in solid state RF/Microwave Power Amplifiers & Sub-Systems, you can set your sight on PST. Our extensive selection of standard designs is strongly supported by a broad spectrum of advanced technological expertise available for customized design and development including: multi-octave/frequency agile systems, remote control IEEE 488 Bus, computer-aided circuit design, thermal protection, built-in test diagnostics, modular maintainability. And, behind the technical know-how, there's our total commitment to full customer cooperation – team-working together to assure on-time delivery of high performance, cost-effective products to meet your applications from EW, communication and radar to laboratory and RFI/EMI testing. To learn more, call the first name in power – call PST.

PST

A COMTECH COMPANY

INFO/CARD 64

POWER SYSTEMS TECHNOLOGY INC.

63 OSER AVE., HAUPPAUGE, NY 11788

TEL. 516-435-8480 • FAX 516-435-4805 • TELEX 221234

Take The Heat Off!

New 5 Volt Log Amps Reduce System Power Dissipation

- Operates at < 1 watt
- 1/3 the power of other comparable log amps
- +5 VDC @ 60 mA; −5 VDC @ 130 mA
- Hermetically-sealed miniature housing

SPECIFICATIONS	MODEL LV750	MODEL LV160
Operating frequency	500-1000 MHz	110-210 MHz
Video rise time	< 15 nsec	< 20 nsec
Video fall time	< 100 nsec	< 125 nsec
Overshoot & ringing	< 5%	< 5%
Input dynamic range	−60 to +5 dBm	−70 to +5 dBm
Linearity	±1.0 at 25°C Fo, ± 2.25 over full temperature and frequency range	
Typical operating temperature	−55°C to +85°C	
Environment	MIL-E-5400	

RHG ELECTRONICS LABORATORY, INC.

161 East Industry Court, Deer Park, NY 11729
(516) 242-1100, FAX: 516-242-1222, TWX: 510-227-6083

RHG

A M/ACOM COMPANY