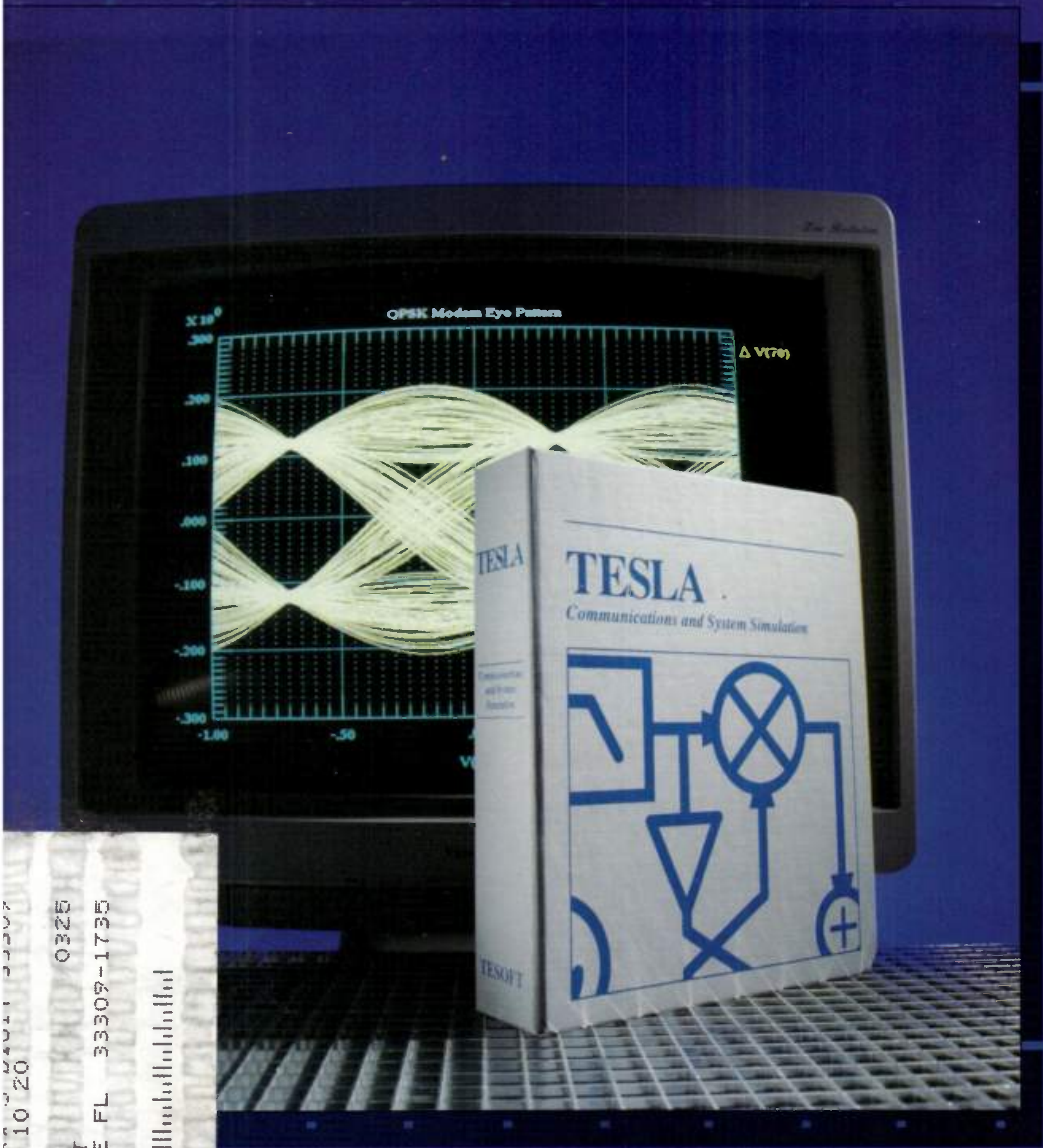
RF design™

engineering principles and practices

February 1994

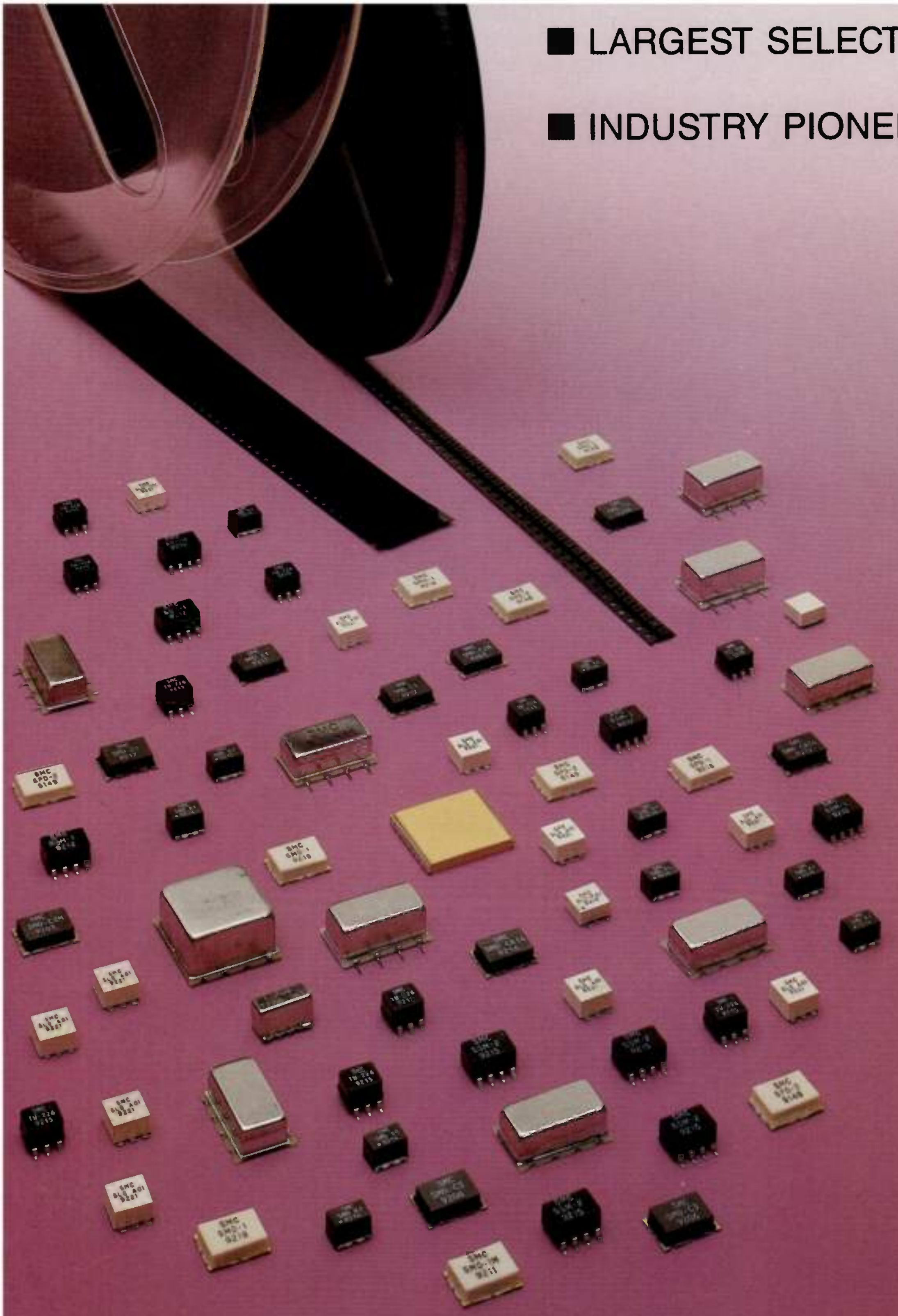


Featured Story

CAD/CAE Methods

Inside —

RF Expo West Preview



■ LARGEST SELECTION

■ INDUSTRY PIONEER

SURFACE MOUNT

MIXERS • POWER DIVIDERS • COUPLERS • FILTERS
I/Q MOD. & DEMOD. • PHASE DETECTORS • PHASE SHIFTERS
ATTENUATORS • VECTOR MODULATORS and more...

SYNERGY®
MICROWAVE CORPORATION

483 McLean Boulevard • Paterson, New Jersey 07504 • (201) 881-8800 • Fax: (201) 881-8361

INFO/CARD 1

GET THE TOTAL PICTURE

WITH AN IFR SPECTRUM ANALYZER

In addition to being a full-featured 22 GHz spectrum analyzer, the AN930 is a powerful measurement tool that can perform frequency or time domain analysis on the complex signals found in many modern communications systems.

A 30 MHz resolution bandwidth filter combined with a powerful set of time domain measurement functions provides the AN930 with a unique ability to capture and analyze pulsed and digital transmissions that previously has been unavailable in any other spectrum analyzer.

A built-in sensitive FM/AM receiver with modulation measurement scales enables direct measurements of FM deviation or AM percent modulation. The accompanying high-quality audio output aids in identification of unknown or interfering signals.

Other standard AN930 features include an automatic limits test function for unattended detection of random or intermittent signals, a built-in frequency counter for precise frequency measurements, RS-232 and IEEE-488 interfaces, and operation from DC power sources.

Optional features including a built-in 2.9 GHz tracking generator, quasi-peak detector, high stability time base, and a rechargeable battery pack add even greater flexibility for solving your unique measurement requirements.

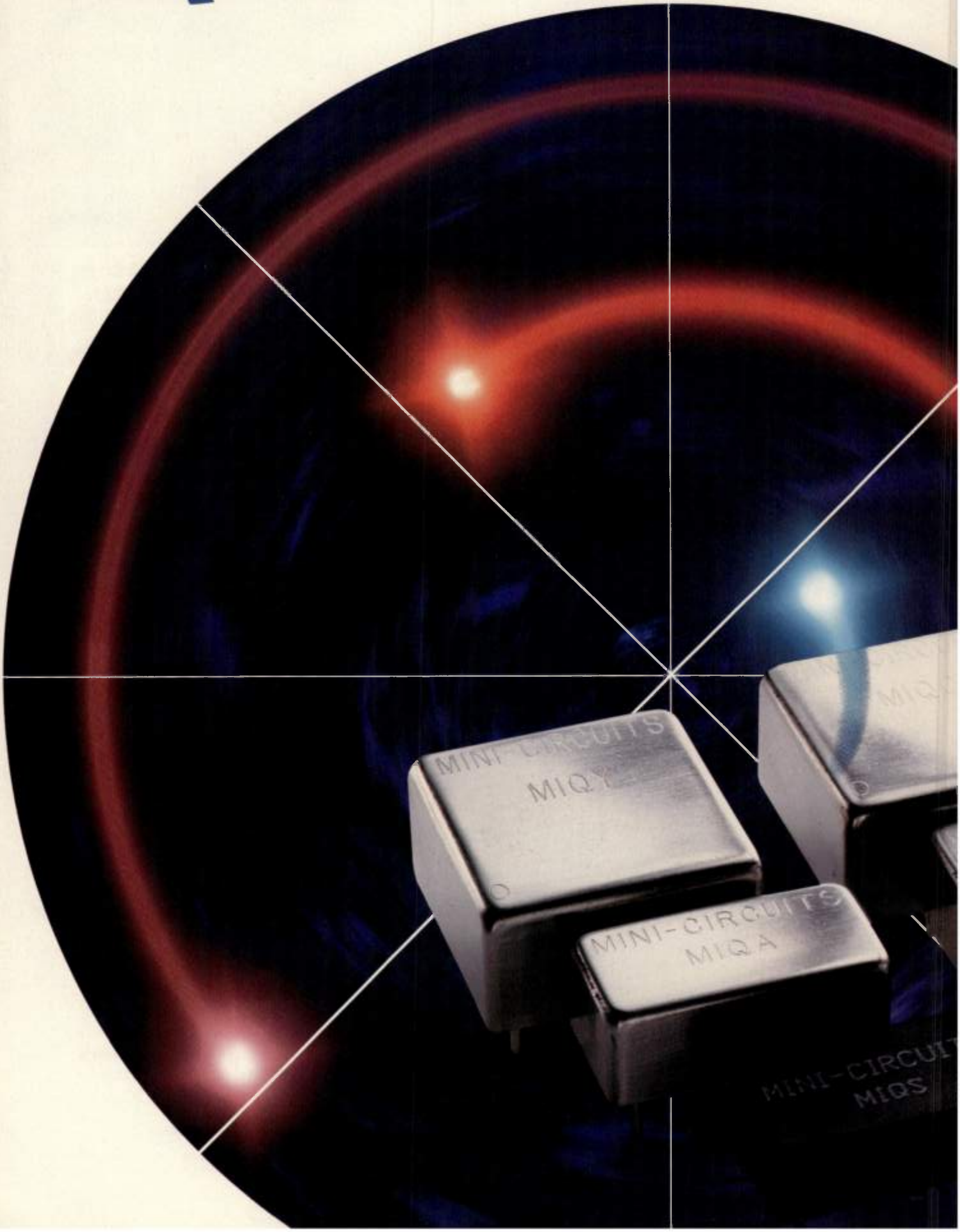
Contact IFR or your local IFR representative for more information or to arrange for a demonstration of the AN930.

RENT DIRECTLY FROM IFR
Call 316/522-4981, Ext. 207 for details

CRAFTED WITH PRIDE IN USA

IFR SYSTEMS, INC.
10200 West York Street / Wichita, Kansas 67215-8935 U.S.A.
Phone 316/522-4981 / TWX 910-741-6952 / FAX 316/522-1360

I&Q MODULATORS



DEMODULATORS

1.15MHz to 1880MHz from $19.95

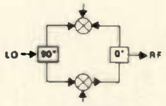
I&Q Modulators and Demodulators…another smart offering from Mini-Circuits that's pushing industry standards to new heights (and prices to new lows)!

Infuse your cellular, radar and communication system project with the powerful new I&Q Modulator and Demodulator, surface mount and plug-in units. Units so reliable, the specified statistical data on performance holds up with rock-solid repeatability unit-to-unit.

For high speed assembly operations, I&Q Modulators and Demodulators are available in tape and reel format, so you can bank on consistent assembly performance for production efficiency time after time…and with prices starting at just $19.95, these powerful and compact units truly are the next generation of value on the market today.

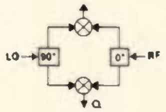
So, call your Mini-Circuits distribution center at a number listed below for guaranteed one week shipment or, turn to our applications department with your special specs for custom units at catalogue prices.

We're redefining what VALUE is all about!



I/Q MODULATORS

MODEL NO	FREQ (MHz) f_L	f_U	CONV LOSS (dB) $\bar{x}$	σ	CARRIER REJ (dBc) Typ	SIDEBAND REJ (dBc) Typ	HARM SUPPRESS (dBc) Typ 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
□ MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
□ MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95



I/Q DEMODULATORS

MODEL NO	FREQ (MHz) f_L	f_U	CONV LOSS (dB) $\bar{x}$	σ	AMP UNBAL (dB) Typ	PHASE UNBAL (Deg.) Typ	HARM SUPPRESS (dBc) Typ 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
□ MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
□ MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
□ MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95

□ NON-HERMETICALLY SEALED
MIQA case .4 x .8 x .4 in.
MIQY case .8 x .8 x .4 in.
MIQC case .8 x .8 x .4 in.
MIQS case .8 x .4 x .2 in.

INFO/CARD 3

Mini-Circuits®

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCT DIRECTORY • EEM • MINI-CIRCUITS' 740-pg HANDBOOK

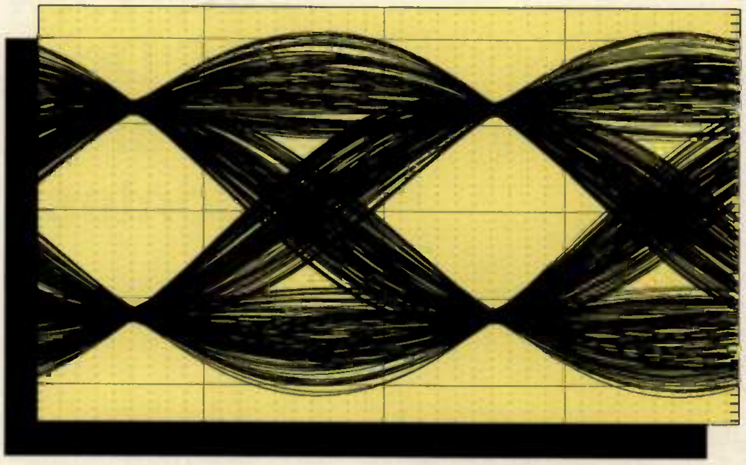
CUSTOM PRODUCT NEEDS… *Let Our Experience Work For You.*

RF design

contents

February 1994

featured technology



cover story

tutorial

design awards

departments

RF DESIGN (ISSN:0163-321X USPS: 453-490) is published monthly and semi-monthly in August. February 1994. Vol.17, No. 2. *RF Design* is a registered trademark of Argus Inc. Copyright 1994 by Argus Business, a division of Argus Inc., 6151 Powers Ferry Road, NW, Atlanta, GA 30339, (404) 955-2500; Scott Smith, President; Wayne Otterbourg, C.P.A., Vice President, Finance; Arthur E. Sweum, Senior Vice President; Dennis Corcoran, President, Argus Trade Shows. Editorial and advertising offices at 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111, (303) 220-0600. Printed in USA. Second-Class Postage paid at Englewood, CO and at additional mailing offices. Subscription office: *RF Design*, P.O. Box 1077, Skokie, IL 60076. Subscriptions are: $39 per year in the United States; $49 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. Authorization to photocopy items for personal use is granted by *RF Design*, provided the base fee of $3 is paid directly to Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 and provided the number of copies is fewer than 100. For authorization, contact the Copyright Clearance Center at (508) 750-8400. The Transactional Reporting Service fee code is: 0163-321X/94/$3.00. For those seeking 100 or more more copies, please contact the magazine directly at (303) 220-0600.

SUBSCRIPTION INQUIRIES: (708) 647-0756.

RF editorial

Announcing the 1994 RF Design Awards Contest

By Gary A. Breed
Editor

Get ready for the new, improved and updated 1994 RF Design Awards Contest!

We are ready once again to recognize the innovation and hard work that results in new ideas and better ways for RF engineers to get the job done.

We have held the RF Design Awards Contest every year since 1986. In that time, the Grand Prizes have gone from a $500 programmable calculator to $20,000+ instruments and software packages! In 1991, we expanded the contest into two separate contests, one for circuit design and one for design software. Also, each year the winners have been presented to the RF engineering community in the July issue. After examination of past contests and consideration of all the factors surrounding them, we have made a few adjustments.

The only major change is a return to a single contest — we decided that judging one contest, and determining one Grand Prize winner is enough! However, the single contest will allow either circuit design or design software entries. The entry rules for each type of entry are very similar to past years' contests (see page 25), but we are implementing some new judging criteria.

The primary goal of the judging is to determine which entry makes the biggest contribution to the art and science of RF engineering. This might be "the greatest good for the greatest number," or a more specialized development that advances the state of the art. We want to recognize the efforts of an RF engineer whose work has the greatest significance for the profession.

This year, the Grand Prize is once again, well, grand! Hewlett-Packard's CAE group will present the winner with a Touchstone/Libra for Windows package from their EEsof operation. This has a value well over $20,000, something to really shoot for!

To encourage all types of entries, we completing a line-up of the best-ever collection of second and third place prizes, plus honorable mention prizes. There is no excuse to hold back your entry because "it can't win." Lots of entries will be winners!

The other significant change is in our timing. The Grand Prize winner will be featured on the cover of our November issue, and will be presented with his or her prize in person at RF Expo East in Orlando. The prize presentation will be followed by presentation of the winning entry at a special awards session.

The deadline for entries is July 29. Entries must be postmarked by this date, and received no later than August 5. So, read the rules and look over the prizes on page 25, then get to work — you've got less than seven months to perfect that idea!

WHAT YOU'VE BEEN WAITING FOR!

Technology of the Future
Available Today

250 Watts CW
.01 - 220 MHz

WORLD'S FIRST

14 Octave 250W
SOLID-STATE RF Amplifier

MODEL 122FC

- Instantaneous bandwidth, no warm-up
- Fully protected
- No VSWR shutdown, drives mismatched loads
- ALC gain leveling & power limit set
- All front panel controls available via remote connector
- IEEE488 / RS232 interface capability
- 19" rack mountable, weight 50 kg
- US $19,950.00

KALMUS
ENGINEERING

The World's Most Complete Line of RF Power Amplifiers

More Than 200 Standard Models to Choose From

1-800-344-3341
(206) 485-9000 fax (206) 486-9657
21820-87th S.E. • Woodinville, WA 98072 • USA
Paris, France
phone 1-4645-0945 fax 1-4645-2403

INFO/CARD 6

RF design
Established 1978

President — Argus Business
Jerrold France

Editorial and Advertising Offices
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111
(303) 220-0600 Fax: (303) 773-9716

Vice President and Group Publisher
David Premo (303) 220-0600

Editor
Gary A. Breed (303) 220-0600

Technical Editor
Andrew M. Kellett (303) 220-0600

Assistant Editor
Ann M. Trudeau (303) 220-0600

Consulting Editor
Andy Przedpelski, *The Shedd Group*

Editorial Review Board
Madjid A. Belkerdid, *University of Central Florida*
Alex Burwasser, *RF Products*
Dave Krautheimer, *MITEQ, Inc.*
Ed Oxner, *Siliconix Inc. (retired)*
Jeff Schoenwald, *Rockwell International*
Raymond Sicotte, *American Microwave Corp.*
Robert J. Zavrel, Jr., *GEC Plessey Semiconductors*

Corporate Editorial Director
Robin Sherman (404) 618-0267

Account Exectives
Jessica Caid (303) 220-0600
Mike Henry (703) 257-1202
Tisha Hill (303) 220-0600
Brian Noto (303) 220-0600
Jeff Peck (303) 220-0600
Cindy Solomonson (303) 220-0600

Classified Advertising Manager
Michael Applegate (404) 618-0217

Vice President — Production and Promotion
Cherryl Greenman (404) 618-0302

Production Manager
Jenny Tague (404) 618-0401

Reprints Manager
Vivian Peterson (303) 220-0600

Creative Director
Brian Buxton (404) 618-0108

Art Director
David Alden (404) 618-0188

Circulation Manager
Shawn DeMario (404) 618-0259

List Rental Manager
Etta Davis (404) 618-0266

Argus Business Corporate Offices
6151 Powers Ferry Rd., N.W.
Atlanta, GA 30339-2941
Tel: (404) 955-2500

BPA

ARGUS BUSINESS
A Division of Argus Inc.

Subscription inquiries: (708) 647-0756

RF courses

Principles of Pulse Doppler Radar: High, Medium, and Low PRF
February 15-17, 1774, Atlanta, GA
Phased-Array Radar System Design
April 19-22, 1994, Atlanta, GA
Principles of Electronic Counter-Countermeasures
April 26-28, 1994, Atlanta, GA
Information: Georgia Institute of Technology, Continuing Education Tel: (404) 894-2547.

RF & Microwave Measurements & Applications
March 7-10, 1994, San Diego, CA
Navstar/GPS: Design Applications
August 1-3, 1994, Washington, DC
High Speed & Microwave Devices & Applications
October 24-27, 1994, Boston, MA
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel: (818) 995–6335. Fax: (818) 995–2932.

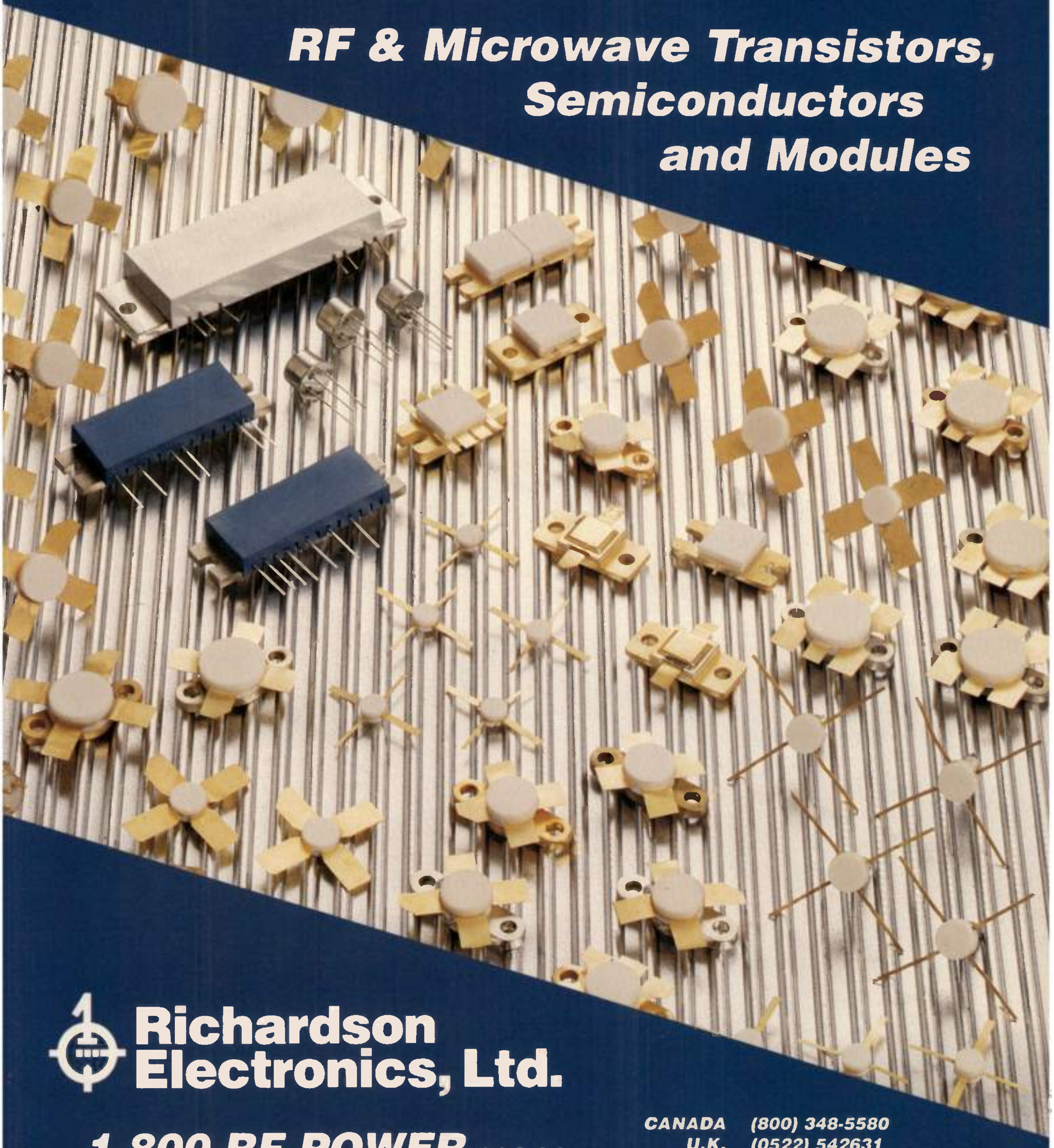
Satellite Communication Systems
April 18-22, 1994, Cambridge, UK
VSAT Networks
April 20-21, 1994, Cambridge, UK
Mobile Cellular and Microcellular Telecommunications
April 20-22, 1994, Cambridge, UK
Information: CEI-Europe/Elsevier, Mrs. Tina Persson. Tel: (46) 122–175–70. Fax: (46) 122–143–47.

Antennas: Principles, Design, and Measurements
March 9-12, 1994, St. Cloud, FL
Information: Northeast Consortium for Engineering Education, Central Florida Facility - Management Office, 1101 Massachusetts Ave, St. Cloud, FL 94769, Kelly Brown - Registrar. Tel: (407) 892–6146. Fax: (407) 957–4535.

DSP Without Tears
February 2-4, 1994, Albuquerque, NM
February 9-11, 1994, Falls Church, VA
April 6-8, 1994, Chicago, IL
May 11-13, 1994, Richardson, TX
May 18-20, 1994, San Jose, CA
Information: Z Domain Technologies, Inc., 325 Pine Isle Court, Alpharetta, GA 30202. Tel: (800) 967–5034, (404) 664–6738. Fax: (404) 442–1210.

Introduction to Fiber Optic Communications
February 1-4, 1994, Toronto, Canada
Information: Learning Tree International. Tel: (800) 421–8166, (703) 893–3555, (203) 417–8888.

No One Stocks More RF & Microwave Transistors, Semiconductors and Modules



Richardson Electronics, Ltd.

1-800-RF POWER (U.S.A.)

40W267 Keslinger Road
LaFox, Illinois 60147
(708) 208-2200

CANADA	(800) 348-5580
U.K.	(0522) 542631
FRANCE	(1) 34.26.4000
ITALY	(055) 420.10.30
SPAIN	(1) 528 37 00
GERMANY	(089) 80 02 13 1
JAPAN	(3) 3874-9933
SINGAPORE	(65) 298-4974

INFO/CARD 10

GIGA-TRONICS 6080A & 6082A SYNTHESIZED RF SIGNAL GENERATORS

Giga-tronics Presents The Alternative To $30,000 And $40,000 RF Synthesizers.

Hewlett-Packard makes a couple of very good RF synthesizers. And if you can afford the luxury of paying $30,000 or $40,000 for the name, by all means, call HP right now. They'll be happy to take your order, and your money.

However, if you're looking for an RF synthesizer with outstanding performance and proven reliability for about half the price, you'd better call Giga-tronics.

Here's why:

Performance.
Check the charts. In virtually every category, the Giga-tronics 6080A and 6082A RF Synthesizers meet or exceed the specs of the HP machines. And they use the same GPIB command set, for direct replacement without expensive new software.

Experience.
Granted, Hewlett-Packard has been around a long time. But, Giga-tronics is no Johnny-come-lately.

Giga-tronics has a 13-year history of building test and measurement gear for the most demanding requirements. We've shipped thousands of instruments for use in the testing of radar, EW and communications systems.

Reliability.
Making reliable RF synthesizers is usually no fluke.

However, in this case, it is.

The Giga-tronics 6080A and 6082A RF Synthesizers give you great performance and proven reliability for a lot less money.

Specifications	Hewlett-Packard HP 8642A	Giga-tronics 6080A	Hewlett-Packard HP 8642B	Giga-tronics 6082A
Frequency Range Switching speed	.1 to 1057 MHz <85 ms	.01 to 1056 MHz <100 ms	.1 to 2115 MHz <85 ms	.1 to 2112 MHz <100 ms
Spectral Purity* Spurious Subharmonics	<-100 dBc None	<-100 dBc None	<-94 dBc <-45 dBc	<-94 dBc <-45 dBc
Phase Noise* @ 20 kHz offset	<-134 dBc/Hz	<-131 dBc/Hz	<-125 dBc/Hz	<-125 dBc/Hz
Residual FM* (.3 to 3 kHz BW)	<2 Hz	<1.5 Hz	<5 Hz	<3 Hz
Output Range* Accuracy Reverse Power Protection	+16 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+17 to -140 dBm ±1 dB >-127 dBm 50 Watts/50 Vdc	+16 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc	+13 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc
Amplitude Modulation Depth Distortion @ 30%	0–99.9% <2%	0–99.9% <1.5%	0–99.9% <2%	0–99.9% <1.5%
Frequency Modulation Max. Deviation* Distortion	3 MHz <2%	4 MHz <1% @ 50% Dev.	3 MHz <2%	8 MHz <1% @ 50% Dev.
Phase Modulation Max. Deviation*	100 Rad.	40/400 Rad.	200 Rad.	80/800 Rad.
Pulse Modulation On/off Rise/fall time Minimum Pulse Width	>40 dB <400 ns <2 μs	>40/60 dB <15 ns (Typ 7.5 ns) <30 ns	>40/80 dB <400 ns <2 μs	>80 dB <15 ns (Typ 7.5 ns) <30 ns
Internal Modulation Source Level Range Waveforms Programmable	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes	20 Hz to 100 kHz 0 to 3 Vpk Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes
Memory Locations (NVM)	51 Full Function	50 Full Function	51 Full Function	50 Full Function
U.S. List Price	$30,340	$16,950	$41,680	$22,950

The question is not why Giga-tronics is so much less,

but rather, why Hewlett-Packard wants so much more.

*Specifications for both the 6080A and the HP 8642A are at 1GHz. Specifications for both the 6082A and the HP 8642B are at 2GHz. Prices and specifications for the HP 8642A and HP 8642B are from the Hewlett-Packard 1993 catalog. Prices for the Giga-tronics 6080A and 6082A are U.S. list prices.

Both the 6080A and 6082A were originally introduced in 1990 by John Fluke Manufacturing Company. To date, thousands have performed flawlessly in the field.

For added confidence, the instruments incorporate self-testing, internal diagnostics and modular design for easy fault isolation and repair.

Service.

If a problem occurs, Giga-tronics technical support staff can often help you find and fix the problem over the phone.

If you need to return an instrument for repair, we can service it at our factory in California, or at one of our worldwide sales and service centers.

But at Giga-tronics, customer service starts even before you become a customer.

Whether you're looking to buy one unit or one hundred, you'll get the same assistance, including a demonstration at your facility.

Price.

Considering all this, the real question is not why Giga-tronics is so much less, but rather, why Hewlett-Packard wants so much more?

So, if you're interested in paying a lot less for great performance and proven reliability, backed by a worldwide network of service and support, call us toll free at **800 726 GIGA** (4442). We'll send you more information and arrange for a demonstration.

Giga-tronics

Giga-tronics Incorporated
2495 Estand Way
Pleasant Hill, California 94523
Telephone 800 726 4442
Telefax 510 680 7736

INFO/CARD 11

RF calendar

March

14-17 **The Second International Symposium on Digital Audio Broadcasting**
Toronto, Canada
Information: DAB Symposium '94, 126 York Street, #401, Ottawa, Ontario, Canada, K1N 5T5. Tel: (613) 594–8226. Fax: (613) 565–2173.

20-24 **National Association of Broadcasters '94**
Las Vegas, NV
Information: NAB '94 Convention, 1771 N Street, NW, Washington, DC 20036–2891. Tel: (800) 342–2460. (202) 342–4972. Fax: (202) 775–2146.

22-24 **RF Expo West**
San Jose, CA
Information: RF Expo West, Registration Coordinator, 6151Powers Ferry Rd. NW, Atlanta, GA 30339. Tel: (800) 828–0420. Fax: (404) 618–0441.

29-30 **IEEE SCV EMC '94**
Santa Clara, CA
Information: David Hanttula, Chairman Santa Clara Valley EMC '94, P.O. Box 2102, Cupertino, CA 95015-2102. Tel: (415) 390-1071.

April

5-7 **Second International Conference on Ultra-Wideband, Short-Pulse Electromagnetics**
New York, NY
Information: Lawrence Carin, Weber Research Institute, Polytechnic University, Six MetroTech Center, Brooklyn, NY 11201. Tel: (718) 260-3876. Fax: (718) 260-3906.

12-14 **Second International Conference on Computation in Electromagnetics**
Nottingham, UK
Information: CEM 94 Secretariat, IEE Conference Services, Savoy Place, London WC2R 0BL, UK. Tel: (071) 344-5478 or 5477. Fax: (071) 497-3663.

12-15 **EMC/ESD International**
Anaheim, CA
Information: EMC/ESD International, Registration Coordinator, 6151 Powers Ferry Rd. NW, Atlanta, GA 30339.
Tel:(800) 828-0420. Fax: (404) 618-0441.

May

23-24 **Microwave & Millimeter-Wave Monolithic Circuits Symposium**
San Diego, CA
Information: Richard B. gold, Pacific Monolithics, 245 Santa Ana Court, Sunnyvale, CA 94086-4512. Tel: (408) 732-8000. Fax: (408) 732-3413 .

23-26 **IEEE MTT-S International Microwave Symposium**
San Diego, CA
Information: MTT-S Symposium 1994, c/o LRW Associates, 1218 Balfour Drive, Arnold, MD 21012

Semiconductor Junctions Measured — NIST and Digital Instruments of Santa Barbara, Calif., using silicon junctions from SEMATECH as samples, are developing scanning capacitance microscopy (SCM) to produce images of the sample's electrical character. The Semiconductor Industry Association's Technology Roadmap identifies nanoscale junction profiling as essential metrology for the development of integrated circuits. Theoretical SCM modeling research is being coupled with the practical measurement and calibration techniques possible with an atomic force microscope. This technology is expected to affect the semiconductor industry by giving developers a critical tool for improving integrated circuits. For technological information, contact Joseph J. Kopanski, A305 Technology Bldg., NIST, Gaithersburg, MD 20899-0001. (301) 975-2089.

Capacitance Standard In Development — NIST has developed a new standard of capacitance based on counting electrons as they charge the capacitor at 0.1 Kelvin. Metrological applications require errors lower than 1 ppm and NIST has demonstrated an electron pump that operates with errors slightly lower than 1 ppm. The device is microfabricated from a linear array of five ultra-small tunnel junctions, each with dimensions of 40 nanometers. For a copy of a paper discussing the experiment, contact Sarabeth Moynihan, Div. 104, NIST, Boulder, CO 80303-3328. (303) 497-7765. Ask for paper No. 43-93.

Cellular Interface Standard — The Telecommunications Industry Association's (TIA) TR 45.4 subcommittee has the task of defining and developing a standard interface between cellular Base Station Subsystems (BSS) and Mobile Telephone Switching Offices (MTSO), to be used throughout Pan America. The Interface Specification submitted by Motorola will support RF interfaces for AMPS (IS-533), NAMPS (IS-88), USDC (IS-54), CDMA (IS-95) and other functions including Intersystems Operations (IS-41). The proposed interface, developed by Motorola and other cellular equipment suppliers, would enable any vendor's base station to work with any cellular switch.

World Communications Development — In November of 1993 the World Telecommunication Advisory Council (WTAC) recommended to the ITU to proceed with the feasibility phase on WorldTel—a funding and development organization to promote worldwide telecommunication expansion. The study, expected to be conducted in early 1994, will focus on the establishment of a commercially run organization whose goal is to cut the widening gap between the information-rich industrialized countries and the information-poor developing countries. WTAC reported that the prospects for reducing the gap without an international effort are very slim. WorldTel is to act as a multinational (not purely intergovernmental) organization and will have no institutional linkage to the ITU. However, the study is expected to be undertaken under the auspices of ITU with the support of the WorldTel Working Group of WTAC. It will be financed by contributions from interested sponsors who will be provided with the opportunity of reviewing the study at the draft stage.

Voluntary Standards Seminar — The Federal Interagency Committee on Standards Policy, chaired by Stanley I. Warshaw, director of NIST's Office of Standards Services, will hold a one-day seminar on the Oct. 1993 revisions to the Office of Management and Budget Circular No. A-119. This meeting is for private-sector and public interests to discuss the revisions' affect on the standards' community. The seminar is Feb. 23, 1994, 9 a.m. in the auditorium of the Department of Commerce, 14th Street and Constitution Avenue, N.W.; Washington, DC 20230. Contact: Office of Standards Services, A603 Administration Bldg., NIST, Gaithersburg, MD 20899-0001. Phone: (301) 975-4000. FAX: (301) 963-2871.

BBS has SPICE Models and Application Notes — Intusoft has setup a SPICE Bulletin Board on CompuServe Information Service. The BBS also contains software utilities and demonstration software and is under the CADD/CAM/CAE Vendor forum an on-line electronic service. On CompuServe type "Go CADDVEN" at any prompt and select the "All CADD/CAM/CAE" section. The Intusoft CompuServe address for e-mail is 71564,3147. Internet users can send Intusoft e-mail via: "71564.3147@compuserve.com".

FM Data Broadcasting Proposals — The NAB and the Electronic Industries Association (EIA) sponsor the National Radio Systems Committee (NRSC) which sets technical standards for broadcasters and manufactuers. Proposals are being sought by the High-Speed FM Subcarrier Subcommittee of NRSC for the new standard that would allow the 6,000 FM radio stations to provide high-speed data broadcasting to fixed and mobile receivers. Cars, for example, would have real-time access to traffic information with data broadcast receivers.

NSI Awards Diamond Depositions Contract — Applied Science and Technology, Inc. was awarded a Phase II contract from NSF for microwave plasma diamond depositions at high growth rates. ASTeX will concentrate on gas phase chemistry changes at high power densities, techniques to control film morphology and increasing the growth rates, all of which will lead to higher deposition rates. This will make diamond coatings more cost effective per carat for use as heat sinks for thermal management, coatings for cutting tools, and free standing thick infrared optics.

Johnstech Moves Headquarters — A producer of test sockets Johnstech International's new address for their corporate and manufacturing headquarters is: 1210 New Brighton Blvd., Minneapolis, MN 55413-1614. Phone: (612) 378-2020. FAX: (612) 378-2030.

RF Power Components New Address — RF Power Components, Inc. has moved to 125 Wilbur Pl., Bohemia, NY 11716. Phone: (516) 563-5050. FAX: (516) 563-4747.

Harris Farinon Canada Moves — As of Jan. 3, 1994, Harris Farinon will have moved 10 km west of their original location to 3 Hotel de Ville, Dollard-des-Ormeaux; Quebec, Canada H9B 3G4. The new numbers are: (514) 421-8400. FAX: (514) 421-4222. Telex: 05-821893. Customer Service: 1 (800) 465-4654.

Geleco RF Business Acquired by LBA Technology — The RF systems of Geleco Electronics, Limited of Toronto, Canada has been purchased by LBA Technology, Inc. of Greenville, North Carolina, supplier of medium wave broadcasting antenna systems. Geleco, producers of antenna tuning units and RF equipment for radio broadcasting, will have their assets and inventory relocated to the expanded LBA Greenville manufacturing facility.

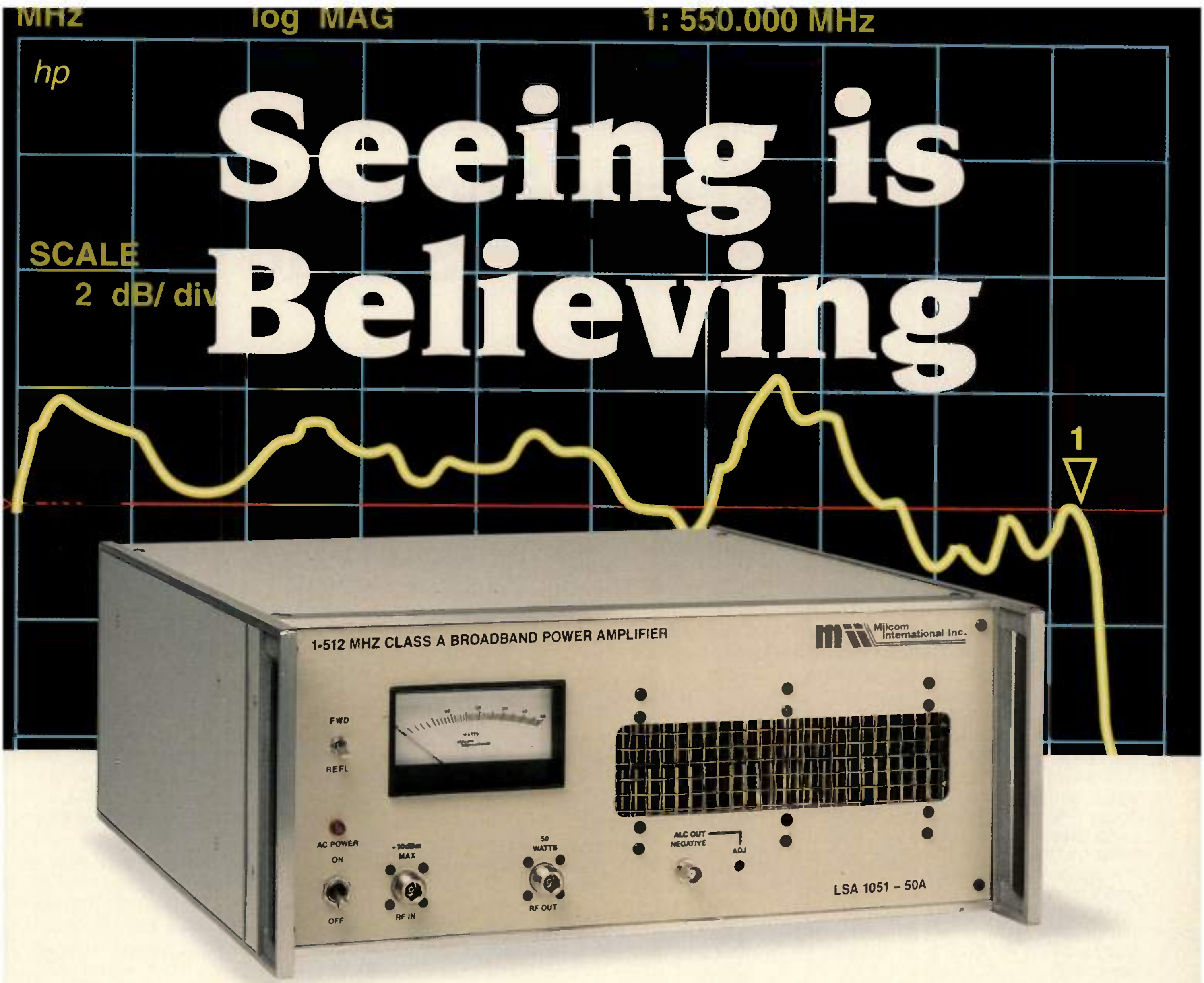
Telecommunication Chip Sets — Analog Devices, Inc. and Aware, Inc. have formed a development partnership to design and build chip sets that will support the emerging standard for asymmetric digital subscriber line, ADSL. This is a new ANSI-standard technology which increases the usable bandwidth of telephone lines to bring video-rate services into the home. These services would include distance learning, video on demand, remote healthcare consultation, and telecommuting. The products will be available in mid-1994 to telecom OEMs. Data rates of 1.5-20 megabits per second can be achieved. Three companies have agreed to use the Analog/Aware chip sets in ADSL products: AT&T Network Systems, Morristown, NJ; Westell, Inc., Oswego, IL.; and Newbridge Networks, Kanata; Ontario, Canada.

Cadence Sells Automated Systems Division — This sale will allow Cadence Design Systems, Inc., San Jose, CA, to focus on software that automates and enhances the design of ICs and electronic systems. Cadence sold its Automated Systems Inc. (ASI) Division, at the end of 1993, to a corporation formed by certain ASI management personnel. ASI manufacturers and provides design services for complex PCBs and is headquartered in Brookfield, Wis.

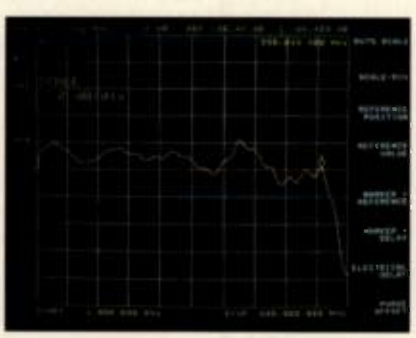
Small Business Research Contract — Superconductor Technologies Inc. (NASDAQ: SCON), which supplies high-temperature superconductor (HTS) products and services, received a $742,000 Small Business Innovative Research contract to build superconducting switches for electronic warfare (EW) subsystems. The new contract allows STI to integrate cryogenic switches with super conductor filters.

INFO/CARD 16

INFO/CARD 17



Milcom's Newest RF Power MOSFET Distributed Amplifier
1-512 MHz, 50 Watts Class "A" Design



The newest introduction in amplifiers is not for the narrow-minded. For a range of 1 - 512 MHz, you won't find another 50 watt amp offering such a wide range and exclusive versatility. You might say it blows the market wide open.

In fact, nothing beats it as an instrument for semi-conductor, passive component, E.M.I. development or production testing. It even produces exceptional results in fields as diverse as laser modulation and medical research.

And it's no wonder. Excellent output VSWR provides constant power into any load. And with features like a built-in power meter, external ALC output, and totally enclosed RF modules for low E.M.I., this 50 watt amplifier sets a new standard for the industry.

So before making your next amplifier purchase, take a good look at the new 50 watt wide band amp from Milcom International. Because seeing really is believing. Give us a call at (714) 554-1710 for more details.

Milcom International Inc.

We Design and Manufacture RF Power Amplifiers

INFO/CARD 18

17500 Gillette Avenue, Irvine, California 92713 • 714-554-1710 • FAX 714-554-3090

Fast Si, New Design Tools and Portability Demands Bring ASICs to RF

By Andy Kellett
Technical Editor

Few RF designers would have even thought of implementing a new design on a single semiconductor chip a decade ago. It would have been possible to implement a complete design, after several expensive design iterations, on a single chip, (or two), of very expensive GaAs. But the need to do so just wasn't there. Today, RF Application Specific ICs (ASICs) have appeared at the confluence of three circumstances: the need for small but complex radio transceivers, the emergence of silicon processes with high f_t, and the availability of fast computers and design software which can reliably predict the behavior of RF integrated circuits.

"A driving force behind ASICs is wireless communications," says Mojy Chian, Senior Principal Engineer at Harris Semiconductor's CAD group, "you want to make a high-frequency product, you want to make it sophisticated, but at the same time you want it to fit in a shirt pocket." Performance requirements and time-to-market have traditionally driven use of ASICs says *ASIC & EDA* magazine Senior Editor, Kella Knack.

Integration provides several benefits for RF applications besides reduced size, says Jack Guedj, Marketing Manager and Applications Engineer for Raytheon's high speed communications products. Among them are better performance, lower power consumption, easier board design and better reliability. There are several ways to arrive at integration: transistor array ASICs, standard cell ASICs, custom design ASICs and application specific standard products. Strictly speaking, an ASIC is any IC designed to perform most or all of the functions for a single end-use. However, when most people think of ASICs they think of one of the species of ASIC that are at least partly designed by the customer.

Picking a type of ASIC requires a balance of design effort and performance. Transistor and tile arrays allow designers to connect individual transistors and passive components, and because the customer only specifies the metalization layers, development time is fast. However, the placement of components is not optimal. Standard cells reduce both die size and interconnects by providing pre-designed function blocks. Not only are the number of interconnections reduced, but so is the risk associated with creating a custom design from scratch says Guedj. Normally a few versions of any type of function (a mixer or amplifier for example) are available, but designs still must be adapted to the tiles that are available. A third approach is a fully custom ASIC. This type of ASIC allows optimal placement of components and minimizes die area. This approach requires the most effort on the part of both the ASIC customer and manufacturer, but as Chian points out, "Typical RF ASICs are small, so transistor-level design is not a far stretch."

Another way to shrink a circuit is to use an application-specific standard-product IC. AT&T Microelectronics produces standard lines of chips, "focusing on the world-wide digital communications standards," says Phil Carrier, Marketing Manager for AT&T's Wireless RFICs. Chips designed for specific applications from the start are important, says Carrier, because,"In subscriber, hand-portable terminals every mA counts." Other manufacturers acknowledge that ASICs are not the best choice in every instance. "In general, if there's a good chip-set that does the job ASICs don't compete," says Bill Dennehy, Director of Marketing for ASICs at Harris Semiconductor.

Some companies are both producers and users of ASICs. While Stanford Telecom does offer standard products, their ability to produce their own ASICs helps them to sell items at the system level, says Charles Frank, Managing Director of ASICs and custom products. "We are unique in being able to combine digital communications expertise with ASIC implementation expertise."

Fast Silicon

Integrating complex RF circuits could only be dreamed about until a few years ago says Dr. Charles Leung, President of Bipolarics. New processes have pushed silicon's f_t above 10 GHz. "Small is the key for fast silicon devices," says Leung "RFIC processes have features as complex as the most advanced DRAM. In addition, we deal with the subtleties involved with RF transistor design," says Dr. Leung. Several companies have developed high-frequency silicon processes and offer them for ASIC manufacture. Despite all the attention given to high-speed silicon processes, GaAs is still used in high-frequency ASICs.

Design Tools

Another key to the emergence of RF ASICs is the availability of design tools capable of accurately predicting an ASIC's behavior before it is fabricated. Most of the time, the ASIC customer is given models of the transistors or tiles that make up the ASIC and they produce a schematic based on those models. The ASIC manufacturer then translates those schematics to silicon (or GaAs) using their own tools and proprietary knowledge of their process. IC design and RF design tools are only beginning to work together in a seamless way. An analog extension to the VHDL design language, called VHDL-A is in the works, but it mostly addresses low-speed analog and mixed-signal designs. Another developing high-level language for IC design is tailored for RF IC design and is called MMIC Hardware Development Language, (MHDL).

Harris Semiconductor has already managed to incorporate RF tools into an IC design system. Called Fastrack, Harris' new system uses Cadence Design Systems' IC design framework and incorporates a number of RF tools such as S-parameter analysis, noise analysis and large-signal distortion analysis. The combination of RF and IC design makes for some new measurements says Chian, "for instance, measurements of the statistical distribution of third order intercept point." Harris takes a "hard line" on making sure ASIC designs are manufacturable says Harris' Dennehy.

The tools, processes and demand for monolithic RF systems are just now converging. The extent to which future RF designs will be done on a single piece of semiconductor remains to be seen. *RF*

Medium Power Bipolar Design Using the NE46134 Nonlinear Model

By Lynne Olsen and Brian Kirk
California Eastern Labs

This article presents a method for determining the source and load impedances of a medium power amplifier using a nonlinear simulator and optimizer. The amplifier is designed to produce 27.5 dBm output power at the 1 dB gain compression point (P1dB) while conjugately matching the input for maximum power gain. This method is compared to two other methods: using measured load pull data, and calculating the optimum load impedance from small signal S-parameters [4]. The nonlinear model was developed by California Eastern Laboratories for the NEC NE46134 medium power bipolar junction transistor (BJT) using the nonlinear simulators LIBRA and XTRACT, both developed by EEsof™.

The benefits of using a nonlinear simulator [8] to evaluate output power, intermodulation distortion, harmonic distortion, time-domain wave forms, and other nonlinear responses have always been apparent. However, only in the last decade have nonlinear simulators become computationally efficient and cost effective enough to be used for power design. This advance is due primarily to: l) the implementation of harmonic balance algorithms, 2) the drastic price reduction in computer hardware with an accompanying increase in computing power, and 3) the availability of nonlinear models that are robust enough to accurately predict the nonlinear responses required. However, power modeling is still in its infancy.

Narrowband, medium power amplifier design consists of determining the optimum load impedance, Γ_L(opt), that will provide the maximum output power. Next, the device is terminated with this load impedance and the source is conjugately matched to provide maximum gain. In this article, the impedances are represented as reflection coefficients. Γ_L(opt) can be determined using one of several methods. The easiest is for the circuit designer to use measured load-pull data, (if it is available from the device manufacturer). If load-pull data is not available, a second method developed and documented in 1983 by S.C. Cripps [2,4,5] can be used. Cripps' method not only determines Γ_L(opt), but also can be used to generate approximate power contours. This method uses small-signal S parameters, which are fairly easy to measure, to approximate the large-signal output impedance of the device. The third method detailed in this article uses a nonlinear model and a nonlinear simulator and optimizer. The optimizer is used to perturb the source and load impedances until the desired power and gain specifications are achieved.

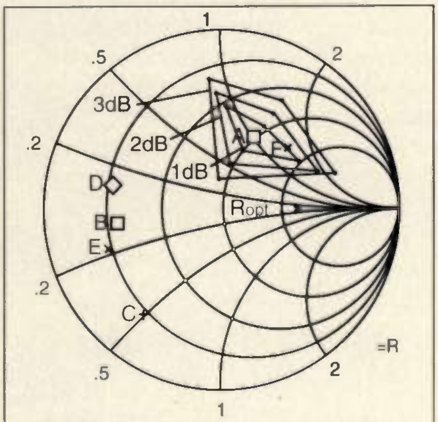
The amplifier design specifications are:
P1dB = 27.5 dBm
G1dB = 7 dB
Frequency= 900 MHz
Bandwidth = 40 MHz

The NEC NE46134 was chosen because of its useful bias range, excellent dynamic range and high output power. This device is available in a low cost surface mount package (the NEC 34), as well as in chip form. The NEC 34 package is similar to the industry standard SOT-89 package style.

For this design, the critical specification is to achieve 27.5 dBm output power at 1 dB gain compression [6]. The NEC NE46134 is biased at 12.5 V, 100 mA to provide best linearity at 27.5 dBm output power.

Measured Load-Pull Data

Load pull-data, also referred to as large signal impedance data, can sometimes be obtained from the manufacturer. The load-pull data provides load impedances that correspond to different output power levels. For any output



Method	Γs	ΓL
Cripps'	B	Ropt
SPICE, opt	C	A
SPICE, conj	D	A
DESIGN	E	F

Figure 1. Power contours and impedances on the Smith Chart.

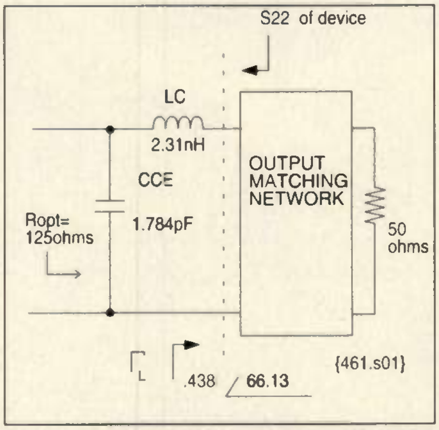


Figure 2. Load impedance derived using Cripps approximation at 12.5 V, 100 mA, 900 MHz.

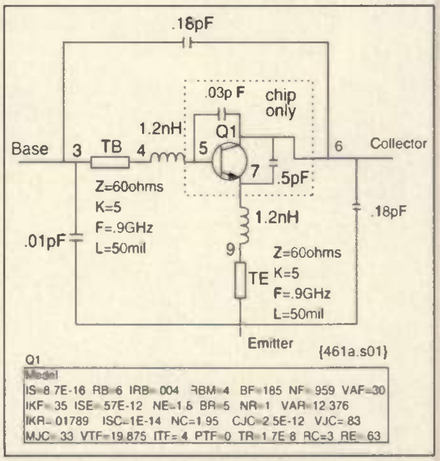


Figure 3. Schematic of the NE46134 nonlinear model.

RF Design Awards Contest

GRAND PRIZE!
Touchstone/Libra for Windows

This PC-based major linear and nonlinear analysis software is provided by the CAE group at Hewlett-Packard Company.

Official Rules

1. Entries shall represent RF functions operating at frequencies from tens of kHz to 3 GHz.
2. Entries may be circuits, circuit design methods, test procedures, or design software programs.
3. If the entry is a circuit, it shall have a complexity equivalent to that of a circuit using 8-10 discrete active devices or 6-8 integrated circuits. The circuit may be a portion of a larger system.
4. If the entry is a design method, it must include an example of a circuit designed using the method described.
5. If the entry is a test method, it must include actual results of the measurement described.
6. If the entry is a computer program, it must operate on either an MS-DOS or Apple Macintosh system. It must be provided in a form that can be operated directly, without additional software (e.g., compiled). Programs must be submitted on disk, with supporting documentation provided in printed form.
7. Entries shall be the original work of the entrant, not previously published or publicly distributed. If developed as part of the entrant's employment, entries must have the approval of the entrant's employer.
8. Only one entry per person is permitted. An entry may have two or more co-authors.
9. Submission of an entry implies permission for publication in *RF Design*, and distribution of software submissions by the RF Design Software Service.
10. Winners are responsible for any taxes, duties, or other assessments which result from the receipt of their prizes.
11. Entries must be postmarked no later than July 29, 1994 and received no later than August 8, 1994.
12. All entries will remain confidential until publication of contest results in the November 1994 issue of *RF Design*.

Judging Criteria

The single objective of the judging is do determine which entry makes the most significant contribution to the advancement of the art and science of RF engineering. Specific judging criteria include:

- *Engineering* — identifying a problem and developing a solution
- *Documentation* — completeness of the entry submission
- *Usefulness* — practicality or wide applicability
- *Technical Merit* — difficulty or magnitude of the work
- Other criteria as deemed appropriate

Send entries to: RF Design Awards Contest
RF Design magazine
6300 S. Syracuse Way, Suite 650
Englewood, Colorado 80111

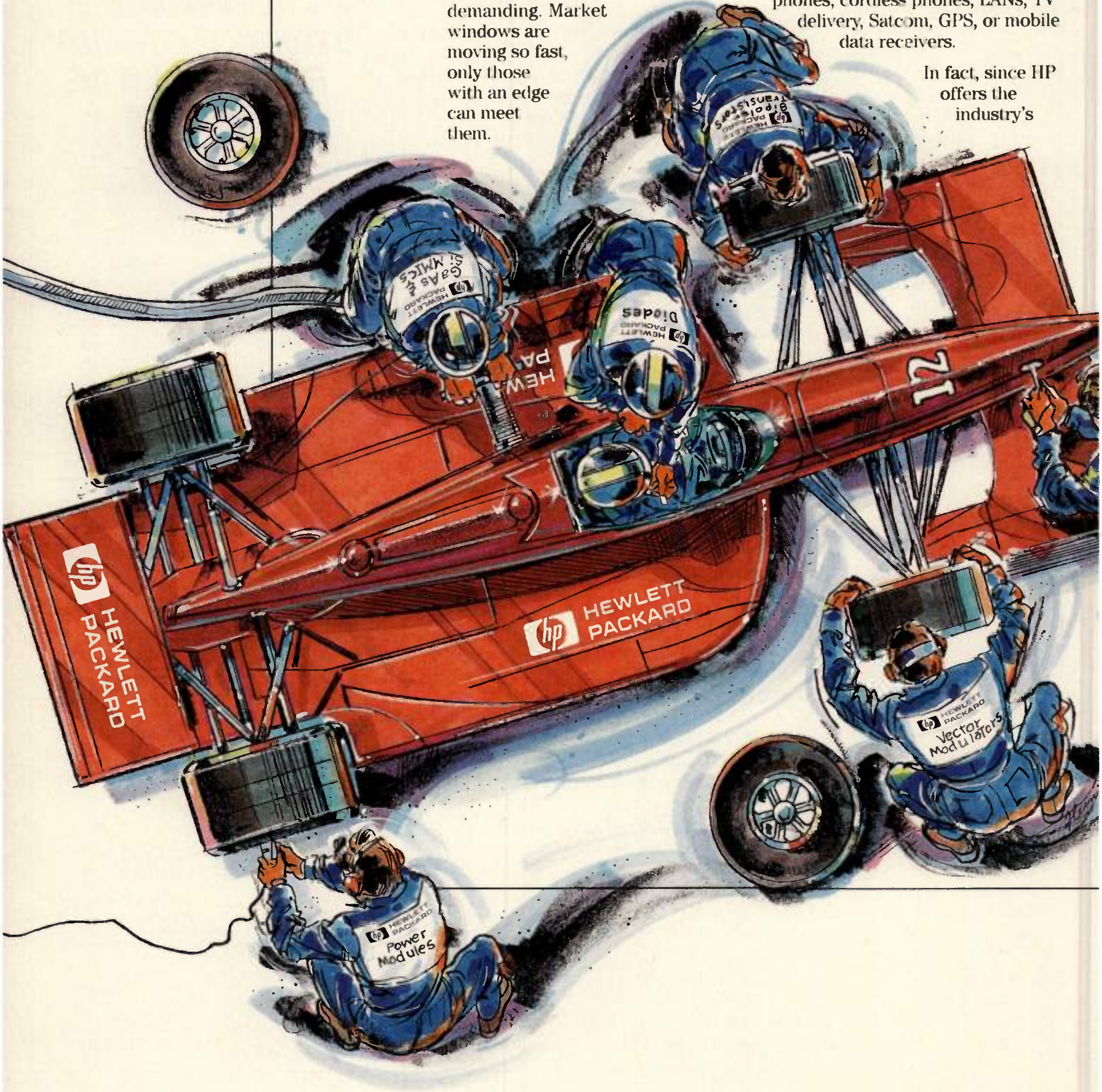
If you're going to win the wirel
be sure you've got an expert cr

HP RF components. We've got what it takes to win.

The wireless race is on. Lead times are getting shorter. Product specifications are more demanding. Market windows are moving so fast, only those with an edge can meet them.

As a leading supplier of RF components for wireless transmitter and receiver applications, the HP team has what you need to win. Whether your applications include cellular phones, cordless phones, LANs, TV delivery, Satcom, GPS, or mobile data receivers.

In fact, since HP offers the industry's

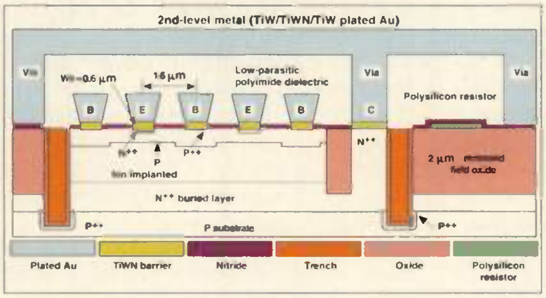


ess race,
ew.

broadest range of RF component solutions—from discrete diodes, transistors and MMICs to RFICs—designers have the distinct advantage of working with a single, reliable, world leader.

Race-tuned technologies deliver the winner's edge.

In racing, performance is everything. Which is why designers greet



Si Bipolar ISOSAT II process.

HP's finely-tuned engines with enthusiasm. RF devices deliver 15 GHz f_T and 35 GHz f_{MAX}, enabling unequalled receiver/transmitter performance at frequencies up to 5 GHz and beyond. HP's Si Bipolar highly integrated, low-power consumption MMICs

HP puts you in the pole position with it's high-volume, low-cost products:

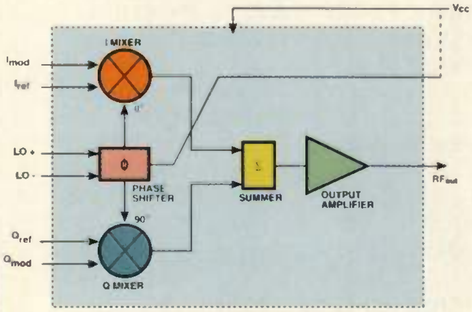
- AT-41511—Si Transistor
- ATF-10236—GaAs FET
- HSMS-2802—Schottky
- HSMS-2822—Schottky
- HSMP-3890—PIN
- IAM-81008—Active Mixer
- INA-03184—Gain Block
- INA-10386—Gain Block
- MSA-0611—Gain Block
- MSA-0886—Gain Block

provide longer battery life and increased talk time. Further, HP GaAs technology provides low-noise PHEMT FETs as well as GaAs MMICs—switches and gain blocks.

Hot off the line: HP's newest team of RF leaders.

The benefits of our new ISOSAT II manufacturing process are well summed up by our newest crew members. HP's HPMX-2003 and 2005 vector modulators provide precision building blocks for the next generation of digital radios. The new AT-3 series transistors offer 13 dB gain and 1.0 dB NF at 1 GHz while biased at 2.7V and 1 mA. And all are available in small surface mount packages.

HP offers the broadest range of RF components today and a clear path to higher RF integration for the future.



HP's Silicon RFIC Vector Modulator.

Also new, our MGA-86576 PHEMT amplifier MMIC delivering 22 dB gain and 2.0 dB NF from 1.5 to 8 GHz. And, HP will soon release power modules for NADC and GSM applications.

HP integration: your fast track to the future.

HP will push the limits with its next releases, including an RF LSI circuit with over 1500 NPNs, 50 PNPs, 50 Cs and Ls, and 1800 resistors for cellular telephone applications. HP's 2-chip (RF & IF) DECT chipset puts you on a clear path to higher levels of RF component integration. The benefits are clear: design becomes easier, saving you time and costs.

The industry's most responsive support crew.

HP's components sales force and worldwide distributor network provide all the tools you need to stay ahead of the pack. Our strategic market focus, broad product line, competitive pricing, and wide range of advanced technologies make HP the ideal RF design partner. For more information, call 1 (800) 537-7715, x7906. But do it now, because the race is on!

HP RF components.
Winning the wireless race.

HEWLETT® PACKARD

INFO/CARD 21

In Canada, call 1 (800) 387-3867, x7906.
In Europe, fax to 31 2503 52977.

CG08304

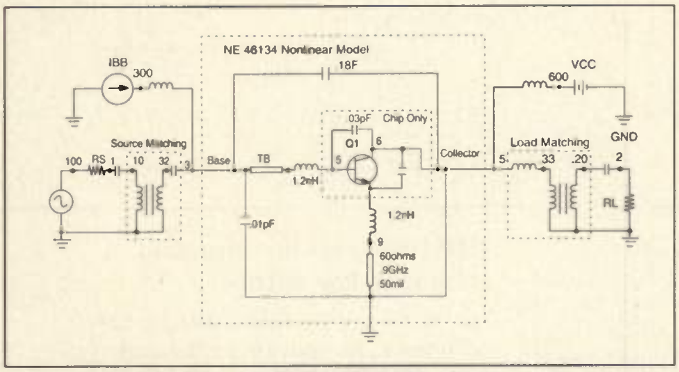


Figure 4. SPICE optimization to determine source and load terminations.

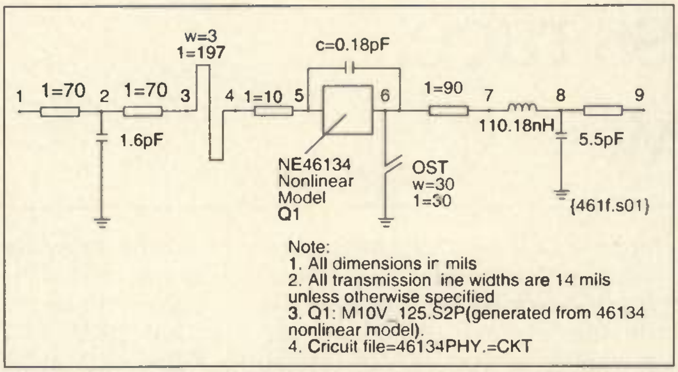


Figure 7. Final schematic including matching networks and layout parasitics.

power less than maximum, there is a locus of impedance values that form a closed contour on the output impedance plane. For maximum output power, the contour converges to a single point.

Once the load pull contours are obtained, the designer notes the source and load reflection coefficients corresponding to the desired output power level and gain specifications. Then the input and output matching networks are developed and the circuit is built and tested. No load-pull data was available from NEC at the time of this writing.

Cripps Approximation

A widely used approximation method documented by Steven Cripps uses small-signal S-parameters to determine Γ_L(opt). Although Cripps' technique was developed to obtain power contours for GaAs FETs, we have found the technique works well with bipolar junction transistors also. The key to successfully implementing the approximation is to develop an accurate model for the output of the device over the frequency range and bias of interest, as demonstrated in California Eastern Laboratories' application note AN-PF-1007 [10].

This method entails calculating the optimum load impedance for the maximum output power. At 12.5 V, 100 mA, the optimum load resistance, R_{opt}, = 12.5 V/100 mA= 125 ohms as shown in Figure 1. This impedance point is then rotated to the output impedance plane of the package. The equivalent output circuit is generated from small-signal S-parameters. Figure 2 shows the output impedance that results from this rotation, Γ_L(opt) = 0.438/66.13°. The output of the device is terminated with this load reflection coefficient and the new input reflection coefficient, S11´, is calculated. The input is then terminated with the conjugate of S11´ (S11´=0.63 /–170.3°). Power, gain, and intermodulation distortion using these terminations are simulated as shown in Table 3. P1dB is 27.1 dBm with an associated gain of 9.5 dB.

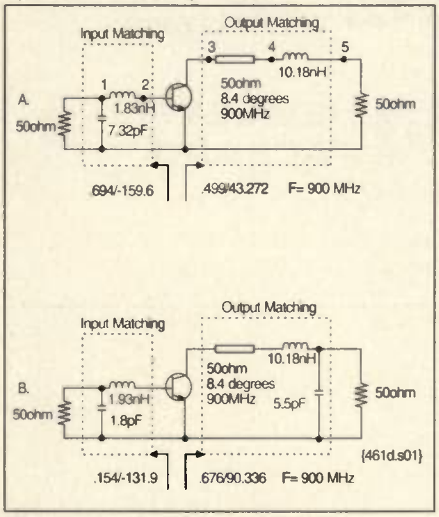


Figure 5. Matching networks.

The design task then becomes an impedance matching exercise to transform the 50 ohm source impedance to S11 conjugate, and to transform the 50 ohm load impedance to Γ_L(opt). Additional power contours can be developed using this approximation. Several have been provided in Figure 1. These contours assist the designer in determining the degradation in output power if the output matching network does not exactly provide Γ_L(opt).

Nonlinear Simulation

Before delving into nonlinear simulation, a brief review of small-signal amplifier design is provided to note the similarities between small-signal linear amplifier design and large-signal nonlinear power design. For small signal design, the S-parameters are used in the well known power gain equations [2]. These power gain equations characterize the bilateral, linear relationships of the device and are implemented in many linear simulators. The simulators automate the task of calculating and plotting constant gain circles. Constant gain circles are very similar to load-pull contours. Both consist of impedance values plotted on the Smith Chart. The difference is that gain circles are circles of constant gain and the power contours are contours of constant power. Theoretically, a nonlinear simulator could be used to generate power contours, since the nonlinear simulator can vary the source and load impedance and calculate the corresponding output power. The maximum output power contour converges to a single point on the Smith Chart. Since the commercially available computer-aided engineering programs haven't automated this process, generating these contours is fairly time consuming.

Using a nonlinear simulator and optimizer to determine the source and load impedances for this design problem at a single frequency and bias range is straightforward. All we have to do is input the nonlinear model parameters and design goals, and have the optimizer vary the source and load impedances until our design goals are achieved. The next step is to design the input and output matching networks using actual fabrication technology, re-simulate the circuit with expected layout parasitics and then, build the circuit. If your measured and simulated results differ, then re-evaluate the device and component models and add any overlooked layout/fabrication parasitics.

Nonlinear Model

The nonlinear model for the NE46134 [1] is shown in Figure 3 and is used to predict the behavior of the device under various power conditions. The nonlinear model consists of the nonlinear chip model using Gummel-Poon [3] parameters embedded in the NEC 34 package model.

Simulation and Optimization

The circuit description consists of the nonlinear model, the DC biasing circuitry, the AC input, and the optimizable terminations indicated as "source matching" and "load matching" in Figure 4. The DC biasing circuitry provides Vce = 12.5 V and Ic = 100 mA. The AC input provides a 900 MHz signal with a power sweep from 0 to 30 dBm in 5 dBm steps.

VISIT US AT THE WIRELESS SHOW BOOTH 612

Is this what BIPOLAR TECHNOLOGY has finally come DOWN TO?

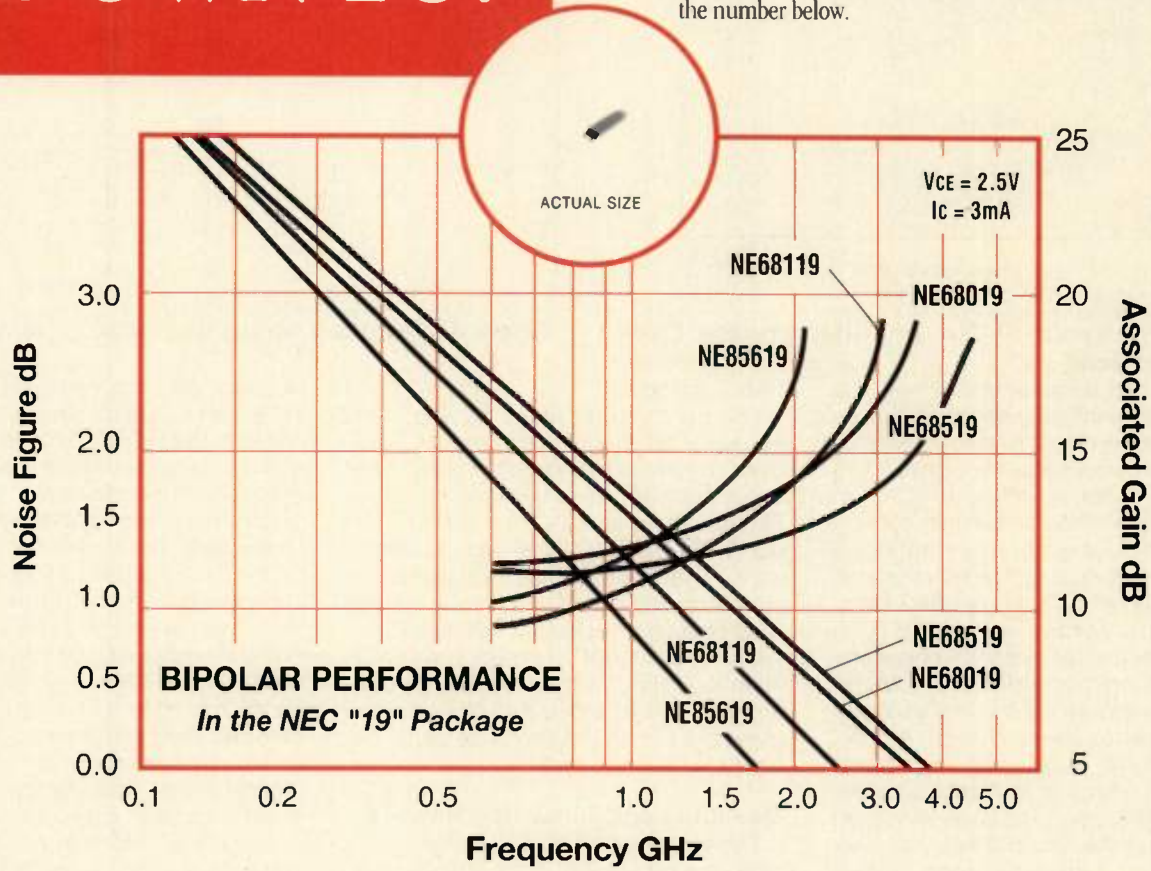
12 GHz f_T Bipolars: one third the size of a SOT-23!

Need performance, but short on real estate?
Our new bipolars from NEC deliver up to 9 dB Gain and 1.5 dB Noise Figure at 1.9 GHz — in an ultra-super mini mold "19" package that's just 1.6 X 0.8 mm!

These bipolars operate below 3V and at low current to reduce battery size and increase battery life for your wireless applications.

Want the performance, but not quite ready for the miniature package? They're also available in traditional SOT-23, 323, and 143 style packages — and a new high performance 4 pin "18" package that delivers MAG of 13.0 dB at 1 V, 1 mA, 900 MHz.

They're available now, on tape and reel, and priced to meet your needs. For Data Sheets and a copy of *Automated Assembly of Miniature Parts*, call your nearest CEL Sales Office or circle the number below.



NEC

NEC Bipolars are available in these packages (shown approx. 2X size)	NEC "19" Pkg Ultra Super Mini Mold	NEC "18" Pkg 4 Pin Super Mini Mold	NEC "30" Pkg SOT-323 Style	NEC "33" Pkg SOT-23 Style	NEC "39" Pkg SOT-143 Style

California Eastern Laboratories

CEL Headquarters, 4590 Patrick Henry Drive, Santa Clara, CA 95056-0964; (408) 988-3500 FAX (408) 988-0279 ❑ Santa Clara, (408) 988-7846 ❑ Los Angeles, CA (310) 645-0985 San Diego, CA (619) 450-4395 ❑ Bellevue, WA (206) 455-1101 ❑ Richardson, TX (214) 437-5487 ❑ Olathe, KS (913) 780-1380 ❑ Woodridge, IL (708) 241-3040 ❑ Cockeysville, MD (410) 667-1310 Peabody, MA (508) 535-2885 ❑ Hackensack, NJ (201) 487-1155 ❑ Palm Bay, FL (407) 727-8045 ❑ Snellville, GA (404) 978-4443 ❑ Nepean, Ontario, Canada (613) 726-0626

INFO/CARD 22

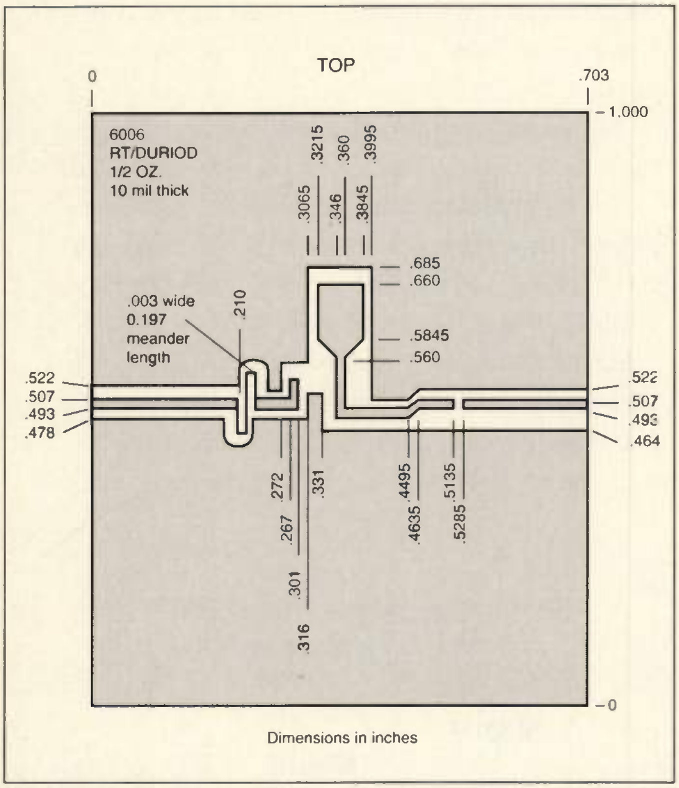


Figure 6. Layout of the amplifier printed circuit board, top view.

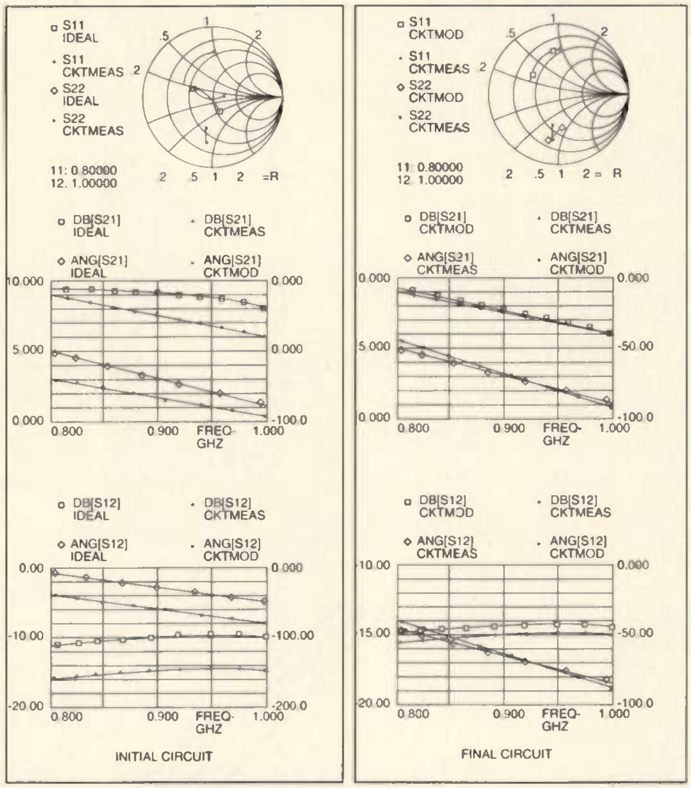


Figure 8. Measured versus simulated S-parameters.

Now for the terminations. There are many circuit configurations that can be used to define the optimizable terminations. The configuration we chose, a single L or C in series with a transformer, provides expedient optimization convergence. This expedience is obtained because the two optimizable variables, N and L (or N and C), singly effect either the real or imaginary term of the complex impedance, but not both. For example, modifying the turns ratio N of the transformer moves the impedance along the constant reactance contour. Modifying the L or C moves the impedance along the constant resistance circle. Whether you use L or C depends on which half of the Smith Chart you think the optimum load impedance is in. If you're not sure whether to use an L or C, both can be used (a series L, C or shunt L, C) at the expense of increased optimization time.

After you define the topology for the terminations, optimize the source and load impedances simultaneously until the design specifications are achieved. The resulting source and load reflection coefficients are used to develop the input and output matching networks. The initial matching networks and final matching networks after bench tuning are shown in Figure 5.

Fabrication

The matching networks derived from the nonlinear optimization method were used for the actual circuit design. The circuit board layout is shown in Figure 6. The substrate used is 10 mil thick, 1/2 ounce RT/DUROID 6006 with a dielectric constant of 6.0. The high dielectric constant and small substrate height were chosen to minimize line lengths.

Using RT 6006 Duroid substrate material without a heat sink is not recommended, otherwise the maximum allowable junction temperature could be exceeded during operation.

Measured and Simulated Results

The circuit was fabricated and three devices were secured in the amplifier test circuit and measured. The initial test results were compared to the design specifications. At 900 MHz, the small-signal gain was higher than the expected 8 dB (8.54, 8.81 and 9.26), the output power was lower than the expected 27.5dBm (25.9, 25.82, 26.35), and the input return loss wasn't very good considering the input was designed to be conjugately matched. Tuning on the bench [7] to achieve 27.5 dBm output power resulted in modifications to the input and output matching circuits as indicated in the schematic of Figure 5. The original 7.32 pF shunt input capacitor was changed to 1.8 pF, and a 5.5 pF shunt capacitor was added to the output. To explain the measured versus simulated discrepancies, we begin by examining the data used in the original design and simulation of the source and load terminations.

The S-parameters used for the Cripps approximation and the development of the nonlinear model in the SPICE optimization were measured on 30 mil thick, 5880 RT/ DUROID. The PC board used for the amplifier, however, has a higher dielectric constant and places the collector tab of the device within 10 mils of the ground plane. This configuration introduces a parasitic capacitance of approximately 0.7 pF between the collector tab and ground. This parasitic capacitance and other layout parasitics were added to the simulation file. Figure 7 is a schematic representation of the complete amplifier, including pertinent layout parasitics. Figure 8 shows the measured versus simulated S-parameters for the initial circuit design shown in Figure 5, and the measured versus simulated S-parameters after adding layout parasitics as shown in the schematic of Figure 7.

For additional comparison, the nonlinear model and optimizer were used to obtain the load impedances for maximum output power, instead of using an

S-parameter file as in Cripps approximation. The input was then terminated with the resulting conjugate of the large signal S11.

All of the preceding discussed source (Γ_s) and load (Γ_L) reflection coefficients are included in Table 1. The different techniques referred to in Tables 1 through 7 are:

1. *Cripps* - use small signal S-parameters to determine the load impedance and match the input to the small signal S11 conjugate.
2. *SPICE,opt* - SPICE optimization of the source and load simultaneously.
3. *SPICE, conj* - nonlinear optimization of the load for maximum power and match the input to the large signal S11 conjugate.
4. *DESIGN* - matching networks used for the initial amplifier layout are the terminations.
5. *DESIGN, final* - Simulation including matching networks and layout parasitics, final simulation.

Also included in the tables are the 2nd and 3rd order intermodulation distortion products.

The formulas used for comparing magnitude and phase differences are:

$$\text{Mag. difference} = (\text{Cripps} - \text{SPICE})/\text{SPICE} \qquad (1)$$

$$\text{Phase Diff.} = \frac{(180 - |\text{Cripps}|) + (180 - |\text{SPICE}|)}{\text{SPICE}} \qquad (2)$$

Using the preceeding formulas, we find the load impedances for Cripps and SPICE,opt differ by only 3% in magnitude and 7% in phase. The source impedances for Cripps and SPICE,conj are fairly close as expected, differing by 3% in magnitude and 12% in phase. The source impedances obtained by simultaneously optimizing the source and load (SPICE,opt) differ from those obtained using Cripps' method by 19% in magnitude and 51% in phase. The large difference between the these two methods is the result of differing constraints. Gain at P1dB is constrained to 7.0 dB in the method that simultaneously optimizes source and load impedances, while Cripps' and the SPICE,conj method terminate the input with S11's conjugate to maximize gain at P1dB.

The source impedances of the DESIGN and SPICE,conj designs differ by 6% in magnitude and 18% in phase. The differences in load magnitude and phase are 9% and 30%, respectively. Power simulations are included in Tables 2 through 6.

A comparison of the measured, simulated, and data sheet P1dB and G1dB are included in Table 7. The simulated 1 dB compression power levels are very close to the measured and data sheet values (27.2 dBm to 27.5 dBm). G1dB, however, varies from 7.0 dB to 9.6 dB. As is to be expected, the three methods which conjugately match the input yield the higher gains of 9.5 dB (Cripps), 8.8 dB (SPICE,conj) and 9.6 dB (DESIGN). The G1dB from the SPICE optimization (7 dB) and the measurement (7.2 dB) are very close to the NEC data sheet specification of 7.0 dB. The entire amplifier G1dB simulation including matching networks and layout parasitics is 7.8 dB, 8% higher than the measured value of

7.2 dB. This difference is because the amplifier parasitics were optimized to produce the lowest comprehensive error (including all S parameters, not just gain) over a 40 MHz band (880 MHz to 920 MHz) instead of at a single frequency of 900 MHz. The parasitics were optimized to achieve 7.2 dB gain at 1 dB power compression at 900 MHz at a slight sacrifice to the overall error. The final amplifier measurement and simulations cover the 800 MHz to 1000 MHz band.

Using a nonlinear model and simulator/optimizer took about four hours total to arrive at the source and load impedances. Two of the hours were used to input the circuit and optimization criteria; another two hours were used for the optimizer to converge using a 386/33 MHz computer with a co-processor. This technique is valid only if the nonlinear model is accurate for the operating conditions being simulated.

INFO/CARD 24

Technique	Γ_S (mag, ang)	Γ_L (mag, ang)
CRIPPs	0.63, −170.3	0.438, 66.13
SPICE, opt	0.75, −125.8	0.453, 61.4
SPICE, conj	0.646, 168.8	0.453, 61.4
DESIGN	0.69, −159.6	0.499, 43.27
DESIGN, final	0.165, −176.7	0.59, 83

Table 1.

Pin (dBm)	Pout (dBm)	Gain (dB)	2nd IMD	3rd IMD
−5	3	8	−46.4	−94
0	8	8	−36.5	−79
5	13	8	−26.6	−64
10	18	8	−16.5	−48.5
20	27.1	7.1	0.4	−6.9
20.3	27.3	7	2.3	−6.5
25	27.6	2.6	8.2	−3

Table 2.

Pin (dBm)	Pout (dBm)	Gain (dB)	2nd IMD	3rd IMD
−5	5.53	10.53	−42.2	−86.4
0	10.53	10.53	−32.3	−71.6
5	15.52	10.52	−22.2	−56.1
10	20.5	10.5	−12.3	−40.3
15	25.4	10.4	−3.5	−19.3
17.6	27.1	9.54	3.6	−6.4
20	27.5	7.5	10.2	4.6
24	27.9	3.9	8.4	5.6
25	28.1	3.1	8.7	4.9

Table 3.

Pin (dBm)	Pout (dBm)	Gain (dB)	2nd IMD	3rd IMD
−5	4.8	9.8	−44	−89.5
0	9.8	9.8	−34.1	−74.9
5	14.8	9.8	−24	−59.5
10	19.8	9.8	−14.1	−44.3
18.5	27.3	8.8	2.6	0.3
20	27.5	7.5	5.4	−1.3

Table 4.

Cripps' technique took about four hours to determine the output equivalent circuit from manufacturer supplied S-parameter data, set up the linear circuit file and rotate R_{opt} to the final load impedance value.

Production Results

A production amplifier using the NEC NE46134 was built and tested by M/A-COM. The amplifier exhibited excellent thermal performance and high linearity using a 25 mil aluminum nitride substrate mounted on a carrier. The dielectric constant was 8.8. M/A-COM was able to fit 70 circuits on a 2.0 inch by 2.0 inch substrate. Mask costs were less than $150.00 and the substrate costs less than $ 1.00 for each amplifier in small quantities. Since linearity was the key design specification, the device was biased at 12.5 V, 100 mA with the input power reduced to achieve an output power somewhat less than 0.5 watts.

Conclusions

1) Both techniques, Cripps approxima-

Pin (dBm)	Pout (dBm)	Gain (dB)	2nd Harm	3rd Harm
–5	5.64	10.64	–41.3	–87.4
0	10.64	10.64	–31.3	–72.7
5	15.63	10.63	–21.2	–57.4
10	20.6	10.6	–11.3	–42.1
15	25.5	10.5	–1.8	–23.1
17.6	27.2	9.6	–12.5	0.9
20	27.5	7.5	–2.9	4.2
25	27.9	2.9	–1.6	–1.5

Table 5.

Pin (dBm)	Pout (dBm)	Pout (dBm)	Pout 3rd (dBm)
	(17, #1)	(01QS)	(18, #2)
0	8.15	7.82	8.12
5	12.95	12.63	12.90
10	17.90	17.53	17.87
20	——	27.04	——
20.3	27.50	——	——
20.37	——	——	27.5
20.93	——	27.7	——
26	29.58	29.75	29.75

Table 6.

	P1dB (dBm)	G1dB (dB)	Simulation conditions
NEC data sheet	27.5	7.0	1 GHz sim.
SPICE, opt	27.3	7.0	900 MHz opt.
CRIPPs	27.2	9.5	900 MHz meas. S-parameters
SPICE, conj	27.3	8.8	900 MHz optimization
DESIGN	27.2	9.6	
DESIGN, FINAL	27.5	7.7	
Measured L/N 17	27.5	7.2	

Table 7.

tion and nonlinear optimization, yield similar results.

2) Using a SPICE optimizer allows the circuit, and changes to the circuit, to be better understood and evaluated. For example, changing the substrate for thermal considerations can effect the small signal gain and power compression characteristics of the device. A properly modeled device and circuit can predict the effects of these changes.

3) With the introduction of more efficient nonlinear simulators in the last decade, power amplifiers, and their layout parasitics, can be simulated prior to fabrication. The accuracy of the simulation depends mainly on the accuracy of the nonlinear device model and the designer's ability to properly model the overall circuit being built, including fabrication parasitics.

4) After fabricating the initial circuit, it became apparent that the computer simulation and measured data were very different. The circuit was tuned on the bench until the measured data agreed with the design specifications and simulated results. The differences between measured and designed quantities are attributed to omission of the layout parasitics in the initial design. If the layout parasitics had been included when determining the source and load reflection coeffieients, the initial measured data would have more closely agreed with the simulation.

5) SPICE simulators permit the designer to predict linear as well as nonlinear behavior such as power compression curves and third order intermodulation prior to circuit layout.

Acknowledgement

Our many thanks to Steven Cripps for his review and discussion of the methods presented here. *RF*

References

1. Olsen, L. and Kirk, B., "Nonlinear Model Verification for a Medium Power Bipolar Transistor", *RF Design*, March 1992. pp. 41-66.
2. Gonzales, Guillermo, *Microwave Transistor Amplifiers, Analysis and Design*, 1984, Prentice-Hall, ISBN 0-13-581646-7, pg. 92.
3. I.E. Getreu, CAD of Electronic Circuits 1, *Modeling the Bipolar Transistor*, Tektronix, Inc., Beaverton, Oregon, 1976.
4. Cripps, S.C., "A Theory for the Prediction of GaAs FET Load-pull Power Contours, " *IEEE/MTT-S DIGEST*,1983, pp. 221-223.
5. Cripps, Steve C., "GaAs FET Power Amplifier Design," Matcom, Inc., Technical Note 3.2.
6. Sechi, Franco N., "Design Procedure for High-Efficiency Linear Microwave Power Amplifiers.", *IEEE MTT-28*, No.11, Nov. 80, pp. 1157-1163.
7. Hall, L.C. and Trew, R.J., "Maximum Effieiency Tuning of Microwave Amplifiers." *IEEE/MTT-S DIGEST*, 1991 pp. 123-126.
8. Nagel, L.W. and Pederson, D.O., "Simulation Program With Integrated Circuit Emphasis (SPICE), " *16th Midwest Symposium on Circuit Theory*, Waterloo, Ontario, April 12, 1973. Available as Electronics Research Laboratory Report No. ERL-M383, University of California, Berkeley, April 12, 1973. A detailed description of SPICE is also available in Nagel, L.W., "SPICE2: A Computer Program to Simulate Semiconductor Circuits," Electronics Research Laboratory Report No. ERL M520, University of California, Berkeley, May 9, 1975.
9. H.K. Gummel and H.C. Poon, "An Integral Charge Control Model of Bipolar Transistors." *Bell System Technical Journal*, No. 49, 1970.
10. California Eastern Laboratories, "Designing High Power GaAs FET Amplifiers Using Single Cell FET Parameters", Application Note AN-PF-1007, 11/88.

About the Authors

Brian Kirk is an Applications Engineer with California Eastern Laboratories. Brian has an MSEE and nine years experience with RF and microwave power amplifier design. Brian can be reached at (408) 988-3500, ext. 232. Lynne Olsen is an engineering consultant for California Eastern Laboratories, specializing in RF and microwave circuit design and component modeling. Lynne can be reached at (406) 587-0334.

Simulating a QPSK Modem

By Don Miller
MCC Panasonic

This paper shows how time domain simulation can provide insights into the operation of a QPSK modem, insights that are unobtainable with frequency domain tools. SPICE-type tools were not used in the simulations outlined here. TESLA, one of the available block level simulators, was used instead. Tools such as these animate the behavior of all the system blocks in parallel. The blocks interact just as they would in the lab. This is much faster than circuit simulation, which solves large matrices of circuit equations. Unlike steady-state nonlinear simulators, a tool like TESLA easily handles complex digital logic and long sequences of data.

RF Engineers are comfortable analyzing the performance of their designs in the frequency domain. For many problems this makes sense because most RF components are characterized as a function of frequency. The effects of most filtering, (and even some nonlinear blocks, such as mixers), are easier to understand in the frequency domain. Often, however, the baseband performance of a design is not so easily analyzed in the frequency domain.

Just as an oscilloscope will be favored over a spectrum analyzer for observing some aspects of system behavior in the lab, alternative software tools will be better suited for simulating some aspects of a design. If a system is linear and time invariant, then linear simulation will be the tool of choice. Nonlinear systems that need be analyzed only in the steady-state case are good candidates for harmonic balance analysis. Time domain simulation is a tool that is useful for simulating systems where transient behavior must be studied or where frequency domain analysis provides little intuitive insight. For example, spectral analysis may show distortion, but a time plot shows the actual clip point of a waveform. However, employing a time simulation tool does not prevent us from looking at frequency domain behavior. This is provided for by the Fast Fourier Transform.

Modulator

The block diagram of a QPSK RF modem is shown in Figures 1 and 2. Figure 1 details the modulator section. Data and clock signals from the random bit generator go to a data stream splitter. It separates each pair of bits into two parallel data streams, each running at half the input data rate. Encoding is applied to the bit streams to determine the mapping of the bit pairs to the output carrier phase state. The resulting bit pairs, which define the current "symbol", are filtered with low pass filters having carefully controlled time responses. The resulting analog waveforms are applied to a quadrature modulator to generate the QPSK signal.

Demodulator

The demodulator circuit in Figure 2 operates almost like a modulator in reverse. The quadrature demodulator drives filters which can be identical to the ones in the modulator. The filtered signals are sliced with a comparator, decoded, and serialized into the same data stream as was transmitted. If only it were that easy! In reality the demodulator is much more complicated than the modulator. Carrier recovery is the problem. The local oscillator signal used in the quadrature demodulation process needs to be synchronized with the incoming carrier frequency (which is suppressed). Often, the demodulator is part of a special phase-locked loop, called a Costas loop, that recovers the carrier. The mixers in the demodulator are part of the phase detector, so the input signal level affects the phase detector sensitivity, (K_F). This means AGC is required! After the data is decoded, we must provide a bit rate clock to the device that is using the data we are delivering. This is yet another PLL! Luckily, we can "ship" clock and carrier to the demod from the modulator during our simulations until we are ready to add the carrier and clock recovery circuitry. This enables us to keep things simple at first and then add complexity as we are satisfied with the basics. Our ability to pick and choose between the real and ideal worlds enables us to simulate only as much of the system as we care or need to. The simulations here will carefully ignore clock recovery and AGC, while illustrating how filter effects and carrier recovery may be analyzed.

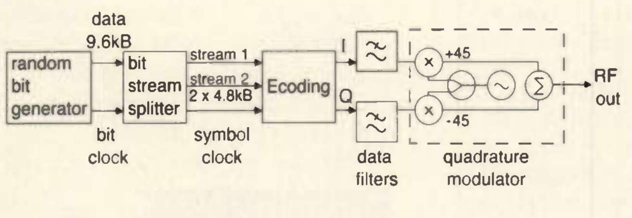


Figure 1. Block diagram of a QPSK modulator.

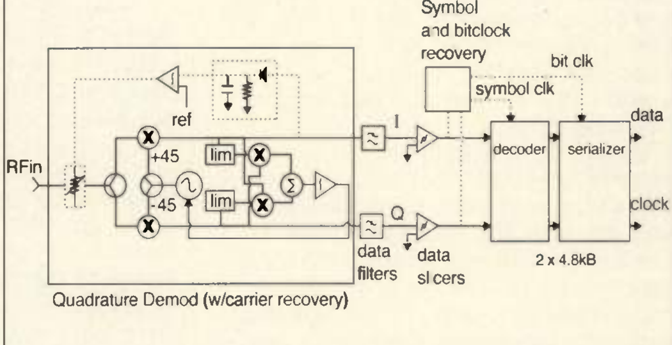


Figure 2. Block diagram of a QPSK demodulator.

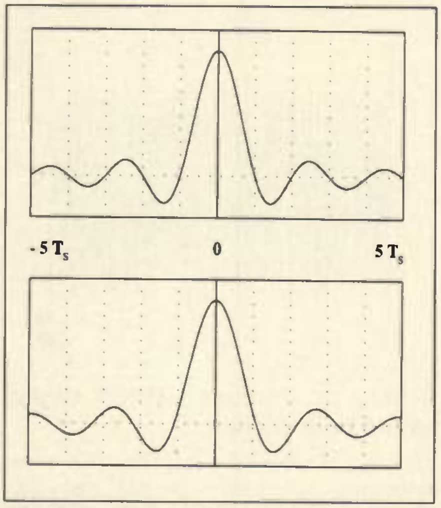


Figure 3. Impulse responses of filters with and without inter-symbol interference.

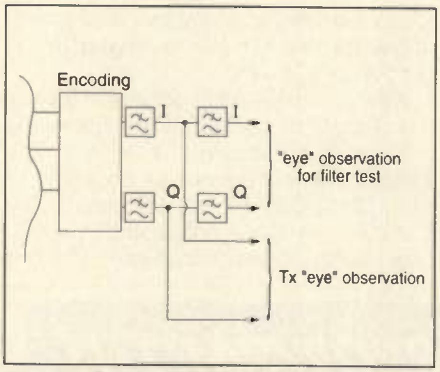


Figure 4. Simulation block diagram

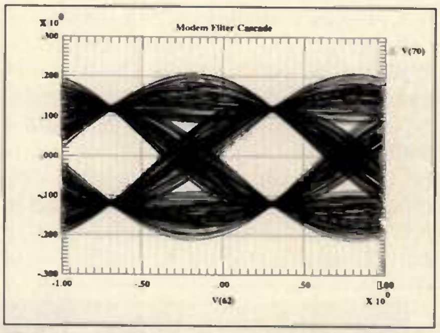


Figure 5. Eye diagram of system in Figure 4.

Filter Performance

After confirming that the data stream splitter and coder operate properly, the first real analysis task on the modulator side will be to confirm proper operation of the low pass data filters. If the filtering in a data link is optimum, the intersymbol interference (ISI) will be zero. Any ringing from the previous symbols or precursors from future symbols will pass through zero at each sample point. Figure 3 shows the impulse response for the filtering in a system with zero ISI, and one with significant ISI. Note that for the filter with zero-ISI, the zero crossings of the impulse response coincide with the sampling points. If our filters have significant ISI, then the nonzero residual time response of the previous symbol will add to the pulse resulting from the next symbol. This interference adds to the uncertainty in interpreting the state of a particular symbol.

We can check the filtering in our simulated modem by doing a simulation with the baseband output of the transmit lowpass filters cascaded into the receive filters. A block diagram of this simulation is shown in Figure 4. The output of the receive I or Q channel filter can be observed using a symbol rate timebase in Lissajous fashion. This display is called an eye pattern. Wide eye openings are indicative of low ISI. The eye pattern shown in Figure 5 was generated by simulating the system in Figure 4 with TESLA. The simulation was done for 300 ms with a 1 ms time-step. The data from 0 to 100 ms was omitted in the plot to keep start-up transients from corrupting the eye pattern. Significant ISI in the simulation output would have indicated that the filters needed work, but things look OK.

We can observe the actual QPSK signal (Figure 6) by simulating the entire modulator as shown in Figure 1. The transmit eye pattern can be observed as well. Significant ISI will be seen in the transmit eye, since only half of the system filtering is present (Figure 7). This simulation was for 1 second at a 1 ms time step (one million points). Only 200 ms of the data was plotted. The full second of simulation was necessary so that ample RF output simulation data could be stored to disk for the upcoming system bit error rate tests.

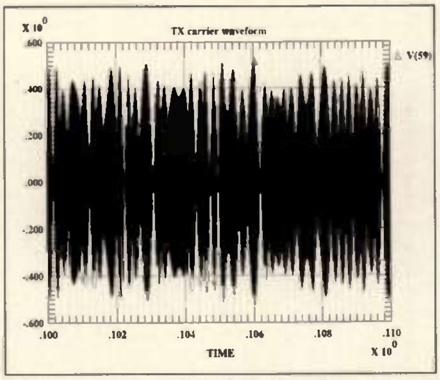


Figure 6. Simulated QPSK signal in the time domain.

The quadrature demodulator can be tested quickly by using an imported local oscillator from the modulator in lieu of the carrier recovery system in Figure 2. If the I and Q channels are displayed in an XY fashion, the phase and amplitude trajectory of the QPSK signal will result. Once the operation of the quadrature demod is confirmed, the carrier recovery circuitry (Costas loop) can be added and debugged.

Carrier Recovery Performance

This system is a second order phase locked loop, and the same methods as used on frequency synthesizers can be applied. The designer must be aware that the phase modulation on the carrier has spectral components that go quite low in frequency, so the bandwidth of the loop must be quite small. In a real system, switched time constants and/or sweep acquisition circuitry may be necessary for acceptable lock times. These types of systems can be simulated with TESLA, but the fast acquisition problem will be ignored here. The system simula-

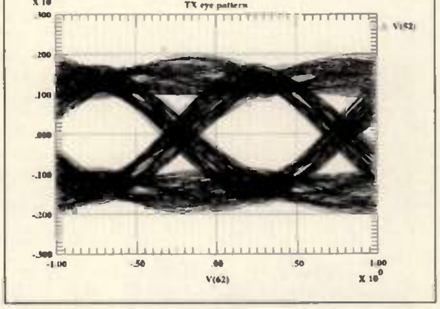


Figure 7. Transmitter eye diagram.

tor will let us set initial conditions so that we can simulate only the locked case, or just the time period immediately surrounding the lock instant. Figure 8 is a composite of four TESLA plots showing the receive constellation in the unlocked state approximately one second before acquisition, nearing the correct frequency as the constellation spins slower a few tenths of a second later, the constellation on frequency just before phase lock, and finally the locked constellation.

Bit Error Rate Performance

The real gauge of modem performance is the bit error rate (BER) in the presence of noise. The simulator has a BER tester model that can be used to this end. It is important to simulate the system at the highest error rate possible in order to keep the simulations short. In the case of QPSK, the variation of BER versus the signal to noise ratio (usually expressed as the energy per bit divided by the noise in a one hertz bandwidth, (E_b/N_0) is published and generally available. The BER of our demod with an input E_b/N_0 of 5.7 dB is about 10^{-2} (Figure 9). The difference in E_b/N_0 (for a given BER) for a real modem and an ideal one is referred to as the implementation margin. An ideal QPSK modem will have a BER of 10^{-2} with an input E_b/N_0 of 4.3 dB. Our radio therefore has an implementation margin of 1.4 dB. This degradation in performance could be due to the small amount of ISI resulting from the system filters, the nonzero bandwidth of the Costas loop, or a characteristic of the coding scheme. The coding scheme used here was differential QPSK. The phase of each symbol is interpreted

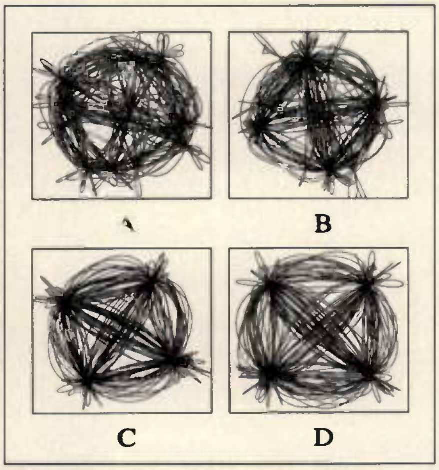


Figure 8. Receive constellation at various stages of signal aquisition and locking.

based on that of the previous one. Unfortunately, this means that any error more or less automatically causes an error in the next symbol. This doubles our bit error rate. Without this degradation, the E_b/N_0 would have been 5.2 dB. This leaves only 0.5 dB error that must be accounted for elsewhere (I feel better about my filters already!).

Occupied Bandwidth

The tools at our disposal have been valuable for looking at things in the time domain, but sometimes we really need a frequency domain tool. For example, if we need to look at the transmitter occupied bandwidth, an oscilloscope type display just would not do much for us. The simulator's FFT facility gives us the tool we need for the task. Figure 10 shows the results of TESLA's FFT com-

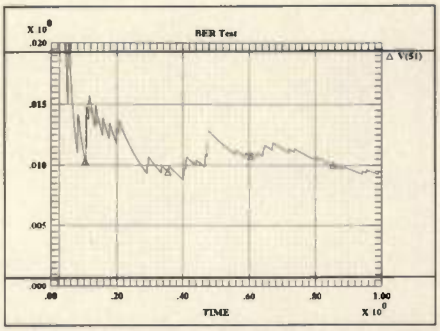


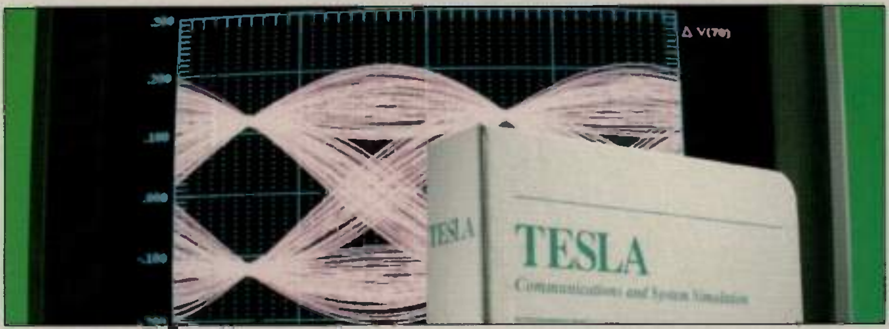
Figure 9. Simulated bit error rate for the modem.

putation on the transmitter output time data. The result is the spectral output of the transmitter.

Conclusions

Outlined here is the sum of well less than a week of total engineering time. A

On the Cover



TESOFT's TESLA system simulator let's an engineer "build" an RF system in block diagram form and perform a time-domain simulation to analyze its performance. FFTs up to 4096 points are available to observe results in the frequency domain.

TESLA has over fifty circuit element models, including amplifiers, filters of all major types, VCOs, mixers, detectors, multiplexers and modulators. Standard digital logic functions and interface functions (A/D and D/A converters, comparators, delay lines, etc.) are available to make a complete system encompassing much more than simply the RF functions.

Software "test and measurement equipment" includes a bit error rate tester, sweep and coherent signal generators, metering in RMS, linear or dB, noise generators, pulse generators, and more.

With a wide selection of models for the system, signal sources and test points, a complex communications system can readily be modeled. Up to 800 circuit blocks with 1000 nodes can be modeled to more than 16 million time points. Data at 100 nodes can be stored for analysis.

Speed is a feature designed into TESLA. Speed in computation is achieved with dedicated models and good software development practices. Speed in usage comes from interactive commands that let the user edit schematics, tweak parameters or plot results from within TESLA.

Development speed comes from schematic capture libraries for the popular OrCAD and P-CAD programs. And, the MODGEN model generator allows custom models to be added to the simulator.

With pressures of time-to-market higher than ever, fast and accurate RF system simulation will help speed the development of new communications products.

For more information, contact TESOFT at 205 Crossing Creek Ct., Roswell, GA 30076, (404) 751-9785, or circle Info/Card #180.

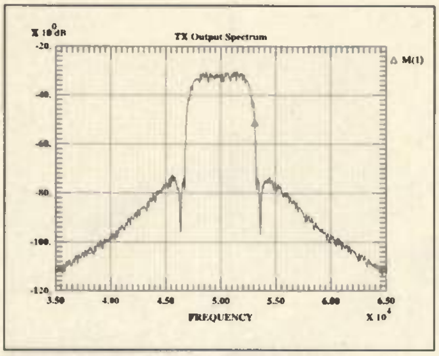


Figure 10. QPSK spectrum.

simple QPSK modem was designed, and several aspects of the design were evaluated. Without touching a single electronic component, we have some idea of the BER performance we can reasonably expect and how long it would take to "lockup" with the loop filter chosen. If modifications need to be made to meet the requirements, we can do it on the simulation before we start burning up time in the lab.

Time domain simulation can be used as a valuable tool to study the effects of design decisions well before the hardware prototyping stage. The skeleton of a system can be simulated using ideal components to test concept, and then models of the real world components can be substituted to study the overall effects on the system. With the cost of computer horsepower plummeting, and the cost of lab time (and time to market) shooting through the roof, many designs can benefit from the initial substitution of keyboard for oscilloscope and spectrum analyzer. *RF*

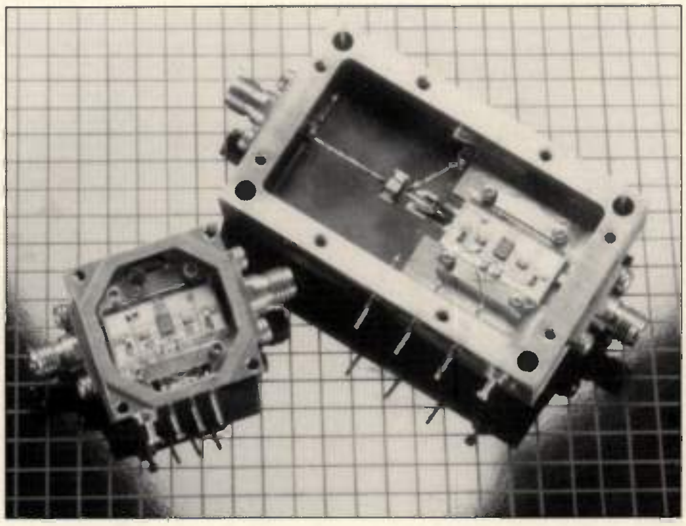
References

1. D.R. Smith, *Digital Transmission Systems*, Van Nostrand Reinhold, New York, 1985.
2. V. Manassewitsch, *Frequency Synthesizers Theory and Design*, Wiley, New York, 1976.
3. J.J. Poklemba, "Pole-zero Approximations for the Raised Cosine Filter Family," *Comsat Technical Review*, Vol. 17, No. 1, Spring 1987, pp. 127-157.
4. J.J. Spilker, Jr., *Digital Communications by Satellite*, Prentice-Hall, Englewood Cliffs, NJ, 1977, pp. 302-312.

About the Author

Donald J. Miller is a staff engineer at Panasonic/Matsushita Communication Industrial Corp. He has a BSEE from Georgia Tech, and has worked at Panasonic for three years. His most recent projects have included cellular transmitter circuits and UHF VCOs. He can be reached at MCC Panasonic, 2001 Westside Parkway, Bldg. 200, Suite 260, Alpharetta, GA 30201.

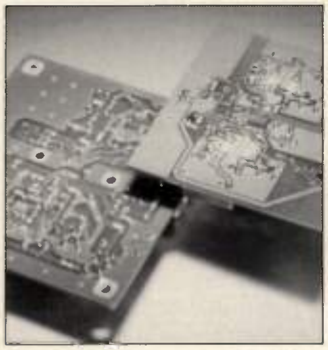
Bi-Phase Modulators



The Components and Subsystems division of Alpha Industries introduces the MX1016 and MX1017 Bi-phase Modulatror Series. the MX1016 series covers the 0.5 to 2 GHz band with 4 dB minimum insertion loss. The MX1017 series covers the 2 to 18 GHz band with insertion loss of 5.5 dB maximum. Bi-phase erroe is 0.75 dB and 7 degrees for both units. Rise time is 10 ns, maximum and switching speed is 10 MHz. With a volume of 0.5 cubic inches, these units utilize carefully matched diodes and proprietary microstrip baluns to yield broad band performance superior to quadrature-hybrid-based methods. Integrated MMIC drivers are available for either TTL or ECL inputs. The drive waveform is shaped to give –60 dBm switching spurious in the RF band for the MX1016 and –70 dBm for the MX1017. Units without drivers are also available. Power requirements are +5 V and –15 V at 40 mA each. Dimensions are 1.00 × 1.00 × 0.50 inches, without the field-replacable SMA connectors.
Alpha Industries
INFO/CARD #250

Dual-Frequency Synthesizers

Three new synthesizers from Philips Semiconductor feature two independent frequency loops, direct drive to a voltage controlled oscillator, operation at supply voltages as low as 2.7 V, plus an auxiliary output port or DAC to control other handset functions. Current consumption is typically only 10 mA. Operating over 400 to 1100 MHz, the UMA1015M's two RF dividers and phase comparators share a common reference divider, which operates up



to 35 MHz. The UMA1018M has two completely independent synthesizers, one operating up to 1.2 GHz, the other, to 300 MHz. The UMA1020M is a 2.4 GHz version of the UMA1018M, and can operate at that frequency on a 2.7 V supply rail. All three synthesizers are controlled via a high-speed 3-wire serial interface. All are supplied in 20-pin, SSOP surface mount packages.
Philips Semiconductor
INFO/CARD #249

RFIC Test System

Hewlett-Packard has announced an RF Integrated Circuit (RFIC) test system that provides complete, single-insertion 0.5- to 5-second test times for RFICs used in wireless communications. The HP 85119A RFIC test system gives semiconductor manufacturers test throughput up to ten times that of rack-and-stack R&D equipment, according to

HP. With the test system, all combinations of common RFIC functions can be tested including amplifiers, mixers, modulators, demodulators, switches and VCOs. The HP 85119A contains a high-speed receiver, a highly repeatable test set, a measurement director and other hardware and software components to create a complete test solution. Price is based on the configuration desired, a tailored RFIC test system can be delivered in 20 weeks.
Hewlett-Packard Co.
INFO/CARD #248

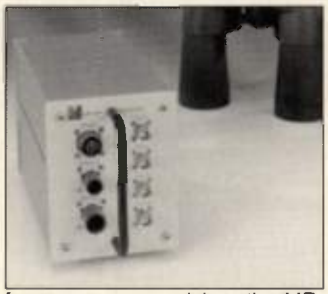
Compact, High Performance OCXO

Oak Frequency Control Group's 4840 OCXO is designed to provide performance and versatility in a compact, two-inch square by 0.75 inch package. The 4840's temperature stability is excellent at $\pm 6 \times 10^{-9}$ from –20 to +70 °C, and aging is only $\pm 7 \times 10^{-10}$ per day. Output level is 10 dBm, and power consumption is 3 W at 25 °C. Output is within 0.010 ppm of final frequency in 5 minutes. Designed to meet the

needs of component engineers involved with today's fastest growing applications, the 4840 covers 7 to 15 MHz and offers multiple options, including Sine or HCMOS outputs, 12 or 15 V supply, and electronic or mechanical frequency control adjustment. Small quantity orders are available in 4 to 6 weeks, and large quantities in 10 to 12 weeks.
Oak Frequency Control Group
INFO/CARD #247

Surveillance Receiver

The MR-203 receiver from Maxim Signal Products features 10 Hz tuning resolution, 1 ppm internal synthesized frequency accuracy and third-order intercept point of +5 dBm, typical. A high-performance tracking preselector operates over the HF/VHF/UHF



frequency range, giving the MR-203 a typical performance of 90 dB image and IF rejection with spurious signals at less than –110 dBm. In addition to an 8 MHz wide IF output, six other IF bandwidths, ranging from 500 Hz to 200 kHz, are standard. Detection modes include AM, FM, CW, SSB, and Log. Manual, spectrum search, band sweep and channel scan operation are all controlable via a serial interface. In the standard configuration, the receiver draws less than 5 W. An optional low-power model draws only 2 W. The MR-203 operates from 9 to 32 VDC over temperature ranges of –20 to +50 °C, in 100% condensing humidity.
Delfin Systems, Maxim Signal Products Div.
INFO/CARD #246

Product Spotlight: Switches

75 Ohm Switches

JFW Industries announces an addition to their RF switch line. Model 75S-134 is a solid state, 75 ohm 1P2T switch with an operating frequency range of 0.3 to 600 MHz. Minimum isolation is 80 dB, and switching speed is 60 MUs. The device requires +12 VDC (100 mA). RF input power is rated at +13 dBm (operating), +27 dBm (non-destructive).

JFW Industries, Inc.
INFO/CARD #245

Cellular Switches

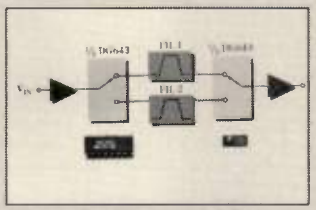
A series of electromechanical switches developed for cellular frequency band applications is offered by Narda. These products include SPDT, multi-throw, and transfer switches. Examples of members of this family are model 020-A0-A1D-0C0, a SPDT unit for switching redundant components in cell and microcell equipment, model 042-B347-A1D-0C2, a latching SP4T unit with TTL-control for switching operating systems at the cell site, and model 063-D1234-D2B-0C1, a TTL-controlled, normally open SP6T unit with type-N connectors and indicator circuits for system ATE.
Loral Microwave - Narda
INFO/CARD #244

High Power Reflective Switch

A SP2T reflective, high power switch for the 1.02 to 1.1 GHz frequency range is offered by Norsal Industries. The switch handles 4 kW pulses at 0.15% duty cycle with 35 dB minimum isolation. It is switched by a +12 V control signal, and draws 400 mA nominally. The switch's PIN diodes are field replaceable with no soldering required. The switch is qualified to MIL-STD-202 and is sealed against moisture.
Norsal Industries, Inc.
INFO/CARD #243

SPDT RF/Video Switch

The DG643, a dual single-pole, double-throw switch, offers typical on-resistance of only 8 ohms and very low on-state capacitance of 10 pF. The switch from Siliconix offers a –3 dB bandwidth of 500 MHz and has a 75 mA current capability. In 1000-piece quantities, the device is priced at $1.80 for a 16-pin plastic DIP and $1.96 for a SO-16 package.



Siliconix
INFO/CARD #242

Electromechanical Switch Line

KW Microwave has added a coaxial electromechanical switch line to its family of products. The typical frequency range for the switches is DC to 26.5 GHz. These multi-throw switches are available in up to six throw positions, with latch, fail-safe, indicator and TTL options.
KW Microwave Corp.
INFO/CARD #241

SP10T Switch

Model DSO820 from Daico Industries is a SP10T PIN diode non-reflective switch that features an operating frequency of 10 to 1500 MHz. The switch requires 15 mA at +5 V. Its insertion loss is 0.95 dB from 10 to 500 MHz, and 1.6 dB from 500 MHz to 1500 MHz. Switching speed is 3.0 MUs (50% control to 10%/90% RF). Isolation is 46 dB to 1000 MHz and 42 dB from 1000 MHz to 1500 MHz, with VSWR of 1.3:1. The TTL-controlled switch comes in a 38 pin DIP package.
Daico Industries, Inc.
INFO/CARD #240

RF products *continued*

AMPLIFIERS

Multi-Channel Cellular Amplifier

A multi-channel, solid-state, linear class-A amplifier module from Microwave Power Devices is designed for low intermodulation, multi-carrier operation. Model LWA880-50 operates over 869 to 894 MHz with linear output of 47 dBm (at 1 dB gain compression). Third order intercept is 54 dBm. A built-in digital attenuator provides 30 dB of control via TTL lines.
Microwave Power Devices, Inc.
INFO/CARD #239

Class AB Amp

AML announces a Class AB multi-channel power amplifier for cellular base station applications. Model APB8596200 is a 200 W

PEP amplifier with 25 MHz instantaneous bandwidths from 850 MHz to 960 MHz. Intermodulation products measured in a two-tone environment at 50 W per tone are –30 dBc min. The amplifier operates at +26 VDC. A power supply is optional, and the amplifier is offered in 19-inch, 24-inch and compact chassis configurations.
AML, Inc.
INFO/CARD #238

Booster Amplifier

An AB linear booster amplifier covering the range of 100 to 500 MHz and delivering 200 W minimum into a 2:1 load VSWR has been released by Power Systems Technology. Model BME 1858-200/2997 exhibits low harmonic distortion (–23 dBc typical) combined with high eficiency (23% typ.). The amplifier accepts 5 to 10 W input and faithfully reproduces an output at the 200 W level, while operating from conditioned vehicular power of +26.5 to +30 VDC.
Power Systems Technology, Inc.
INFO/CARD #237

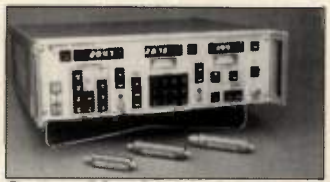
TEST EQUIPMENT

Pulse Modulator

Marconi Instruments has introduced a pulse modulator for testing civilian and military radar. The 6145 adds pulse modulation capability to the integral synthesized signal generator of the company's 6200 series Microwave Test Sets, as well as any other microwave source. The modulator covers 70 MHz to 20 GHz and has 5 dB of insertion gain. On/off ratio is greater than 70 dB, and rise/fall times are less than 5 ns. Price of the 6145 is $6185.
Marconi Instruments, Inc.
INFO/CARD #236

Noise Figure Meters

Maury Microwave announces the availability of the MT2075C and MT2075C06 noise gain analyzers. The MT2075C has uncertainty better than ±0.05 dB and the capability of accepting signals in the range from 10 to 2047 MHz.



Option 06 adds a high-speed processor that reduces measurement time by a factor of more than four.
Maury Microwave Corp.
INFO/CARD #235

SIGNAL PROCESSING COMPONENTS

Voltage Variable Attenuator

A voltage variable attenuator covering 30 to 1000 MHz has been added to Hybrid-Tek's product line. The HTAA102 features a high third order intercept point of +40 dBm, while maintaining a dynamic range of 15 dB. The

INFO/CARD 38

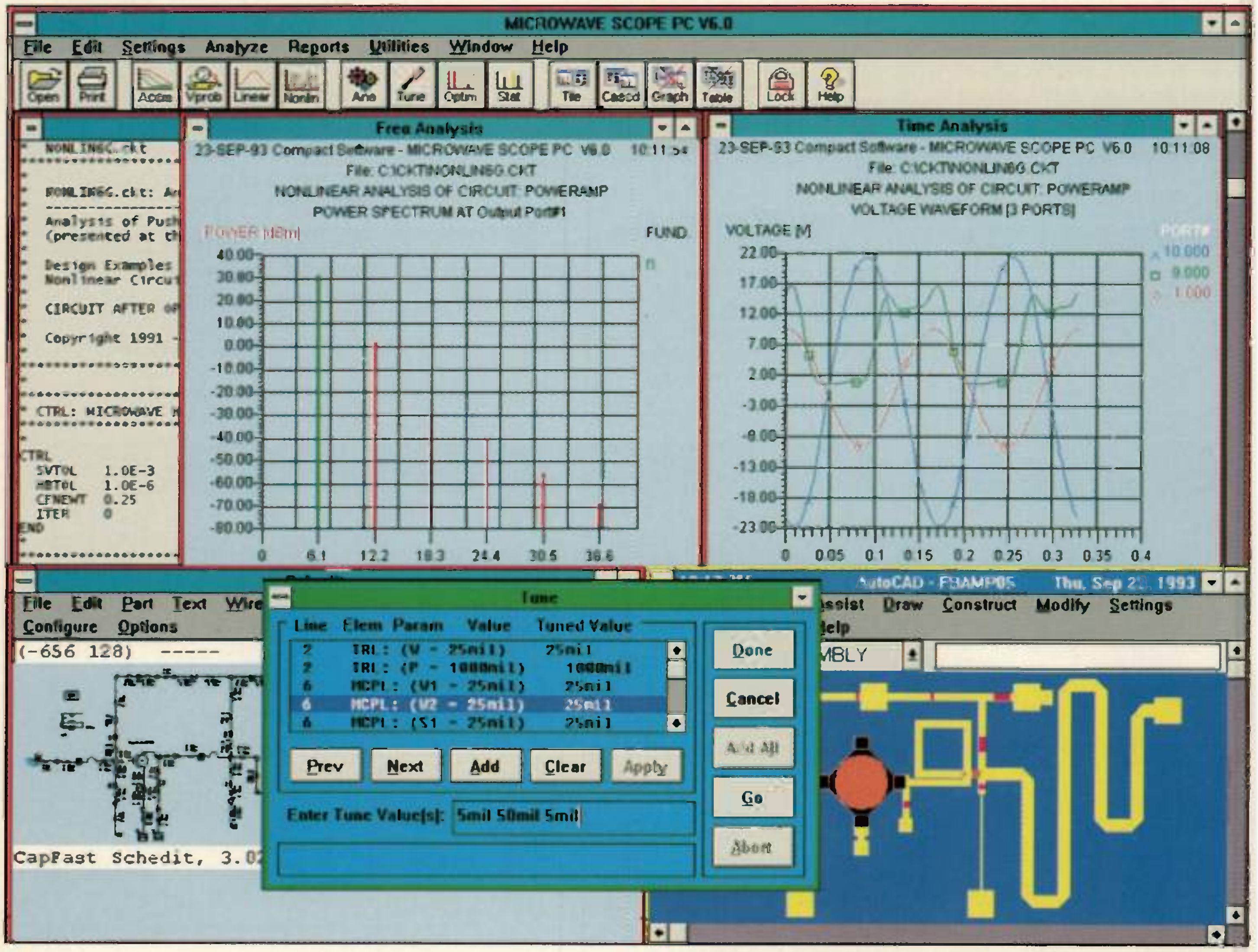
INFO/CARD 39

ENHANCED TUNE MODE

VERSION 6.0

Serenade® PC for Windows™

Super-Compact®, Microwave Harmonica®, and Microwave Scope®
RF, Microwave, and Lightwave Circuit Simulators
Integrated with Schematic and Layout Editors



Compact Software®

201 McLean Boulevard
Paterson, NJ 07504
Tel: (201) 881-1200
FAX: (201) 881-8361

INFO/CARD 40

Super-Compact®
Linear Circuit Simulator

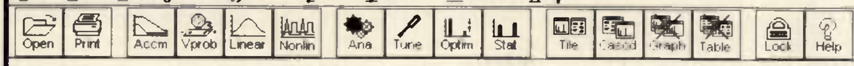
Microwave Harmonica®
Nonlinear Circuit Simulator

Microwave Scope®
Lightwave Circuit Simulator

Serenade® PC for Windows™

MICROWAVE SCOPE PC V6.0

File Edit Settings Analyze Reports Utilities Window Help



Super-Compact, Microwave Harmonica, and Scope for Windows allow you to interact with powerful linear and nonlinear circuit simulator "engines" using superbly intuitive and easy-to-use interfaces. Simple menus, dialog boxes, and "fill-forms" are used, in addition to a new netlist editor, to make the product very easy to learn and use.

Simulators link to Serenade Schematic and Layout Editors

Serenade PC is a suite of CAD tools for schematic entry and automatic generation of circuit and subsystem layouts. Each engine can be used as a stand alone or inside a design system.

* Schematic Editing
* Netlist Extraction
* Schematic Back-Annotation
* Symbol Editing
* Layout Generation and Editing

In order to receive complete literature and a ***free demo software kit****, please fax or send this page to Compact Software, or to the representative in your country.*

European Support Center
Austria, Denmark, Finland, France, Germany, Italy, Luxembourg, Norway, Portugal, Spain, Sweden, Switzerland
Technical Software Service (Germany)
FAX: 49-7309-3275 - PHONE: 49-7309-5075

Belgium – See The Netherlands

Ireland – See United Kingdom

Israel
U.S.I.E. Ltd.
FAX: 972-3-93-02558 - PHONE: 972-3-93-45979

Japan
Seki Technotron Corp.
FAX: 81-3-3820-1433 - PHONE: 81-3-3820-1714

The Netherlands
BFI Ibexsa Electronics, S.A.
FAX: 31-20-65-31-353 – PHONE: 31-20-65-350

South Africa
Microwave & Electronic Technology
FAX: 27-12-663-2978 - PHONE: 27-12-663-2975

Taiwan
Evergo Corporation
FAX: 886-2-712-2466 - PHONE: 886-2-715-0283

Turkey
Momentum Projects & Consulting
FAX: 90-1-257-7663 - PHONE: 90-1-257-7170

United Kingdom
BFI Ibexsa Electronics, S.A.
FAX: 44-622-882469 - PHONE: 44-622-882467

Name: ____________________

Title: ____________________

Company: ____________________

Address: ____________________

____

Fax #: ____________________

Phone #: ____________________

Interested in:

__ Super-Compact
__ Microwave Harmonica
__ Microwave Scope
__ Serenade Schematic Editor
__ Serenade Layout Editor

Platform: __Workstation __PC

CSBQ001F

Compact Software®
201 McLean Boulevard • Paterson, NJ 07504
Tel: (201) 881-1200 • FAX: (201) 881-8361

attenuator has control voltage range of 0 to +10 V and draws only 20 mA. The HTAA102 is available in TO-8 and surface mount flat pack packaging, and in 50 ohm versions.
Hybrid-Tek, Inc.
INFO/CARD #234

Cellular Filter

K&L's dielectric resonator filter is centered at 882 MHz. The 3 dB bandwidth is 26 MHz. The filter is capacitively coupled and inductively loaded to provide more than 80 dB rejection at 740 MHz and 1024 MHz. Insertion loss is 2.2 dB maximum at mid-band.

The unit is protected in a solid housing measuring 1.6 × 0.83 × 0.6 inches, with a drop-on laser sealed cover.
K&L Microwave, Inc.
INFO/CARD #233

Wideband Mixer

The RMS-30 mixer covers the 200 to 3000 MHz frequency band, and has IF response down to DC. The RMS-30's surface mount package is all ceramic and measures 0.25 × 0.31 × 0.275 inches. The mixers have all-welded internal construction and can withstand temperatures from –55 to 100° C. The RMS-30 is offered for off-the-shelf delivery at $6.95 in qty. of 10 to 49, and includes a 5-year guarantee.
Mini-Circuits
INFO/CARD #232

Step Attenuator

The 3200 series programmable step attenuators are designed for use in automatic test equipment and OEM systems operating in the DC to 2 GHz range. This series is available in four standard attenuation ranges and cell configurations. Power rating is 1 W avg., 50 W peak. Standard connectors are SMA female, and SWR is 1.25 from DC to 1 GHz, and 1.35 from 1 to 2 GHz.
Lucas Weinschel
INFO/CARD #231

SAW Filters

Two new SAW, coupled-resonator filters, the RF1210 and the RF1211, operate at 303.875 and 315 MHz, respectively. Both filters have 1.2 dB insertion loss, a 3 dB BW of 600 kHz and selective nulls placed 10.7 and 21.4 MHz below their center frequencies. The RF1210 and RF1211 are available now, and cost $2.71 each the 1000's.
RF Monolithics, Inc.
INFO/CARD #230

SEMI-CONDUCTORS

Capacitive-Load Op Amps

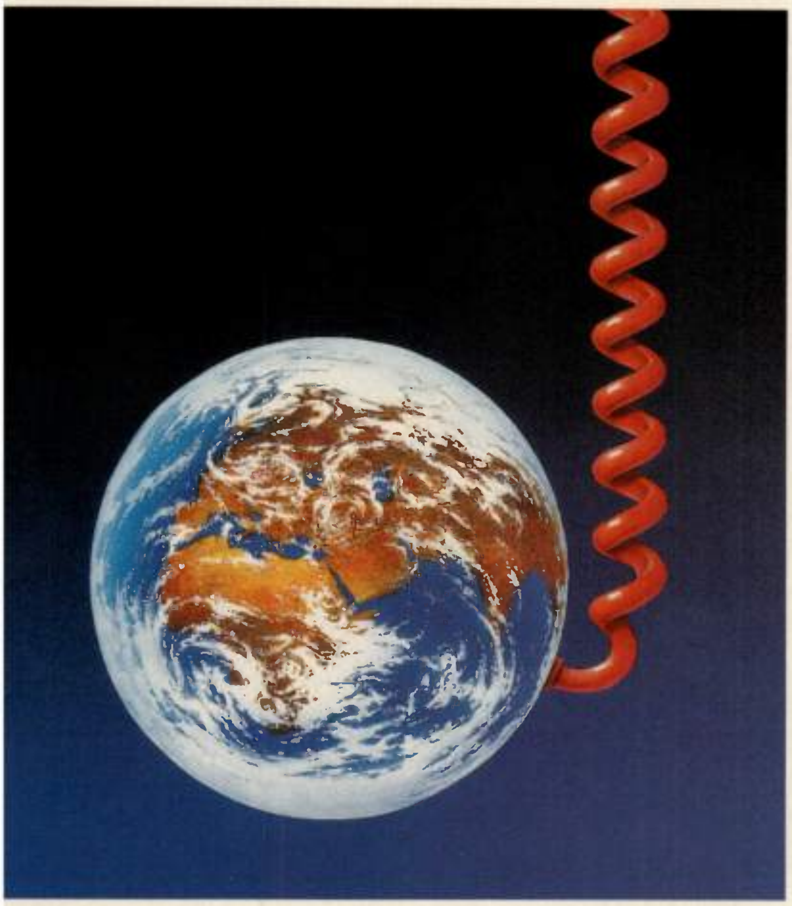
Linear Technology's CLOAD™ high speed op amps are based on a new topology that prevents oscillation with capacitive loads. In addition, this topology results in very high slew rate with lower supply currents, lower noise, lower input bias current, lower input offset voltage and less drift than previous circuits. The first members of this family are available with gain bandwidths of 12, 25, 50 and 70 MHz and in single-, dual- and quad-op amp versions.
Linear Technology Corp.
INFO/CARD #229

Class AB, 1 GHz, 5W MOSFET

The WRLS0945 provides 5 W of class AB output power with 10.0 dB of gain from a 12.5 V supply. This device will withstand a 30:1 mismatch at rated power output at 925 MHz. The transistor is packaged in a high-dissipation, ceramic SO-8 surface mount package. Pricing at 100 pieces is $27, with delivery from stock.
RF Products, Inc.
INFO/CARD #228

Designing telecommunications equipment? Here's how to put your world on a string.

Quite simply, tap into the proper sources. Because, while in one sense the world's a lot smaller, it can seem pretty big when the support you need is on the other side of it.



It needn't be that way in passive components. Because Murata's always nearby. Whether you're building Global Positioning Systems in Singapore, RF modems in Milan, or telephone systems in Thailand.

And we're there in a big way. With the technical expertise that ensures speed and flexibility in meeting new design requirements. With the high-volume manufacturing and distribution resources that–in getting parts where and when you need them–shrink the world to "neighborhood" size. And, of course, with undisputed Murata quality, backed by our unique 1.0 QRS (100% quality, reliability, service) program.

Oh, yes–product line breadth. You'll find our line, the largest, from chip caps to piezoelectric gyroscope systems, can make a world of difference in calculating the economic rewards of vendor reduction efforts.

Call or write for details: Murata Electronics North America, Marketing Communications, 2200 Lake Park Drive, Smyrna, GA 30080; 1-800-831-9172, Fax: 1-404-684-1541. Because, if it's the telecommunications world you're after, you'll want to string along with us.

muRata®

MURATA ELECTRONICS NORTH AMERICA, INC.

INFO/CARD 43

Receiver Basics — Part 1: Performance Parameters

By Gary A. Breed
Editor

Receiver designs range from the simplest TRF remote control units to ultra-high performance communications and surveillance receivers. This tutorial, the first of two parts, introduces the fundamental performance concepts that receiver designers must understand.

Performance drives the design of receivers. Once the basic functions of frequency range and modulation types have been defined, the design of a receiver will be determined by the requirements for sensitivity, distortion, noise, dynamic range, and other performance parameters. These fundamental parameters are identified and presented here. For detailed information on any of these parameters, readers should investigate the references given at the end of the article, as well as other sources.

Signal Level Specifications

Sensitivity — This is the "generic" term for the ability of a receiver to pick out weak signals. It is not a specification, but rather a descriptive term.

Signal-to-Noise Ratio (S/N) — S/N is the ratio of the level of the signal to the level of the noise. Many specifications are written for Signal-Plus-Noise to Noise ratio (S+N)/N, the level by which the signal exceeds the noise level, since (S+N)/N is readily measured.

Noise Figure (NF) — A figure of merit which is simply the ratio (in dB) of the S/N of the output versus the S/N of the input of a circuit or system. Accurate measurement of NF requires a calibrated noise source (a known noise level).

Minimum Discernible Signal (MDS) — This is one specific measure of sensitivity, which includes the bandwidth of the system. The accepted method of measuring MDS is with any automatic gain control functions disabled. A signal is applied and the generator is adjusted until the signal-plus-noise is 3 dB above the no-signal noise level. At this point, the applied signal power is equal to the no-signal noise power, since their sum is two times the latter. Noise power is proportional to the square root of bandwidth, so an MDS measurement will be different at differing bandwidths, even in the same receiver. Therefore, MDS performance specifications must include the measurement bandwidth.

Desensitization Level — Where MDS was a weak signal, desensitization is a strong-signal specification. Typically, a desensing of 1 dB is specified, the level of a strong signal which reduces a nearby weak signal by 1 dB. Usually, this means that the strong signal has begun to saturate the mixer diodes or an amplifier transistor.

Third Order Intercept Point — This specification is a figure of merit for intermodulation distortion (IMD). Nonlinearities are measured by introducing two signals that are close together in frequency, then increasing their levels and observing the level of the two close-in third order distortion products (2F1–F2 and 2F2–F1). Square-law behavior is predominant, so the slope of desired versus third-order signals is 3:1 (in dB); for each 1 dB increase in the test signals, the IMD increases by 3 dB. With this kind of slope, at some point, the IMD would equal the test signal. This is physically impossible, since the circuit will go into compression before this point is reached, but if the levels are plotted in the square-law region, the lines can be extended to the imaginary intersection, which is the intercept point. As the intercept point increases, so does the range of signals that do not create high IMD levels. Specifications must note whether they are referenced to signal levels at the input or the output of the circuit or device.

Dynamic Range — This defines the range of signals that a receiver can handle with a specified performance. This may be the range from MDS to 1 dB compression, or blocking dynamic range. It may also be the range from MDS to the point where third order IMD equals MDS, which is spurious-free dynamic range (SFDR). In some cases, it may be specified as the difference between MDS and a level with specified IMD (e.g. –40 dBc).

Unwanted Signal Specifications

Image Rejection — The first mixer stage responds to be either the sum or difference of the desired signal and the local oscillator. The signal that represents the opposite case is undesired, and must be kept from reaching the mixer by filtering. The measure of the filter's performance is image rejection, with measurement usually made by applying an image signal at the input and increasing its level until it is detectable. A test signal within the desired receiver passband is then applied and its level adjusted until it is the same as the earlier image signal. The difference in amplitude of these two test signals is the image rejection.

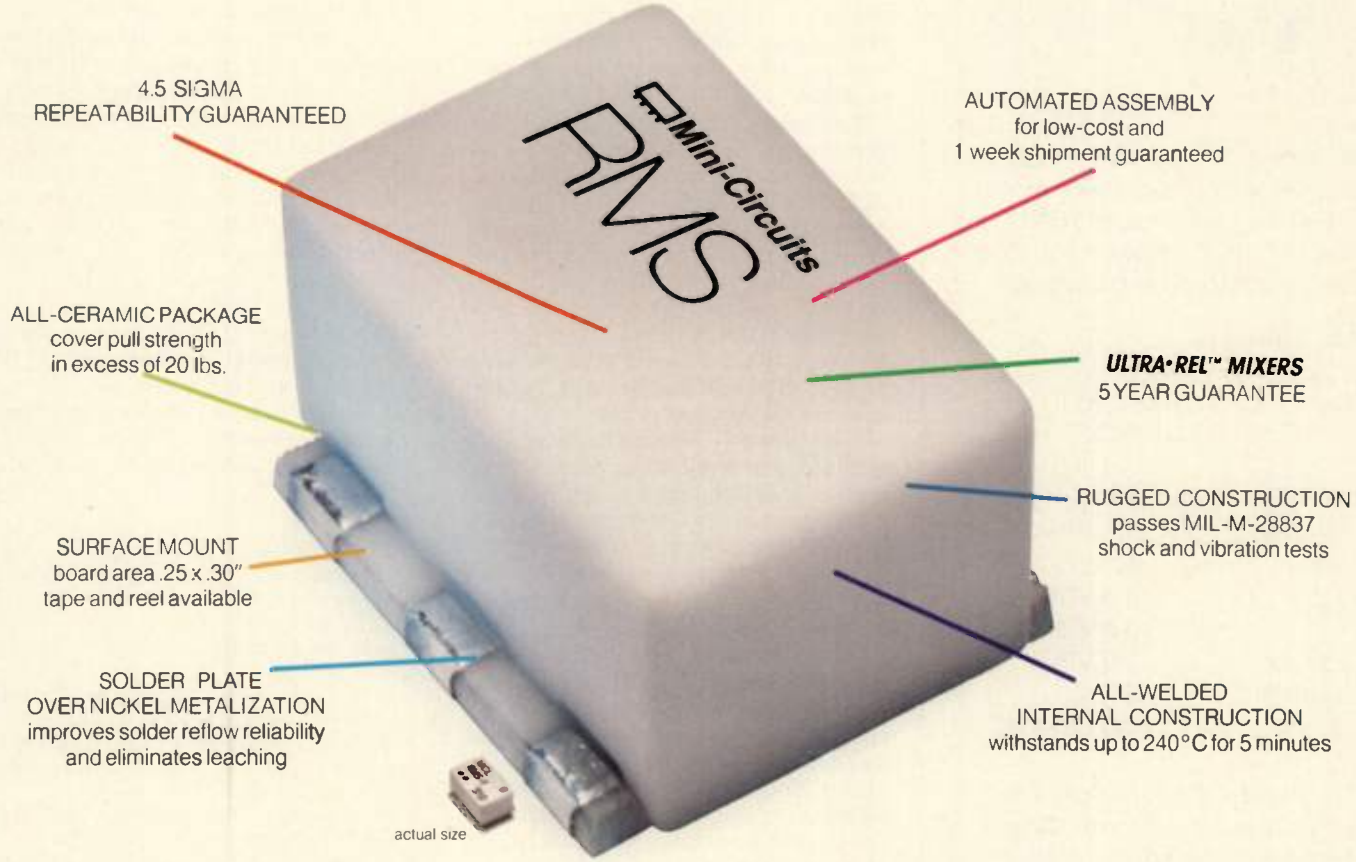
IF Rejection — A signal that is within the IF passband may find a path past the filters and mixers and be coupled into the IF circuitry. IF rejection is the measure of attenuation between the receiver input and the IF circuit. Measurement is the same as image rejection, except that an IF signal is applied as the first test signal.

Spurious Rejection — Signals at any other frequency than those noted above are considered spurious. They are identified by sweeping a test signal across a band at least as wide as the receiver's intended tuning range, while tuning the receiver through its entire range. Exhaustive testing is needed to find all possible frequency combinations, but sweeps made a several different frequencies within the receiver tuning range will usually identify any significant problems. Measurement is done in the same manner as image and IF rejection.

Internally-Generated Spurious Signals — With the antenna input terminated, the receiver is tuned through its entire range. Any internally-generated signals will be detected as if they were weak CW signals. Typical specification of internally generated spurious signals is a maximum level, equivalent to a specified external signal level.

Unwanted Modulation Rejection — AM rejection in an FM receiver is a common application of this specification, as

MIXERS UNPRECEDENTED IN VALUE.



ALL-CERAMIC 5 to 3000MHz from $3.95 (10-49 qty)

Now you can buy very low-cost, high-performance commercial mixers with the ruggedness and reliability required for military applications. That's value! ...Only from Mini-Circuits.

Model	LO (dBm)	Freq. (MHz) LO,RF	IF	Midband, dB Conv. Loss	Isol L-R	Isol L-I	$ ea. (10-49)
RMS-11X	+7	5-1900	5-1000	7.1	29	31	3.95
RMS-11F	+7	350-2000	DC-400	5.5	31	30	4.95
RMS-30	+7	200-3000	DC-1000	6.5	26	22	6.95
RMS-25MH	+13	5-2500	5-1500	7.5	32	32	7.95

finding new ways ...
setting higher standards

Mini-Circuits®

WE ACCEPT AMERICAN EXPRESS AND VISA

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

Distribution Centers NORTH AMERICA 800-654-7949 • 417-335-5935 Fax 417-335-5945 EUROPE 44-252-835094 Fax 44-252-837010

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCT DIRECTORY • EEM • MINI-CIRCUITS' 740-pg HANDBOOK.

CUSTOM PRODUCT NEEDS... *Let Our Experience Work For You.*

F166 REV. ORIG.

INFO/CARD 44

well as AM carrier feedthrough in a SSB receiver. Measurement is made by the equivalent level method noted above.

Overall Performance

System Gain — The overall gain must be sufficient to provide an output at a usable level when the input is the MDS. For example, with an MDS of –120 dBm to drive an audio output of 0.1 watt (20 dBm), the power gain must be 140 dB.

Synthesizer Resolution — How fine must the tuning steps be? In analog-tuned receivers, coverage was continuous, but with digital frequency synthesis, discrete step sizes are required. Specifications may require steps as small as 1 Hz or 10 Hz, while some channelized receivers will only need 25 kHz per step resolution.

Synthesizer Switching Time — This may also be described as synthesizer settling time after switching to a new frequency. This specification is not critical in fixed-frequency or channelized receivers, but it is all-important in frequency-hopping, frequency-agile and continuous-tuning receivers. Some receivers may switch a synthesizer between the transmit and receive modes. Specifications will reflect demands for turnaround time.

Phase Noise — Related to all types of oscillators and synthesizers, phase noise is specification of spectral purity, usually given in dB/$\sqrt{Hz}$ (a power density function) at a particular offset from the center frequency. A specification of –120 dBc/$\sqrt{Hz}$ at 10 kHz offset means that noise energy at in a one Hz bandwidth 10 kHz away from the carrier frequency should be 120 dB lower than the carrier. In a very sensitive receiver, too much phase noise will cause reciprocal mixing or mask weak signals.

Frequency Stability — This simple specification defines the allowable frequency drift over time. In some cases, the specification follows regulations for the radio service being received. In other cases, the modulation type and bandwidth usually dictate stability requirements. Spread spectrum systems and some very narrow band modes typically require the greatest stability.

Demodulation Linearity — Accuracy of demodulation may include harmonic and intermodulation distortion specifications for audio signals or differential phase and gain requirements for video signals. Digital signal demodulation is usually not separated from full-system performance, which is measured in terms of bit error rate (BER).

Electromagnetic Interference (EMI) — Ideally, electronic equipment only performs its intended function, no more, no less. In practice, however, most electronic equipment will generate electromagnetic energy at more than one frequency. A receiver's oscillators can be a source of unwanted radiation, with a maximum level given as part of the receiver specification. Part 15 of the FCC Rules and Regulations includes limits on radiation from electronic equipment, and is the most common specification in the U.S. Specifications are typically given in field intensity (mV or µV per meter at a specified distance).

Electromagnetic Susceptibility (EMS) — Any electronic circuit will be affected by external electromagnetic fields, if those fields are strong enough. Susceptibility to external fields is a performance issue that has not been widely addressed outside of military applications. Proposals have been put forth that would specify that electronic equipment perform in the presence of 1 V/m or 3 V/m fields.

Summary

Receiver design is a major topic in RF engineering. This short tutorial has attempted to identify the overall performance specifications that an engineer may need to address for a particular design. *RF*

Bibliography

1. U. Rohde and T.T.N. Bucher, *Communications Receivers*, McGraw-Hill, 1988.
2. W.E. Sabin and E.O. Schoenike, editors, *Single-Sideband Systems & Circuits*, McGraw-Hill, 1987.
3. R.C. Dixon, *Spread Spectrum Systems*, John Wiley & Sons, 1976.
4. C. Slater, "Spectrum-Analyzer-Based System Simplifies Noise Figure Measurement," *RF Design*, December 1993, p. 24.
5. C. Fantanas, "Introduction to Phase Noise," *RF Design*, August 1992, p. 50.
6. J. Donohue, "A Program for the Design and Analysis of Receivers," *RF Design*, October 1993, p. 101.
7. G.A. Myers, "User-Friendly Error Curves for Digital Radios," *RF Design*, April 1992, p. 39.
8. M. Bartz, "Designing Effective Two-Tone Intermodulation Distortion Test Systems," *RF Design*, November 1987, p. 59.
9. B. Kasmir, "Fundamentals of Receiver Design for Part 15 Applications," *RF Design*, September 192, p. 35.
10. R. Hawkins, "Combining Gain, Noise Figure, and Intercept Point for Cascaded Circuit Elements," *RF Design*, March 1990, p.77.
11. N. Ayrandjian, "Simple Computation of Spurious-Free Dynamic Range," *RF Design*, January 1987, p. 65.

RF Expo West '94 — A Special Focus On Data Communications

RF and digital technologies were once considered to be separate, but that has all changed!

Transmission of digital information using RF is an integral part of many new communications systems, including digital cellular, PCS, advanced paging, RF identification and data collection systems. In addition, advanced digital networks, both wireline and fiber optic, have unique hardware and system performance requirements that involve high-frequency and high-speed design techniques.

To meet the needs of engineers designing tomorrow's digital communications systems, we have added a special set of sessions covering Data Communications and integrated it into our comprehensive program.

These sessions at RF Expo West make our conference an even greater value for the attending engineers!

RF expo WEST

March 22-24, 1994

San Jose Convention Center

San Jose, California

SPECIAL COURSES

RF Expo West will feature five highly popular special courses March 21, 1994 through March 24, 1994. CEUs are available for all special courses (except Digital Modulation) through the Georgia Tech School of Electrical Engineering.

March 21, 1994 — Introduction to RF Circuit Design Part 1: Fundamental Concepts (CEUs Available)

This course presents the fundamental concepts of RF systems, components, transmission lines and impedance matching. RF system concepts of gain, bandwidth, linear and nonlinear circuits and amplifier classes are followed by the network concepts of resonance, bandwidth Q and maximum power transfer. Practical components, their models characterization and specification are then discussed. Transmission line theory, traveling wave behavior, the Smith chart, and practical realization of transmission lines are discussed, covering the concepts of impedance, loss, dispersion and physical construction. The final topic is impedance transformation networks, including lossless and lossy elements, graphical and analytical design, phase shift and bandwidth considerations, balanced networks and attenuators.

Instructors are Dr. Robert K. Feeney and Dr. David R. Hertling of the Georgia Tech School of Electrical Engineering

March 21, 1994 — Digital Modulation and Spread Spectrum (for Personal Wireless Communications)

This advanced-level class covers an essential topic for designers of new wireless communications systems — the transmission of digital information.The course begins with principles and system architectures for complex I-Q, QPSK, pi/4 DQSK, FQPSK, and other modulation schemes. Standards for specific cellular and PCS standards are introduced. A theoretical analysis of spectral and power efficiency follows, including adjacent channel interference, linear/nonlinear amplification and BER performance. Advanced modulation techniques such as 16-QAM, trellis coding and multilevel digital FM are presented. A section on spread spectrum covers pseudo-noise sequences, correlation, direct sequence, CDMA and slow frequency-hopping (TDMA) principles. The near-far problem and operation in mobile environments are discussed. The course concludes with a discussion of performance in complex mobile, cellular and PCS systems. The instructional level assumes a BSEE and experience in RF design.

Instructor: Dr. Kamilo Feher, professor, University of California — Davis.

CEUs Available

March 22, 1994 — Introduction to RF Circuit Design Part 2: Active Circuit Design (CEUs Available)

Active circuits are covered in this course, from basic models to advanced computer-aided design methods, from simple two-port concepts to large signal amplifiers and oscillator design. The two-port model includes definition of power gain, noise, cascaded elements and terminations. Scattering parameters used to describe two ports are introduced, including their definition and physical meanings. Computer-aided design and analysis using SPICE and commercial software is described noting models, analysis techniques and optimization methods. S parameter based design of amplifiers is presented, followed by large signal amplifier design and the large signal concepts of dynamic range, intermodulation distortion and load pull. Non-reciprocal networks (couplers, combiners and hybrids) are introduced, and the course concludes with oscillator design fundamentals.

Instructors : Dr. Robert K. Feeney and Dr. David R. Hertling, Georgia Tech School of Electrical Engineering.

March 23, 1994 — Filter and Matching Network Design: L-C and Distributed Circuits — HF to Microwaves (CEUs Available)

This course is designed for the practical engineer, packing a wealth of practical and useful information on these passive RF circuits into eight hours. Engineers with all levels of experience will benefit from the review of fundamental information on filter response and classic topologies for filters and matching networks, followed by design methods for implementation of L-C and distributed element filters and matching networks, from low radio frequencies to microwaves. Key performance parameters such as group delay and phase characteristics are covered, as are techniques for implementing the design of these networks using modern computer-aided synthesis, analysis and optimization.

Instructor: Randy Rhea, Eaglewave

March 24, 1994 — Oscillator Design Principles (CEUs Available)

Learn the fundamentals of oscillator design. Historically, oscillator design has been obscured with pages of equations for particular configurations. In this course, basic concepts are applied to design various oscillators using a unified approach. Attendees learn how to evaluate oscillator designs accurately. L-C distributed element, SAW and crystal oscillators are studied. Also considered are output level, starting time, harmonic levels and phase noise performance.

Instructor: Randy Rhea, Eaglewave.

Look to RF Expo West Exhibitors to Bring You These Products:

CAD/CAE SOFTWARE & SYSTEMS
software
systems - hardware

COMPONENTS
capacitors
crystals
diodes
inductors
integrated circuits
resistors
transformers
transistors
vacuum tubes

EMC PRODUCTS
absorbers
AC line filters
anechoic chambers
ESD control devices
gaskets/finger stock
shielded enclosures
shielding
surge & transient protectors
test equipment & systems

MATERIALS & HARDWARE
cabinets & enclosures
ceramics
components/hybrid packages
crystal blanks
electronic hardware
equipment racks
ferrites, other magnetics
heat sinks
insulating materials
PC boards
sockets
substrates

MODULES & HYBRIDS
amplifiers
detectors
filters
frequency multipliers
limiters
mixers
modulators
noise sources
oscillators
resonators

SERVICES
antenna measurement
circuit assembly
consultants
custom hybrids
custom ICs & ASICs
EMC testing
equipment calibration
instrument rental/leasing
PC layout/fabrication
plating/coating
software development
training/education

SYSTEM BLOCKS & SUBASSEMBLIES
amplifiers
frequency converters
frequency synthesizers
motion/proximity sensors
receivers
RF modems
tone encoders/decoders
transmitters

TEST EQUIPMENT
amplifiers (lab)
antenna measurement systems
calibrators/standards
dummy loads
field intensity meters
frequency counters
modulation meters
network analyzers
noise figure meters
noise generators
oscilloscopes
power meters
probes
pulse generators
RLC/impedance bridges
signal level meters
signal/sweep generators
spectrum analyzers
SWR meters
test fixtures
wave/distortion analyzers

TRANSMISSION COMPONENTS
antenna positioners
antennas
attenuators
coaxial cable
directional couplers
equalizers
filters
isolators/circulators
loads
multicouplers
multiplexers/diplexers
phase shifters
power dividers/combiners
relays
RF connectors
switches
terminations
tuners

Only At RF Expo West

Previous RF Expo West Exhibitors Have Included:

Advanced Electronic Systems
Advantest
Alan Industries, Inc.
Allen Avionics, Inc.
Allis Associates, Inc.
Alpha Industries
Am. Tech. Ceramics Corp.
AML
AMP, Inc.
Amphenol RF/Microwave Operations
Amplifier Research
Anritsu Wiltron Sales Co.
Applied Engineering Products
ATN Microwave
Balo Hermetics Co.
Besser Associates
Bird Electronic Corp.
California Eastern Labs
Compac Development Corp.
Compact Software Inc.
Compex Corp.
Connecting Devices, Inc.
Cougar Components
CTS Corp.-Frequency Control Div.
Delphi Components
Dielectric Laboratories
E.F. Johnson
Eagleware
EEsof, Inc.
Ehrhorn Technological Operations, Inc.
EMC Technology, Inc.
Emhiser Micro-Tech
ENI
Erbtec Engineering, Inc.
ETF Technology, Inc.
Faraday Technology Ltd.
FDK America, Inc.
FERRETEC, INC.
Fotofabrication Corp.
Frequency Management
Frequency Products Corp.
Giga-tronics Inc.
Goguen Industries Inc.
Harris Microwave Semiconductor
Harris Semiconductor
Hewlett-Packard Co.
Hewlett-Packard Company -Comm. Components Division
IFR Systems, Inc.
Instrument Specialties Co., Inc.
Integrated Microwave Corp.
Inter-Continental Microwave
International Crystal Mfg. Co.
ITT GTC
ITT Sealectro
JFW Industries, Inc.
K&L Microwave, Inc.
Kalmus Engineering International, Ltd.
KDI/Triangle Electronics
Kyocera America, Inc.
LCF Enterprises
Loral Microwave - FSI
M/A-COM
Magnum Microwave Corp.
Mark V Assoc.
Matrix Corp.
MC Microwave, Inc.
Menlo Industries
Merrimac Industries, Inc.
Micro-Coax Components, Inc.
Microelectronics
Microwave Power Devices, Inc.
Milcom International
MilliWave
Morrow Technologies
Motorola Semiconductor Products
Motorola, GEG
Motorola, Inc. (Wireless Data Land)
Penstock
Philips Semiconductors
Philips Semiconductors (FL)
Piezo Crystal Co.
Polyfet RF Devices
Polyflon Co.
Proxim, Inc.
PT Technology (PTT)
Q-bit Corp.
QUALCOMM
Racal-Dana Instruments Inc.
Radiall, Inc.
Republic Electronics Corp.
RF Micro Devices, Inc.
RF Monolithics, Inc.
Richardson Electronics, Ltd.
SaRonix
Sawtek, Inc.
Schoenduve, Inc.
Sciteq Electronics, Inc.
SGS-Thomson Microelectronics, Inc.
Signal Technology Corp.
Sprague-Goodman Electronics
Stetco, Inc.
Tecdia, Inc.
Tegmen Corp.
Tektronix Inc.
Tele-Tech Corp.
The Marketing Co.
THOMSON Components and Tubes Corp.
Toko America, Inc.
TRILITHIC, Inc.
Trontech, Inc.
Vanguard Electronics Co.
Varian Power Grid Tube Products
Voltronics Corp.
Watkins-Johnson Co.

Schedule of Events

Monday, March 21, 1994

7:00 a.m.-6:00 p.m. Registration Open

8:00 a.m.-5:00 p.m. Special Courses

Tuesday, March 22, 1994

7:00 a.m.-6:00 p.m. Registration Open

10:00a.m.-6:00 p.m. Exhibit Hall Open

8:00 a.m.-5:00 p.m. Special Courses

8:30 -11:30 a.m.

Morning Sessions

Session A-1: **RF Data Communications I**

- FQPSK, A Modulation that Outperforms Pi/4 DQPSK in Both Radiation Effects and Battery Power Dissipation While Maintaining Equal Capacity
- Theory and Development of a Digital Amplitude Modulator
- A QPSK Demodulator IC for Compressed Video Applications

Session A-2: **Power Amplifiers I**

- Low Cost RFIC Power Amplifiers for Wireless Applications
- HF and VHF Linear Power Amplifiers Using SSTS and SLAMs
- Comparative Study of Four Broadband Microwave Amplifier Concepts

Session A-3: **Filter Design**

- Dielectric Filter Design
- Microstrip Techniques and Filter Design
- SAW Resonator Oscillator Design Utilizing Linear RF Simulation

11:30 a.m.-1:30 p.m.
Deli Luncheon served in Exhibit Hall

1:30-4:30 p.m.

Afternoon Sessions

Session B-1: **Oscillators**

- Injection Lock
- Oscillator Design for Lowest Phase Noise

Ssesion B-2 **Product Design and Manufacturing**

- Improving Product Design/Development by Identifying Key Customer Values and Product Features
- Filter Designed for Manufacturing

Session B-3: **RF Materials**

- A High Power RF Package Using Aluminum Nitride Ceramic
- Microwave Based Measurements of Layered Homogeneous Dielectric Medium
- Conducting Solutions/Liquids as a New Transmission Medium for Microwaves

5:00-6:00 p.m. Cocktail Reception

Schedule of Events

Wednesday, March 23, 1994

7:00 a.m.-6:00 p.m. Registration Open

10:00 a.m.-6:00 p.m. Exhibit Hall Open

8:00 a.m.-5:00 p.m. Special Courses

8:30 -11:30 a.m. Morning Sessions

Session C-1: **Data Communications II**
- IF Amplifiers and Quadrature Demodulators for Digital Communication Receivers
- An FSK Modulation Data Receiver for 900 MHZ Using a Low Cost Silicon Monolithic IC Chip Set
- A Low Power Spread Spectrum CMOS RFIC Operates at a Center Frequency of 2.45 GHz for Use in Radio Identification Applications

Session C-2: **RF Power II**
- Linearisation Techniques for RF Amplifiers
- Some Improvements on the Feedforward Technique
- Amplitude Modulation in Class E Power Amplifiers

Session C-3: **RF Components**
- RF Circuit Components: Measurements, De-embedding and Equivalent Circuits
- SMD Component Evaluation for RF Circuit Design
- Numerical Simulation of Silicon Hyperabrupt Diodes for VCO and Filter Applications

1:30-4:30 p.m. Afternoon Sessions

Session D-1: **Wireless Communications**
- The Design of UHF and VHF Loop Antennas
- Techniques for Open Loop Modulation of a Wideband VCO for DECT
- A Covert Video Communications System

Session D-2: **Synthesizers**
- Frequency Synthesizer Technology in the Nineties
- Modulation Domain Analysis of Oscillators and PLLs
- NCO - The Next Generation Oscillators

Session D-3: **Communications Systems**
- LINK 16: Tactical Advantage in the 21st Century
- A Simple Technique for Assessing HF Automatic Link Establishment Radio Interoperability
- The Art of CW Rejection in ESM Receivers

5:00-6:00 p.m. Cocktail Reception

6:00-7:30 p.m. Ham Radio Reception
San Jose Hilton and Towers

Thursday, March 24, 1994

8:00 a.m.-1:00 p.m. Registration Open

9:00 a.m.-1:00 p.m. Exhibit Hall Open

8:00 a.m.-4:00 p.m. Special Courses

8:30-11:30 a.m. Morning Sessions

Sesson E-1: **Data Communications III**
- Multi-Mode Radio Transceiver Design
- Design an Infrared Data Link Using an Integrate FSK Transceiver
- Data Communications by Means of Reflective Transmission

Session E-2: **Circuit Design Methods**
- Ground Current Control in RF and High Speed Digital Circuits
- Design Microstrip Components With a Dielectric Cover Without Buying Additional Software
- Crosstalk Between Coupled Transmission Lines, and Circuit Theory Approach Versus Field Theory Approach in Shielding Evaluation

Session E-3: **Integrated Circuit Solutions**
- Three-Paper Session on RFIC Design Solutions

RF expo WEST

March 22-24, 1994
San Jose Convention Center
San Jose, California

Special Events

Don't Miss The Ham Radio Reception!

Now a standing-room only tradition at the RF Expos, the next Amateur Radio Reception will be held on Wednesday night, March 23, 1994, at the San Jose Hilton and Towers. This lively evening of munchies, drinks and oustanding door prizes is a popular gathering place — giving you the opportunity to see old friends and make new ones.

Deli Luncheon

A deli luncheon will be served in the Exhibit Hall on Tuesday, March 22, 1994 from 11:30 a.m. until 1:30 p.m. All full, 3-day registrants will receive one luncheon ticket. Additional tickets will be available for purchase.

Cocktail Receptions

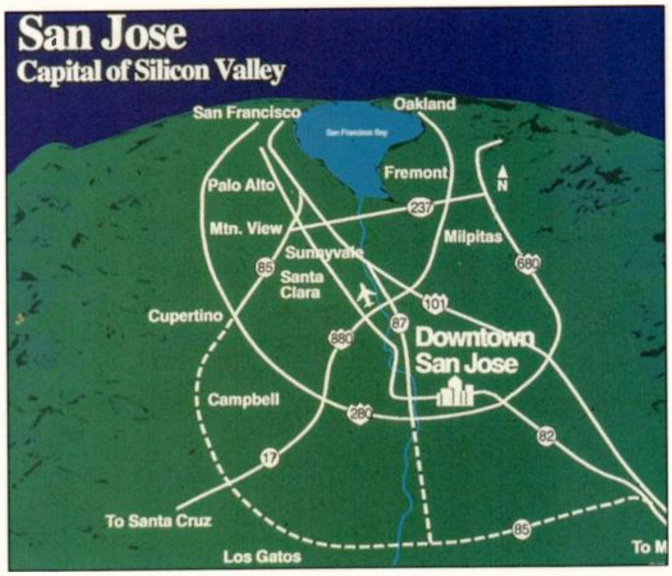
A time to socialize with fellow attendees and exhibitors, a cocktail hour will be held in the Exhibit Hall on Tuesday, March 22, 1994 and Wednesday, March 23, 1994 from 5:00 until 6:00 p.m. each evening. Drink tickets for the event are included with all full, 3-day registrations.

See San Jose

San Jose has a light rail system, operating seven days a week from 6:00 a.m. until midnight. Trolleys run every 10 minutes weekdays and Saturdays, and every 15 to 30 minutes during the evening, Sundays and holidays. Tickets can be purchased from the machines located at light rail stations.

RF Expo West— In the Heart of Silicon Valley

RF Expo West is attended by electronics engineers and engineering managers working with radio frequencies. Engineers new to high frequency circuits benefit from the fundamental and tutorial programs offered. Senior engineers receive updates on the latest developments in high frequency technology.



Hotel Accommodations

The Fairmont Hotel San Jose will be the headquarters hotel for RF Expo West. A special room rate of $105 single and double will be available for reservations made prior to February 20, 1994. Reservations made after this date cannot be guaranteed at the group rate, but the hotel will make every effort to accommodate any late requests.

Fairmont Hotel San Jose
170 South Market Street
San Jose, CA 95113
(408) 998-1900

Additional accommodations are available at:

San Jose Hilton and Towers
300 Almaden Boulevard
San Jose, CA 95110
(408) 287-2100
Rates: $85 single/$105 double

Car Rental Information

Avis has been selected as the official car rental company for RF Expo West 1994. To take advantage of the special discounted rates, please call 1-800-331-1600 and identify yourself as an RF Expo West attendee or refer to file number B155437.

Register Now To Guarantee Your Early Registration Discount (must be postmarked by March 11, 1994)

Send registration form to:
Argus Trade Shows
RFEW Attendee Registration
6151 Powers Ferry Road, NW
Atlanta, GA 30339-2941

Or Call:
Registration Coordinator: Linda Croy
(800) 828-0420
Fax: (404) 618-0441

RF expo WEST

March 22-24, 1994
San Jose Convention Center
San Jose, CA

RF expo WEST

1994 REGISTRATION FORM

March 22-24 1994 • San Jose Convention Center • San Jose California

A

Name
Title
Company
Address
City
State Zip - Country
Telephone (area code) - - Fax

B

BADGE SHOULD INDICATE: Please enter letter in box)

- A Broadcast, CATV Video Equipment
- B Instrument & Test Equipment
- C Govt., Military, Aerospace EXM & EW Equipmen
- D Communications Equipment
- E Component Manufacturer
- F Lab & Consultants
- G Other

C

RF Expo Proceedings Available
Please check the appropriate box in Section D.

$70 Registered Attendees
$145 Non-Attendees

D

FEES:	Early Bird Registration (Prior to March 11, 1994)	Regular Registration (After March 11, 1994)	Amount Due
☐ 3-Day Pass (includes sessions/exhibits)	$250	$325	$
☐ 1-Day Pass (includes sessions/exhibits)	$100	$125	$
☐ Exhibits Only Pass (for duration of show)	$ 20	$ 35	$
☐ Proceedings (registered attendees only)	$ 70	$ 70	$
☐ Proceedings Only (non-attendees)	$145	$145	
☐ Special Courses(use subtotal from Box F)		N/A	$
	TOTAL AMOUNT DUE		**$**

A 20 % discount will apply to registrants after the first four full paid registrants from the same company. In order to quality for the discount, all registration fees and forms must be received at the same time. Does not apply to special courses.

E

Circle the sessions you plan to attend. This does not commit you to any specific sessions, but is necessary for planning seating arrangements.

Date	8:30-11:30a.m.	1:30-4:30p.m.
Tues, 3/22/94	A1 A2 A3	B1 B2 B3
Wed., 3/23/94	C1 C2 C3	D1 D2 D3
Thurs. 3/24/94	E1 E2 E3	

F

SPECIAL COURSES:

(Registration cut-off March 11, 1994. After that date, registration taken on a space-available basis.)
Registration Fee includes: lunch, RFEW Exhibits pass, textbook, and class notes where applicable.

Please check

Monday, March 21, 1994 8:00 a.m. - 5:00 p.m.
SC1) Digital Modulation and Spread Spectrum ☐
SC2) Introduction to RF Circuit Design, Part I ☐
Tuesday, March 22, 1994 8:00 a.m. - 5:00 p.m.
SC3) Introduction to RF Circuit Design, Part II ☐
Wednesday, March 23, 1994 8:00 a.m. - 5:00 p.m.
SC4) Filters and Matching Network Design ☐
Thursday, March 24, 1994 8:00 a.m. - 4:00 p.m.
SC5) Oscillator Design Principles ☐

Special Course Fees:
- $275 for one course.
- $465 for two courses
- $660 for three course
- $770 for four courses

Number of Courses ________ Special Courses Subtotal $________

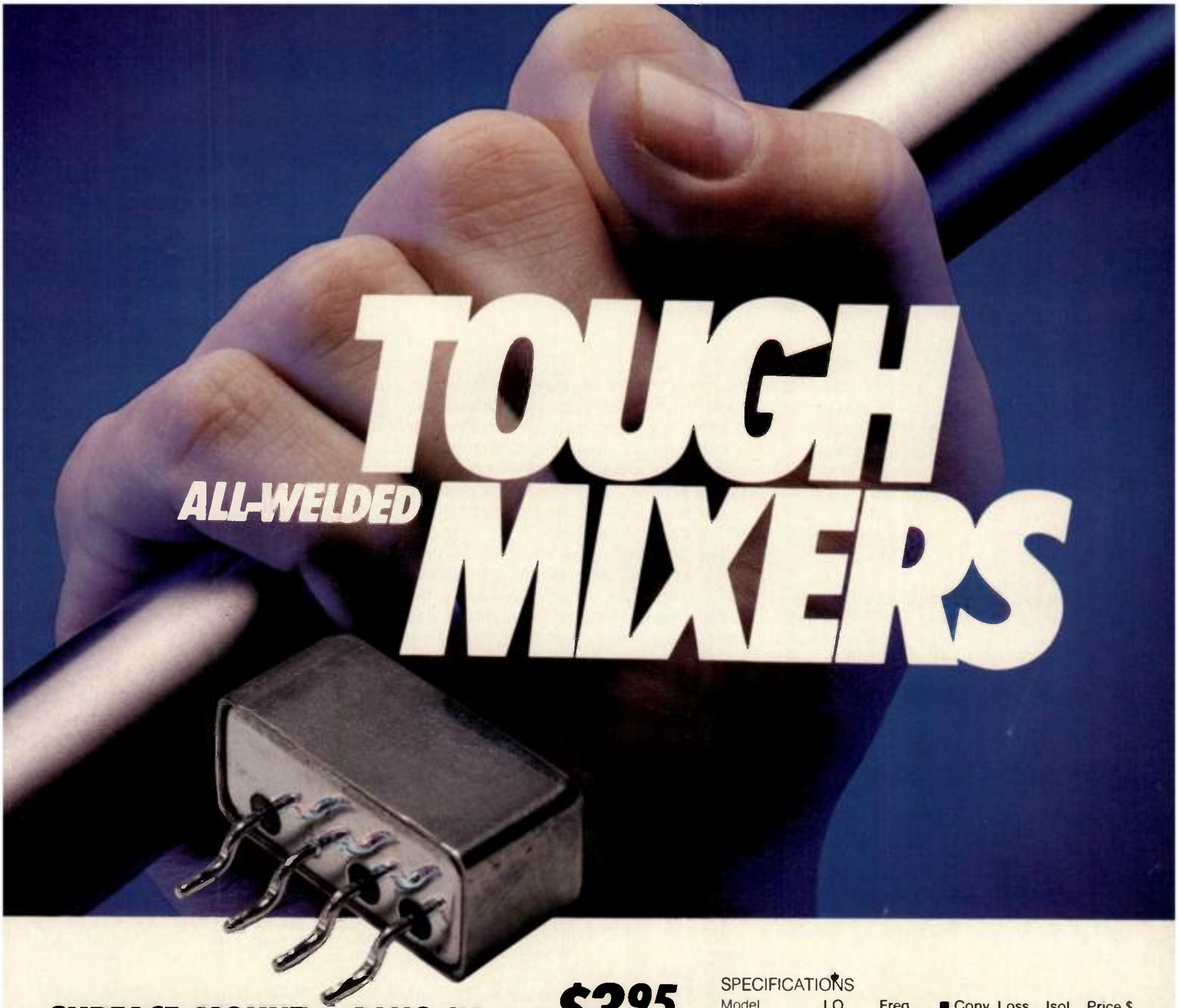
MAIL this completed Registration Form to:
Argus Trade Shows
RFEW Attendee Registration
6151 Powers Ferry Rd. NW
Atlanta, GA 30339
Registration information contact:
Registration Coordinator : Linda Croy
(800) 828-0420
Fax: (404) 618-0441

G

METHOD OF PAYMENT: Checks or Credit Cards ONLY (NO bills issued and NO POs accepted)
Enclosed is a check for $ ________ Check# ________ (Make all checks payable to Argus Trade Shows)
Charge: $ ________ to: ☐ Am Ex ☐ Visa ☐ Master Card
Account # ________ Exp. Date________
Name of Card Holder________
Authorized Signature________

H

CANCELLATION POLICY: No refunds or credits will be issued to no-show registrants. Argus Trade Shows and Argus Inc. will not assume any responsibility for penalties imposed by other groups in the event that the conference/tradeshow is cancelled for any reason. This cancellation policy is strictly enforced. NO exceptions.



SURFACE-MOUNT or PLUG-IN FROM $3.95 (10 qty)

Expose Mini-Circuits' TUF-mixers to 250°C for five minutes, or to the extreme shock and vibration stresses of MIL-M-28837, or to 200 cycles of thermal shock from -55° to +100°C...they'll survive without any change in specs. They are mighty tough mixers!

Available with LO drive levels from +7 to +17dBm, performance features include very low conversion loss flat over the entire band, high isolation (L-R, L-I), and well-matched VSWR at all ports.

All-welded internal and external construction is used to assemble and package the TUF-unit in its tiny 0.5 by 0.2 by 0.25 in. metal case, for plug-in or surface-mount* assembly.

TUF-Ultra-Rel™ mixers are guaranteed for five years and boast unprecedented "skinny" sigma (δ) unit-to-unit repeatability as shown in the Table.

Tough, tiny, and with tight repeatability...Mini-Circuits' Ultra-Rel™ TUF-mixers with a five-year guarantee, priced from $3.95...available only from Mini-Circuits.

actual size

ULTRA-REL™ MIXERS

5-YR. GUARANTEE

with extra long life due to unique HP monolithic diode construction, 300°C high temp. storage, 1000 cycles thermal shock, vibration, acceleration, and mechanical shock exceeding MIL requirements.

SPECIFICATIONS

Model	LO Power (dBm)	Freq. LO/RF (MHz)	■ Conv. Loss (dB) $\overline{X}$	δ	Isol. L-R (dB)	Price,$ Ea. 10 qty
TUF-3	7	0.15-400	4.98	0.34	46	5.95
TUF-3LH	10		4.8	0.37	51	7.95
TUF-3MH	13		5.0	0.33	46	8.95
TUF-3H	17		5.0	0.33	50	10.95
TUF-1	7	2-600	5.82	0.19	42	3.95
TUF-1LH	10		6.0	0.17	50	5.95
TUF-1MH	13		6.3	0.12	50	6.95
TUF-1H	17		5.9	0.18	50	8.95
TUF-2	7	50-1000	5.73	0.30	47	4.95
TUF-2LH	10		5.2	0.3	44	6.95
TUF-2MH	13		6.0	0.25	47	7.95
TUF-2H	17		6.2	0.22	47	9..95
TUF-5	7	20-1500	6.58	0.40	42	8.95
TUF-5LH	10		6.9	0.27	42	10.95
TUF-5MH	13		7.0	0.25	41	11.95
TUF-5H	17		7.5	0.17	50	13.95
TUF-860	7	860-1050	6.2	0.37	35	8.95
TUF-860LH	10		6.3	0.27	35	10.95
TUF-860MH	13		6.8	0.32	35	11.95
TUF-860H	17		6.8	0.31	38	13.95
TUF-11A	7	1400-1900	6.83	0.30	33	14.95
TUF-11ALH	10		7.0	0.20	36	16.95
TUF-11AMH	13		7.4	0.20	33	17.95
TUF-11AH	17		7.3	0.28	35	19.95

*To specify surface-mount models, add SM after P/N shown.
■ $\overline{X}$ = Average conversion loss at upper end of midband ($f_u/2$)
δ = Sigma or standard deviation

WE ACCEPT AMERICAN EXPRESS AND VISA

P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

Distribution Centers/NORTH AMERICA 800-654-7949 • 417-335-5935 Fax 417-335-5945 EUROPE 44-252-835094 Fax 44-252-837010

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCT DIRECTORY • EEM • MINI-CIRCUITS' 740-pg HANDBOOK.

INFO/CARD 46

F 145 REV G

Software for Lumped Element Design

M. Saroja
ISRO Satellite Centre

This 1993 Software Contest entry is a package of routines for the design of lumped element circuits, including power dividers, matching networks, bandpass filters, attenuators, etc. The package, dubbed RFDSK (RF Designers Software Kit) by the author, is written in GWBASIC and will run on any IBM or compatible PC.

At RF and lower microwave frequencies, transmission line methods (e.g. microstrip) are too large to be practical, and lumped element design is used. References 1-4 were used as the basis for this program, which is intended to help designers construct various passive circuits in this frequency range. As long as the Q of the components used is high enough, circuit performance should approach that of well-made distributed designs.

Power Divider Example

It is best to illustrate program usage with an example. Let us design a 2-way power divider with the following specifications:

Source impedance:	50 ohms
Load impedance:	50 ohms
Frequency range:	9-11 MHz

When the program is run, it first gives an introduction, then displays the Main Menu. Selection 1 is for a power divider. Input values are then entered, or default values (in brackets) can be selected by just pressing ENTER. For example, source and load defaults are 50 ohms. Now, the program calculates preliminary parameters such as center frequency and bandwidth, then it asks the user to validate the information. If the bandwidth is more than 20 percent, a warning is given. Input parameters can be changed at this stage, if desired.

The program uses the tank capacitance value as the basis for calculation. After entering a value or selecting the default value, the tank inductance is calculated and the design proceeds. If the coupling capacitors are too small, as in the case of very narrow band, high frequency designs, the design procedure can be repeated until a realizable value is achieved.

The choice of either maximally flat or Chebyshev response can be selected by entering a ripple value — zero for maximally flat, or the chosen value for Chebyshev response. Once the value has been entered, the program calculates the individual component values for the corresponding circuits. The program also calculates midband insertion loss based on the unloaded Q of the coil, VSWR, bandwidth, etc.

RFDSK gives element values for both tank and pi type sections with performance and input parameters listed for reference, a shown in Figure 1. The circuit of the prototype power divider is given in Figure 2.

Conclusion

This program has been used to design lumped element N-way power dividers, impedance matching networks, Butterworth and Chebyshev filters, and attenuators. Simple data entry allows anyone to use the program, yet it provides sufficient latitude in selected component values to generate realizable designs. The program has been used in the successful design of circuits for HF and VHF radar systems — including RF and IF amplifier matching networks and filters.

This program is available from the RF Design Software Service; see page 73 for ordering information.

Acknowledgments

The author would like to thank Sri. S. Balasubramanian and Sri. K.V. Janardhanan for their guidance and help.

References

1. E.J. Wilkinson, "An N-Way Hybrid Power Divider," IRE Trans. Microwave Theory and Tech., Vol. MTT-8, pp. 116-118, Jan. 1960.
2. J.J. Taub and B. Fitzgerald, "A Note on N-Way Hybrid Power Dividers," IEEE Trans. Microwave Theory and Tech., Vol. MTT-12, pp. 260-261, Mar. 1964.
3. J.J. Taub and G.P. Kurpis, "A More General N-Way Hybrid Power Divider," IEEE Trans. Microwave Theory and Tech., Vol. MTT-17, pp. 406-408, Jul. 1969.
4. G.L. Matthei, L. Young and E.M.T. Jones, Microwave Filters, Impedance Matching Networks and Coupling Structures, McGraw-Hill, 1964.

About the Author

M. Saroja is an engineer in the Payload Checkout Facility Division of the ISRO Satellite Centre, ISRO, Bangalore, PIN : 560017, India.

OUTPUT DATA

Centre frequency (MHz):	9.85	Power dividing ratio:	1
Bandwidth (%):	20.00	Number of sections:	1
Passband lower (MHz):	9.00	Ripple (db):	0.00
Passband upper (MHz):	11.00	Passband VSWR:	1.00
Unloaded Q:	500	Midband loss (db):	0.09
Resonant capacitance:	74.04	Tank inductance (nH):	3525.59
Source impedance(ohms):	50.00	Load impedance (ohms):	50.00

NOTE: All capacitances are in pf.

Press any key to see next page ?

TANK DESIGN

Cc = 115.67 C1 = 260.51
Cc = 132.66

PI DESIGN

Cc = 481.16 Cleft 1 = 843.68 Cright 1 = 772.57
Cc = 377.39

Figure 1. Power divider output screen.

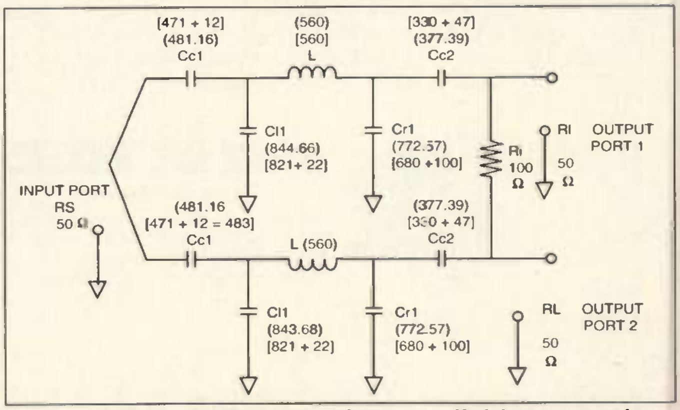


Figure 2. Circuit diagram of power divider example.

Broadband Transmission Line Transformer Family Matches a Wide Range of Impedances

By Donald A. McClure

The family of broadband transmission line transformers introduced here achieves impedance matching flexibility that is not possible with existing designs, such as the well-known Guanella devices [1]. In 1972, the author prepared a patent disclosure document [2] describing this method, but a patent application was not filed and the information was not made public. After more than twenty years, and with his personal retirement, the author now presents this transmission line transformer family for industry-wide dissemination.

To begin, we should review the example of a typical Guanella transformer shown in Figure 1. A number of transmission lines of equal length and characteristic impedance are all connected in parallel at one end and all in series at the other. These connections provide voltage transformation ratios that are equal to the number of lines used, and impedance transformations that are the squares of those simple integers. The impedance ratios are thus restricted to 4, 9, 16, 25 and so forth, or their inverses. These ratios may be useful, but it is often frustrating that other ratios can not be attained without cascading Guanella structures.

We shall see that Guanella devices constitute a special case of a more general connection scheme that can provide voltage ratios of any rational number without the need to cascade two or more transformers. Rational numbers are defined to be of the form m/n, where m and n are integers. For lack of a better name, it is convenient to term these m/n devices as RAVOR transmission line transformers — the name being an acronym of *RA*tional *VO*ltage *R*atio. In the same vein, devices made in the Guanella connections could be called IVOR transformers for *I*nteger *VO*ltage *R*atio. The IVOR devices are clearly a special case of the RAVOR family in which either the m or n integer is 1. The existence of the RAVOR family has generally been overlooked except for a rather recent article [3] in which some connections were derived in an entirely different manner from the method described here.

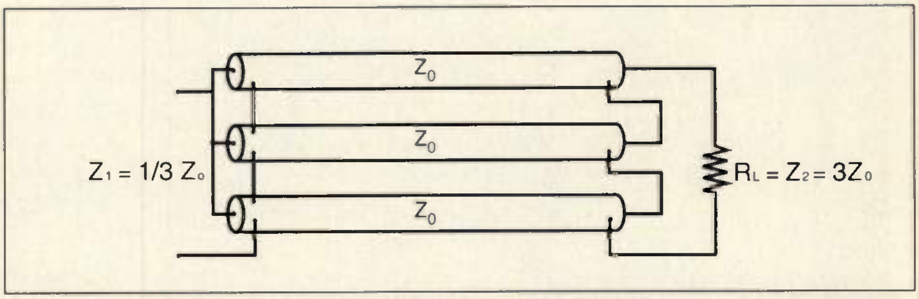


Figure 1. A simple 1/3 voltage ratio Guanella transformer as an example of prior art.

Transmission Line Connections

If a group of equal-length transmission lines of equal characteristic impedance are connected at one end in arbitrary combinations of parallel and series, how should the lines be connected at the other end to obtain frequency-independent behavior of the input and output impedances? Calculations of input impedance based upon equality of input and output powers, or simply physical experimentation, will quickly show that the connections at the output end cannot be arbitrary with respect to the input end without the producing mismatches and frequency-selective behavior. With some possible trivial exceptions, broadband behavior can be achieved in only two ways:

1) Output connections are exactly the same as the input connections. This arrangement results in no voltage or impedance transformation and does not constitute a transformer, but it can be useful to achieve a composite cable of some Z_0 other than that of the constituent cables.

2) Output connections are exactly the opposite of the input connections. That is to say, that any transmission lines or groups of transmission lines which are connected in parallel at one end of the transformer must be connected in series at the other end, and vice versa.

This second method of interconnection describes the family of RAVOR transformers. Figure 2 shows an example of the RAVOR devices, a transformer with a voltage ratio of 5/2, constructed to provide transformation from 50 to 8 ohms. This transformer will operate over decades of frequency with low loss and low standing wave ratio (SWR).

The General Principle

The series-parallel interchange interconnection of transmission lines having equal length and equal characteristic impedance, Z_0, causes the driving port and load port impedances, Z_1 and Z_2, respectively to be related in the following manner (neglecting time delay):

$$Z_1 = KZ_0$$

$$Z_2 = \frac{1}{K} Z_0 = R_{Load}$$; it follows that:

$$Z_1 Z_2 = KZ_0 \frac{1}{K} Z_0 = Z_0^2$$; and:

$$Z_0 = \sqrt{Z_1 Z_2}$$

The characteristic impedance of the lines is the geometric mean of the input and load impedances. The coefficient K is the quotient of two integers, the values of which are determined by the way in which the transmission lines are con-

RF TRANSFORMERS

Over 80 off-the-shelf models...
3KHz-1500MHz from **$1.95**

Having difficulty locating RF or pulse transformers with low droop, fast risetime or a particular impedance ratio over a specified frequency range?.... Mini-Circuits offers a solution.

Choose impedance ratios from 1:1 to 36:1, in connector, TO-, flatpack, surface-mount, or pin versions (plastic or metal case built to meet MIL-T-21038 and MIL-T-55631 requirements*). Coaxial connector models are offered with 50 and 75 ohm impedance; BNC standard, other types on request.

Ultra-wideband response achieves low droop and fast risetime for pulse applications. Ratings up to 1000M ohms insulation resistance and up to 1000V dielectric voltage. For wide dynamic range applications involving up to 100mA primary current, use the T-H series. Fully detailed data appear in our 740-pg RF/IF Designer's Handbook.

Need units in a hurry?... all models are covered by our exclusive one-week shipment guarantee.

Only from Mini-Circuits.

*units are not QPL listed.

INFO/CARD 49

Mini-Circuits®

P O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718) 332-4661

For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER Vol. 23 • MICROWAVES PRODUCT DIRECTORY • EEM • MINI-CIRCUITS' 740-pg HANDBOOK.

CUSTOM PRODUCT NEEDS... ***Let Our Experience Work For You.***

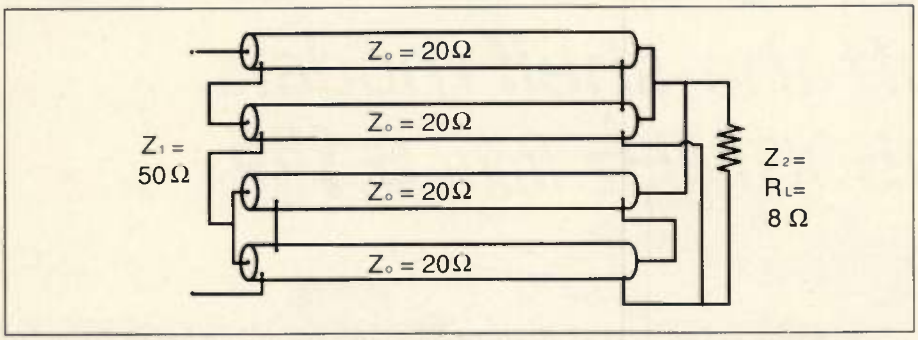


Figure 2. RAVOR transformer providing 50 to 8 ohm transformation.

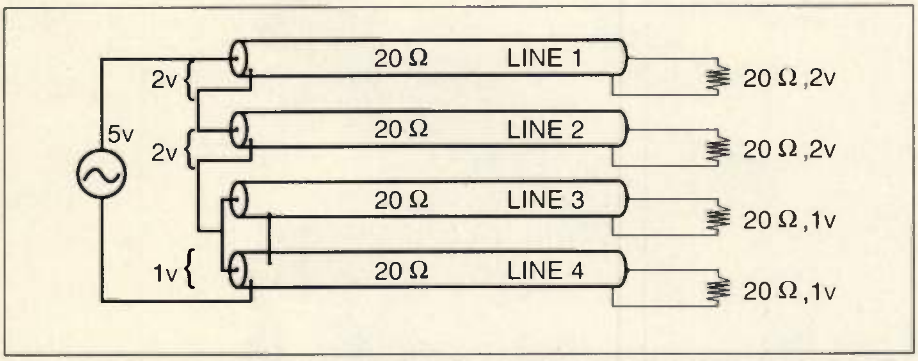


Figure 3. Input connection of Figure 2, with each line terminated in Z_0, showing voltage distribution.

nected. It is also the voltage transformation ratio of the transformer.

The coefficient K can always be expressed in the form m/n, where m and n are integers, and is thus a rational number.

Current-Voltage Duality

A current-voltage duality exists between the two ends of the transformer, resulting from the series-parallel interchange of connections between one end and the other. One way of expressing the duality is that the input current loop equations and the output voltage nodal equations have exactly the same form and coefficients, shown as follows:

Input Loop equation: $V_1 - I_1 KZ_0 = 0$

Output Nodal equation: $I_2 - V_2 KY_0 = 0$

where: I_1 = Input current
I_2 = Load current
$Y_0 = 1/Z_0$

Similar equations apply to a lossless, conventional transformer of turns ratio K, which would also exhibit duality.

The duality relationship causes the voltages and currents to be distributed among the termination ends of the lines so that each line operates as though it were terminated in its characteristic impedance. Thus, the transformers can operate over extreme bandwidths, limited at the high frequencies only by the stray inductances of the end connections. The low frequency limit Is determined by the amount of inductive reactance that can be attained along each conductor so that the input and and output ends are effectively isolated from one another and common-mode currents are nil.

To illustrate how the series-parallel interchange results in properly terminated lines, Figure 3 depicts the same input connection as in Figure 2, but with the output of each line terminated in a resistance equal to the Z_0 of the line. Five volts of RF is applied to the input. Because lines 1 and 2 each present 2 volts to their respective loads, the loads may be paralleled to yield a composite load of 10 ohms with no effect at the driving end. The currents in the loads of lines 3 and 4 are the same, hence the loads and lines may be respectively series connected to obtain 2 volts across 40 ohms. Now, the 3 and 4 series combination provides 2 volts, as does each of lines 1 and 2. Therefore, the series 3-4 combination may be paralleled with lines 1 and 2 to give a total output of 2 volts. The 40 ohm load of the 3-4 combination acts in parallel with the 10 ohm load of the 1-2 combination to yield a composite load impedance of 8 ohms.

It is apparent from the above discussion that the individual 20 ohm resistors of Figure 3 can be replaced by a single 8 ohm load if the lines are connected as in Figure 2. No change will occur in the input voltage distribution or impedance when the substitution of a single load is made, provided that there is sufficient inductive reactance along each conductor to isolate the voltages at the load end from those at the input end.

End-to-End Isolation

If 5 volts were applied to the input of the transformer of Figure 2, 2 volts will appear at the output, leaving a 3 Volt drop along the center-conductor of the upper-most cable, which could cause a large, unwanted current to flow. Such currents are reduced to insignificant values by making each conductor have a high inductive reactance throughout the intended frequency range. The low-frequency reactance can be enhanced by winding the lines into individual coils, or by winding them on, or surrounding them by, high permeability materials such as ferrite. For the 2 MHz to 100 MHz range, winding each coaxial cable on a ferrite toroid having an initial permeability of about 125 works well. For proper operation, there should be no magnetic or electric coupling between the transmission lines.

Impedance Calculations

With confidence that the lines making up the transformers are properly terminated, the driving point impedance may be written by inspection of the input connections. In the case of the connection in Figure 2, writing in general form:

$$Z_1 = 2Z_0 + \frac{Z_0}{2} = \frac{5}{2}Z_0 \text{ ; therefore:}$$

$$K = \frac{5}{2}$$

The above example illustrates the way in which the ratio $K = m/n = V_1/V_2$ appears in the impedance equations. A similar inspection of the output end yields:

$$Z_2 = \frac{\frac{Z_0}{2} \cdot 2Z_0}{\frac{Z_0}{2} + 2Z_0} = \frac{Z_0^2}{\frac{5}{2}Z_0}$$

$$= \frac{2}{5} Z_0 = \frac{1}{K} Z_0$$

Connection Notations

There are so many possible transformer configurations that it is convenient to use a system of shorthand notation to describe the connections without sketching the cables and wiring. The device of Figure 2 is fully described, except for impedance levels, by the symbology:

2S, 2P > S

which means: two lines are connected in series to form a group; two other lines are paralleled to form a group; then the two groups are connected in series. The opposite end of the transformer is connected in the opposite fashion and need not be described. In this case it is denoted by:

2P, 2S > P

The transformer connections are completely defined by either the input or output end notations above.

Table 1 lists voltage ratios and corresponding connection schemes for values of K with a denominator up to 9. Equivalent ratios (e.g. 2/3 and 4/6) are not duplicated. The author has determined connections for ratios up to a denominator of 13, a total of 57 different voltage ratios. Of these, only 12 can be achieved by a single-stage Guanella transformer, which means the RAVOR principle provides 45 additional ratios to choose from!

Also, all of the transformers of the RAVOR family, including the Guanella types, may be used as baluns (BALanced to UNbalanced converters) because of the necessary isolation from input to output.

While all ratios of the form m/n are theoretically realizable with this class of transformer, there are obviously practical limits to the number of transmission lines that can be used. As of this writing, the author has conducted a systematic search for all the connection possibilities up to and including six lines. Some ratios resulting from the use of more lines have also been found for the purpose of knowing the simplest connection for all of the ratios shown in Table 1. Using six lines, there are 53 different

Voltage Ratio K	Connections	Minimum No. Lines
1/2	2P*	2
1/3	3P*	3
2/3	2P, 1 > S	3
1/4	4P*	4
3/4	3S, 1 > P	4
1/5	5P*	5
2/5	2P, 2S > P	4
3/5	2P, 1 > S; S, 1 > P	4
4/5	4S, 1 > P	5
1/6	6P*	6
5/6	3P, 2P > S	5
1/7	7P*	7
2/7	2S, 3P > P	5
3/7	2P, 3S > P	5
4/7	3P, 1 > S; S, 1 > P	5
5/7	2S, 2P > S; S, 1 > P	5
6/7	2P, 1 > S; S, 2S > P	5
1/8	8P*	8
3/8	2P, 1 > S; S, 2P > P	5
5/8	2S, 1 > P; P, 1 > S; S, 1 > P	5
7/8	2P, 1 > S; S, 2P > P; P, 2P > S	7
1/9	9P*	9
2/9	3P, 2S > P; P, 1 > P	6
4/9	2P, 4S > P	6
5/9	4P, 1 > S; S, 1 > P	6
7/9	3S, 2P > S; S, 1 > P	6
8/9	2P, 1 > S; S, 1 > P; P, 1 > S; S, 2S > P	7

*Guanella (integer) ratios

Table 1. Voltage ratio and connection data for RAVOR transformers with fractional ratios through a denominator of 9.

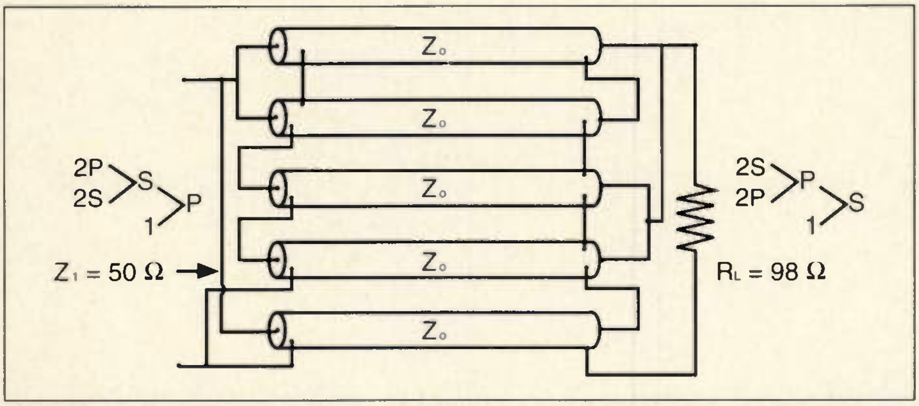


Figure 4. 5/7 ratio RAVOR configuration approximating a 1:2 impedance transformation (Z_0 = 70 ohms).

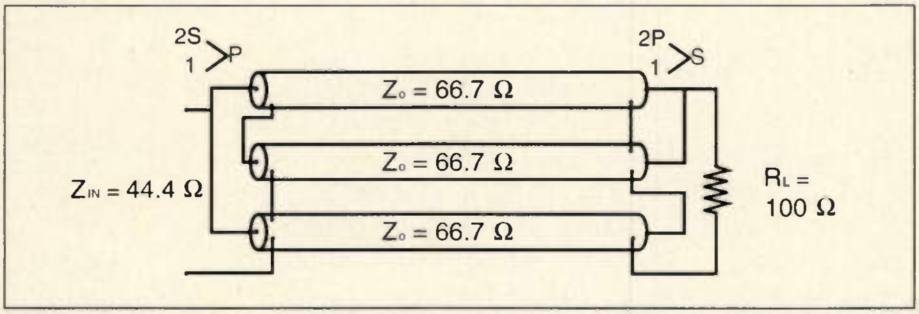


Figure 5. The 2/3 ratio RAVOR is a simpler but less accurate way to approximate a 1:2 transformation.

combinations that can be made, not all of them useful. Using seven and eight lines, there are hundreds of connections and corresponding ratios, but to use such a large number of lines and ferrite cores is to reach beyond the limits of practicality.

Configuration Selection

As an example of the use of Table 1, postulate that it is desired to make a transformer that will provide a 50 ohm to 100 ohm conversion. The voltage ratio, K, is found to be $\sqrt{50/100}$ = 0.707. Look through Table 1 to find a ratio that approximates 0.707. The ratio 5/7, which in decimal form is 0.7143, differs from 0.707 by only about 1 percent and is thus an excellent approximation.

Because 5/7 is a ratio of two prime numbers, it is already in its lowest form. Table 1 indicates the connections for the low impedance end of the transformer and five transmission lines are required. The configuration is sketched in Figure 4. The Z_0 of the lines is chosen to be 70 ohms, the geometric mean between 98 and 50 ohms.

A test transformer using the configuration of Figure 4 was constructed using five equal lengths of 50 Ohm cable (RG-196), each wound on a ferrite toroidal core of Indiana General type Q1 material which has an initial permeability of about 125. The frequency response of the test transformer was essentially flat from 3 to 300 MHz, and the voltage transformation ratio was 5/7, as expected.

For some purposes, a less accurate approximation to a 1/2 impedance ratio than that provided by the five-line configuration of Figure 4 would suffice. Returning to Table 1, it is seen that the simplest structure to approximate the 0.707 voltage ratio is the three-line device which yields a K of 2/3, or 0.667. The connection is sketched in Figure 5.

If the transformer of Figure 5 were loaded with 100 ohms at the output as shown, and the line Z_0 were chosen to be 66.67 ohms, also as shown, impedance at the input (left) end would be 44.44 ohms. In a 50 ohm system, the transformer would thus introduce an SWR of 1.125:1, which may be a tolerable number.

Summary

The article describes the theoretical basis for, and the general principles of, a class of broadband RF transmission-line transformers having voltage transformation ratios of rational form, m/n, where m and n are integers. The described configurations overcome the simple integer transformation ratio limitations of the older Guanella designs which represent a special case of these principles. The theoretical basis of operation is viewed in the light of current-voltage duality due to the series-parallel, parallel-series interchange of connections between the ends.

Design tools are provided in the form of a configuration selection procedure, and a table of ratios and the corresponding connections. These aids enable the reader to determine quickly the required number of transmission lines and the connection scheme to obtain the desired transformation. The table lists 19 rational ratios and their connections, in addition to 8 Guanella integer ratios and connections. Two examples of configuration selection are included.

With regard to synthesis of a transformer configuration, it can be shown that the connections for any ratio can be determined by using a continued fraction expansion, but sometimes connections requiring fewer lines can be found by the use of partial fraction expansions.

Future articles are planned, covering synthesis, construction and measured performance of RAVOR transformers.

Acknowledgement

Many thanks to Dr. Jerry Sevick of Basking Ridge, NJ for his encouragement and useful suggestions. ***RF***

References

1. G. Gaunella, New Method of Impedance Matching in Radio Frequency Circuits, the *Brown Boveri Review*, September 1944, pp. 327-329.

2. Donald A. McClure, "A Family of Broadband Transformers," RCA Corporation patent disclosure document, April 28, 1972, RCA Docket no. 66148. Note: the RCA Patent Operations office decided not to seek patents for the many transformer configurations disclosed.

3. Daniel Myer, "Equal Delay Networks Match Impedances of Wide Bandwidths," *Microwaves & RF*, April 1990, pp. 179-188.

About the Author

Don McClure is an engineer retired from RCA. He can be reached at 12 W. Azalea Lane, Mt. Laurel, NJ 08054; tel. (609) 778-7328.

RF Expo West Program and Short Courses Schedule

Tuesday, March 22 8:30-11:30 a.m.

Session A-1: RF Data Communications I

FQPSK, A Modulation that Outperforms Pi/4 DQPSK in Both Radiation Effects and Battery Power Dissipation While Maintaining Equal Capacity
Hussein Mehdi
University of California, Davis

Theory and Development of a Digital Amplitude Modulator
Timothy P. Hulick
Acrodyne Industries

An I-Q Demodulator IC for Compressed Video Applications
Eric Bausback
California Eastern Laboratories

Session A-2: Power Amplifiers I

Low Cost Antenna Interface RFIC for Wireless Applications
Peter S. Bachert
RF Micro Devices, Inc.

HF and VHF Linear Power Amplifiers Using SSTs and SLAMs
Adrian I. Cogan, Kenneth Sooknanan, Lee Max, Microwave Technology, Inc.

Comparative Study of Four Broadband Microwave Amplifier Concepts
Samuel R. Lauretti, Rui Souza
CPQD-Telebras/NEC

Session A-3: Filter Design

Dielectric Filter Design
Tsang-Fu Chang
Kaimei Electronic Corp.

Microstrip Techniques and Filter Design
Raymond S. Pengelly, Raytheon

Tuesday, March 22 1:30-4:30 p.m.

Session B-1: Oscillators

SAW Resonator Oscillator Design Utilizing Linear RF Simulation
Alan R. Northam
RF Monolithics, Inc.

Injection Lock
Mike Black, Texas Instruments

Oscillator Design for Lowest Phase Noise
Ulrich L. Rohde, Compact Software

Session B-2: Product Design and Manufacturing

Fundamentals of Design for Manufacturability
Radha Setty and Harvey Kaylie
Mini-Circuits

Improving Product Design/Development by Identifying Key Customer Values and Product Features
Bruce A. Murray
Erbtec Engineering, Inc.

High Frequency High Bandwidth IF Crystal Filter Designed for Manufacturing
Jose Miguel Fernandez Gomez
Tiempo Frecuencia y Electronica, S.A.

Session B-3: RF Materials

A High Power RF Package Using Aluminum Nitride Ceramic
Dr. Gerald Miller
Carborundum Microelectronics

Microwave Based Measurements of a Layered Dielectric Medium
Dr. Rick Keam
Industrial Research Ltd.

Realisation of Microwave Circuit, Components & Antennas Using a New Transmission Medium of Conducting Liquids such as Mercury & Salt Solutions
Kosta Yogeshwar Prasad
ISRO Space Applications Centre

Wednesday, March 23 8:30-11:30 a.m.

Session C-1: Data Communications II

IF Amplifiers and Quadrature Demodulators for Digital Communication Receivers
Bill Pratt, RF Micro Devices, Inc.

An FSK Modulation Data Receiver for 900 MHz Using a Low Cost Silicon Monolithic Integrated Circuit Chip Set
Harry Swanson, Motorola

Five Short Courses Offer Formal Training

Digital Communications and Spread Spectrum — Dr. Kamilo Feher, instructor. An advanced class for engineers working on wireless personal communications applications. Monday, March 21, 8:00 a.m. to 5:00 p.m.

Introduction to RF Circuit Design Part I: Fundamental Concepts — Drs. David Hertling and Robert Feeney, instructors. This entry-level class assumes a BSEE, but little experience. Part I emphasizes passive circuits, transmission line and matching principles. Monday, March 21, 8:00 a.m. to 5:00 p.m.

Introduction to RF Circuit Design Part II: Active Circuit Design — Drs. Feeney and Hertling continue with basic design principles. Small-signal and large-signal amplifier design is the major emphasis. Part I or II may taken alone or together as a two-part course. Tuesday, March 22, 8:00 a.m. to 5:00 p.m.

RF Filter Design: LC and Distributed Circuits – HF to Microwaves — Randy Rhea, instructor. Beginner to intermediate class covering all major filter types and methods. Lumped element and microstrip implementation are covered extensively. Wednesday, March 23, 8:00 a.m. to 5:00 p.m.

Oscillator Design Principles — Randy Rhea, instructor. Another beginner to intermediate level class, covering the design of oscillator circuits. The instructor's unified approach removes the mystery from oscillator design. Thursday, March 24, 8:00 a.m. to 4:00 p.m.

A Low Power Spread Spectrum CMOS RFIC for Radio Identification Applications
John R. Tuttle
Micron Communications Inc.

Session C-2: RF Power II

Linearisation Tecniques for RF Amplifiers
Dr. P.B. Kenington
University of Bristol

Some Improvements on the Feedforward Technique
Mauro De Lima Coimbra
CPQD-Telebras

Considerations of Using Collector Amplitude Modulation in Class E Power Amplifier With Finite DC-Feed Inductance
Mihai Albulet, Sergiu Radu
Technical University IASI

Session C-3: RF Components

RF Circuit Components: Measurements, De-embedding and Equivalent Circuits
Les Besser, Besser Associates

Numerical Simulation of Silicon Hyperabrupt Diodes for VCO and Filter Applications
Ricardo Borges, M/A Com

Wednesday, March 23 1:30-4:30 p.m.

Session D-1: Wireless Communications

The Design of UHF and VHF Loop Antennas
Dr. Ian J. Dilworth, University of Essex

Techniques for Open Loop Modulation of a Wideband VCO for DECT
Daniel E. Fague
National Semiconductor Corp.

A Covert Video Communications System
Roger Bracht, Tom Kuckertz
Los Alamos National Laboratory

Session D-2: Synthesizers

Frequency Synthesizer Technology in the Nineties
Uri Yaniv, CTI

NCO - The Next Generation Oscillators
T.J. Apren, ISRO-VSSC

Session D-3: Communications Systems

LINK 16: Tactical Advantage in the 21st Century
Lester E. Polisky, Sentel Inc.

A Simple Technique for Assessing HF Automatic Link Establishment Radio Interoperability
David Wortendyke
U.S. Department of Commerce

The Art of CW Rejection in ESM Receivers
Sherman R. Vincent, Raytheon

Thursday, March 24 8:30-11:30 a.m.

Sesson E-1: Data Communications III

Multi-Mode Radio Transceiver Design
Dr. A. Bateman, University of Bristol

Design an Infrared Data Link Using an Integrated FSK Transceiver
Gaylene Phetteplace, Motorola

Data Communications by Means of Reflective Transmission
Claude A. Sharpe Texas Instruments

Session E-2: Circuit Design Methods

Ground Current Control in RF and High Speed Digital Circuits
Earl McCune
RF Communications Consulting

Design Microstrip Components With a Dielectric Cover Without Buying Additional Software
Denis Jaisson, S.A.T.

Circuit Theory Approach Versus Field Theory Approach in Shielding Evaluation
Sergiu Radu, Mihai Albulet
Technical University IASI

Session E-3: Integrated Circuit Solutions

Digital Processor Performance and Integration
Mark Gill, Analog Devices

RF/IF Processes and Circuits for Wireless Communications
Bob Clark, Analog Devices

Digital Receivers and DDS for Base Stations
Scott Berhorst, Analog Devices

To register for RF Expo West, or, to get more information, call: 800-828-0420.

The RF Coupler: A 20th Century Workhorse

By Ann Marie Trudeau
Assistant Editor

RF couplers are considered a mature product, so RF designers probably haven't expected any modifications for what is now considered a basic tool. Nearly everything that could have been done to a coupler has been done. But now, designers are having to look at this taken-for-granted item. The reason for this turnaround is that the marketplace is being inundated by cable TV, cellular, the future personal communication network, and the magnetic resonance imaging (MRI) industries. RF designers have had to take another look at couplers to see what can be changed so that the industry can respond to the market demands for smaller, more consistent and cheaper couplers.

Cellular Market

The cellular industry affects companies which in turn have changed their manufacturing techniques to meet the customer's need for low cost products. Automatic testing of base stations is a focus of the RF industry and companies are responding in various ways.

Arthur Butts of RLC Electronics said that the worldwide market for RF couplers could easily be $50 million. Presently their clients want high end applications for the cellular industry, primarily for the systems which involve cellular base stations. Butts said that at least one company selected RLC directional couplers because of their maximally flat 32 dB.coupling response in processing the signal.

Mini-Circuits' Director of Engineering Radha Setty said that customers can't afford to tune components during high-speed volume production and this has led to their innovative approach of putting what would normally be considered a customized coupler on the shelf as a standard part. The savings are passed on to the customer.

"That means that we have to produce components that are surface mount, smaller, and provide very repeatable performances," he said. Setty felt that the cellular RF coupler market will lend itself more to surface mount, high performance couplers.

They have also responded to higher power in a smaller size by designing the coupler so it didn't have to dissipate any heat. Setty said that Mini-Circuits is researching RF magnetics to get more accurately repeatable performances.

Jerry Moore, director of marketing for Sage Laboratories, said that Sage manufacturs caseless hybrids called Wireline™ and Wirepac™ for the cellular industry. He's aware that surface mounts do reduce cost but he had some reservations. "There are some applications where surface mounts don't give you the best trade off," Moore said.

MRI Use Grows

But, to show that companies are diversifying their coupler markets Sage Laboratories also uses Wirline couplers in Magnetic Resonating Imagery (MRI). The MRI creates detailed images of the human body, requiring very high magnetic fields to do so. This creates problems for the RF connector because most low frequency couplers have ferrites, or magnetic material, in them. "So they came to us and we made a coupler that they can use that does not have any ferrite material in it," Moore said. "It solves their problem because it can be used in these high magnetic fields. This is an interesting aspect of our product. The coupler is 70" long, but because it looks like a piece of cable we coil it tightly so that it takes up only six to eight inches of space," he said.

Another company totally agrees with the effect of MRI on the trade. "Up and coming are the devices for these scanner machines," Bob Wells, lead engineer of Lorch Electronics, said. "That's a major chunk of a new market."

Wells said that they had to go to packaging that was essentially non-magnetic except for the pin contacts and they are brass plated so that there wasn't a magnetic contact.

A Need

No single testing measuring or instrument can fit all applications, so there will always be a need for RF couplers. According to John Yochum, contract manager for Bird Electronics, "I think there is always going to be a market place for RF couplers, the reason being that until suppliers like us can produce products that would meet everybody's needs then there wouldn't be a need for an RF coupler." Bird, well known throughout the industry, produces the couplers that are used in their wattmeters.

Interesting Applications

Lossy coax is used in tunnels and subways in Europe and is made with slots in it so it radiates a little bit, according to Glenn Werlau of Werlatone Inc. Used on ships or in confined spaces where a radio signal can't radiate or be piped around using an extremely wide bandwidth. Werlatone sells RF couplers that split off the power to different compartments or levels.

A company that has original coupler patents from the 1950s certainly has seen changes from those days. Tony Ramsden, Vice-President of Marketing says that Merrimac Industries responds to a stronger market because more signals are monitored in radar systems, communication's transmitters and automatic test systems. "We got a large corner of that market and it's used in the automatic measurement of chips which are still in the wafer form," he said.

Also, the military still has requirements that have to be met and John Duncan of Tele-Tech said that military radio applications are the company's biggest RF coupler demand but sees that the only advancement for RF couplers would be an improvement in materials for stripline couplers. "A coupler is as old as a dinosaur," Duncan said.

RF Summary

However, unlike the dinosaur the RF coupler is not extinct but has turned into a modern day workhorse. Plodding, steady, unseen for the most part, but doing its job because the industry is counting on it. *RF*

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 Michael Applegate at **(404) 618-0217** today.

RF career opportunities

IOWA MIDWEST
RF/MICROWAVE **WIRELESS**
WORK WITH AN RF ENGINEER IN YOUR MOVE TO THE MIDWEST!

My clients need top-notch RF Design Engineers and Managers, 3 to 10+ years experience. HF to 3.0 GHz, Receivers, Transmitters, Power Amplifiers, Synthesizers, Spread Spectrum, ASIC/MMIC Design, Modems, Communications DSP.

DON GALLAGHER MSEE

Phone: 319-895-8042 Fax: 319-895-6455
1145 LINN RIDGE RD. MT. VERNON, IA 52314

40 YEARS OF RF ENGINEERING, MANAGEMENT, AND PLACEMENT OF ENGINEERS

INFO/CARD 60

RF DESIGN MARKETPLACE
Get In • It Works
404-618-0217

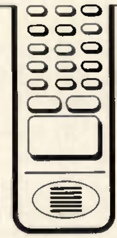
SUNBELT OPPORTUNITIES

Several of our growing commercial major electronic companies located in the southeast have asked us to identify candidates in the mid-level experience range.

1) BSEE – to design analog/RF circuitry for receiver/transmitters in 300-900 MHTZ – P-Spice
2) BSEE – RF Test Engineer – 50 MHTZ to 1 GHTZ. Spectrum analyzers, net work analyzers; HP Basic
3) BSEE – High power amplifier design engineer – Class AB 100-200 watts; 800-900 MHTZ
4) BSEE – Power supply design engineer – switch mode; power factor correction
5) MSEE – To design high efficiency power MMICS for military systems. L-Band thru KU Band (2-18 GHtz). Knowledge of non-linear modeling.

F-o-r-t-u-n-e
PERSONNEL CONSULTANTS OF RALEIGH, INC.
P.O. Box 98388R • Raleigh, NC 27624-8388
Phone: 919-848-9929 • Fax: 919-848-1062
Stan Deckelbaum

INFO/CARD 61



...YOUR CAREER

Cellular Engineers: Design/develop Rf and analog circuits for high capacity cellular systems. Requires minimum of 2 years experience in any of the following: DSP, ASIC Design, Cae Development, Digital Moduclation, Digital Mobile Communications, Channel Equalizers, Transmitter-Receiver Synthesizer or Audio Design, Digital Signal Processing.

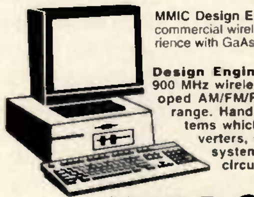
Regional Sales Manager: Responsible for sales, promotion and technical support within a specified geographical region with the support of field sales representatives. Identifies new opportunities and coorcinates efforts to secure contracts. Responsible for ensuring that field sales representatives are satisfying the customer's needs and providing technical training. This position requires a BS degree in electrical engineering with 1-3 years experience in the RF components industry. This person could be a design engineer with a desire to begin a sales career.

Product Marketing Manager: Our client, a well known microwave firm, seeks an experienced professional to perform classical marketing functions for a product line; i.e., develop short and long term business plan, determine marketplace, etc. Excellent compensation package along with executive benefits.

Consumer Electronics Engineer: Design and development of microwave common waveguide horn antennas, X and Ka-band Gunn Diode oscillators, mixers, VCO's filters/receiver front ends. BSEE

Filter Design Engineer: B.S. (prefer M.S. or Ph.D.). Minimum 3 years experience in the filter design and development of Broad Band, comb-line, strip line, interdigital, low pas and high pass filters, multiplexers, diode switches, (phase shifters), attenuators and microwave sub-systems desirable.

RFIC Design: MS or PhD in Electrical Engineering with minimum 5 years related experience preferred. The candidate should have a good knowledge and experience in Linear Bipolar High Frequency IC design and measurement techniques in design IC's like Amplifiers, Mixers, Oscillators, VCO's, Prescalers, Synthesizers, Limiting Amplifiers, etc. operating up to 2 GHz in Bipolar or BiCMOS technologies.



MMIC Design Engineer: Develop L/S band GaAs MMIC power amplifiers for commercial wireless communications. Requires: M.S. or BSEE, +2 years experience with GaAs MMIC design, simulation, packaging and test.

Design Engineer: Responsible for the design and development of 900 MHz wireless consumer electronic products. Designed and developed AM/FM/FSK transmitters/receivers in 902-926 MHz frequency range. Hands-on experience on HF/VHF/UHF systems and subsystems which includes LNAs, medium power amplifiers, down converters, saw and coaxial resonator oscillators, VCOs, AM/FM IF systems, RF modulators/demodulators, PLLs & Audio video circuits.

MICRO COMMUNICATIONS EXECUTIVE SEARCH
871 Turnpike St. • North Andover, MA 08145
We specialize in the placement of communications both nationally and internationally.
FOR THESE AND OTHER OPENINGS
CALL COLLECT: TEL: 508-685-2272 FAX : 508-794-5627

INFO/CARD 62

Advertiser Index

RF career opportunities

AXONN CORP. is the leading supplier of high performance, low cost, embedded spread spectrum technology. Axonn's Fortune 500 customers integrate our SW and HW designs into an impressive array of innovative, very high volume applications. Our designers work hand-in-hand with engineers worldwide to create future product lines. Axonn continually researches new, patentable RF communication techniques. If you want challenge, variety, design creativity and the growth available in a smaller company, call or FAX your resume.

SENIOR & STAFF RF DESIGN ENGINEERS

Hands-on design experience required with frequency synthesizers, receiver design, transmitter design and 900 to 2400 MHz. Must be proficient with RF modeling software such as Touchstone or Eagleware and familiar with surface mount. 5 to 10 years experience required for Senior position.

Phone: (504) 282-8119 Fax: (504) 282-0999

INFO/CARD 63

Interested in placing an ad in RF DESIGN MARKETPLACE?

Contact:
Michael Applegate
6151 Powers Ferry Rd. N.W.
Atlanta, GA 30339
Phone: (404) 618-0217
Fax: (404) 618-0342

RF products

ANALOG & RF MODELS

SPICE models from DC to 10 GHZ
Full non-linear models including:
RF pin diodes, class C, opto, & logic.
We also do measurements and consulting.
Give us a call at **(602) 575-5323**

INFO/CARD 64

RF products & services

O.E.M. Electronic Products

- Computerized • RF Systems
- Spread Spectrum Communications
- Custom, RF/Digital ASICs • 14 Year History
- *Harris* and *Hitachi* Authorized Design Center
- Complete, Fulltime Professional Staff

by: LOCUS, Inc

1842 Hoffman St., Madison WI 53704
TEL 608/244-0500 FAX 608/244-0528

INFO/CARD 65

COMTRONIX SYSTEMS, INC.

CUSTOMIZED

SOLID STATE•HIGH POWERED•VHF/UHF

AMPLIFIERS

DESIGNED AND BUILT TO YOUR SPECIFICATIONS

UP TO 200 WATTS
HIGHEST QUALITY/BEST PRICES

CALL OR SEND FOR INFORMATION TEL **413/785-1313** FAX **413/739-1352**

INFO/CARD 66

NOVA RF Systems, Inc.
The Complete RF/Microwave Solution

— RF/Microwave Systems
— Custom Design/Consulting
— Simulation Software
— Synthesizers (PLL/DDS)
— Complete Lab/Machine Shop
— TDMA/CDMA/Spread Spectrum

International Inquiries Welcome
1740 Pine Valley Dr. Vienna, VA 22182
(703) 255-2352

INFO/CARD 67

CAL CRYSTAL LAB., INC.•COMCLOK, INC.

Need Clock Oscillators or Crystals? Call 1-800-333-9825 • 714-991-1580
Quartz Crystals 50Khz to 200Mhz
TTL Clock Oscillators 250Khz to 70Mhz
HCMOS Clock Oscillators 3.5Mhz to 50Mhz
Tri-State, Half Size and Surface Mount also available on request
Fast Service - 3 weeks or less
Special frequencies our specialty
1142 N. Gilbert, Anaheim, CA 92801 • FAX 714-491-9825

INFO/CARD 68

KTS ELECTRONICS
"Where your dreams turn into reality"

- STD. 5 AND 10 MHZ OCXO
- TCXO • VCXO • TC-VCXO
- VCO's • CLOCK OSCILLATORS
- CUSTOMIZED CRYSTAL FILTERS STD. 10.7 MHZ, 21.4 MHZ and 45 MHZ
- L/C FILTERS

Call or Fax requirements.

16406 N. Cave Creek Rd. #5
Phoenix, AZ 85032-2919
Phone & Fax (602) 971-3301

INFO/CARD 69

RSG-10
SIGNAL GENERATOR

The $2495 profit generator
Quality crafted in the USA

Finally, a synthesized signal generator that's designed to help you generate more than just signals. The Ramsey RSG-10, is the signal generator you can afford, the signal generator that's designed to do what a signal generator is meant to do- provide a very stable, accurate, easy to control signal from 100 Khz to 1.0 Ghz.

For the price, you wouldn't expect any more. But, there is more to the RSG-10. An intelligent microprocessor controlled/programmable memory, for example, can store up to 20 of your most commonly used test set-ups. And unlike other units, just one touch of the memory exchange button is all it takes to quickly shift from one test set up to another. You get more work done, easier and faster.

At $2495, the Ramsey RSG-10 is your profit generator.

RAMSEY

RAMSEY ELECTRONICS
793 CANNING PARKWAY, VICTOR, NY 14584
Fax (716) 924-4555
TELEX: 466735 RAMSEY CI

ORDER DIRECT—CALL 1-800-446-2295

VISA MasterCard

INFO/CARD 70

RF Design Industry Marketplace

Get In • It Works

404-618-0217

WHERE COMMUNICATION MEETS INNOVATION

It's right here at Philips Semiconductors. Our RF and Data Communications products are truly cutting-edge, and we have the resources and dedication to keep the innovations right on schedule—which is to say, ahead of their time. The ideas generated here are truly improving people's lives, from cellular telephone breakthroughs to the latest networking advancements. So if you're looking for an exciting environment where communication meets innovation, join Philips Semiconductors in one of the following opportunities.

SENIOR RF CIRCUIT DESIGN ENGINEERS

Primary responsibilities include product definition, circuit design and production release of integrated circuits for the RF communications market. In addition to a MS/PhD in EE, your skill set should include knowledge in linear bipolar high frequency IC design and measurement techniques and excellent communication and project leadership skills.

SENIOR TEST ENGINEERS

You will define and develop test plans and strategies for mixed signal products, generate and develop ATE hardware/software, debug new silicon, and work closely with the new product introduction team. A background with RF and Synchromaster is a plus.

RF BASEBAND/MODEM ENGINEER

Design and debugging of baseband modulator/demodulator and radio control circuitry on board level wireless data products is your primary focus. This will involve implementation of wireless data modem circuits using Philips IC technology and integration of a complete solution in a team environment. Experience in modem and digital modulator/demodulator design is essential; knowledge of cellular or wireless LANs is a plus.

PRODUCT ENGINEER

Responsibilities include characterization and yield analysis for new RF products and sustaining products released in full production to include cost reduction activities. RF expertise is highly desirable.

RF DESIGNER

Primary responsibility will include RF systems and circuit design and debugging on board level wireless data products to include implementation of transmitter and receiver circuits using Philips RF IC technology. You need experience in UHF/Microwave circuit design. Knowledge of cellular or wireless LAN design and FCC type acceptance is a plus.

Unless otherwise indicated, the above positions require a BS/MSEE or equivalent and a minimum of 3-5 years of related experience.

Philips Semiconductors offers competitive compensation and a comprehensive benefits package. Please send your resume to: Philips Semiconductors, Staffing Department RFD, MS 07, 811 East Arques Ave., Sunnyvale, CA 94088-3409, or fax to (408) 991-2656. We believe in maintaining a safe work environment for all employees and require pre-employment drug and alcohol testing. Philips Semiconductors is a division of Philips Electronics North America Corporation, and an Equal Opportunity Employer. Principals only, no phone calls, please.

Philips Semiconductors

PHILIPS

PHILIPS

INFO/CARD 71

RF software

Spectrum Sharing Software

Comsearch introduces the third generation of their spectrum sharing software. The UNIX®-based software allows potential bidders on PCS spectrum to select a PCS technology, define a range of PCS technical parameters and thus identify areas in any market where spectrum is limited. The software incorporates both demographic analysis and databases containing data on every type of antenna and radio used in the 1.9 and 2.1 GHz bands today.

Comsearch
INFO/CARD #196

Radio Modem OS

An operating system for radio modems features an Adaptive Dynamic Access Protocol (ADAP), and a novel power conservation feature. TurboLink 2.2 from Monicor Electronic Group extends portable modem battery charge by as much as 65%. Its ADAP drops inactive nodes from the network poll cycle, increasing data throughput and access time. In addition, TurboLink 2.2 extends the maximum number of portable network modems from 49 up to 99. Price is quoted at $40 per portable unit plus a nominal labor charge for upgrades performed by the factory.

Monicor Electronic Corp.
INFO/CARD #197

New SPICE Models

Comlinear's latest library of SPICE models includes their CLC522 wideband variable-gain amplifier, the CLC532 high-speed 2:1 analog multiplier, and the new ultra-low noise, wideband op amp, the CLC425. Software release MMD.04 is supplied without charge on a 5.25 inch IBM PC-compatible disk.

Comlinear Corp.
INFO/CARD #198

Power Meter Calibration

System IIA from Lucas Weinschel allows a user to perform automatic calibration and transfer of calibration factors for the most commonly used power sensors and power meters. Both analog and digital power meters can be calibrated with or without the IEEE-488 bus options. Typically, a 10 MHz to 18 GHz power sensor can be calibrated at all standard NIST calibration frequencies in less than five minutes. The software runs on both the HP-9000 Measurement Controler and IBM compatibles with IEEE-488 bus interface.

Lucas Weinschel
INFO/CARD #199

Expanded Design Family

Release 6.0 of MicroSim's Design Center family of products includes an analog, small-circuit simulator, which runs in extended DOS memory. The program simulates approximately 100 transistors, and requires a minimum of 1 Mb of extended memory. Cost is $1495 and includes "Probe", a mid-analysis waveform analysis tool.

MicroSim Corp.
INFO/CARD #200

RF recruitment

RF companies

Companies and institutions mentioned in this issue's editorial pages

100 WATTS 1-2 GHz BANDWIDTH

Class A Linear Power Amplifiers For Advanced Performance Plus Super Solid State Reliability: 30,000 Hrs. MTBF

- Modular Maintainability
- Reduced Spares Inventory
- IEEE 488 Bus (option)

- Automatic Circuit Protection
- Built-In Thermal Protection

These new generation Series AR rack-mount instruments are truly the state-of-the-art in Class A linear power amplifiers for RF/microwave applications. The Model AR1929-100, for example, delivers 100 watts over an instantaneous bandwidth of 1-2GHz. Design and performance features include excellent linearity, wide dynamic range and a 50dB gain rating. Other AR models offer power outputs from 2 to 100 watts and frequency ranges from 1-500MHz to 1-2GHz. All models include a built-in power supply, forced-air cooling, and completely modularized design for maximum maintainability – common, pre-aligned spare modules allow easy field replacement plus reduced spares inventory. They are ideal TWT replacements, for applications such as EMI/RFI susceptibility testing, frequency-agile multi-carrier ECM/EW jammers, fast rise time pulse amplifiers, and broadband sweep generator boosters.

Write or call for complete tech information – ask for Product Data 1010B – or to inquire about any of our other product areas: Class AB, C, narrow band and pulsed; powers up to 10KW; frequencies up to 4,000MHz.

PST

A SUBSIDIARY OF COMTECH TELECOMMUNICATIONS CORP.

POWER SYSTEMS TECHNOLOGY INC.

105 BAYLIS ROAD, MELVILLE, NY 11747
TEL. 516-777-8900 • FAX 516-777-8877

INFO/CARD 54

When you're out in front, chances are you'll get there first.

Unique HMIC™ silicon process.

From cellular base stations to automotive sensors, from the global positioning system to pen-based computers, you'll find M/A-COM's components, subsystems and systems wherever you find today's most advanced RF and microwave technology.

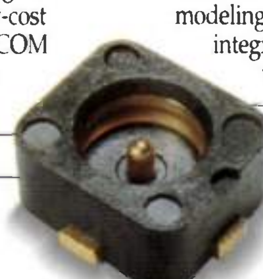
Since we combine technological expertise with high-volume, low-cost manufacturing capabilities, M/A-COM is the partner of choice for the world's most competitive companies.

We cover the spectrum.

Our semiconductor-based design, manufacturing and packaging technologies offer customers unequalled advantages.

We use predictive, physics-based, computer-integrated modeling and design methods to reduce development risk and expense. And link on-wafer testing with continuous flow manufacturing to cut production costs and enhance performance.

As a result, our products surpass both market and budget requirements.

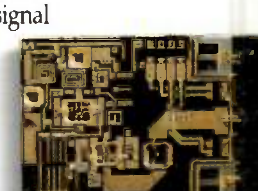


Microwave coaxial surface mount connector.

We speak digital.

We are creating the seamless communications and transportation networks of tomorrow. As applications for wireless technology increase, the interface between microwave and digital technology becomes increasingly important. Our high-speed digital signal processing capabilities transparently link microwave technology to the digital world. Our expertise in areas such as miniaturization, voice and data compression, and end-to-end systems modeling and simulation is creating the integrated, multifunction solutions which will be the standards of the wireless industry.

M/A-COM's GaAs technology sets the industry standard.



Switch, Limiter and LNA integrated into a common medium.

Choose your partner.

The most important technological choices are made in the earliest stages of the product development process, and demand an understanding and awareness of each system and its technological needs. This is when M/A-COM's strengths and experience are of greatest benefit. Our expertise, our ability to adapt to the changing needs of both commercial and government industries, and our commitment to our customers make us your best choice as a technology partner. A partner you can count on to help you get to your destination first.

To learn more, call us at 1-800-366-2266. In Europe, +44 (0344) 869 595. In Asia, +81 (03) 3226-1671.

M/A-COM

INFO/CARD 55