WIRELESS LEADERSHIP 16 YRS

RF design™

engineering principles and practices

October 1995

Four-IC Chip Set Supports Spread-Spectrum WLAN

Featured Technology —
PLDs Enhance PLL Performance

EMC Techniques —
A Technique for Measuring and Reducing EMI

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The UFX-BER delivers a winning combination of stability, repeatability, and ease of use. It's fully automated, capable of setting and maintaining a precise ratio between a user-provided carrier and internally generated noise. The instrument calibrates and displays the ratio as either C/N, C/No, or Eb/No. Accuracy of 0.21 dB RSS is maintained over a wide range of frequencies and carrier output power levels. All at the touch of a single button.

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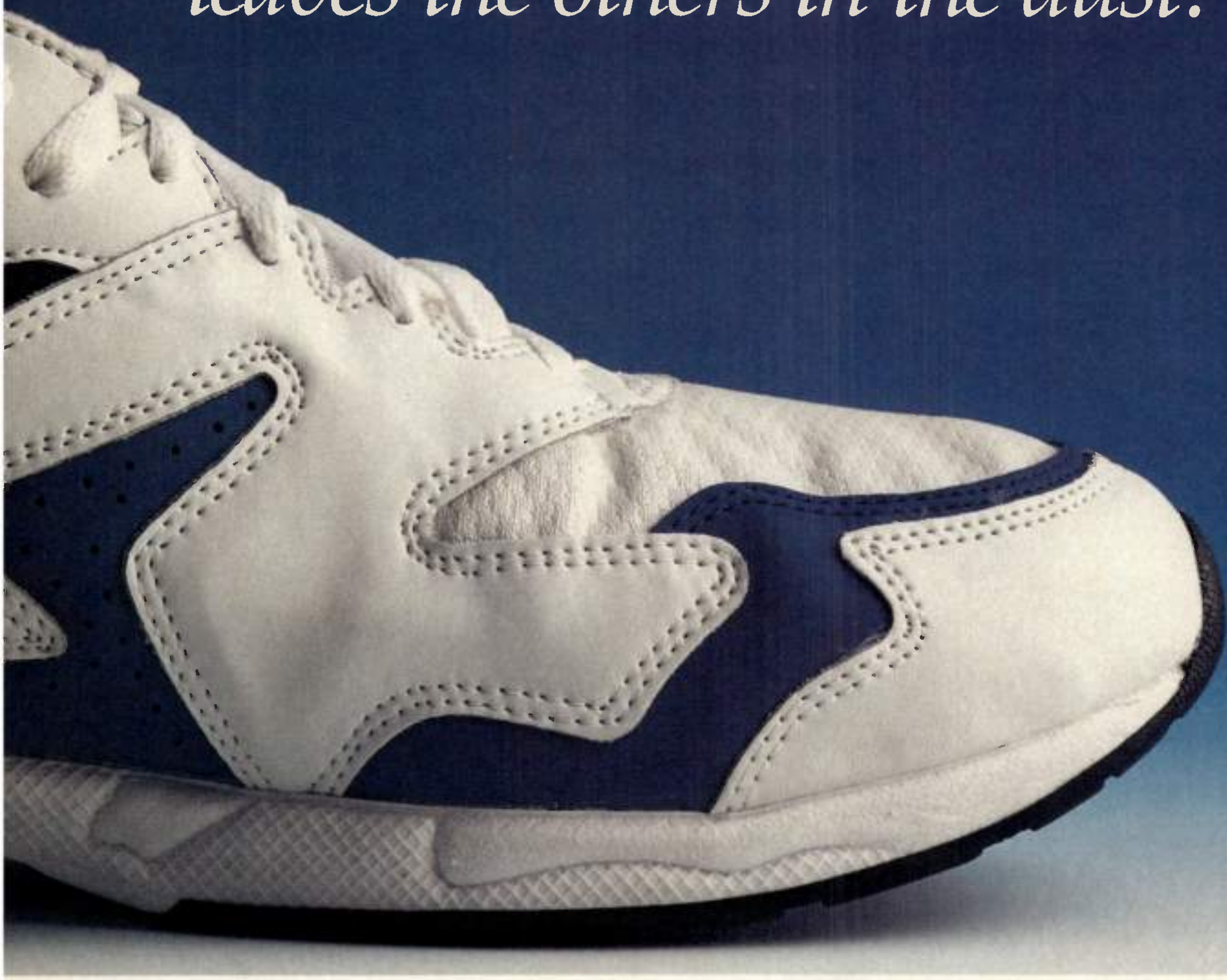

of noise into your digital communications link, you can accelerate the measurement of BER as a function of carrier-to-noise ratio.

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Model No.	Frequency Range	Applications
UFX-BER-70	50 to 90 MHz	General purpose
UFX-BER-CATV	50 to 860 MHz	Cable TV
UFX-BER-BS/IDR	50 to 90 MHz, 68 to 72 MHz, 100 to 180 MHz	Intelsat, Sat Com
UFX-BER-892	822 to 962 MHz	IS-95 (CDMA), IS-54 (TDMA), Part 15
UFX-BER-1545	1530 to 1560 MHz	Inmarsat
UFX-BER-1850	1710 to 1990 MHz	DECT, DCS-1800, PHP, PCS-1900

For information on UFX-BER circle #1

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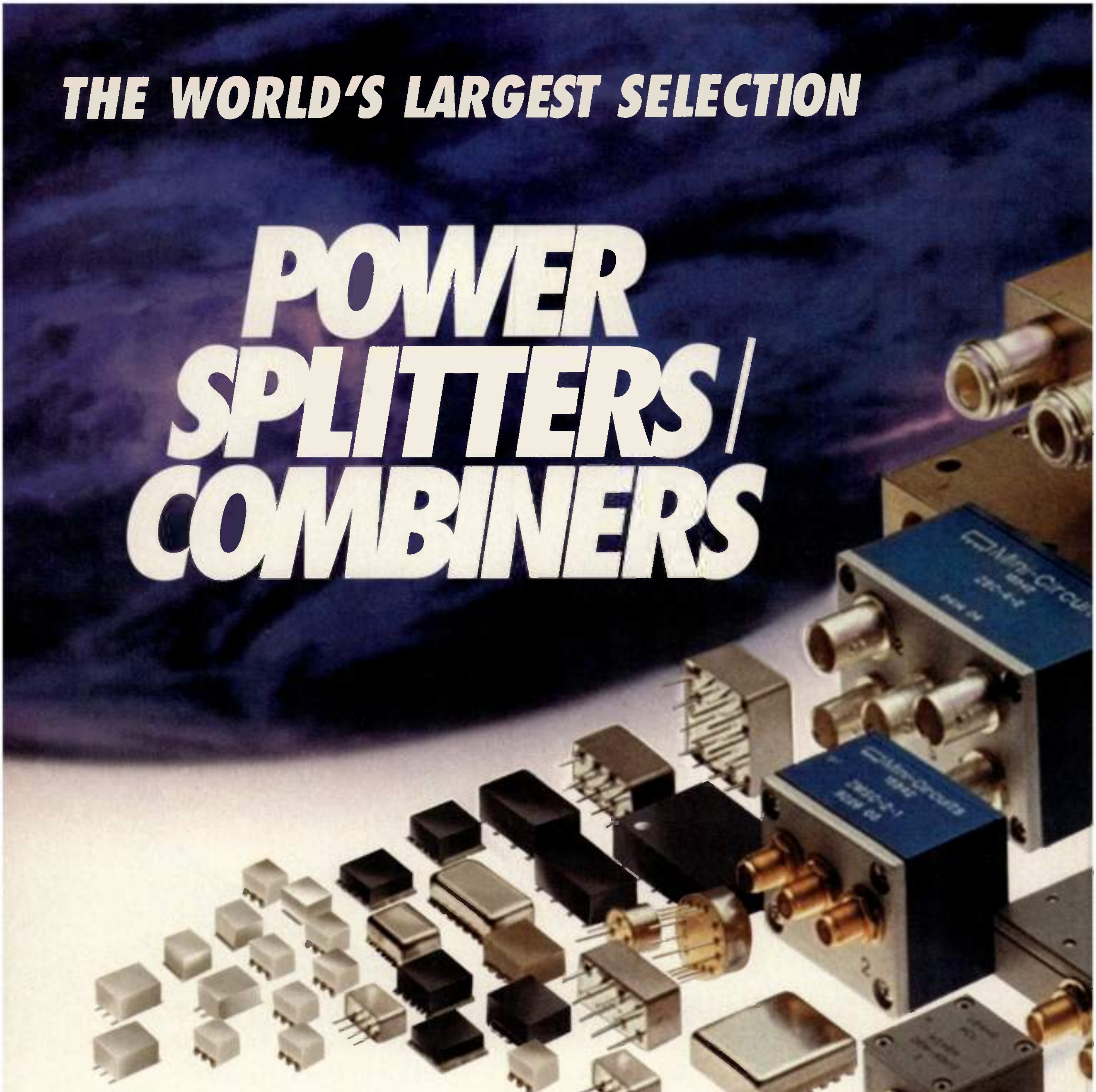
For Application Notes circle #69



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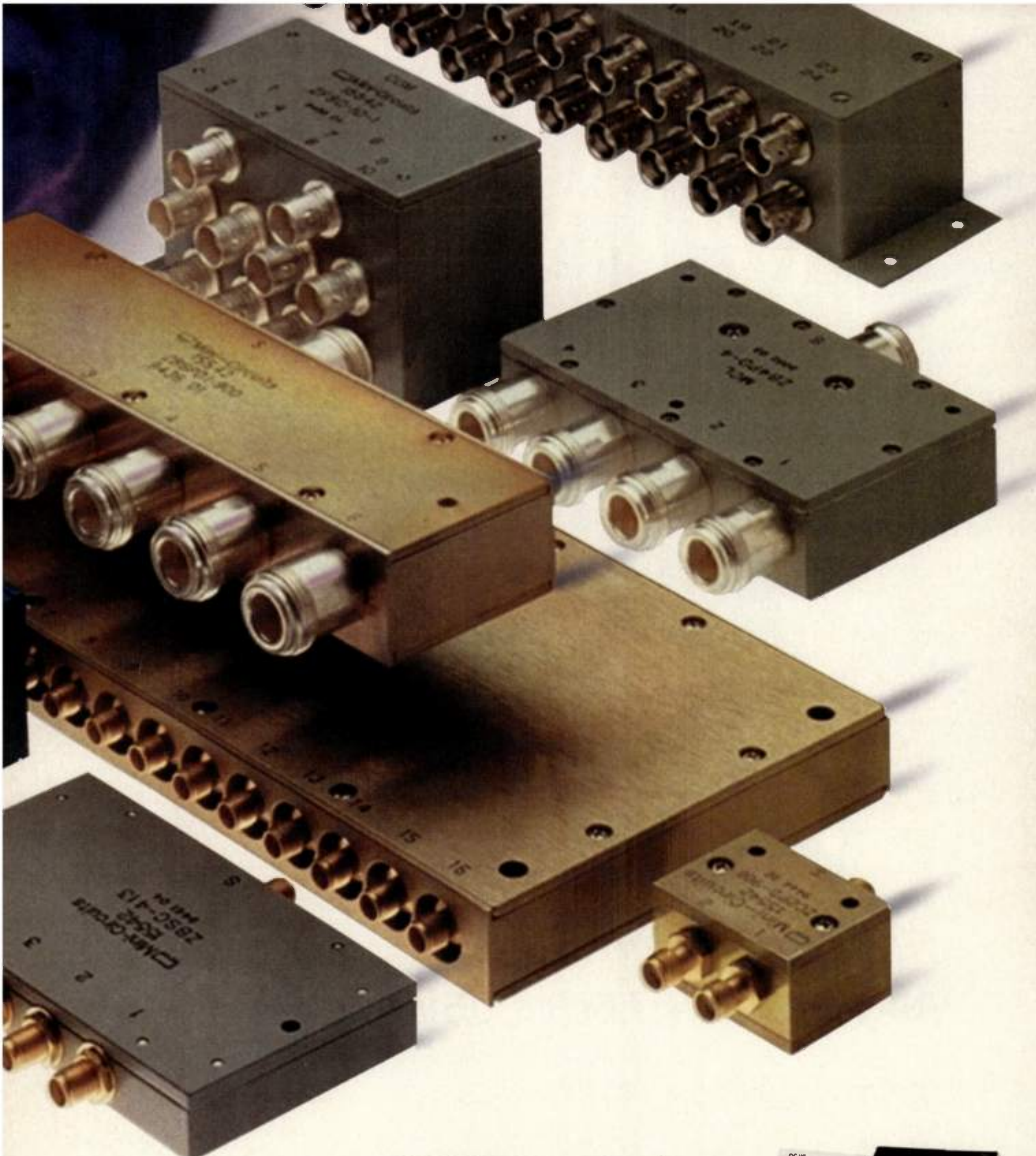

RF IF Designer's Handbook

RF design

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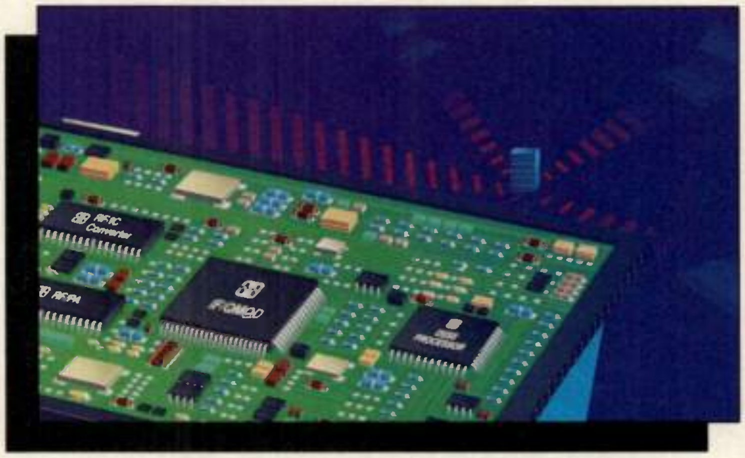
October 1995



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RF editorial

Interference Threatens Wireless' Success

By Gary A. Breed
Editor

There is a potential environmental disaster lurking in the shadows beyond the wild success of wireless communications — *interference*. The rapidly growing use of electrical and electronic equipment of all types is causing a corresponding increase in the noise level in urban areas.

Just like smog limits our visibility and creates discomfort, this "electronic smog" restricts the range and reliability of wireless communications devices. If that new PCS multi-function communicator doesn't work like it's supposed to, customers will be very unhappy. Interference is a real problem, requiring analysis and action.

Where does this noise come from?

Some interference sources are obvious, like the AM radio station that is a mile-and-a-half from my house. A couple of my telephones have music in the background, and I have to be careful in my home electronics lab to be sure measurements aren't being affected.

Other causes of interference are unseen and often unexpected. Any common electrical apparatus can be a big problem — kitchen appliances, power tools, doorbell and furnace transformers, waterbed heaters and aquarium heaters all can create an arc. These arcs generate lots of RF energy (that's how the first radio transmitters created signals!). As consumers, we buy and use more electrical devices than ever, so this kind of noise will continue to increase.

The amount of electronic equipment in our homes and offices is increasing faster than electrical appliances. We have computers on our desks, and computer circuits in places we don't expect. Microwave ovens have microprocessor controllers, as do television sets, cable TV boxes, video games, CD players and other audio equipment. Every one of these devices has digital signals that create RF energy, with at least a little bit being radiated despite FCC Part 15 requirements. Some of these units can have problems, be tampered with, or simply be put close to other equipment that picks up their unwanted signals.

Finally, we have to add up the effects of all radio devices that are supposed to create signals. A typical household can easily have ten or more wireless devices — cordless phones, garage opener, baby monitor, intercom, extension speakers, radio control toys, security system, etc.

Individually, each of the above sources may be benign, but taken as a whole, they can create a substantial soup of RF energy that can prevent them from operating as we expect. And this is just in our homes! Can you guess the effect of large numbers of new paging transmitters, microcells and PCS base stations?

The challenge is to create products that resist interference and create as little unwanted energy as possible. With current market demands, is there any motivation to do this? Will the FCC be able to help control the problem in the face of pressure for deregulation? Or, will things come crashing down when we finally get to the point where our wireless devices choke to death in the "electronic smog"?

Think about it.

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"Another very important way we're addressing EMC is through our new affiliation with Thermo Voltek Corporation, a company focused upon all aspects of EMC. As a member of the Thermo Voltek family, we share their mission and can now offer our customers enhanced sales and service capabilities through Thermo Voltek's worldwide organization."

"As we move closer to global EMC regulations, Kalmus remains steadfast to its engineering heritage and is committed to producing reliable and cost effective RF amplifiers for EMC testing. Call Kalmus or your Thermo Voltek distributor for complete information."

Frank Kalmus
Technical Director

Frank Kalmus is the founder of Kalmus (formerly Kalmus Engineering Inc.), a division of Thermo Voltek Corporation. As Kalmus' principal design engineer, he has designed over 200 RF amplifiers used for EMC test, medical/MRI, general laboratory, and communications applications.

STRAIGHT TALK ABOUT EMC AMPLIFIERS.

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INFO/CARD 5

RF design

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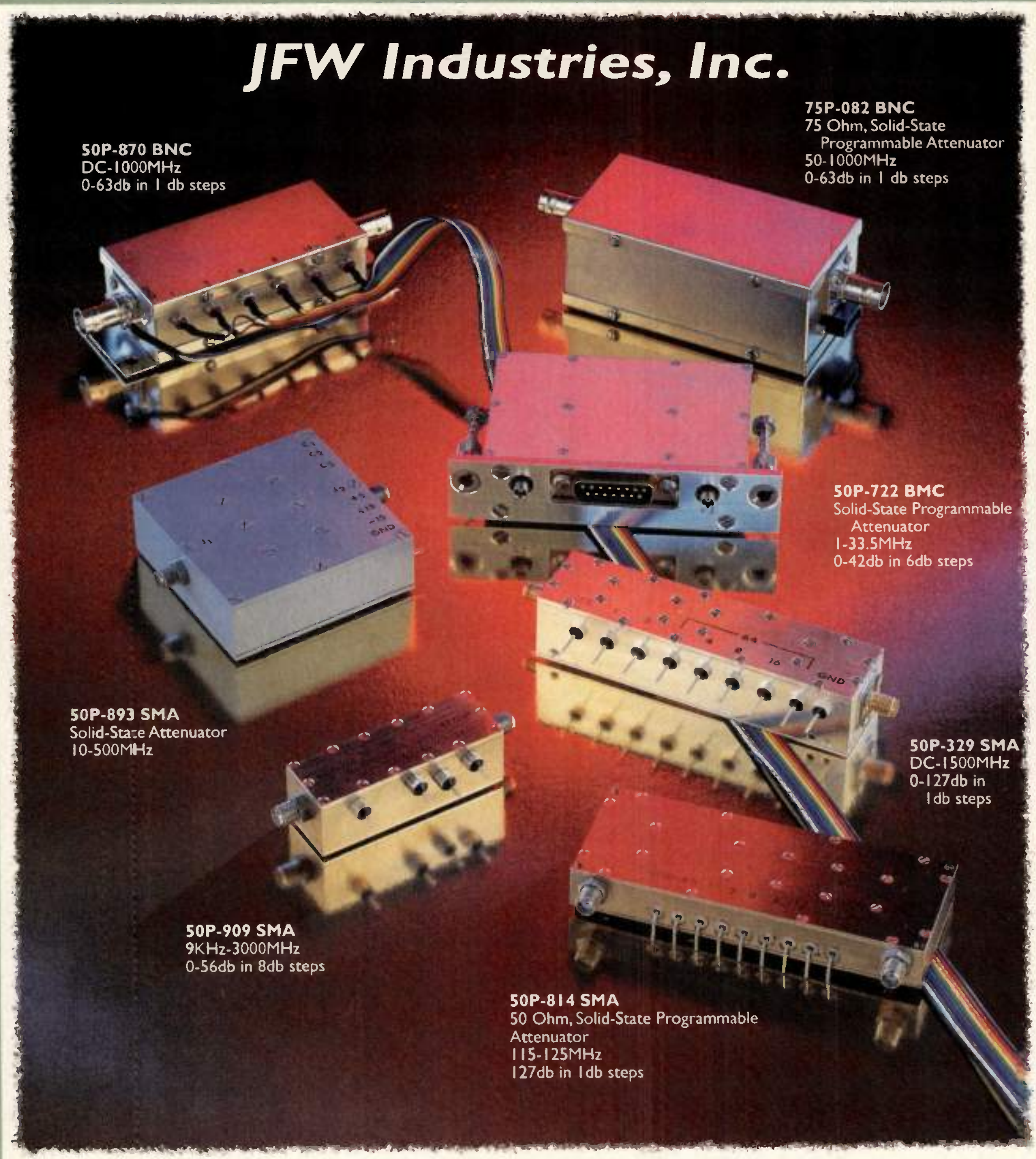

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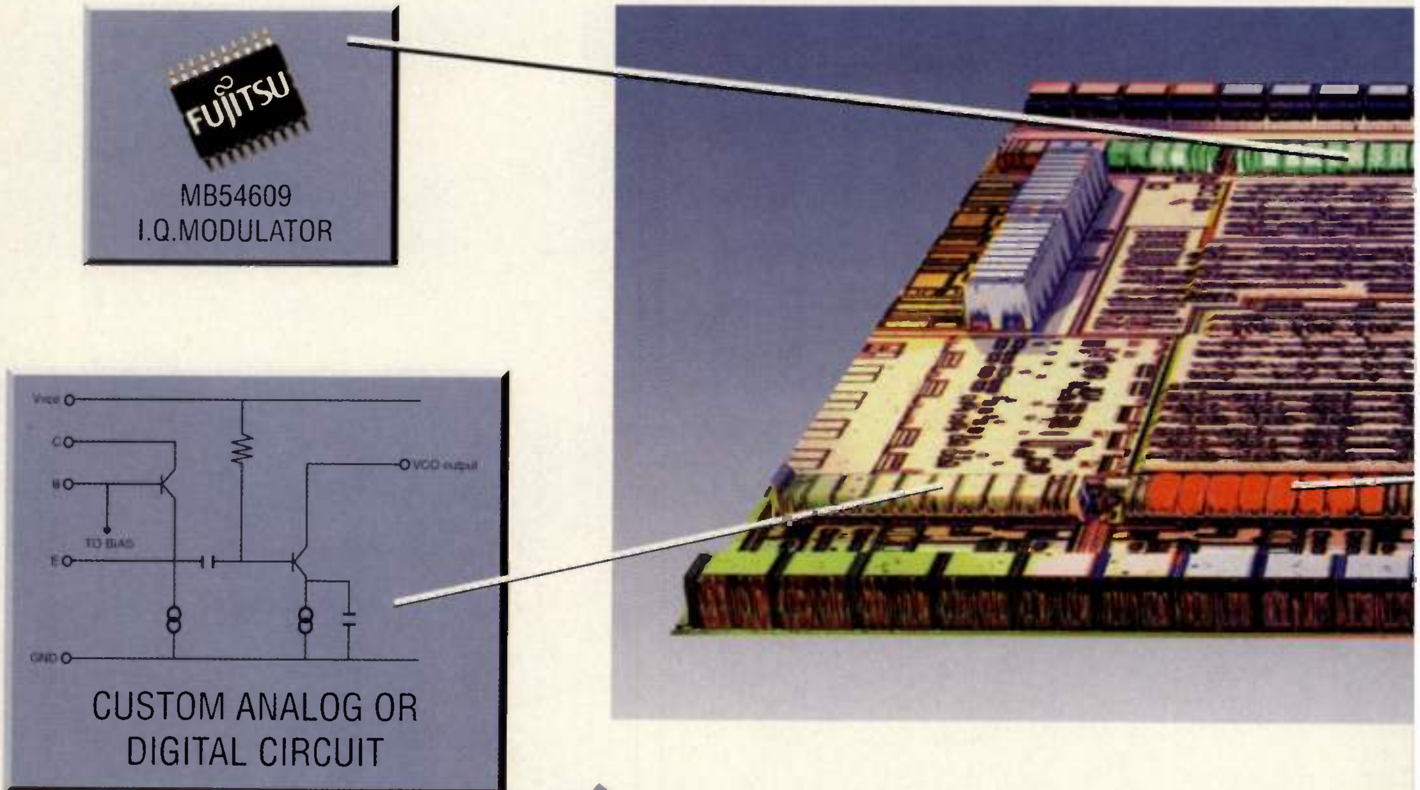

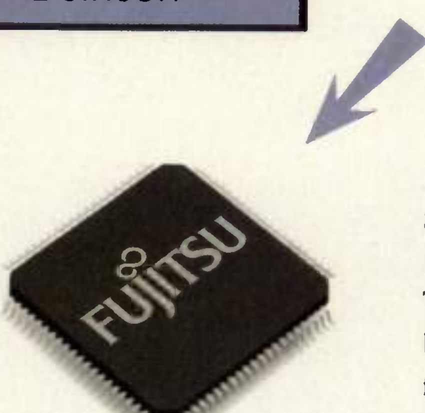

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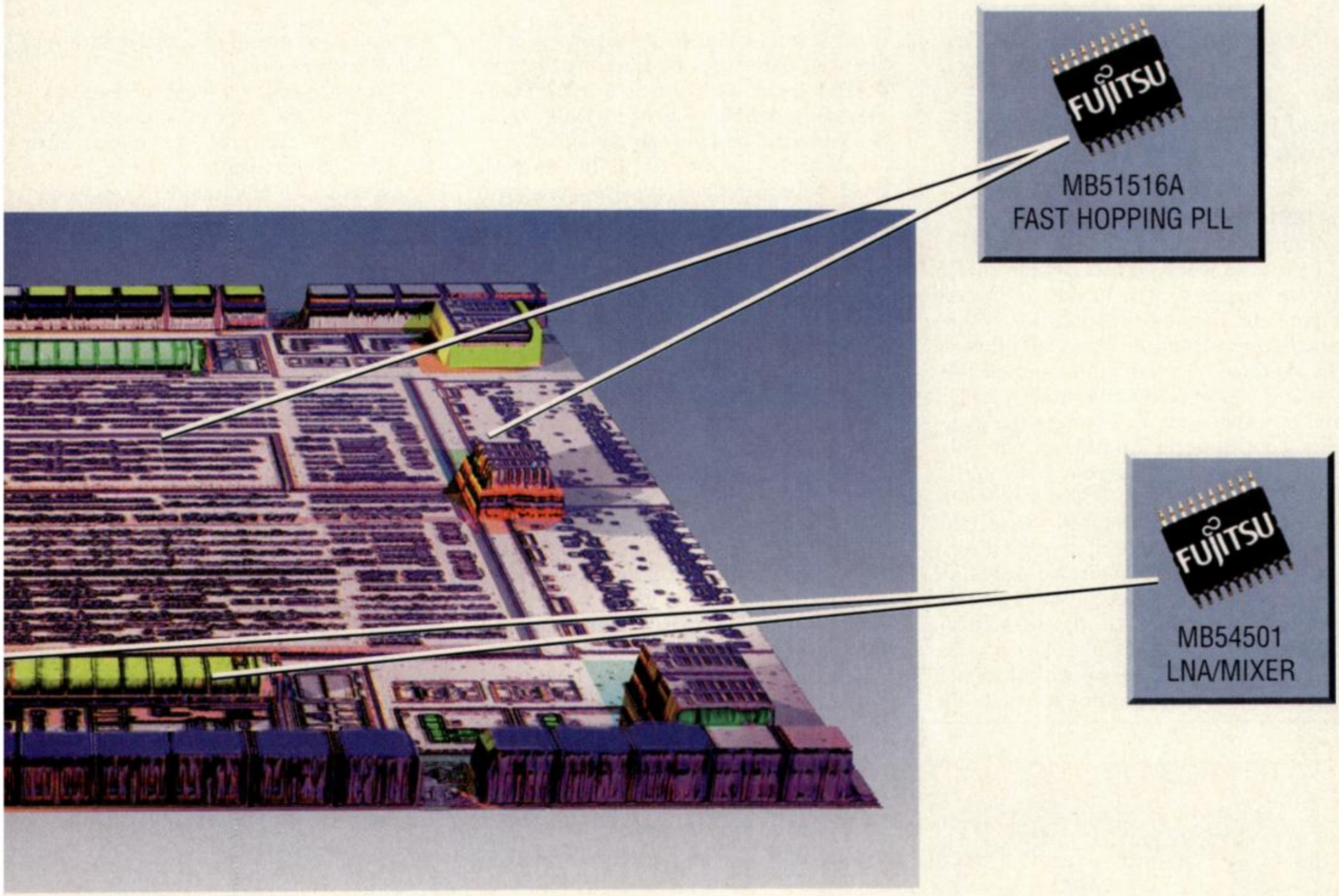

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INFO/CARD 9

RF letters

Letters should be addressed to: Editor, RF Design, *6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Letters may be edited for length and clarity.*

Experience vs. Credentials

Editor:

I enjoyed your recent article in *RF Design* magazine, ["A Review of Classic Filter Responses" July 1995]. What caught my attention was your phrase, "In keeping with our philosophy of presenting concepts that assume a BSEE and no experience...". I quite often experienced the opposite side of the coin before starting my current job about a year and a half ago. When I had left Motorola after nearly ten years, the reaction to the résumé I circulated during my job search came in two stages. In the first stage, prospective employers reacted negatively to my associates degree, with comments like, "... actually, we're looking for someone with a higher degree...", but after reading the rest of it (and a lot of raised eyebrows), they changed their tune. By the time they got finished reading the résumé, a few interviewers thought I was over-qualified for the position I had been applying for.

Certainly, I'm not the only one with good, solid practical experience, so the $64,000 question is: when will people realize a degree isn't the cure-all, be-all, and end-all to mark a person's qualifications?

Klaus Spies

Design DéjàVu

Editor:

Recent letters to the editor reminded me that reinventing is more common than inventing. One of my client's advertising slogans is "We Reinvented it First." The U.S. Patent office has issued a patent on a method of using a diffraction grating to correct for lens imperfections that was invented and published 140 years earlier. It recently issued a patent on a method of broadcast audience surveying that was used 70 years ago and is described in books on the subject in current use.

The most prolific area of reinvention is DSP, where the most famous case is the FFT which is improperly named after the reinventors instead of the inventors. I have seen the binomial FIR tap weight reinvented three times. It was first used before WWII in phased array antenna beam forming.

James Long, Ph.D., P.E.

Belated Ackowledgement

In July's article, "AM Receiver for Low Power Wireless Systems," two contributors were inadvertently left off. California Eastern Laborartories would like to thank Earl Clark of RF Monolithics in Dallas, TX for his technical assistance with the SAW resonators in the applications circuit for the UPC2768. CEL would also like to thank Mike Handfield of Animatronics in Rochester, MI. His efforts in the development of the oscillator external tank circuit helped make the application of this product a success.

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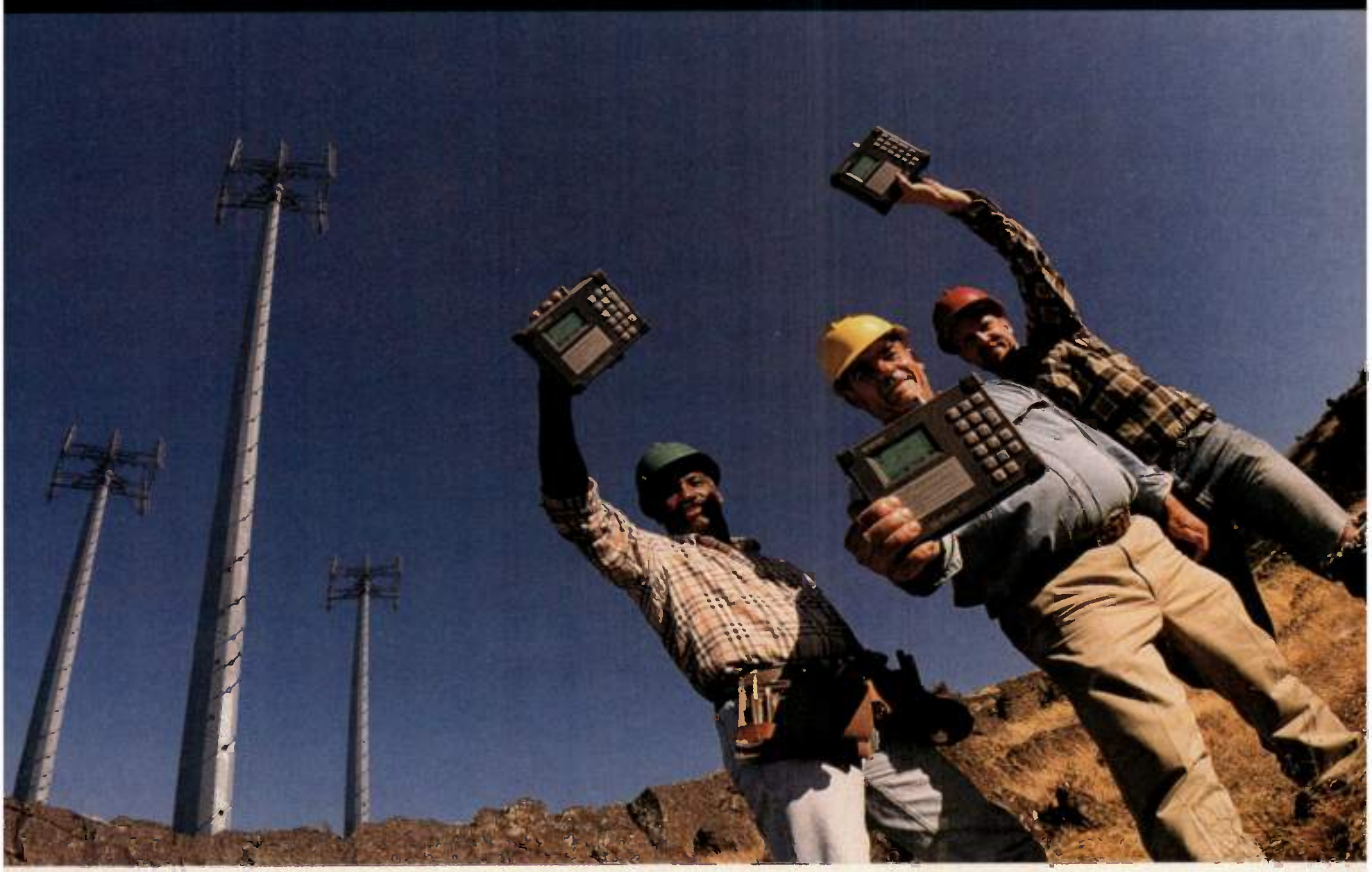

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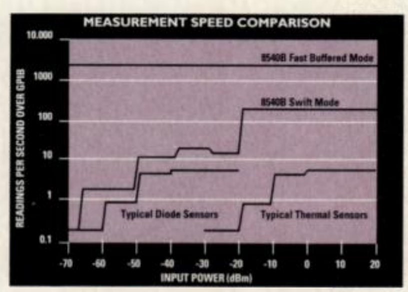

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INFO/CARD 12

RF calendar

October

22-26 **International Symposium on Microelectronics**
Los Angeles, CA
Information: (800) 535-4746, (703) 758-1060, fax: (703) 758-1066, e-mail to ISHM@aol.com

24-25 **Radio Solutions '95**
Birmingham, UK
Information: LPRA Secretariat, Brearley Hall, Luddenden Foot, Halifax, HX2 6HS. Tel./Fax: +44 (0)1422 886 950.

28-1 **IPC 1995 Fall Meeting**
Providence, RI
Information: Nancy Feaster, IPC, 2215 Sanders Road, Suite 250, Northbrook, IL 60062-6135. Tel.: (708) 509-9700. Fax (708) 509-9697.

November

7-9 **Applications Conference on Communcations Techology at Wescon '95**
San Francisco, CA
Information: Wescon '95, 8110 Airport Blvd., Los Angeles, California 90045. Tel.: (800) 877-3668 or (310)215-3976. Fax: (310) 641-5117. World Wide Web: http: //wescon.com/wescon. E-mail: wescon@ieee.org.

30-1 **46th Conference of the Automatic RF Techniques Group**
Scottsdale, AZ
Information: Harmon Banning. Tel.: (302) 368-3700. Fax (302) 292-4607.

December

10-13 **IEEE International Electron Devices Meeting**
Washington, D.C.
Information: Melissa Widerkehr, 101 Lakeforest Blvd., Gaithersburg, MD 20877, Tel.: (301) 527-0900. Fax: (301) 527-0994.

11-15 **20th International Conference on Infrared and Millimeter Waves**
Orlando, FL
Information: Dr. Jim Wiltse, Georgia Tech Research Insti tute, Georgia Institute of Technology, Atlanta, GA 30332-0801. Tel: (404) 894-3494. Fax: (404) 894-9875.

January

17-19 **RF Design Seminar Series**
Dallas, TX
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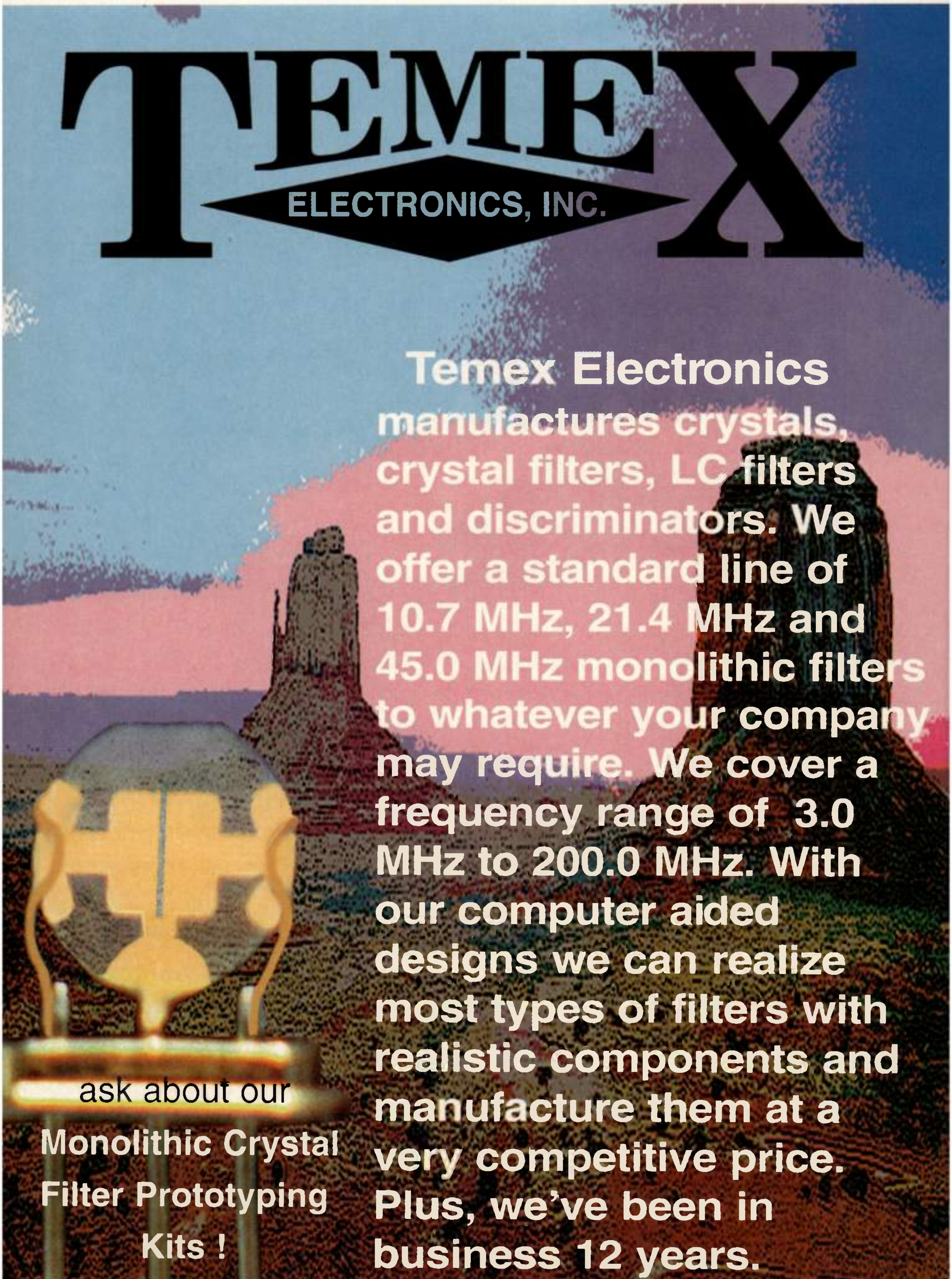
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4	TE5010	3	3.75	30	14.0	-	-	3	2.0	60	1500//+3
6	TE5020	6	3.75	60	12.5	-	-	4	2.0	70	1500//+3
8	TE5030	6	3.75	60	10.0	90	12.5	5	2.0	80	1500//+3
2	TE5040	3	6.50	20	30.0	-	-	1	1.0	50	2700//0
4	TE5050	3	6.50	30	15.0	-	-	2	2.0	75	3100//0
6	TE5060	6	6.50	60	19.5	-	-	3	2.0	90	3100//0
8	TE5070	6	6.50	60	13.0	80	17.5	4	2.0	100	3100//0
2	TE5080	3	7.50	20	35.0	-	-	1	1.0	50	3000//0
4	TE5090	3	7.50	30	17.5	-	-	2	2.0	75	3300//0
6	TE5100	6	7.50	60	22.5	-	-	3	2.0	90	3300//0
8	TE5110	6	7.50	60	15.0	80	20.0	3	2.0	100	3300//0
2	TE5120	3	15.0	20	70.0	-	-	1	1.0	35	5000//-1
4	TE5130	3	15.0	30	35.0	-	-	2	2.0	60	5000//-1
6	TE5140	6	15.0	60	45.0	-	-	2	2.0	90	5000//-1
8	TE5150	6	15.0	60	30.0	80	40.0	3	2.0	100	5000//-1

21.4 MHz

NO. POLES	TEMEX P/N	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM.(Rp//Cp) OHM/PF
2	TE5180	3	3.75	15	12.5	-	-	2	1.0	50	850//+6
4	TE5190	3	3.75	30	12.5	-	-	3	2.0	70	850//+5
6	TE5200	6	3.75	60	12.5	-	-	4	2.0	90	850//+5
8	TE5210	6	3.75	60	10.0	80	12.5	5	2.0	100	850//+5
2	TE5220	3	6.50	15	20.0	-	-	2	1.0	50	1300//+2
4	TE5230	3	6.50	30	22.5	-	-	3	2.0	70	1400//0
6	TE5240	6	6.50	60	22.5	-	-	4	2.0	90	1400//0
8	TE5250	6	6.50	60	17.5	80	22.5	4	2.0	100	1400//0
2	TE5260	3	7.50	15	25.0	-	-	2	1.0	50	1500//0
4	TE5270	3	7.50	30	25.0	-	-	3	2.0	70	1600//0
6	TE5280	6	7.50	60	25.0	-	-	4	2.0	90	1600//0
8	TE5290	6	7.50	60	20.0	80	25.0	4	2.0	100	1600//0
2	TE5300	3	15.0	15	50.0	-	-	2	1.0	45	3000//0
4	TE5310	3	15.0	30	45.0	-	-	3	2.0	60	3000//-1
6	TE5320	6	15.0	60	45.0	-	-	3	2,0	90	3000//-1
8	TE5330	6	15.0	60	33.0	80	45.0	4	2.0	100	3000//-1

45.0 MHz

NO. POLES	TEMEX P/N	MODE	PASSBAND dB	PASSBAND ±KHz	STOPBAND dB	STOPBAND ±KHz	LOSS dB	RIPPLE dB-MAX	ULT. REJ. dB-MIN.	TERM.(Rp//Cp) OHM/PF
2	TE9420	3-OT	3	3.75	18	16.0	3	1	40	2000//-1.0
4	TE9310	3-OT	3	3.75	30	12.5	3	1	70	2000//-1.0
2	TE7420	3-OT	3	7.50	18	28.0	2	1	40	3000//-1.0
4	TE7430	3-OT	3	7.50	40	30.0	3	1	70	3000//-1.0
2	TE7440	3-OT	3	15.0	15	47.0	2	1	40	8000//-1.5
4	TE7450	3-OT	3	15.0	30	50.0	3	1	70	8000//-1.5
2	TE7730	FUND	3	15.0	15	50.0	2	1	40	1100//+1.5
4	TE7740	FUND	3	15.0	40	60.0	3	1	70	800//+1.0

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RF courses

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November 28-December 1, 1995, Atlanta GA
Radar Signal Processing: Theory, Technology and Application
January 31-February 2, 1996, Atlanta, GA
Coherent Radar Performance Estimation
February 5-8, 1996, Atlanta, GA
Information: Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel: (404) 894-2547.

Antennas and Antenna Systems: Practical Design, Implementation, and Testing
October 23-26, 1995, Washington, DC
Analog and Digital Cellular Networks: CDMA versus TDMA
October 30-November 1, 1995, Washington, DC
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Terrestrial Microwave Communications Engineering
November 13-16, 1995, San Diego, CA
Digital Transmission Systems
November 13-17, 1995, San Diego, CA
Electromagnetic Interference and Control in Modern Communications Systems
November 13-17, 1995, Alexandria, VA
Video Transmission and Broadcasting Via Satellite
November 20-21, 1995, Washington, DC
Satellite Communications Engineering Principles
November 28-December , 1995, Alexandria, VA
Advanced Developments in Radar
December 4-7, 1995, Washington, DC
Modern Digital Modulation Techniques
December 4-8, 1995, Alexandria, VA
New HF Communications Technology: Advanced Techniques
December 4-8, 1995, Washington, DC
Satellite Communications with Emphasis on Mobile Systems
December 6-8, 1995, Alexandria, VA
Information: The George Washington University, Continuing Engineering Education, Academic Center, Room T-308, 801 22nd Street, N.W., Washington, DC 20052. Tel: (202) 994–6106 or (800) 424–9773. Fax: (202) 872–0645.

DSP Without Tears™
December 4-6, 1995, San Jose, CA
January 8-10, 1996, Atlanta, GA
Information: Z Domain Technologies, 325 Pine Isle Court, Alpharetta, GA 30302. Tel.: (800) 967-5034 or (404) 587-4812. Fax: (404) 518-8368. E-Mail: dsp@mindspring.com

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Engineering the Telecommunications Network
October 30-November 2, Madison, WI
Information: Francis P. Drake, Program Director, University of Wisconsin—Madison/Extension, The Wisconsin Center, 702 Langdon St., Madison, WI 53706. Tel.: (800) 462-0876 or (608) 262-1299. Fax: (800) 442-4212 or (608) 265-1299.

Networks for Digital Wireless Access
November 8-10, 1995, Burlingame, CA
Information: University of California, Berkeley Extension, South Bay Program, 800 El Camino Real, Suite 220, Menlo Park, CA 94025. Tel.: (415) 323-8159.

Short Course on Microwave and RF Measurements for Wireless Communications
November 28-29, 1995, Scottsdale, AZ
Short Course in Electromagnetic Interference Metrology
January 22 & 23, 1996, Anaheim, CA
Information: Robert M. Judish, NIST, 325 Broadway, Boulder, CO 80303. Tel.: (303) 497-3380, Fax: (303) 497-3970, e-mail: judish@boulder.nist.gov.

MPEG-2 & Alternative Video Compression Standards & Techniques
November 6-8, 1995, Palo Alto, CA
Error Correcting Codes with Applications to Communications Systems
December 11-14, 1995, Washington, DC
Information: University Consortium for Continuing Education, 16161 Ventura Boulevard, M/S C-752, Encino, CA 91436. Tel.: (818) 995–6335. Fax: (818) 995–2932.

EMC Workshop — Immunity Measurements
October 24 & 25, 1995, Surrey, England
Pre-Compliance and Diagnostic Emissions Tests
October 26 &27, 1995, Surrey, England
EMC Testing
November 21, 1995, Bristol, England
Information: Ms. Nikki Harris, Conference Group, Technical Services Division, ERA Technology Ltd., Cleeve Road, Leatherhead, Surrey, KT22 7SA England. Tel.: 44 (0)372-367027. Fax: 44 (0) 372-377927.

EMC Training Courses
October 24, 1995, Warwick, England
October 25, 1995, Reigate, England
October 26, 1995, Sheffield, England
November 14, 1995, Luton, England
November 15, 1995, Gloucester, England
November 16, 1995, Manchester, England
Information: Nigel Harvey, SGS EMC Services, Hutton Building, St. Michael's Way, Sunderland, SR1 3SD. Tel.: 44 (0) 191 515 2663. Fax: 44 (0) 191 5125 2670

Applied RF Techniques I
October 23-27, 1995, Los Altos, CA
Applied RF Techniques II
October 30-November 3, 1995, Los Altos, CA
RF and Wireless Made Simple
(For Technical Managers and Marketers
November 6 & 7, Los Altos, CA
Wireless RF System Design
November 6-10, Los Altos, CA
Information: Besser Associates, 4600 El Camino Real #210, Los Altos, CA 94022. Tel.: (415) 949-3300. Fax: (415) 949-4400.

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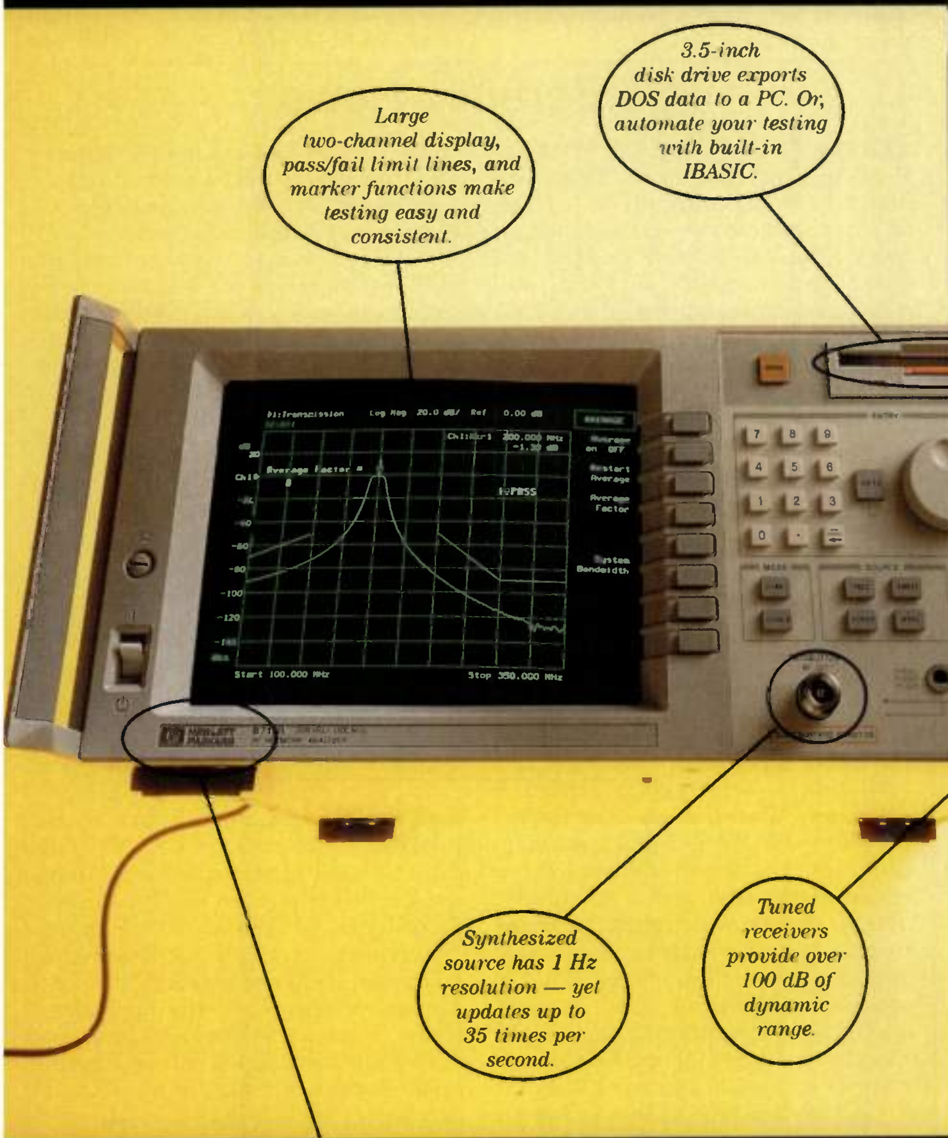

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New Technology Will Shrink Microchips

A new form of microlithography replaces light with neutral atoms to write patterns on silicon. Demonstrated by Harvard University and National Institute of Standards and Technology (NIST) scientists in August, the new method offers the promise of oneday manufacturing integrated circuits or other microfabricated objects about 10 times smaller than currently possible with light-based lithography methods, according to NIST. The scientists' results are reported in the Sept. 1 issue of *Science*.

Nickel-Based EMI Shield Developed

A research team at the State University of New York in Buffalo, NY reports that it has developed a polymer containing nickel-coated carbon filaments that can effectively shield electronic devices from electromagnetic interference. Deborah Chung, principal investigator for the team, said the material achieves 87 dB of shielding at 1 GHz. By comparison, solid copper insulation achieves 90 dB shielding. Chung also described the polymer-based shield as being much lighter and more moldable than copper. The 0.4 micron-diameter nickel fibers constitutes only 7 percent of the body material of the shield. Chung said she has a patent pending on the polymer and it is currently in the process of commercialization.

Frequency Control Abstracts Now On-Line

The abstracts of all the papers ever published in the Proceedings of the Frequency Control Symposium since 1956 are now available on-line via the Internet. Instructions for downloading are as follows:

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The file names are ABSTRACT.EXE, OTHER.EXE, which are self-extracting compressed files (for PCs), and a READ-ME.TXT, which is a text file explaining what the .EXE files contain. Uncompressed text ASCII files are also available in the same directory: ABSTRACT.TXT contains all the abstracts, AWARDS.TEXT contains information about the Cady, Rabi and Sawyer awards, CHAIRMAN.TEXT contains a list of symposium chairmen since 1956, PROCDGS.TXT contains information for all the Frequency Control Proceedings since 1956.

FCC Expands Role of GTEM Cells

The Federal Communications Commission announced that it will accept GTEM cells as alternate sites for making radiated emissions measurements for equipment authorizations beyond Part 15 of the FCC rules, which nor-

Conference News

Call for Papers: CEEM '96 Asia-Pacific Conference on Environmental Electromagnetics — In an effort to promote the exchange of new research and to foster friendship and scientific cooperation, environmental electromagnetic experts from China and Japan and other countries will host CEEM '96 in Xi'an, China next November 5-7. The sponsors, China Institute of Communications, Beijing University of Posts and Telecommunications and the Institute of Electrical Engineers of Japan, have invited paper submissions on the following topics: antenna theory; CAD in antenna; scattering; EMI sources; lighting surge, EMP and ESD; EMI coupling and crosstalk; EM wave propagation theory; space electromagnetics; electromagnetic field theory; application of propagation model to telecommunications; EM environment; EMC measurement; EM sensor; shielding and grounding — technique and material; EM energy, absorber, anechoic material; filter, transformer and isolatator; immunity and susceptibility/system, device and component; EMI prediction, analysis and reduction technique; spectrum management and monitoring; biological effects; EMC in wire communications; EMC in radio communications. Authors should submit three copies of a 35-50 word abstract and a 500-700 word summary by June 20, 1996. The submission should include the author's name, address and affiliation. Send submissions to CEEM '96, c/o Prof. Gao Yougang, P.O. Box 171 Beijing University of Posts and Telecommunications, Beijing, 100088, China. Tel.: 86-10-2019988 ext. 722. Fax: 86-10-2028643.

Virginia Tech Symposium Issues Call for Papers — Sponsors of the 1996 Virginia Tech Symposium on Wireless Personal Communications invite authors to submit abstracts for technical papers describing original work in wireless communications. The symposium will be held June 5-7, 1996 in Blacksburg, VA. Examples of appropriate topics include: novel wireless products, applications of DSP techniques to wireless communications, diversity and multiple access techniques, simulation and performance analysis of wireless systems network issues, propagation measurement and prediction, supporting technologies for wireless systems, and business opportunities in wireless. Authors should send a 200-400 word abstract to Dr. Brian D. Woerner, MPRG - Bradley Department of Electrical Engineering, Virginia Tech, 850 University City Blvd., Pointe West Commons, Suite 1, Blacksburg, VA 24061-0350. Or call Jenny Frank at (540) 231-2958. E-Mail: mprg@vt.edu. http: //www.ee.vt.edu/ee/research. Deadline for submissions is December 15, 1995.

Call for Papers: Microwave Symposium — The 1996 IEEE-MTT-S International Microwave Symposium week will be held in San Francisco, California, June 16-21. Papers describing original work in the microwave field are currently sought. Any paper concerned with the utilization and application of microwave theory and techniques will be considered. Authors should indicate their preference for presentation length: Full length (20 minutes), short (10 minutes), or interactive forum. Full-length papers should report significant contributions, advancements or applications. Short papers typically report specific refinement in the sate-of-the-art. The interactive format gives authors the chance to present theoretical or experimental material in poster format, display hardware, perform demonstrations, and conduct informal discussions. Mail submissions to MTT-S Symposium 1996, c/o LRW Associates, 1218 Balfour Drive, Arnold, MD 21012.

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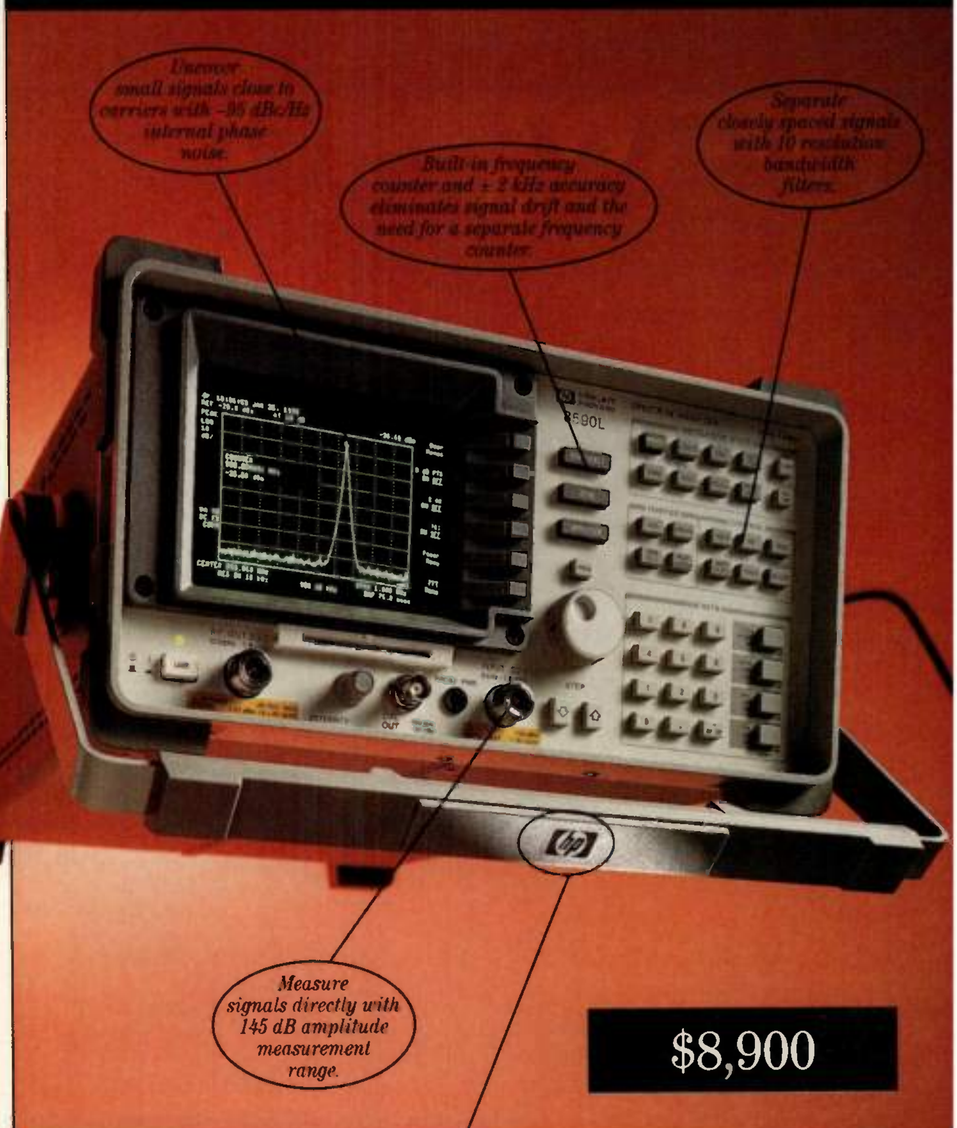

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mally are obtained at an open area test site. In 1993, the FCC began to allow GTEM cells as alternate test cites for equipment authorization for Part 15. The GTEM cells, however, must be used under limited conditions. According to the FCC, GTEM test cells have several benefits, including a faster time for measurements, reduced testing costs and an alleviation of testing delays due to poor weather. Questions regarding GTEM cell testing can be addressed to Thomas Phillips at (301) 725-1585, Ext 218. Fax: (301) 344-2050. Internet: tphillips@fcc.gov.

Contracts

PAC/AMP to Provide Multi-Couplers to Canada's CDC — Pacific Amplifier Corporation was awarded a development contract from Computing Devices Canada (CDC) on the Iris program to provide a broadband RF active multi-coupler subsytem last August. The active multi-coupler will significantly reduce co-site interference generated when multiple transceivers are used in co-located environments.

Amplica, Inc. Wins $1.4 Contract — Amplica, Inc. of Newbury Park, CA announced in August that it has been awarded a $1.4 million contract from Litton Systems, Inc. Amplica will manufacture major assemblies for the APX-109 IFF system. Founded in 1972, Amplica designs, manufactures and markets RF/microwave components, sub-assemblies and sub-systems used in commercial communications and microwave defense equipment.

Scientific Atlanta to Provide Ground Systems for Space Imaging, Inc. — Scientific Atlanta received $7.6 million from E-systems, Garland Division to provide three ground stations to support Space Imaging, Inc.'s (SII) remote sensing program. Thornton, Colorado-based SII provides satellite imagery of the earth to commercial users. SII will launch its first commercial satellite in late 1997.

Market News

Automotive Electronics Market to Increase — The total demand for automotive electronics is expected to reach $16.1 billion by 1999, a $4.8 billion increase from 1994, according to BIS Strategic Decisions. High technology applications such as head-up displays and collision warning systems are predicted to become the fastest growing segment with 16 percent annual growth, increasing from $470 million in 1994 to $970 million in 1999. Vehicle-security applications such as keyless-entry, alarm and electronic vehicle immobiliser systems are expected to grow at 13 percent a year from $588 million in 1994 to $1.08 billion by 1999, according to the report.

Digital Wireless Communications Market for IC's Booming — The global market for semicustom and custom integrated circuits used in digital wireless communications (DWC) terminals and RF base station equipment carriers is expected to "skyrocket" from $974 million in 1994 to $5.1 billion in the year 2000, according to Kenneth W. Taylor & Associates.

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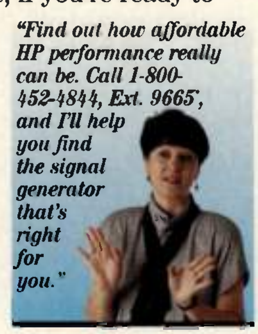

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According to the recent 225-page study, custom ICs will be particularly important for reducing size, weight, and power consumption of advanced hand-held terminals associated with DWC applications.

Collision Warning Systems See Promising Road Ahead — A study released by the Allied Business Intelligence, Inc. estimates a $200 million U.S. market for automotive collision warning systems by the end of the century. The figure is based on U.S. production of approximately 10 million cars and light trucks, an insertion rate of 5 percent by the year 2000 and an average selling price of $500 per system.

Expansion of European Mobile Communication Markets Expected — European mobile communication services and equipment markets are expected to reach US$30.1 billion by 1998, according to BIS Strategic Decisions. Mobile communication equipment is predicted to reach US$8.1 billion within the same time frame. The mobile communications market is one of the fastest-growing sectors of European telecommunications market, BIS said.

Asian, Mideast Markets Lead Electronic Warfare Growth — According to a report from Frost & Sullivan, non-U.S. sales of electronic warfare systems will grow from $3.67 billion in 1994 to $5.36 billion by the year 2001 at a 6 percent compound annual rate. The western European share of sales will dip from 39 percent of the market in 12994 to 37 percent in 2001 and that of eastern Europe from 16 to 10 percent while the Asia-Pacific share rises from 29 to 30 percent and the Middle East from 12 to 15 percent in the same period, the report stated. "Chip and wire" modules are being replaced by gallium arsenide microwave integrated circuits (MMICs).

Major Growth for SiC Markets Predicted — A new study on silicon carbide (SiC) technology and market applications predicts that SiC-based optoelectronic devices will increase. This year's $4 million market will rise to $90 million by 2000 and to $200 million by 2005, according to the report released by Strategies Unlimited. The figures represent a 48 percent annual growth rate for SiC-based components.

Business Briefs

Fluke Corp. Achieves National Lab Accreditation — The National Institute of Standards and Technology (NIST) has accredited the Fluke Corporation for its Primary Standards Laboratory. The NIST National Voluntary Laboratory Accreditation Program (NVLAP) evaluates the quality standards and technical competencies of public and private laboratories that provide testing and calibration services. Fluke is accredited for electrical parameters including DC volts, AC/DC difference, AC volts, AC current, DC current, thermal voltage and resistance.

Daden to Merge with TRAK — TRAK Microwave Corporation of Tampa, Fla. and Daden Associates of San Clemente, Calif. announced in August they have entered into an agreement in which TRAK will acquire Daden's assets, pending approval of the boards of directors of both companies as well as Daden's shareholders.

BCP Awarded Pre-Scramble Encoding Patent — Broadband Communications Products, Inc. (BCP), has received a patent on a pre-scramble encoding method and device for digital communications. According to BCP, the purpose of the invention is to ensure scrambled data signals, which might be sent over fiber optic lines, have adequate signal balance and frequent data transitions.

Vectron Acquires Efratom's Product Line — Vectron Laboratories of Norwalk, Conn. announced last August that it has acquired the EMXO product line from Efratom of Irvine, Calif. The product line consists of oven-sized crystal oscillators for low-power and fast warm-up applications. Because of its cold-weld, vacuum-sealed enclosure and unique design and construction, the EMXO line of oscillators can achieve significantly better performance than other technologies, according to Vectron.

Fujitsu and LXE to Jointly Develop Wireless LAN Products — Mobile computing manufacturer, Fujitsu Personal Systems, Inc. announced in August that it has teamed up with LXE, a developer of wireless data communication systems, to develop high-performance wireless LAN solutions. The two companies said they plan to integrate LXE's LAN radio and internal antenna with Fujitsu's Stylistic 500 high-performance tablet computer, which is designed for mobile workers involved in decision support activities. The resulting wireless LAN will be capable of running Windows applications at 1.6 Mbps, according to the companies.

Scientific-Atlanta Announces Corporate Consolidation — Scientific-Atlanta, Inc. announced in August that it has consolidated its factory services, technical services, training, spares and after-market customer programs into one worldwide organization. Donald Upton, former president of the company's Private Networks Division, has been appointed president of the new World Wide Service Organization reporting to Larry Enterline, president of International Division for the Broadband Communications Group.

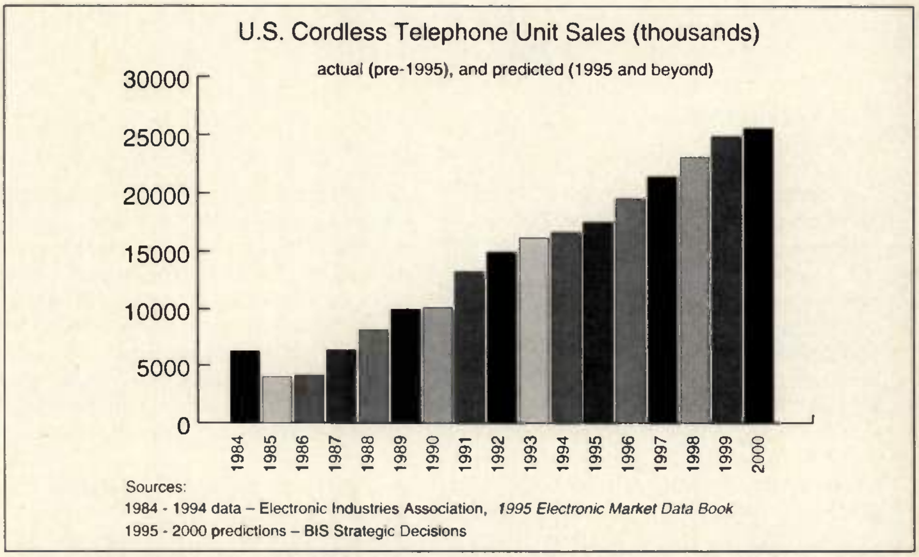
Proxim to Integrate Wireless Technology with Kalidor — Supplier of wireless data communication products, Proxim, said in July that will integrate its RangeLAN2™ 2.4-GHz, frequency-hopping, spread-spectrum wireless LAN technology with Kalidor's K200 family of rugged pen-based computers. The new product is designed for mobile applications requiring a durable, water-resistant solutions such as healthcare, warehousing, manufacturing and field inspection.

Varian Announces Sale Completion — Varian Associates, Inc. announced last August that it has completed the sale of its Electron Devices business to an investor group for approximately $200 million in cash, and the assumption of certain liabilities. Varian's chairman said that most of the proceeds from the sale will be used to buy back shares of the company's stock. The company currently has approximately 22.8 million actual shares outstanding.

More Radios in Consumers' Shopping Baskets

By Andy Kellett
Technical Editor

Recently, the RF industry has been driven by PCS and cellular – large-scale, capital-intensive systems. However, inexpensive transmitter receiver pairs meant to operate over distances of just a few meters are showing up more and more on consumers' shopping lists. These devices are regulated under Part 15 of the FCC's regulations, and they are just as likely to be purchased at a hardware store or toy store as an electronics store. Everyday, new RF "gadgets" are joining cordless telephones, wireless doorbells, garage door openers, wireless stereo headphones and other short-range RF devices in the consumer market.



Actual (pre-1995) and predicted (post-1995) unit sales for cordless telephones.

An Established Success – Cordless Phones

Cordless phones are an early example of a successful Part 15 device. As the accompanying graph illustrates, cordless phone sales have steadily increased since they were first given spectrum by the FCC.

Early cordless phones operated on a single channel around 46 MHz. As more people bought these phones and they started to interfere with each other, manufacturers have had to build phones using more than one channel. Models with as many as 25 channels have been manufactured, while many cordless phones are now using the 900 MHz band. Recently, manufacturers have introduced phones which operate near 2400 MHz, and a BIS Strategic Decision report predicts that replacement of 46 MHz cordless phones with 900 and 2400 MHz models, along with upgrades to models with more features, will maintain the positive sales growth cordless phones have enjoyed since their introduction.

Piggybacking on the Cellular/PCS Boom

Cordless telephones are sold in large enough numbers that devices are manufactured specifically for that market. However, many of the new RF products being produced owe their commercial viability to the cellular/PCS boom.

The devices developed for the cellular industry are being produced in such numbers that their price has been driven down to the point that they can be used in inexpensive consumer items, says Norm Hilgendorf, a product manager for Richardson Electronics. "The parts are exactly the same," says Hilgendorf of the devices used in both cellular phones and low-cost consumer devices.

An example of the types of wireless products whose commercial viability has piggybacked on the success of cellular are wireless stereo headphones. One maker of these headphones is Recoton, who produces a set of headphones using a low-power, narrowband transmitter tunable from 912 to 914 MHz.

Recoton's wireless headphones use discrete transistors and a standard radio IC, says a Recoton R&D technician. Though standard parts are used, Recoton has added enough engineering to get patents on parts of their headphone design. "To design the circuitry to be reliable and at low cost was not an easy accomplishment," says Peter Ildau, Vice President of Corporate Communications for Recoton.

Interference had to be dealt with in the increasingly crowded 900 MHz band where the headphones operate. "Most of the cordless phones at 900 MHz are spread spectrum," says Ildau, "but we made the headphones tunable so the user could get away from non-spread-spectrum transmitters."

Conclusion

"We are really just beginning to see these applications take hold," says Richardson's Hilgendorf. Whether any new low-cost RF device will become a "killer application," with widespread success no one is sure, but there do seem to be plenty of new candidates. *RF*

Use Programmable Logic Devices to Enhance Phase-Locked Oscillator Performance

By Larry Martin
Consultant

A recent project required an 800 MHz phase locked oscillator. The original concept for the block diagram of this loop is shown in Figure 1. The system required a 10 MHz reference oscillator, a 40 MHz output, and an 800 MHz output, both derived in some manner from the 10 MHz reference. The 40 MHz output was derived by multiplying the 10 MHz reference, and the 800 MHz output was generated by phase-locking a low-noise 800 MHz oscillator to a reference frequency that was also derived from the 10 MHz frequency reference. The loop was to be designed with a minimum number of components to keep the PCB real estate at a minimum. Other concerns were the phase noise of the 800 MHz signal and the spurious outputs on both the 800 MHz output and the 40 MHz output.

It appeared as if a Programmable Array Logic (PAL) device could be used to implement the counters and phase detector in a single part. (Before this implementation was developed, a breadboard of the loop was constructed using conventional ECL and ACMOS logic functions which served as a baseline design and provided a phase-noise and loop-performance benchmark).

The logic in the PALs and PLDs (Programmable Logic Devices) discussed in this article was designed using the Tango suite of design tools from Accel Technologies, Inc. Schematics of the desired logic were drawn using Tango Schematic and the components were taken from the Tango PLD parts library. A netlist was generated after the logic was designed. Then, using a vendor-supplied program, this netlist was converted to the proper input format for the Tango PLD program. The PLD program used this file to generate a JEDEC-standard file that was used to program the PAL. For more on PLDs, see the accompanying sidebar (pg. 37).

Implementing the Phase/Frequency Detector

One of the first concerns was how to implement the phase/frequency detector portion of the loop. Many small PALs do not have sufficient internal feedback paths to allow an easy implementation of the logic, which was taken from the Motorola 4044 datasheet [1]. The digital logic of this phase/frequency detector was implemented in a GAL16V8-7, an electronically-erasable, 20-pin EECMOS PLD manufactured by Lattice Semiconduc-

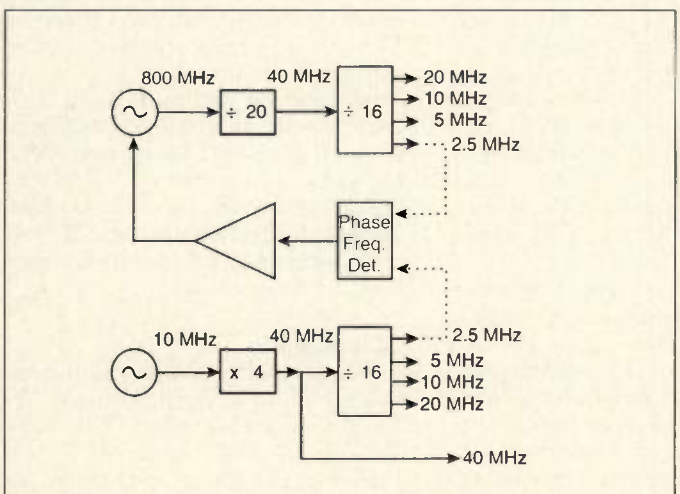


Figure 1. 800 MHz phase-locked oscillator block diagram.

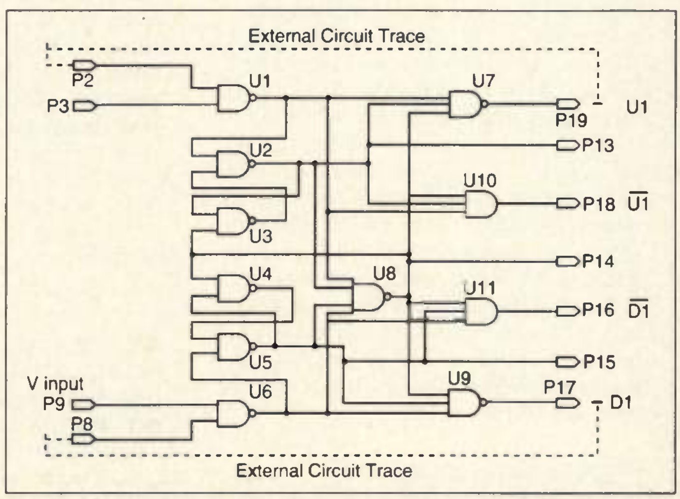


Figure 2. Logic gate implementation of a phase/frequency detector.

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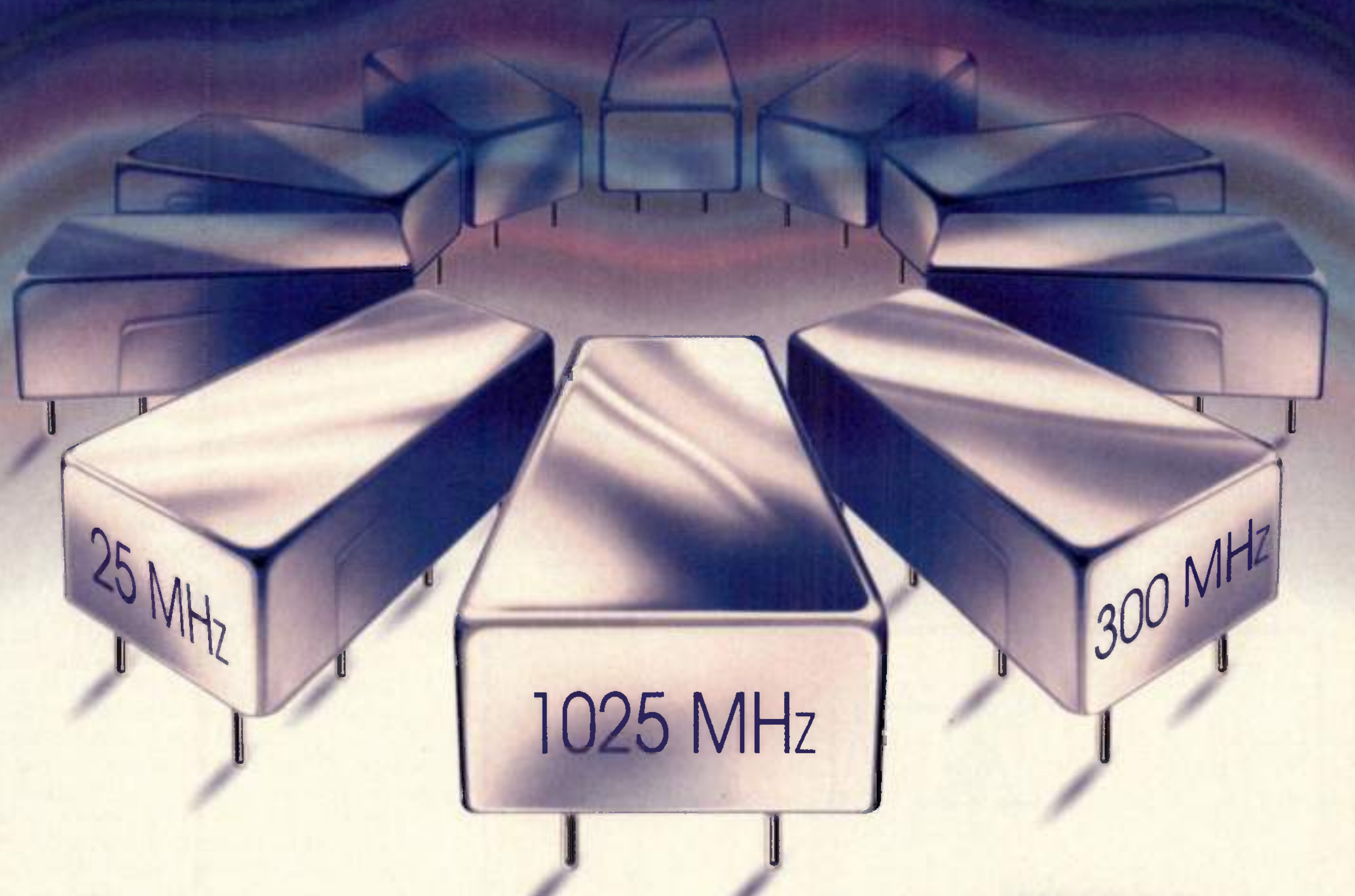

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POS-75	37.5-75	-110	-27	17	11.95
POS-100	50-100	-107	-23	18	11.95
POS-150	75-150	-103	-23	18	11.95
POS-200	100-200	-102	-24	18	11.95
POS-300	150-280	-100	-30	18	13.95
POS-400	200-380	-98	-28	18	13.95
POS-535	300-525	-93	-26	18	13.95
POS-765	485-765	-85	-21	22	14.95
POS-1025	685-1025	-84	-23	22	16.95

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tor [2]. This part is specified with input-to-output delays of 7.5 nsec and clock-to-output delays of 5 nsec. The logic in the part can be configured as combinatorial circuits or logic containing up to eight flip-flops. The combinatorial logic mode was used in this circuit.

Several iterations were required before the logic implementation of the phase/frequency detector shown in Figure 2 was arrived at. Because these types of parts do not provide sufficient internal feedback paths, additional external feedback paths were added to it to provide the latch functions necessary for the phase/frequency detector operation. These paths *do* add to the logic delay times because the signals must go on and off the chip, but the pulse widths at the outputs of the phase detector were measured to be about 5 nsec when the loop was locked.

The initial implementation of the phase detector used a minimum of output pins in an attempt to minimize ground bounce and stray spurious signals from the sharp logic edges. Extra logic was to be used to implement the counter circuits. This initial implementation did not work due to the part's internal race conditions. A NAND gate, (U8 of Figure 2), was added to create added logic delays. I also added the logic complements of the normal outputs, which served two functions. The first was to provide differential outputs to minimize power supply and ground current spiking (one output turns off while the complementary output turns on, thus balancing the switching currents). The second was that this allowed the loop to be constructed using either the true or the complement outputs to see if either of the pairs of outputs had better noise performance.

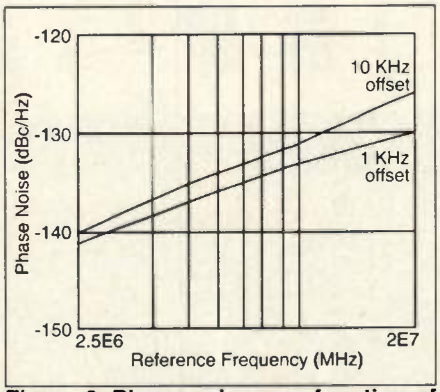

Figure 3. Phase noise as a function of reference frequency for the PLD implementation of the phase detector.

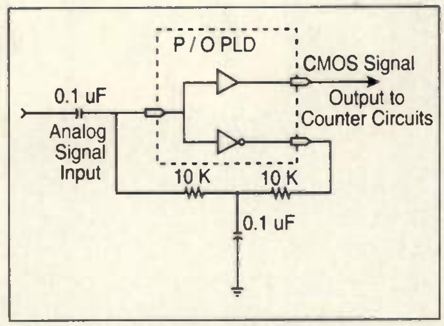

Figure 4. Analog to CMOS converter.

Phase Noise Measurements

The PLD phase-detector replaced the detector in Figure 1 and the inputs to the detector were connected in turn to the 2.5, 5.0, 10 and 20 MHz outputs of the counters. The phase noise of the loop was measured at 1 kHz and 10 kHz offsets and is summarized in Table 1. Though the divider number was changed, no compensation for the loop bandwidth was made because the data were only taken to determine the phase noise floor of the loop (to evaluate the phase detector and frequency divider noise effects). The loop bandwidth was deliberately made large so that the phase noise of the VCO would not be a contributing factor. This phase noise was comparable to the noise measured when the phase detector was constructed using discrete ACMOS logic.

The loop response was also swept to determine if the phase detector had any significant nonlinearities that could affect the loop bandwidths. No discontinuities in the outputs of the phase detector were found in the breadboard circuit. The inputs to the loop amplifier were then connected to the complementary outputs of the phase detector and the noise re-measured. Table 1 shows that the noise levels of the circuit did not measurably change.

One interesting point that should be

Programmable Logic Basics

By Larry Martin

Various types of Programmable Logic Devices (PLDs) are being used to replace conventional CMOS and TTL logic devices in many applications. In some cases this results in a smaller printed circuit board while in other cases a better performing circuit may be the end goal. PLDs range in size from simple Programmable Array Logic (PAL) parts (PAL is a registered trademark of AutoVec) that contain fewer than 100 equivalent gates to Field Programmable Gate Arrays (FPGAs) of more than 20,000 gate complexity. The simple parts may be in a 20-pin package while the packages for the more complex parts may have more than 300 pins. The propagation delays through the logic paths range from about 35 nsec for the slowest parts to less than 5 nsec for the fastest parts. The parts with internal flip-flops can be clocked at maximum rates from less than 16 MHz to high speed parts that can be clocked at over 200 MHz.

Semiconductor technologies for these parts range from factory programmable GaAs parts to both TTL and ECL fuse-programmable parts. In addition, there are a variety of CMOS parts that may be antifuse programmed, and there are reprogrammable parts based on electronically erasable technologies (EEPROM), ultraviolet erasable (UV-EPROM) technologies and static-RAM programmable parts. The reprogrammable parts can be reused many times to make modifications as the design progresses, while the one-time programmable parts are usually less expensive to use once a part is in production. Some vendors offer conversion services to produce lower-cost, mask-programmable parts if the production volume is high enough.

There are many vendors of these parts. Triquint is the only vendor of GaAs PLDs, while AMD, Cypress, National, Phillips (Signetics) and Texas Instruments offer bipolar and CMOS parts. Actel, Altera, Atmel, ICT, Intel, Lattice, Xilinx and others offer various kinds of CMOS parts. Phillips and National also offer several ECL PLDs. This field is rapidly changing, with vendors offering more parts every day.

There are a number of ways to design the circuit for a PLD implementation of the circuit. One method is to create Boolean logic equations to describe the circuit. This was one of the earliest methods of developing these circuits and is still used for many applications today. An extension of this method is to use state-machine concepts to implement counters and other timing circuits. Another popular method is to design the circuit by drawing schematics of the logic. These schematics are used to create a netlist file that defines the primitive parts such as logic gates and flip-flops and the connections between the parts. The logic design is converted to a fuse map file (known as a Joint Electronic Device Engineering Council, or JEDEC, file) by a logic compiler.

Some PLD vendors offer low-cost (or free) design tools for their specific parts, while there are a number of third-party design tools that are vendor-independent. The PLD compiler and schematic drafting program that were used in this article are Tango PLD and Tango Schematic (Tango PLD is no longer a supported product) from Accel Technologies. Other vendors include ORCAD, Minc, Data I/O, Logical Devices, MicroSim and Viewlogic Systems. (This is not a complete list by any means.)

There are a number of vendors of logic programmers that can be used to program these parts. The programmer used to program the parts used in this article was made by Advin Systems. Other vendors (again, this is not a complete list of vendors) include BP Microsystems Data I/O, Logical Devices, Prologic Systems, Stag Microsystems and System General.

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Reference Frequency (MHz)	Phase Noise (dBc/Hz) 1 kHz offset	10 kHz offset
2.5	–90	–91
5.0	–91	–93
10	–93	–95
20	–94	–98

Table 1. 800 MHz PLO phase noise versus reference frequency.

noted is that as the divider number is decreased by a factor of two, the phase-noise floor of the loop at the VCO output does not decrease by 6 dB. The measured noise, referred to the phase detector comparison frequency, is plotted in Figure 3. This noise has about a 4 to 5 dB/octave slope (as a function of reference frequency). This noise would be independent of reference frequency if the phase detector were ideal.

Implementing a Phase/Frequency Detector and Counters on a Single PLD

The above data show that a phase/frequency detector can be implemented in a CMOS PLD. The next step in this design was to implement the two counters and the phase detector in a single PLD. The design was implemented in a 24-pin part that can be programmed to contain as many as 16 flip-flops. The part used in the development of this loop was an Intel D85C060-10, which is specified with a clock-to-output delay of 6.5 nsec and an input-to-output delay of 10 nsec [3]. Unlike the 16V8 type of part, this PLD is UV-erasable.

The sine wave to CMOS converter on the reference input and the ECL to CMOS converter between the divide-by-twenty and the PLD were also implemented on the chip to save parts and to minimize the area of the PCB. These converters were implemented using both inverting gates and non-inverting gates. As shown in Figure 4, the outputs of the inverting gates were fed-back to the inputs through a RC network. This provides DC bias so that the gates function as linear amplifiers. This implementation is used when the output signal swing matches the logic level requirements of the input signal.

More Phase Noise Measurements

The counter outputs were again con-

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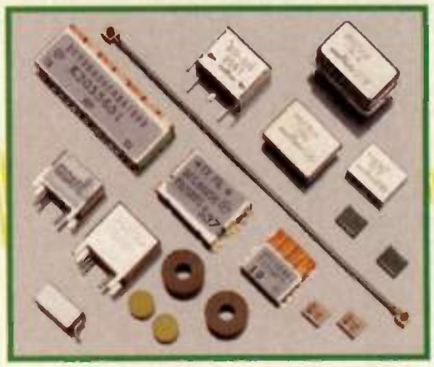

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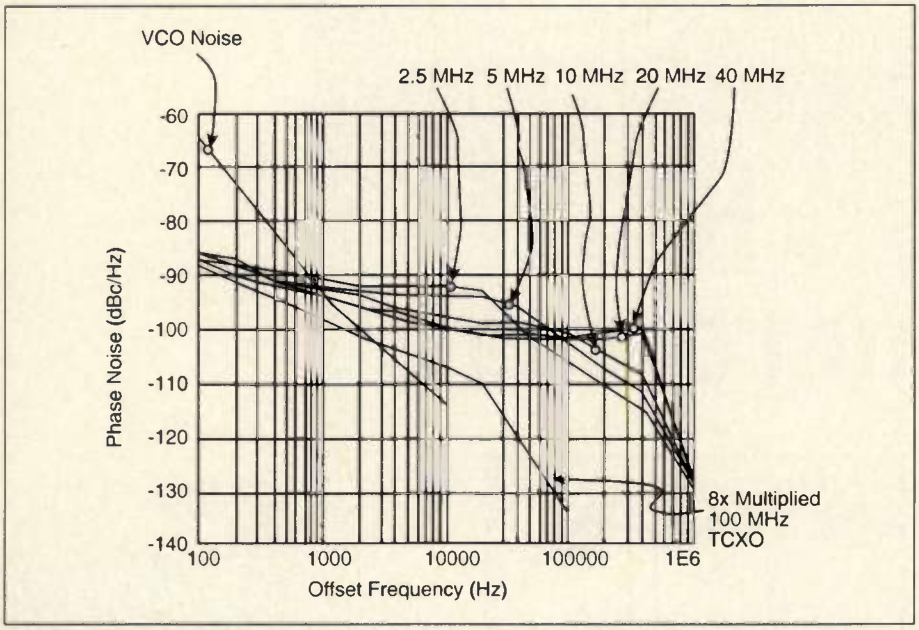


Figure 5. Phase noise of the 800 MHz PLO with phase/frequency detector and counters implemented on one PLD. Noise for each reference frequency is shown, as well as phase noise of the un-locked VCO.

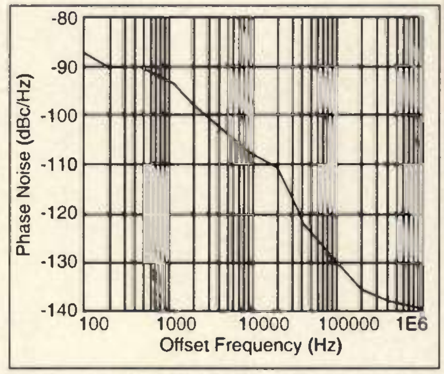


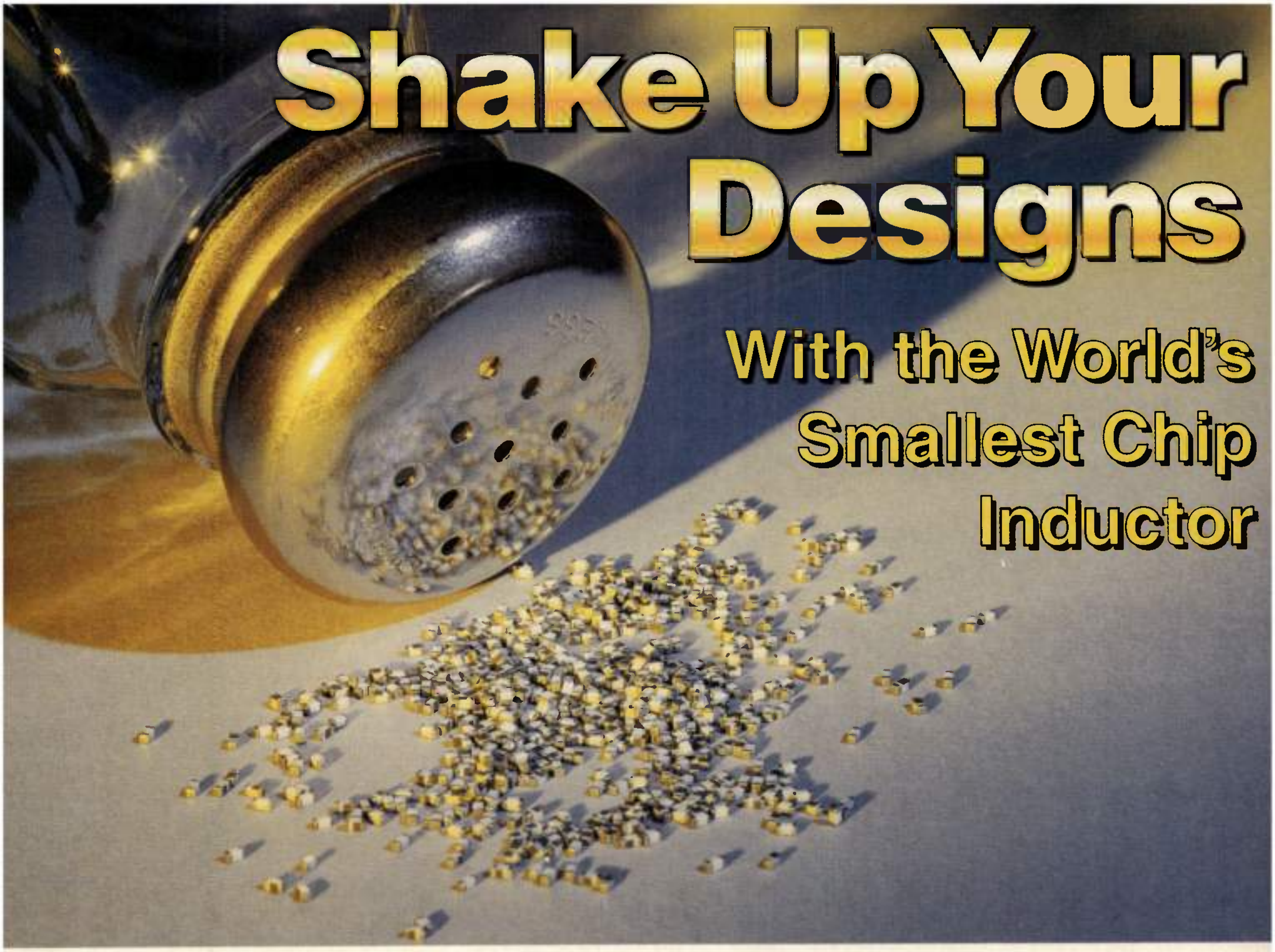
Figure 6. Optimized phase noise of the 800 MHz PLO.

nected in sequence to the phase detector and the phase noise of the loop was re-measured. This phase-noise data is summarized in Table 2. This data is also plotted in Figure 5. Again, note that the phase noise does not decrease at the 6 dB rate originally expected. Additional data were also taken at the 40 MHz reference frequency as well as all of the earlier reference frequencies. (The noise of the 800 MHz VCO used in this loop is also plotted in Figure 5 as is the noise of a multiplied (×8) 100 MHz TCXO. All of the phase noise data in this article was measured on an HP 8568A spectrum analyzer).

The current that the PLD required varied little with the phase detector operating frequency, and was measured to be 87.5 mA at 5 V (at a 2.5 MHz operating frequency) and increased to 89.4 mA at a 40 MHz operating frequency. Some additional power could probably be saved by turning off all of the unused counter outputs, but I could not get the software to disable these outputs. Table 2 lists the PLO's phase noise performance as a function of reference frequency.

The data at 1 kHz and 10 kHz offsets are restated in Table 3 to provide a noise floor at the reference frequency of the loop. I have also included data from a different phase-locked oscillator that used the same type of PLD but was constructed with either a 1 MHz or 2 MHz reference frequency. This data shows that the noise floor of the loop again varies as a function of the reference frequency and is not independent of the operating frequency of the phase detector.

The loop was again swept to see if there were any significant interactions between the frequency dividers and



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Offset	Reference Frequency at the Phase Detector				
Freq.	2.5 MHz	5 MHz	10 MHz	20 MHz	40 MHz
100 Hz	87	86	86	87	87
200 Hz	88	87	88	88	90
400 Hz	89	91	91	91	92
1 kHz	91	92	93	94	94
2 kHz	92	93	94	96	96
4 kHz	92	94	96	98	97
10 kHz	92	94	98	100	100
20 kHz	93	94	99	101	101
40 kHz	100	96	99	101	102
100 kHz	106	102	101	102	102
200 kHz	111	108	105	102	101
400 kHz	115	112	109	101	100
1 MHz	130	129	130	128	129

Table 2. 800 MHz PLO phase noise as a function of reference frequency, counter and phase detector circuit implementation.

Reference Frequency	Phase Noise (dBc/Hz) referred to the Phase Detector Frequency	
	1 kHz offset	10 kHz offset
1 MHz	148	149
2 MHz	144	147
2.5 MHz	141	142
5 MHz	136	138
10 MHz	131	136
20 MHz	126	132
40 MHz	120	126

Table 3. 800 MHz PLO phase noise as a function of phase detector frequency. Data referred to the phase detector frequency.

phase detectors that could affect the loop bandwidths. I found no significant interactions.

The above data was used to optimize the phase noise of the loop using the methods outlined in reference 4. The final reference frequency was chosen to be 10 MHz and the loop bandwidth was picked to be 1 kHz, which was then used to choose the RC components in the loop integrator. The phase noise of this loop was measured and is plotted in Figure 6. The noise data for frequencies greater than 10 kHz is probably the phase noise of the 8568A spectrum analyzer. The 10 MHz spurious sidebands were measured to be < 80 dBc and appear to be due to the PCB layout or power supply coupling rather than the tune path through the loop.

Final Implementation

The low overall noise of the PLO allowed the block diagram shown in Figure 1 to be simplified by taking the 40 MHz output signal from the output of the divide-by-20 circuit. This eliminated the expense of the 10 MHz x4 multiplier and filter circuits, reduced the size of the PCB, and reduced the parts-cost of the circuit. The final phase-lock circuits consist of a 24-pin SOIC PLD, an 8-pin SOIC divide-by-20 and an 8-pin SOIC operational amplifier. *RF*

References

1. Motorola 4044 Phase/Frequency Detector Data Sheet, Motorola MECL Databook, DL122/D Rev. 5, pp. 6-14 to 6-37.

2. GAL 16V8B-7 Data Sheet, Lattice 1992 GAL Data Book, pp. 2-1 to 2-24.

3. Intel 85C060-10 Data Sheet, Intel 1993 Programmable Logic Data Book, pp. 2-31 to 2-49.

4. L. Martin, "Program Optimizes PLL Phase-Noise Performance", *Microwaves & RF*, April 1992, pp. 78 to 91.

About the Author

Larry Martin is a consultant working with a variety of analog, digital and RF circuits such as frequecy synthesizers and phase locked loops. He has a BSEE from Kansas State University and a MSEE from Stanford. His mailing address is P.O. Box 997, Sebastopol, CA 95473-0997 and he can be reached by telephone at (707) 829-0633, or by e-mail at larrym@wco.com.

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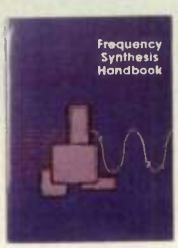

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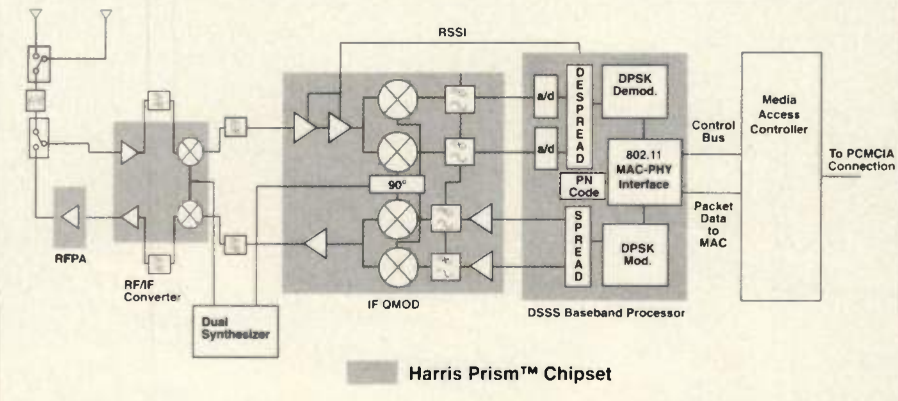

Prism (™) consists of 1.) 2.4 Ghz RF/IF Converter, 2.) 2.46GHz RFPA, 3.) IF/QMOD, 4.) DSSS Baseband Processor

Figure 1. Wireless data transceiver schematic diagram, showing the functions performed by Harris Semiconductor's PRISM chipset.

Spread-Spectrum Modulation Schemes

Both frequency-hopping (FH) and direct-sequence (DS) spread-spectrum modulation techniques will be used in the 2.4 GHz ISM band. FH transmitters change frequency pseudorandomly. A typical FH system consists of a transmitter with an FSK data modulator, followed by a synthesizer that centers the narrow-band FSK waveform on the various frequency channels. The synthesizer is driven by a PN code generator. An FH receiver includes a synthesizer PN code generator and an FSK demodulator. Transmitter and receiver share a common time-synchronized PN code. Narrowband noise only affects the system during dwell time at that frequency.

Multiple FH systems can operate simultaneously over the same total bandwidth if they all use hopping sequences that guarantee few frequency collisions.

In contrast to FH systems, DS systems spread their energy by rapidly changing phase, so that the signal is continuous only for very brief time intervals, called chips. These chips are several times shorter than the actual data bits. In DS, the second modulation is usually phase modulation. If the bandwidth of the spreading signal is large relative to the data bandwidth, the spread-spectrum transmission bandwidth is dominated by the spreading signal and is nearly independent of the data signal. Therefore, the energy of the DS system is not confined within the data bandwidth of the original PSK narrowband signal, but is distributed over the spreading bandwidth defined by the chips. In most cases this spreading causes the DS waveform to be near or below the noise floor.

DS has potential operational benefits compared to FH. For example, due to its low power spectral density (PSD), DS can operate at, or even below, the noise floor of a given environment. One implication of this is that DS waveforms are not necessarily disruptive to other communications on the same frequencies, regardless of whether they are broadband or narrowband.

Also, in DS, the received signal-to-noise ratio (SNR), which is a function of the ratio between the data rate and the chip rate, can be negative. The higher the chip rate with respect to the data rate, the lower the signal level and the more negative the spread-signal's SNR. This ratio of the two rates is referred as the processing gain (PG). PG means a DS receiver can still recover a signal even when

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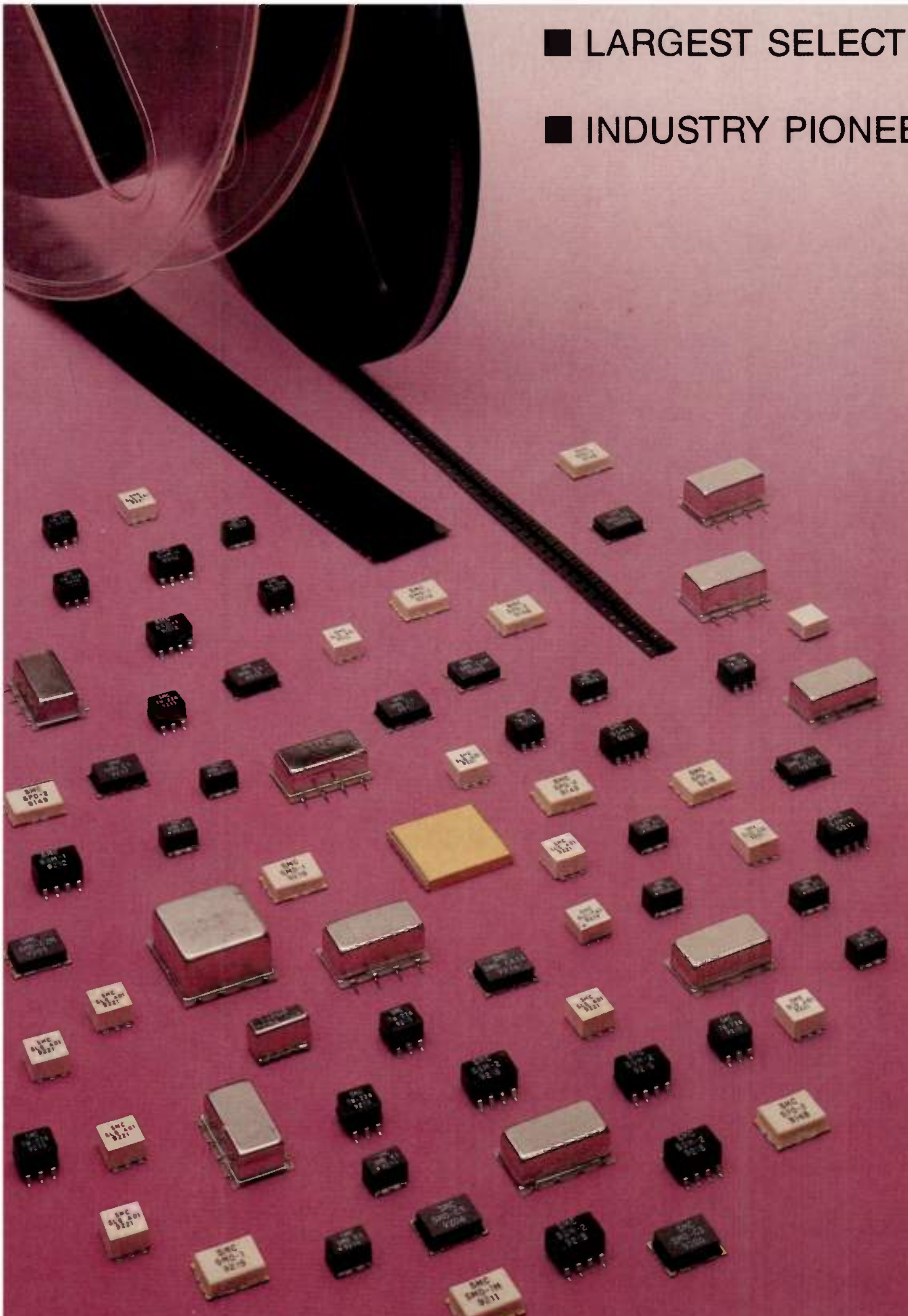

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Americas 1-800-366-2266 • Europe/Middle East/Africa 44 (1344) 869 595 • Asia/Pacific 81 (03) 3226-1671 the interfering signal has a higher SNR than the spread waveform. Not only is the signal of interest amplified, every signal that does not correlate with the spreading code is attenuated.

Another implication of this is that multiple DS systems can operate simultaneously over the same bandwidth if each transmitter uses a different spreading code. The characteristics of the spreading code are critical because the network code set must exhibit low cross-correlation characteristics among its individual codes. For the sake of interoperability, in the IEEE 802.11 DS system, only one 11-bit spreading code is used.

To successfully de-spread the received signal, the receiver not only needs to use the identical PN code, but also phase-align it with the incoming received code. Autocorrelation measures the degree of similarity of the signal with its phase-shifted replica over all phases. A PN replica is multiplied with the incoming waveform and the result is integrated to obtain the correlator output. The reference is shifted in phase until the output of the integrator peaks.

One way to implement code synchronization is by using a state machine as a matched filter. This implementation is similar to a digital FIR filter in which the coefficient filter taps are PN code reference (replica) inputs. The impulse response of the match filter is a time-reversed replica of the desired signal. Match filters are generally practical for short codes, such as those used in IEEE 802.11 and PRISM. As PN codes grow in length, match filter implementations become less cost effective.

Practical Direct-Sequence Spread Spectrum

Until recently, the direct-sequence approach to spread-spectrum systems has primarily been used in sophisticated, custom and costly military applications. Consequently, there have not been any standard off-the-shelf solutions for commercial use. Systems designers were put off by the lack of ICs specifically designed to support DS. Even if they elected to create systems based on standard parts and ASICs, they faced the problems of high parts count and incompatibility of signal and threshold levels. As a consequence, most proposals and actual implementations for ISM-band digital radios have been frequency hopping.

Now, all-silicon PRISM integrates DS functionality from 2.4 GHz to baseband in four PCMCIA Type-II-compatible packaged ICs that support data rates from 256 kbps to as high as 4 Mbps. With overall system level performance objectives in mind, such elements as impedance matching, signal and threshold level compatibility, gain distribution and associated performance and cost trade-offs have been optimized for each IC.

General Architecture for Wireless Data Transceiver at 2.4 GHz

PRISM provides the functionality depicted in the shaded blocks in Figure 1. The silicon RF/IF converter operates at carrier frequencies of 2.4 to 2.5 GHz, supporting receive-signal low noise amplification and frequency down-conversion. In transmit mode, it handles up-conversion and signal pre-amplification.

The IF/QMOD IC incorporates broadband, high-gain limiting, demodulation, modulation, and all I & Q baseband filtering functions necessary to support half duplex phase shift modulations including differential BPSK and QPSK signaling.

Interfacing directly with the IF/QMOD, the baseband processor IC integrates A/D conversion functions, spreading/de-spreading, and other necessary DSP. It supports PN codes up to 16 bits long. It also incorporates a flexible interface to a Media Access Control (MAC) chip. This interface was engineered to connect directly to the IEEE 802.11 media access controller (MAC) IC recently announced by Advanced Micro Devices, and is easily adaptable to other MAC chips.

The fourth PRISM chip, a silicon 2.4-GHz RF power amplifier, supplies the linear amplification required to meet FCC Part 15 spectral mask characteristics for the 2.4 GHz ISM band.

The four devices form the basis of a complete DSSS reference design package including antenna-to-MAC schematic, component identification, and detailed application note, to be available in January, 1996. PRISM operates with a single 2.7 to 5 V supply and provides power management, including support for a sleep mode.

Single conversion minimizes the number of IF filters and local oscillators. The transition between analog and digital was carefully chosen to exploit the advantages of DSP, while avoiding the high supply current penalty commonly associated with high-speed A/D conversion.

Based on this architecture, a highly integrated IF signal processing IC with over 400 MHz bandwidth and 84 dB of conversion gain was designed. Such a wide IF bandwidth makes a high IF center frequency possible, which in turn allows image suppression with economical two- or three-pole front-end filters. Front-end gain is sufficient to accommodate moderate SAW IF filter losses.

PRISM is able to use limiting IF amplifiers because of its short PN codes and resulting modest processing gain. With DBPSK or DQPSK signaling, and codes of 16 bits or less, the required signal-to-noise ratio at the limiter inputs is positive. In consequence, limiting IF systems actually perform slightly better than AGC IF systems in benign environments. Even when multipath or interfering signals are present, limiting-IF system performance is only slightly less than an AGC IF.

The use of limiting IF amplifiers lowers system cost because they are not as complex as AGC amplifiers. Also, AGC feedback loops for CSMA systems are difficult to close when fast (less than 1 μs) response is required. Challenges arise because of the conflict between fast acquisition to packet preambles and the need for feedback loop stability.

Using low cost DSP techniques in the baseband processor maximizes overall system performance. For example, the second LO, used to provide quadrature demodulation in the receive path, is not part of a carrier-recovery loop. Instead, a proprietary PSK demodulator achieves performance levels close to those of a complex coherent system, without the burden of an external loop. The required simple fixed-frequency LO is easily implemented.

Other DSP techniques that improve system performance include the despreading and demodulation scheme, which is optimized to exploit the impact of limiting IF amplifiers. This results in improved receiver sensitivity at a given bit-error rate (BER). Another special DSP technique is leveling, providing full utilization of the internal A/D converter dynamic range.

Transceiver Operation

Dual antennas can be used to combat the effects of delay spread (multipath). Delay spread is a general problem in mobile applications, and in environments where there are many reflective surfaces, such as factory floors and modern office buildings. With PRISM, dual antennas may be utilized at both ends of the link, or only at one. In small form-factor applications, such as PCMCIA Type-II WLAN cards, systems could use a single antenna on the PCMCIA card and antenna diversity at the access point or base station.

In designs that take advantage of antenna diversity, a low loss diversity switch follows the antennas. Antenna selection is completely automated by the baseband processor and takes place during the preamble of each packet.

A bandpass filter is next in the signal-processing chain. Its passband covers the entire 2.4 GHz ISM band. This should be a high-quality, three-pole dielectric filter, because a high-performance filter at this point allows lower cost filters to be used downstream. The filter provides receive image suppression and rejects strong out-of-band signals. During transmit, this same filter provides harmonic attenuation and suppression of the first LO.

The T/R duplex switch should have a low insertion loss (–1 dB), low noise Figure (1 dB), and good isolation (20 dB).

PRISM RF/IF Converter

The highly integrated RF/IF converter IC incorporates on-chip spiral inductors and interdigitated MOS capacitors to provide internal matching on all high frequency ports (50-ohm), as well as higher impedances for the IF ports, thus supporting simple connection to IF filters. No large, costly, IF baluns are required. One LO input is required, with internal connections between the transmit and receive mixers. The IF passbands extend well beyond 400 MHz.

In the receive path, a two-stage LNA establishes the receiver noise figure. An optional external image rejection filter (between the LNA and mixer) can enhance overall system sensitivity. This filter can be a simple two-pole monolithic LC filter with up to 3 dB insertion loss. The single-balanced receive mixer is optimized for high conversion gain, low noise figure, and high third-order intercept. The IF output is a differential signal derived from two open-collector outputs, a structure that supports high-gain IF impedance-matching networks. As an option, just one of the outputs can be used with an LC network, for a lower-cost interface to the SAW filter on the output.

In the transmit path, the RF/IF converter uses a double-balanced up-conversion mixer to minimize the amount of LO leakage in the transmit output. The chip allows use of an external sideband-selection filter, with characteristics similar to those in the receive image-reject filter. An on-chip two-stage exciter amplifier eases RF power amplifier gain requirements.

IEEE 802.11 Standard

The PRISM chip set supports the emerging standard of the IEEE 802.11 (Global) Wireless Local Area Network subcommittee. The committee was formed to develop standards that allow interoperability of spread-spectrum wireless products on the U.S. 2.4 GHz ISM band. (The committee also addresses infrared wireless LAN standards.) A final, approved standard is expected in the first quarter of 1996.

Listed below are the specifications targeted for the 802.11 direct-sequence physical layer:

Modulation type:
DBPSK 1 Mbps (Preamble-PHY header)
DQPSK 2 Mbps (Preamble- PHY header and MAC packet data

PN spreading code: 11-bit Barker sequence

Processing gain: 10 dB

Data scrambler: Polynomial $1 + x^{-4} + x^{-7}$

Frequency band: 2.4 GHz to 2.4835 GHz

Transmit power-on and power-down ramp time: 2.0 µs.

Receiver minimum input level sensitivity:
–80 dBm for a 8×10^{-3} FER, for a packet length of 1024 bytes

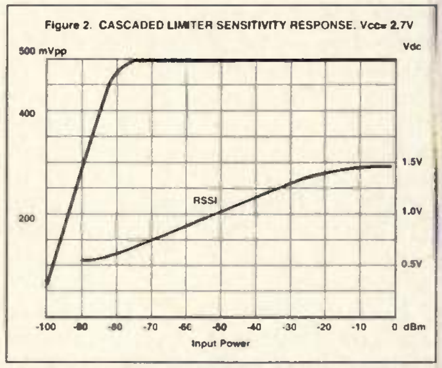

Figure 2. Cascaded limiter sensitivity response; V_{cc} = 2.7 V.

IF Filtering

Both the receive and transmit IF paths use IF filtering. A highly selective SAW filter provides receiver selectivity. At the recommended 280 MHz IF, and an 11 Mcps chipping rate, the filter bandwidth should be approximately 17 MHz. Insertion loss should be less than 15 dB, and group delay should be less than 100 ns.

In the transmit path, the selectivity of the transmit filter is not as critical, as only harmonic outputs of the IF/QMOD need to be removed. Therefore, a simple two-pole LC transmit filter may be used.

Frequency Synthesis

In both transmit and receive a dual-frequency synthesizer provides the LO signal for both the RF/IF Converter and the phase splitters in the IF/QMOD IC. By maintaining identical IF frequencies in both transmit and receive paths, there is no frequency switching and therefore no settling time requirements. This enhances transmit/receive turn-around time, a key issue in CSMA data applications.

PRISM RF Power Amplifier

The all-silicon linear RF power amplifier matches 50-ohm characteristic impedances and provides 20 dB variable gain control and a 23 dBm or 200 mW 1 dB compression output power level. To limit spectral regrowth (sidelobe energy growth), the amplifier operates 3 dB below the 1 dB compression point, that is, at 20 dBm. As a result, and assuming 4 dB insertion loss for the antenna diversity scheme, +16 dBm of linear 2.4 GHz transmit power is available at the antenna.

PRISM IF/QMOD

In the IF/QMOD IC, a two-stage

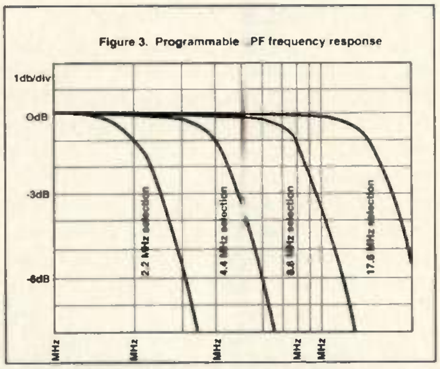

Figure 3. Programmable LPF frequency response.

limiting amplifier in the receive path provides sufficient gain and bandwidth to exhibit a −84 dBm −3 dB limiting sensitivity at frequencies up to 400 MHz. The limited output is typically 200 mV, and is compensated over temperature. An internal RSSI (Received Signal Strength Indicator) provides linear (±3 dB) RSSI coverage over a 70 dB (minimum) dynamic range. Internal RSSI load resistors support temperature-compensated performance. The RSSI signal is routed to the internal 6-bit RSSI A/D converter on the baseband processor, where it is used for Clear Channel Assessment (CCA). Figure 2 illustrates the cascaded limiter sensitivity and RSSI performance over various input power levels.

Following limiting, the IF signal (up to 400 MHz) is routed to a quadrature demodulator featuring an internal, quadrature LO network that achieves accurate phase performance (±2 degrees) over a of 10 to 400 MHz bandwidth. The digital divide-by-two topology that achieves this performance requires the applied LO to be twice the IF frequency.

Proprietary feedback circuits maintain phase accuracy over a wide range of LO input levels (to −20 dBm) and duty cycles. With a 1 kohm differential input impedance, the demodulator input compression point exceeds 1 Vp-p, making it suitable for use with the limiter output or with any external AGC, should system designers wish to bypass the on-board limiters. The I/Q baseband signals exhibit ±2 degree phase balance and ±0.25 dB amplitude balance.

The quadrature modulator utilizes the same quadrature LO network and provides an accurate IF output from 10 to 400 MHz. As a result of the excellent phase and amplitude balance (identical to the receive performance), sideband suppression in SSB operating mode is typically 40 dB.

The IF/QMOD IC also provides programmable baseband I/Q lowpass filtering. Dual fifth-order Butterworth filters are internally multiplexed between the transmit and receive channels. These filters offer four digitally-selectable cutoffs: 2.2, 4.4, 8.8, and 17.6 MHz. These cutoffs correspond to DSSS chip rates of 2.75, 5.5, 11, and 22 Mcps. In addition, the filters may be tuned ±20 percent above or below the fixed cutoffs by an external resistor. Figure 3 shows the filter response for the four filter selections.

RECEIVER		TRANSMITTER	
Frequency range:	2.4 - 2.4835 GHz	Frequency range:	2.4 - 2.4835 GHz
Step size:	1 MHz	Step size:	1 MHz
Noise figure:	10 dB	Output power:	+16 dBm
Sensitivity:	< −87 dBm @ 10^{-5} BER	Spurious outputs:	ISM
Input intercept:	−15 dBm	IF frequency:	280 MHz
IF frequency:	280 MHz	TX/RX switching speed:	< 1 µs
IF bandwidth:	17 MHz	Supply voltage:	2.7 to 5.5 V
RX/TX switching speed:	< 1 µs	Supply current:	400 mA, 100% duty cycle
Supply voltage:	2.7 to 5.5 V		
Supply current:	150 mA		

Table 1. System specifications for the reference design using the PRISM set.

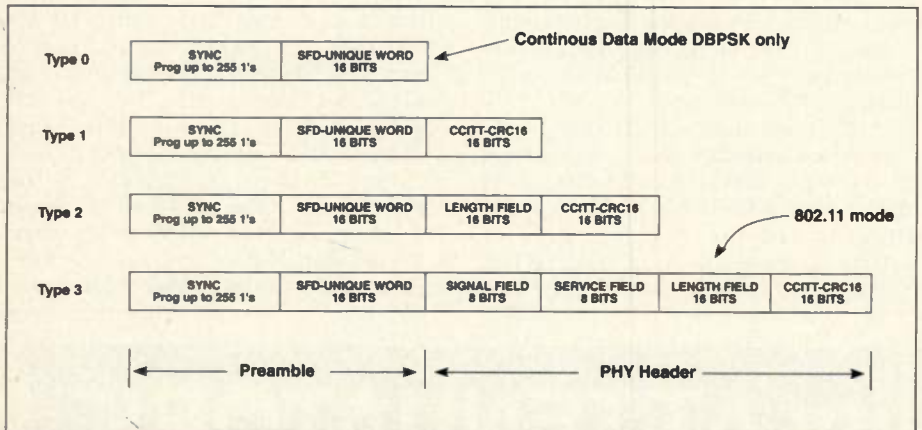

Figure 4. Preamble and PHY — Header configuration.

The filter response was selected to meet FCC transmit spectral mask requirements. Specifically, the first sidelobe attenuation of the transmitted, spread DBPSK and DQPSK signal is typically −35 dBc relative to the peak sin(x)/x signal.

The relationship between data rate, symbol rate, chip rate and filter bandwidth selection is best illustrated with the following examples :

Example A:
Data rate = 2 Mbps QPSK
Symbol rate = 1 Msps
Chip rate = 11 Mcps (using 11-bit Barker Code)

To meet a spectral reshaping of 35 dBc from main lobe to side lobe, the ratio of the fifth-order Butterworth 3 dB cutoff frequency to the chip rate must be 0.80. Therefore the filter bandwidth should be 8.8 MHz.

Example B:
Data rate = 280 kbps QPSK
Symbol rate = 140 ksps
Chip rate = 2.75 Mcps (using 16 bit PN code)

In this case, using the same approach, the filter bandwidth should be 2.2 MHz.

In the receive path, the filter functions as an anti-aliasing baseband filter. Buy using the external resistor adjustment, systems designers can trade transmitted spectral mask performance for received ISI (Inter-Symbol Interference) performance.

In receive mode, the demodulated, filtered I and Q signals (up to 500 mV_{p-p}) are routed to the baseband processor IC. In transmit mode, the digital I and Q signals from the baseband processor feed to the IF/QMOD IC. To avoid spectral regrowth, once the transmit single-bit inputs are filtered by the fifth-order Butterworths, the rest of the transmit chain must operate linearly. In other words, all further transmit elements must be operated well below their 1 dB compression points. Despite this characteristic of BPSK and QPSK modulation, the improved receiver performance over simpler non-coherent modulations such as GFSK results in an overall system performance advantage, especially at high data rates.

PRISM Baseband Processor

In the baseband processor, the analog I and Q signal outputs from the low-pass filters are digitized by 3-bit A/D converters at 22 Msps, twice the chip rate. An AGC control signal is available for designs that use an AGC amplifier in the IF strip.

The quantized I and Q baseband paths are correlated against a reference PN code, using separate matched filter correlators. The reference PN is programmable from 11 to 16 chips.

The correlators de-spread information of interest back to its original data rate and spreads interfering signals and noise. To demonstrate processing gain to meet the requirements of FCC Part 15.247, the baseband processor IC allows spreading to be disabled and the magnitude monitored via an 8-bit test port .

After the digitized I and Q signals are converted to polar form, the phase information is processed by the DPSK demodulator, which supports both DBPSK and DQPSK. In IEEE 802.11 packet protocols, DBPSK is used for preamble and physical layer packet header information, and DQPSK is used for data packets. Signal acquisition is performed using DBPSK. Otherwise, selection of either modulation scheme is determined by the signaling field in the header. A digital phase locked carrier tracking loop allows coherent QPSK data processing.

Once signal acquisition is achieved, symbols are processed through a self-synchronizing de-scrambler, which is pre-programmed with the same polynomial used at the transmitter. Under IEEE 802.11, the DS physical layer uses the polynomial: $1 + x^{-4} + x^{-7}$. Data bits are processed by the PHY header-detection state machine, where each of the fields in the header is processed in real time and checked for transmitted CRC errors. The PHY header-detection state machine is programmable, supporting the four PHY header formats in Figure 4.

Flexible MAC-PHY Interface

A bi-directional high-speed serial interface between the baseband processor and the MAC layer (Figure 5) handles data packet information, and a serial control port is used for configuring and reading the status of the baseband processor's 57 internal registers. The PHY header can be generated from either the internal registers or from the MAC.

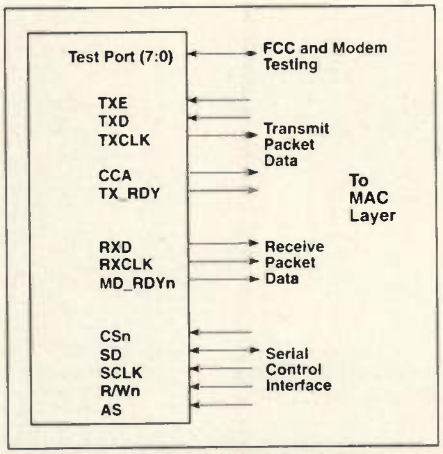

Figure 5. Interface between the baseband processor and the MAC layer.

Transmitting packetized data is initiated by the MAC. Using IEEE 802.11's CSMA/CA transmit protocol, the medium is monitored prior to data transmission to minimize data collisions. To accomplish this, the baseband processor monitors the RSSI output from the IF. Within the baseband processor, this RSSI signal is quantized with a 6-bit ADC and processed by the CCA state machine, which determines when RSSI has been below a certain threshold for a given time- out period. The CCA energy-detect and watchdog timers are programmable. The CCA can also be bypassed.

System Specifications

PRISM operates from single supplies from 2.7 to 5.5 V and are packaged in SSOP and TQFP packages compatible with PCMCIA Type-II form factor.

Use of PRISM within the DS reference design for a 2-Mbps application should results in the performance levels listed in Table 1.

This performance levels are suitable not only for IEEE 802.11 applications, but for other applications at data rates ranging from 256 kbps to 4 Mbps. The PRISM reference design should reduce system design time and development cost by more than 80 percent, and the resulting faster time-to-market will provide OEMs with the benefits of early market penetration and associated early revenue.

For more information on the PRISM chip set, contact Harris Semiconductor at 1-800-4-HARRIS (1-800-442-7747), ext. 7354, or circle Info/Card # 250. *RF*

About the Authors

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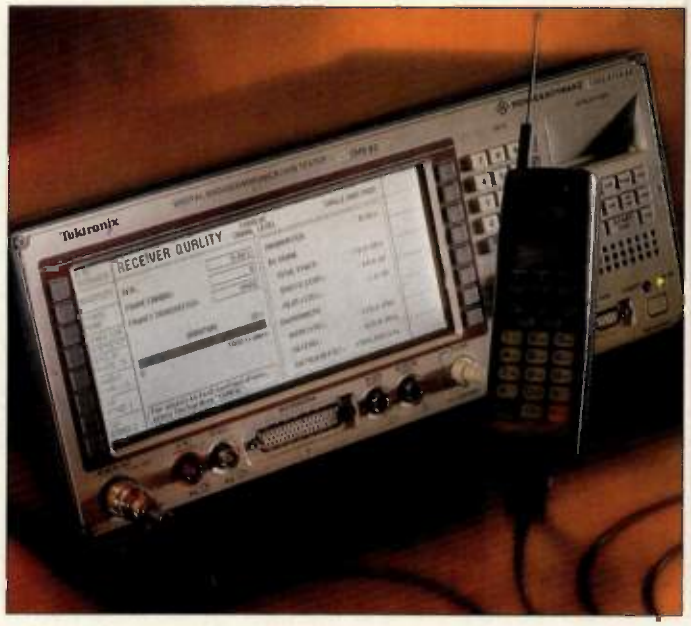
R. Douglas Schultz received his BSEE from Penn State University in 1981. He founded Integrated RF Solutions in 1994 and specializes in commercial radio development and custom integrated circuit design.

CDMA Test Set

Tektronix has introduced the CMD80 Digital Communications Test Set, the world's first stand-alone test set to establish and sustain Code Division Multiple Access (CDMA) calls. The CMD80 is designed to provide comprehensive manufacturing and field-service testing of digital cellular and Personal communications Services (PCS) mobile phone using CDMA technology. Development of the CMD80 is the first joint engineering effort between Tektronix and Rhode & Schwarz. The CMD80 essential acts as a base station in a box. It supports receiver quality measurements, including FER (frame error rate), frame errors and frames transmitted. It also performs transmitter quality measurements such as Rho (ρ); error vector; Tx magnitude; frequency and phase error; Tx origin offset; and carrier feedthrough. The CMD80 also features power control measurements, including open-loop timing and gated power, and hand-offs, such as analog hand-off for dual-mode testing. The test set utilizes a Qualcomm CDMA chip set, and conforms with TIA IS95 and IS98 performance qualifications, with measurement coverage for 800 MHz cellular frequencies. The CMD80 is available for immediate ordering and is U.S. priced starting at $48,000, with delivery four weeks from receipt of order.

Tektronix
INFO/CARD #250



695 to 810 MHz VCO

Z-Communications has introduced the V504MC02 miniature surface mount VCO for basestations and applications operating in the 695 to 810 MHz region. The 115 MHz bandwidth is tuned with a 1 to 11 volt control voltage; average gain for the V504MC02 is 15 MHz/V. Typical phase noise performance is –100 dBc/Hz at 10 kHz offset from the carrier. The VCO

delivers 13 ±2 dBm into a 50 ohm load when powered by a 12 VDC supply voltage. Current draw is less than 35 mA over the operating temperature range of 0 to 70 °C. The VCO exhibits high linearity in the output frequency with respect to tuning voltage. The pushing figure for the V504MC02 is less than 2 MHz/V with a change in nominal supply voltage. The unit measures 0.50 × 0.50 × 0.20 inches and is IR reflowable.

Z-Communications, Inc.
INFO/CARD #249

MPEG 2 Transport Demultiplexer

The VES2020 is a digital video broadcast (DVB)-compliant MPEG 2 transport demultiplexer IC for set-top applications. The new device from VLSI Tech-

nology accepts MPEG 2 transport streams and packetized elementary streams (PES) of up to 60 Mbps, parsing the streams to frame them as MPEG 2 packets. The VES2020 supports up to 32 different packet IDs . The packets are then routed to either an MPEG 2 video decoder, MPEG audio decoder, or host microcontroller for downstream processing. An optional MPEG 2 reference platform is also available, which accepts MPEG 2 transport packets and outputs NTSC/PAL composite output. The VES2020 will sample in October, with production quantities available in early 1996. The device comes with firmware and will be available in either a 160- or 208-pin MQFP package. Prices in the U.S. will be $40 in 1,000 unit quantities.

VLSI Technology, Inc.
INFO/CARD #248

PCS-Band Power Divider

Anaren's model 4A1305 is an in-phase, two-way power divider operating from 1.75 to 2.3 GHz. The power divider has a minimum isolation of 16 dB, a maximum insertion loss of 0.35 dB and maximum VSWR of 1.38:1 (input) and 1.38:1 (output). Maximum amplitude imbalance is specified at 0.2 dB and 1.5 degrees, respectively. Maximum input power handling is 5 W average/CW (when terminated into a 1.2:1 VSWR). The surface mount package measures only 0.65 × 0.48 × 0.075 inches (l × w × h) and has edge plated channels for reliable soldering and

inspection. Prices range as low as $4.95 in large quantity orders and are available on tape and reel.

Anaren Microwave, Inc.
INFO/CARD #247

2-18 GHz, 50Ω-Matched Amp

Amplica has introduced a low-noise broadband microwave amplifier in the company's new 20 GHz, 50 ohm EZ-Pak® sur-

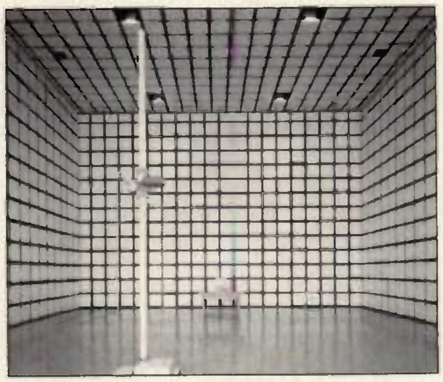
face mount package. The EZ-Pak architecture supports multi-stage topologies, with each stage soldered to the mother board. The amplifier provides 16 dB gain (nominal), with ±1.5 dB (maximum) gain flatness and a +10 dBm power output at 1 dB compression across the full 2 to 18 GHz bandwidth. The package measures just 0.63 × 0.40 × 0.12 inches. In Amplica's new EZ-Pak SMT package, the amplifier's 50 ohm input and output impedance is held to a VSWR of 2.5 to 1 across the entire 2 to 18 GHz band. Nominal power consumption for the device is 100 mA at 8 ±0.5 V. The new 2 - 18 GHz amplifiers are available at unit prices under $400 in quantity.

Amplica, Inc.
INFO/CARD #246

ANECHOIC CHAMBERS & ABSORBER MATERIALS

Standard Chambers

Lindgren RF Enclosures introduces five standard anechoic chamber configurations as part of their new FACTS (Free-Space Anechoic Chamber Test-site Systems) line.



Each of the five standard FACTS are designed to accomplish standard, internationally-recognized, electromagnetic compatibility testing. All FACTS are constructed from double steel laminated shielding modules which are de-mountable, allowing them to be moved and reconstructed with no loss in performance. FACTS chambers are available from smaller chambers for pre-compliance scanning, up to chambers that are FCC listable for full compliance testing at 10 m distances.

Lindgren RF Enclosures, Inc.
INFO/CARD #245

Low Profile Absorber

FerroSorb™, a low profile composite of high performance anechoic absorber and precision manufactured ferrite tile, has been successfully installed and tested by Rantec in a 3 m / 10 m EMC chamber at Compaq Computer Corp. in Houston, TX and at IBM in Research Triangle Park, NC. These chambers have been tested to both ANSI C63.4 emission and IEC 1000-4-3 immunity standards. Since it is dramatically smaller than the typical eight-foot absorber it replaces, outer chamber dimensions can be reduced by 25 percent and construction costs drop by up to 30 percent.

Rantec
INFO/CARD #244

SIGNAL SOURCES

Standard-Package TCXOs

MTI offers a complete line of TXCO products in 14-pin DIL packages. The 440-series, through-hole TCXOs are available at frequencies from 9.9 MHz to 40 MHz. The series' phase noise measures –65 dBc/Hz at 1 Hz offset and a noise floor of –150 dBc/Hz. The 440-series measure only 0.72 × 0.465 × 0.20 inches, with sinewave outputs to +7 dBm.

MTI - Milliren Technologies, Inc.
INFO/CARD #243

Comb Generator

EMF Model 96085 comb generator consists of a fundamental 200 MHz crystal controlled oscillator, amplifiers, and a step diode multiplier. The standard stability is ±5 ppm from 0 to +60 °C; options for wider temperature ranges, frequencies, and stabilities. Phase noise is 135 dBc at 1 kHz off-

set. A voltage-tuning option and a phase-locked option are also available, allowing the Model 96085 to be phase-locked to a system reference oscillator.

EMF Systems, Inc.
INFO/CARD #242

3.3 V, 110 MHz Oscillators

SaRonix has expanded its surface-mount, 3 volt oscillator product line with new ACMOS parts specified up to 110 MHz. The STA Type F series oscillators are available from 50 to 110 MHz and come in standard 10 × 13 mm SMT plastic packages. The S1703 series is intended for lowest-profile PCMCIA-applications, with a total height of 1.75mm. The series is available from 1.5 to 50 MHz. Both series are specified for both 3 and 3.3 V operation. In 100-piece quantities, prices for the series range from $4 to $5 for the NTH Type F series and $5 to $7 for the S1703 series.

SaRonix
INFO/CARD #241

AMPLIFIERS

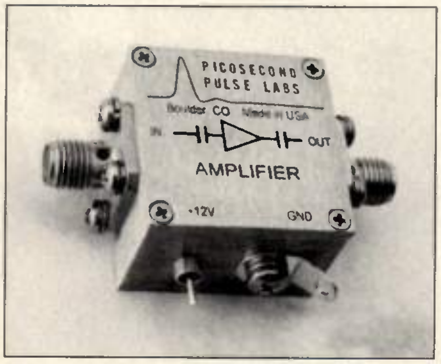
Bi-Directional Amplifiers

3dbm announces the availability of its RADCom (Redundant Amplifier For Distributed Communications) series of bi-directional amplifiers. The amplifiers are designed to with leaky-coax or distributed antenna systems. The series features "hot standby" in the forward direction, fanless cooling, local alarm displays, and small foot prints.

3dbm, Inc.
INFO/CARD #240

Broadband Amplifiers

The PSPL 5800A series of ultra broadband amplifiers are well suited for both pulse or RF applications. All are stable, 50



ohm amplifiers which can be cascaded for higher gain. Various models are available to allow the user to optimize risetime, bandwidth, noise figure, VSWR, or maximum power output. All are AC-coupled. The highest performance amplifier (the 5830) has 12 GHz bandwidth, 28 ps risetime and 12 dB gain.

Picosecond Pulse Labs, Inc.
INFO/CARD #239

Multi-Octave Class AB Amp

Model BHE88967-400 from Comtech Microwave is a class AB amplifier covering the 800 to 960 MHz frequency range with an output power of 400 W PEP. Typical gain is 60 dB, with IMD products of –28 dBc at full power output. Power requirements are +24 VDC at 28 amps. The amplifier measures 16 × 16 × 7 inches.

Comtech Microwave Products Corp.
Power Systems Technology Div.
INFO/CARD #238

500 - 2500 MHz, 18 dBm Amp

Mini-Circuits has introduced an amplifier covering 500 to 2500 MHz with typical output power of 18 dBm. The unconditionally stable ZFL-2500 typically has a 6.5 dB noise figure in the cellular band. The amplifier operates from +5 VDC, has typical gain of 31 dB (with typical flatness of ±1.0 dB), and maximum input/output VSWR of 2.5:1. The SMA-F connectorized ZFL-2500 sells for $99.95 in quantities less than 10.

Mini-Circuits
INFO/CARD #237

TEST EQUIPMENT

Arbitrary Waveform Generator

Racal Instruments has introduced a 100 MHz, C-sized, VXIbus arbitrary waveform generator. The 3151 ARB offers programmable output voltages, up to 1 ppm internal reference, external clock input, nine standards waveforms, multiple trigger modes, multiple-unit synchronization, and 50 MHz arbitrary waveforms. The Model 3151 is fully compliant with the latest revision of both the VXIbus and VX*Iplug&play* specifications. The 3151 starts at $3,500.

Racal Instruments, Inc.
INFO/CARD #236

Dielectric Measurement

The Damaskos Model 1000-T, two-port scalar coax fixture measures ε', ε'', and σ of dielectric materials from 1 to 1000 MHz. The fixture comes with a carrying case and a verification sample. Data reduction is performed by Damaskos' "SCALEPS" software.

Damaskos, Inc.
INFO/CARD #235

Signal Generators

The 2023 and 2024 signal generators from Marconi Instruments offer a wide range of fully-programmable modulation formats, GPIB and RS232 interfaces, and frequency coverage from 10 kHz to 1.2 GHz for the 2023, and 10 kHz to 2.4 GHz for the

2024. Phase noise is guaranteed at –121 dBc/Hz at 20 kHz offset from a center frequency of 470 MHz. Modulation formats include amplitude, frequency, phase and pulse. An internal programmable source has a frequency range of 0.01 Hz to 20 kHz. A VXI version of the 2024 is also available.

Marconi Instruments, Inc.
INFO/CARD #234

RF Antenna Measurement

A low-cost, fully automated, RF antenna test system form Hewlett-Packard measures, plots and analyzes antenna performance. The automated HP 85375 system can perform antenna pattern comparisons in about half the time of manual systems.

The system includes Windows-based software, and a network analyzer which can be used independently of the antenna measurement system. U.S. price for the HP 85375A is $65,000.
Hewlett-Packard Co.
INFO/CARD #233

SIGNAL PROCESSING COMPONENTS

Helical Filter

PTI's Model 8138 is a high Q filter having a center frequency of 1618 MHz, with less than 1.0 dB insertion loss. The minimum 3 dB bandwidth is 50 MHz. Rejection at 1410 MHz and 2070 MHz is 40 dB. VSWR is less than 1.3:1. Frequencies and bandwidths can be customized for other applications.
Piezo Technology, Inc.
INFO/CARD #232

Four-Pole Hopping Filters

New Four-Pole MAXI-POLE™ digitally-tuned hopping filters from Pole/Zero are well suited to co-site applications and other high-interference situations. Higher selectivity (as compared to their standard two-pole products) with wider passband is provided by the four-pole response. The line covers 1.5 to 1000 MHz. The tunable filter bands are 1.5 - 4, 4 - 10, 10 -30, 30 - 90, 90 - 200, 200 - 400, 400 - 700, and 700 - 1000 MHz. Typical insertion loss/bandwidth product is 18. Power handling capability is one W inband and 5 W in the stopband. Prices start at $1,650 for a single unit.
Pole/Zero Corp.
INFO/CARD #231

CDMA IF SAW Filter

Thomson Microsonics has developed an 85.38 MHz SAW filter, part number FB E528, in a hermetic SMT package. Compatible with code division multiple access

(CDMA) phone architectures, it has typical insertion loss of 15 dB and a 5 dB bandwidth > ±630 kHz. The part has excellent out-of-band rejection and no discernable triple transit. It is currently available in high volumes.
Thomson Components and Tubes Corporation
INFO/CARD #230

User-Configurable Lowpass Filters

The Shape Shifter Model SL55 is a user re-configurable lowpass filter with cut-off frequencies from 800 to 5500 MHz. The stepped-impedance tubular filter can be configured with up to 11 sections and has typical insertion loss of 1 dB at 5 GHz and 0.2 dB at 1 GHz. The specific parameters of the kit's hardware are embedded in the synthesis routines of the included design software, allowing for rapid design and construction of the lowpass filters. No soldering is required for re-configuration.
Gatewave
INFO/CARD #229

150 W Isolator

SMT announces an isolator covering the frequency range of 5.85 to 6.425 GHz with 150 W power handling capability. Minimum isolation is 23 dB, maximum insertion loss is 0.3 dB, and maximum VSWR is 1.15:1.
Sierra Microwave Technology
INFO/CARD #228

High Isolation Mixer

MITEQ's DMX0418 and DMY0418 series of mixers feature RF and LO operation from 4 to 18 GHz with an IF from DC to 4 GHz. These devices have conversion loss of 6 dB and 30 dB of IF to RF isolation at the RF/IF crossover (4 GHz). They perform as up- or downconverters covering most EW bands and communication applications. MITEQ offers a medium/high dynamic range option (-M, LO = +16 dBm) (-H, LO = +20 dBm).
MITEQ
INFO/CARD #227

SEMICONDUCTORS

Quadrature Modulator

Maxim Integrated Products introduces the MAX2452, a very low power quadrature modulator operating from a single supply of 3 V and drawing only 4.1 mA. A CMOS-compatible shutdown control lowers the supply current in the off state to only 2 µA typically. The MAX2452 comes with an integrated oscillator and divide-by-8 prescaler. The modulator accepts I and Q baseband signals with amplitudes up to 1.35 Vpp and bandwidths up to 15 Mhz. It produces a differential IF output as high as 80 MHz. The modulator is available in a 16-pin narrow SOIC; prices start at $3.23.
Maxim Integrated Products
INFO/CARD #226

Digital Wireless Receiver

Philips Semiconductors has announced the availability of its SA639 IF receiver. The SA639 features low power consumption - only 8.3 mA at 2.7 V minimum - and offers very high sensitivity. The part can be used with both single- and dual-conversion architectures with input frequencies as high as 1 GHz. The bandwidth of the IF amplifier is approximately 40 MHz, with 44 dB (V) gain from a 50-ohm source, and a limiter bandwidth of 28 MHz with about 58 dB (V) gain from a 50-ohm source. Output range is greater than 90 dB. The SA639 is available in a 24-lead TSSOP package. Price is $2.12 per unit in 25,000-piece quantities.
Philips Semiconductors
INFO/CARD #225

GaAs Power Amp IC

ITT GTC announces the availability of a high-gain RFIC power amplifier operating in the 898 - 942 MHz frequency band. The ITT334104BD is a two-stage amplifier with 27 dB power gain, and 1.2 W power output. Typical power added efficiency (PAE) of the device is greater than 55 percent and it is possible to attain PAE > 60 percent under selected operating conditions. The device can withstand 10:1 VSWR under CW condi-

tions and is stable with any combination of battery voltage, load VSWR and RF drive signal. The ITT334104BD is mounted in a standard 16-pin narrow SOIC plastic package. Production is slated for 4Q95 and the part is priced at less than $10.00 in quantities of 1,000.
ITT GTC
INFO/CARD #224

SS IC Evaluation Kit

American Microsystems offers an evaluation radio for their S20043 direct sequence spread spectrum transceiver IC. The S20043ERU will transmit or receive data messages in the 915 MHz ISM band at data rates of 2.4k, 100 k, and 400k bits per second. The S20043-radio is priced at $3,000 per unit, including license to use the radio design and complete Gerber files and schematics.
American Microsystems, Inc.
INFO/CARD #223

3.6 to 4.2 GHz Class A MESFETS

A new series of NEC power GaAs MESFETs is now available from California Eastern Laboratories. Designed for C-Band power applications, these NEZ3642 series Class A devices are internally

matched (in/out) and deliver high P_{out}, high efficiency, and high gain. Pout for the NEZ3642-15D is 42.5 dBm, 39.5 dBm for the -8D, and 36.5 dBm for the -4D. Linear gain is 10.0, 11.0, and 11.5 dB for the -15D, -8D, and -4D, respectively. Power added efficiency is 37, 40, and 43 percent for the -15D, 8D, and 4D.
California Eastern Laboratories
INFO/CARD #222

Power Amp ICs

Celeritek has announced a series of low-cost power amplifiers for PCS base station applications in the 900, 1,950, and 2,450 GHz frequencies. The CFK2162-P series is a family of high-gain FETs with +33 dBm power output and efficiency greater than 45 percent. The devices operate from a +5 V supply and offer high linearity at 2 W. The series is packaged in the standard SOIC-8 power package. Production quantities of 500 are available 30 - 45 days ARO and are priced at $29.00 per unit.
Celeritek
INFO/CARD #221

High-Speed Op Amp

A voltage-feedback amplifier with unity-gain bandwidth of 100 MHz and current consumption of only 2.5 mA is offered by National Semiconductor. The LM6171 has a slew rate of 3,600 V/µs and low distortion for both AC and DC. The op-amp operates from ±15 V power supplies for large output swings and greater dynamic rang and signal-to-noise ratio. A-grade versions of the LM6171AIM, in 8-pin SOIC packaging, and the LM6171AIN, in an 8-pin DIP package, are priced at $1.49 each in quantities of 1,000.
National Semiconductor
INFO/CARD #220

Low Forward Voltage Schottky Diode

A new family of low forward voltage Schottky barrier diodes from Toshiba America Electronic Components operate from one to three amps. Maximum forward voltage is 0.37 V, with a blocking voltage of 30 V. The family is geared toward battery-operated equipment requiring the lowest possible forward voltage drop. Part numbers U1FWJ44N, U2FWJ44N, and U3FWJ44N have operating currents of 1 A, 2 A, and 3 A, respectively. In 5000-piece quantities, the 1 A device sells for $0.30, the 2 A device for $0.41, and the 3 A device for $0.53.
Toshiba America
Electronic Components, Inc.
INFO/CARD #219

SUBSYSTEMS

30 - 2,000 MHz, VME Receiver

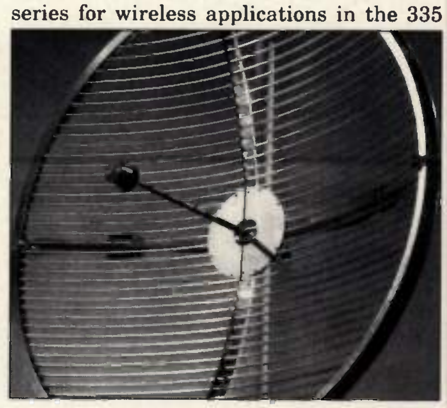
EDGE Industries has teamed with Inter-ad, Ltd. to create the Model 8901 VMEbus receiver. Packaged in a single 6U-wide VME card, various versions of this receiver are available to cover frequency bands within the 30 to 2,000 MHz range. The receivers have 1 Hz resolution and can switch frequency within 200 µs. Dynamic range is 80 dB, and both AM and FM detection are provided.
Edge Industries, Inc.
INFO/CARD #218

Noise Modules

Noise Com has enhanced its NC 500 series with the introduction of surface-mountable noise modules. The series delivers symmetrical white Gaussian noise and flat output power. The modules contain complete biasing networks and do not need external components. Modules covering 0.2 - 500 MHz, 0.2 - 1 GHz, and 0.2 MHz - 2 GHz are available. Output ENR is either 31 dB or 51 dB. Prices start at $49.
Noise Com, Inc.
INFO/CARD #217

335 - 2,500 MHz Antennas

Andrew Corp. announces the availability of its GRIDPAK® microwave antenna series for wireless applications in the 335



to 2,500 MHz frequency bands. GRIDPAK antennas feature a patented grid rod retaining design that securely locks the grid rods to the antenna's outer frame. The construction reduces windloading. They are available with air-dielectric feeds featuring 7/8-inch EIA flange input, or with foam dielectric feeds that require either a 7/8-inch EIA connector, a Type F female flange, or a Type N female input.
Andrew Corporation
INFO/CARD #216

70 MHz Dual-Channel ADC

Pentek has introduced a dual-channel, high-speed, 10-bit A/D converter board that operates at sampling rates up to 70 MHz for high-frequency bandwidth signal processing. Model 6472 is a single-slot 6U VMEbus board featuring both signal conditioning and clock generation circuitry. The converter provides front panel access to the receiver through a standard flat ribbon connector, rather than the VMEbus, conserving bus bandwidth and eliminating on-board memory buffering. Model 6472 is priced at $7,995.
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LRFMS-1L-SM15*	+3	2-500	DC-500	6.0	32	30	$ 4.95
LRFMS-1-SM6	+7	0.5-500	DC-500	6.0	32	30	$ 2.95
LRFMS-1A-13-SM6	+13	2-500	DC-500	6.0	44	36	$ 7.95
LRFMS-1A-17-SM6	+17	2-500	DC-500	7.0	44	35	$ 9.95
LRFMS-2L-SM6	+3	500-1000	DC-1000	5.6	30	20	$ 5.95
LRFMS-2-SM6	+7	5-1000	DC-1000	7.0	35	30	$ 3.95
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LRFMS-2-13-SM6	+13	5-1000	DC-1000	7.0	35	30	$ 8.95
LRFMS-2-17-SM6	+17	5-1000	DC-1000	8.0	28	30	$ 10.95
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INFO/CARD 46

Antenna Basics for Wireless Communications

By Gary A. Breed
Editor

Antennas are essential in order for radio communications to happen. Maybe your antenna is a common cellular antenna with a coil in the center, a loop printed around the edges of a pager's circuit board, or a multi-element directional array for a PCS base station. Each of these antennas has a job to do and a set of design parameters that can be quite restrictive. This tutorial describes some of the common wireless antennas, with notes on the environmental, cost, and size factors that influence their design.

Four basic antenna types are predominant in wireless communications: dipole, monopole, loop and patch. First, let's look at a brief summary of the primary characteristics of each antenna type:

The dipole antenna (Figure 1) — The dipole is the smallest self-resonant antenna structure, a conductor that is one-half wavelength long at the frequency of operation. The mechanical length of a dipole is always shorter than a half wavelength in free space, due to the effects of conductor size, dielectric constant of the surrounding medium, coupling to the antenna feedline or nearby objects, and "end effect" (a behavior associated with the abrupt change at the tips of the dipole conductor). A dipole usually has its feedpoint connection at the center, which has a nominal free-space resistance of 73 ohms for conductors with diameters that are small in terms of wavelength. This value can vary significantly with large conductors and with the effects of other conductors (including ground) within one or two wavelengths.

The monopole antenna (Figure 2) — A monopole is a dipole with half of its length replaced by an "image" created by an infinite (or very large) ground plane. The length of a resonant monopole is one-quarter wavelength, with the same factors that affect mechanical length as those noted above for a dipole. In the ideal case of an infinite, perfectly conducting ground plane, a monopole includes the "reflection" of the missing half of the corresponding dipole, and its radiation is in half-space (see note on terminology). Therefore, the feedpoint resistance is half that of a dipole, or about 36 ohms, and its theoretical radiated power density is twice as much as a dipole since the same driving power is now radiated into half the volume. These theoretical behaviors are essential for analysis, but in actual use, such ideal conditions may only be approached in the nearby environment. When considering performance at a significant distance, these conditions never exist.

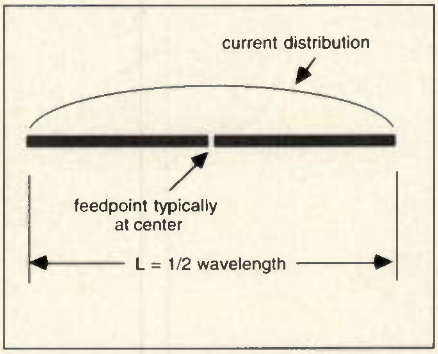

Figure 1. Configuration of a basic dipole antenna showing the normal feed point location at the center.

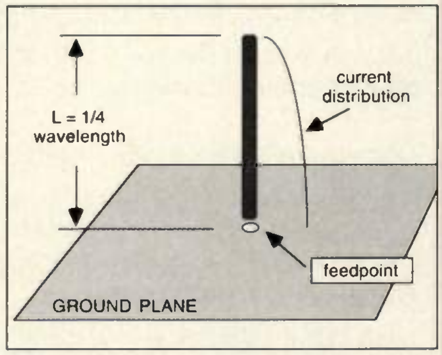

Figure 2. The monopole is half of a dipole, with a conducting ground plane representing the other half.

The loop antenna (Figure 3) — A closed loop is self-resonant when its circumference is one wavelength. For wireless communications, it is most useful to discuss small loops, since a one-wavelength loop will have the relatively large sizes of 34 cm circumference at 900 MHz and 204 cm circumference at 150 MHz. Small loops primarily create and respond to the magnetic field component of an RF signal.

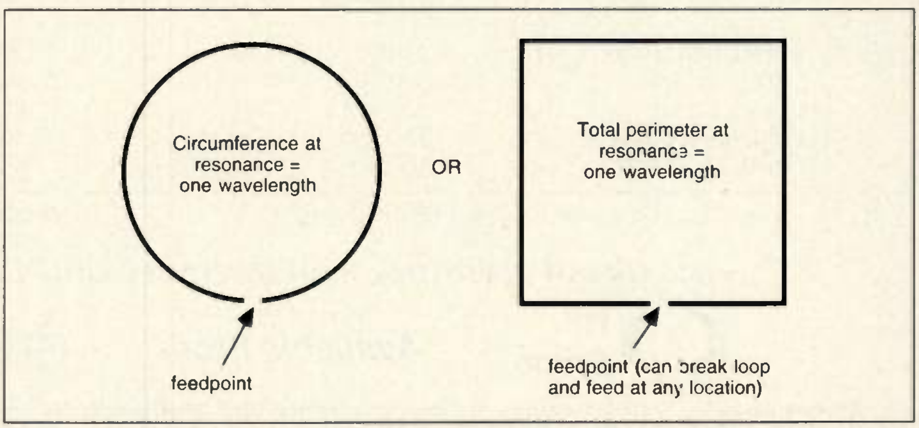

Figure 3. A loop configuration is resonant when the circumference or perimeter equals one wavelength, and its feedline can be attached at any location.

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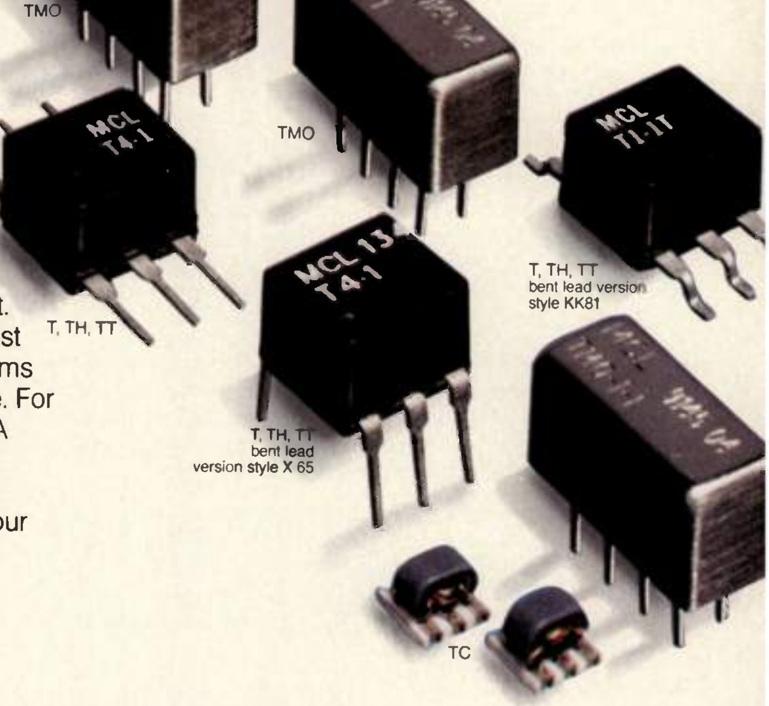

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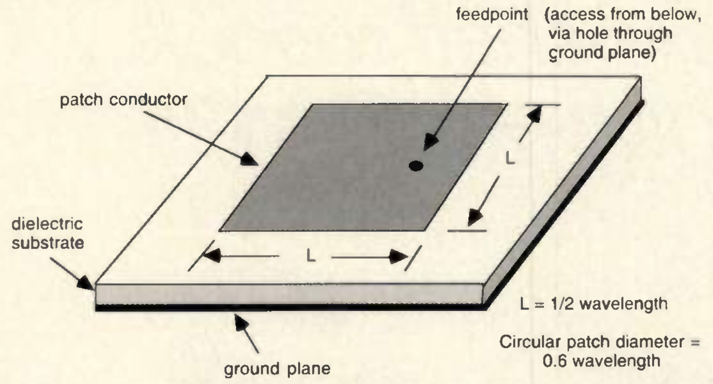

Figure 4. Patch antennas use a conducting surface shape, usually round or square, with a dielectric substrate between the patch and a ground plane.

This can be a useful advantage, since most man-made interference sources create predominantly electric field radiation, which is the characteristic of a short dipole. Small loops have a very low radiation resistance, which requires an impedance-transforming network of some type to be of any practical use.

The patch antenna (Figure 4) — The basic microstrip patch is a square or round "island" of a conductor on a dielectric substrate, backed by a conducting ground plane. Patches are usually etched or machined from double-sided printed circuit board material. The feedpoint is either at the edge or through a hole in the ground plane at a specific off-center point which results in a practical feedpoint resistance. A square patch exhibits resonance when it is one-half wavelength on a side, and a circular patch is resonant when its radius is about 0.3 wavelength (0.6 wavelength diameter). Because a ground plane is part of the antenna, radiation characteristics are generally analyzed in half-space like the monopole.

Numerous other antenna types may be used in wireless communications (e.g. horns, log periodics, slot antennas and others), but these four represent nearly all portable uses, with base station applications typically using arrays of these basic types.

Hand-Held and Body-Worn Antenna Examples

Here are some of the common antenna configurations for wireless communications that have been developed to meet a specific set of performance and convenience requirements.

The "rubber duck" antenna is unquestionably the most common type used in portable communications. It is a monopole that uses a lumped or distributed inductance to obtain resonance at a length much shorter than one-quarter wavelength (Figure 5). The inductance is usually a coiled wire, encapsulated in a flexible plastic sleeve that gives the antenna its unusual name. In a classic two-way radio operating at 160 MHz, a quarter wavelength is 47 cm. A rubber duck style antenna will rarely be more than

Antenna Terminology

Current distribution — The manner in which antenna current varies along the length of an antenna.

Directivity — The concentration of radiated energy in one or more directions; the degree that an antenna's radiation varies from that of an isotropic radiator (see *gain*).

Gain — Gain is a measure of the degree of concentration of energy radiated by a given antenna. Although different expressions of the same concept, gain tends to be used for quantitative discussion, while directivity is used mostly in qualitative descriptions.

Half-space — The space above a surface, intended to represent antennas operating in conjunction with an idealized flat earth and the space above it. Radiation in half-space can be visualized as being projected onto a hemisphere, while isotropic radiation is projected onto a sphere.

Feedpoint impedance (or just impedance) — The complex impedance seen at the feedpoint of an antenna. Many antenna structures have impedance transforming properties; only in some simple antennas will the resistive component of the feedpoint impedance be the same as the radiation resistance.

Free space — The idealized location of an antenna with no external influences, including ground. In practice, separation of an antenna from ground or other objects by several wavelengths will approximate free space for most impedance and basic radiation characteristics, but not for propagation over distance.

Ground plane — A plate, surface, or group of wires, that provides the "image" half of a monopole antenna, approximating an infinite flat conducting surface.

Isotropic radiator — A fictional point-source antenna that radiates equally in all directions (spherically), used as a reference when describing antenna radiation patterns, gain and directivity.

Polarization — The orientation of the wavefront transmitted from an antenna, also the optimum orientation for received signals. Polarization can be linear (vertical, horizontal, or any angle in between); circular (with "right hand" or "left hand" sense as the waves spiral through space); or elliptical (like circular, but asymmetrical).

Radiation resistance — The resistive component of the intrinsic impedance of an antenna.

Wavelength — The distance required for a complete cycle of the radiated sine wave, either at the speed of light (free space) or reduced by the dielectric constant of the medium containing the antenna.

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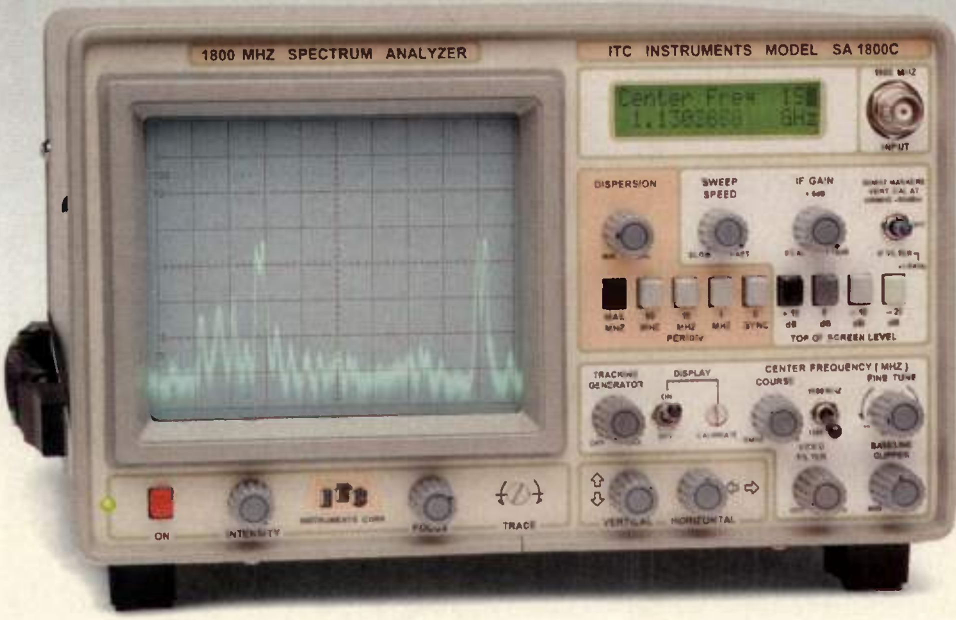

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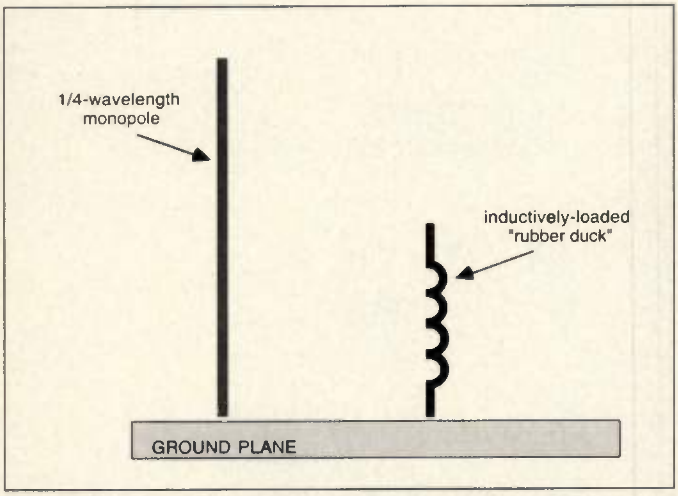

Figure 5. Inductive loading, often as a continuously-wound coil, shortens the physical length of the "rubber duck."

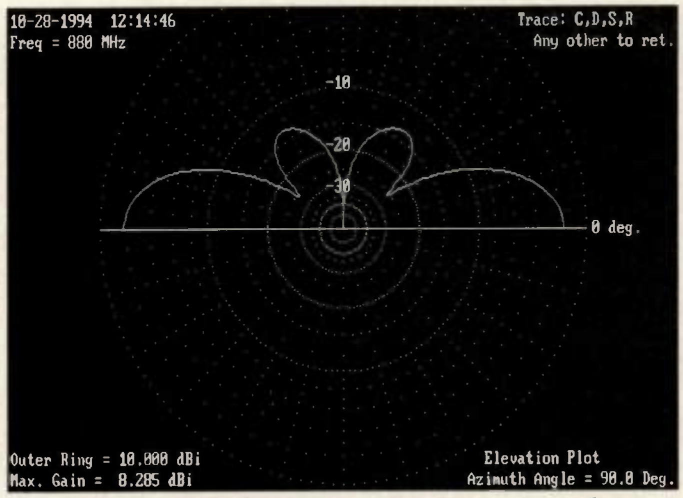

Figure 6. The typical cellular whip with center coil has a radiation pattern of this general shape.

16 cm long. The effect of shortening the antenna is reduced efficiency due to losses in the inductive loading circuit. Reduced efficiency means reduced communications range and reliability compared to a full-size monopole, but the tradeoff is usually acceptable. A few antenna models are offered with an extendable mast, converting the shortened antenna to nearly a full one-quarter wavelength, improving coverage in marginal communications situations.

Pagers are generally restricted to antennas that are contained inside the case. Such an antenna may be a random-length conductor, in essence a "scrunched" or bent monopole, or it may be a loop. Either type can be etched onto the perimeter of the printed circuit board, minimizing manufacturing steps and cutting product cost. Since pagers are receive-only (two-way paging is coming soon), low antenna efficiency can be mitigated by adding circuit gain, within the practical limits of current consumption and susceptibility to interference (a low input IMD intercept point). Also, matching network components can be small and inexpensive since they do not have to withstand transmitted RF power.

A significant factor in antenna effectiveness in all hand-held or body-worn applications is the ground plane or counterpoise provided by the device's case and the body of the person using it. At VHF and UHF, the radio case is much smaller than the one-quarter wavelength that would comprise the "other half" of a dipole. Capacitive coupling to the user's body provides a significant improvement. Measured data have shown a typical increase in signal strength of 3 to 10 dB when the radio equipment is used as intended, either hand-held or body-worn, compared to the same equipment operated in free space. You may have noticed a similar effect with a portable FM broadcast receiver, getting better reception while holding the radio, or when placing it on a conducting surface such as a automobile body.

Hand-held cellular phones usually have either a one-quarter wavelength monopole, or some variation of the inductively-shortened monopole. Although the shorter wavelength reduces the dependence on coupling to the hand or body of the user, compared to lower frequency equipment, the varying position of the unit causes shifts in the polarization of the antenna. Combined with the effect of multipath reflections experienced in all mobile and portable communications, the unit will experience a wide variation in signal levels, which can cause audible fading and drop-outs.

Mobile Radio Antenna Examples

The most common antenna for mobile cellular installations is a glass-mounted whip with a phase-reversing coil in the center. This design is a one-quarter wavelength monopole below the coil, and a half-wavelength end-fed dipole above the coil, each having in-phase currents. This antenna has a gain of 8.3 dBi (assuming a perfectly conducting ground plane), as shown in Figure 6. The improved directivity in the horizontal plane provides better communications performance than a simple monopole, but at the modest cost of increased size.

VHF/UHF mobile antennas are predominantly one-quarter wavelength monopoles. This antenna type is both electrically and mechanically simple, keeping cost to a minimum. Performance is good since this is a self-resonant antenna with no additional lossy reactive components for matching or length compensation. There are a few specialized mobile antennas offering low-profile mounting or other reduced size and reduced visibility advantages, but they are not in widespread use.

Microwave mobile communications is presently a small part of the wireless market. Global Positioning System (GPS) receivers and the coming Personal Communications Services (PCS) operate at frequencies once considered microwaves, where shorter wavelengths change some of the constraints that must be considered. GPS receivers most often use some variation of crossed dipoles to obtain omnidirectional coverage and relative insensitivity to polarization changes. Patch antenna designs are also used in a significant number of GPS installations. GPS differs from cellular or PCS in that signals arrive from overhead rather than on the horizon. An optimum GPS antenna pattern is hemispherical, while PCS should have a pattern emphasizing horizontal radiation. Smaller versions of cellular-style antennas are anticipated for PCS, but we will likely see some innovative new designs.

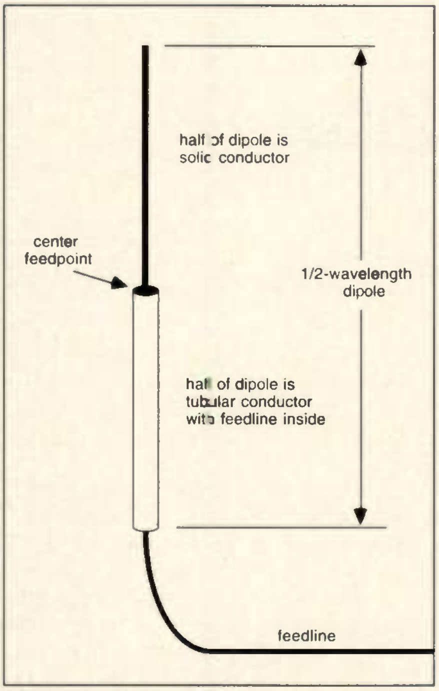

Figure 7. Construction of a vertical dipole, with a tubular sleeve having the dual purpose of providing the lower half of the dipole, while isolating the feedline .

WLAN Antenna Examples for Portable and Base Operation

Most WLAN equipment in operation today operates in the 915 MHz or 2.4 GHz unlicensed bands. Antennas for these systems are usually based on dipole designs, with some use of monopole and patch antennas. The number of systems in operation is still quite small, so the present antenna selections may not prove to be the solution of choice as this wireless application grows. Many WLAN installations today use a vertical dipole at the individual computers, with the feed connection made through the lower half of the dipole radiator (Figure 7). The vertical dipole is usually shosen in order to put some distance between the antenna and the computer, minimizing the effect of the enclosure on the antenna pattern. The vertical orientation also provides omnidirectional coverage in the horizontal plane.

The fixed antennas that connect to the wired portion of the network and its associated server is likely to be either a dipole array or a patch antenna. While WLAN portable unit antennas are generally omnidirectional, intended to serve computers that are moved from place to place, fixed antennas are often directional, with patterns chosen to cover a particular area. For example, a fixed antenna placed in the corner of a room can have full coverage of the area using a 90-degree beamwidth (in the horizontal plane). Or, the antenna can be placed in the center of a wall and cover a room with a 180-degree beamwidth.

Summary

This has been just a brief overview of antennas used in wireless communications systems. By describing how the basic antenna types have been used or adapted for wireless, it is hoped that you will improve your understanding of these systems beyond circuit design considerations. The references listed below are excellent sources of additional information on this subject. *RF*

Bibliography

1. Kazimierz Siwiak, *Radiowave Propagation and Antennas for Personal Communications*, Artech House, 1995.
2. K. Fujimoto and J.R. James, editors, *Mobile Antenna Systems Handbook*, Artech House, 1994.
3. Richard C. Johnson, editor, *Antenna Engineering Handbook*, McGraw-Hill, 1993.
4. John Kraus, *Antennas*, McGraw-Hill, 1988.
5. Gerald L. Hall, editor, *The ARRL Antenna Book*, 17th edition, American Radio Relay League, 1994.
6. Garry C. Hess, *Land Mobile Radio System Engineering*, Artech House, 1993.
7. Thereza Macnamara, *Handbook of Antennas for EMC*, Artech House, 1995. (Although not intended for wireless communications, this book contains excellent tutorial material on basic antenna theory and design.)

Design Method for a Coaxial-Resonator Oscillator

By Danny I. Polidi
Space Systems/Loral

This article describes a method for designing a coaxial-resonator oscillator (CRO). By modeling the oscillator as a cascade of a resonator and an "active circuit," any linear simulator can be used to optimize the circuit for the best S parameters for oscillator operation. This article illustrates that a CRO is not only smaller and easier to tune than a dielectric-resonator oscillator (DRO), but its design can also be completed quickly and efficiently. Data for a 2.3 GHz CRO is also presented.

At low frequencies the CRO is preferable to a dielectric-resonator oscillator (DRO) because the disk-shaped dielectric-resonator in a DRO can be quite large and difficult to tune.

A DRO employs ceramic material as a resonator. This resonator is commonly in the shape of a puck. For purposes of this discussion, a DRO is an oscillator that has a resonator with this shape. A CRO uses a resonator in the shape of a coaxial line, or tube, with metalization through the center as well as on the outside. The length of the coaxial-resonator depends on the frequency of interest and can be either a 1/4-wave resonator with metalization at the far end or a 1/2-wave resonator with no metalization on either end.

To give an example of the relative sizes of these two types of oscillators, a DRO at 2.3 GHz would require a puck with a diameter of approximately one inch. By comparison, the dimensions of a coaxial-resonator for a CRO at 2.3 GHz are 1.05 cm long and 0.60 cm wide.

In a DRO, the height of the puck determines the frequency of oscillation, and is therefore critical. Tuning is achieved by grinding the puck and changing its height. In contrast, the length of a resonator in a CRO remains constant. Tuning is achieved by altering the surrounding circuit elements. The latter method is both faster and less subject to error.

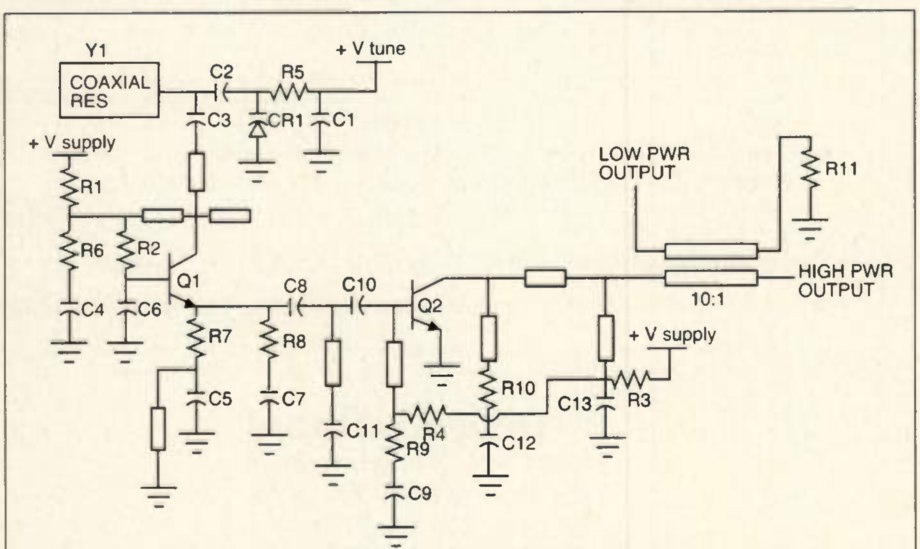

Figure 1. A coaxial resonator oscillator designed using the techniques discussed above. This design also incorporates an amplifier and hybrid power splitter.

A Design Method for CROs

The design of a CRO begins with the transistor. Once a suitable transistor has been selected, the next step is to check for stability (K) and maximum possible gain (G_{max}). It is possible to "customize" these parameters with various circuit elements. The coaxial-resonator has a mounting foot which can be soldered directly to the circuit. A capacitor can then be used to control the coupling of the resonator to the circuit. By decreasing the capacitance, the resonator will be lightly coupled and therefore will not load the circuit. A second capacitor can be used to control the coupling of a varactor to the resonator and the rest of the circuit. The varactor can be used with a control voltage in a phase-locked loop to tune the frequency of oscillation and maintain lock. By increasing the capacitance at the varactor, the tuning bandwidth can be increased. Matching is added using distributed elements. The circuit frequency can be made tunable by adding a high-impedance, 1/2-wave transmission line between the transistor and the resonator.

The circuit design can be simulated with a linear analysis program, designating the "active" circuit as a two-port with port one being the output and port two being the resonator port. The "resonator" should be designated a one-port, low-impedance, 1/2-wave transmission line, and the entire "oscillator" a one-port circuit that com-

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MODEL	LO (dBm)	FREQUENCY (MHz) LO/RF	I F	MIDBAND (dB, typ.) Conv. Loss	Isolation L-R	L-I	$ea. (qty. 1-9)
JMS-1	+7	2-500	DC-500	5.75	45	45	4.95
JMS-1LH	+10	2-500	DC-500	5.75	55	45	8.45
JMS-1MH	+13	2-500	DC-500	5.75	60	45	9.45
JMS-1H	+17	2-500	DC-500	5.90	50	50	11.45
JMS-2L	+3	800-1000	DC-200	7.0	24	20	7.45
JMS-2	+7	20-1000	DC-1000	7.0	50	47	7.45
JMS-2LH	+10	20-1000	DC-1000	6.5	48	35	9.45
JMS-2MH	+13	20-1000	DC-1000	7.0	50	47	10.45
JMS-2H	+17	20-1000	DC-1000	7.0	50	47	12.45
JMS-2W	+7	5-1200	DC-500	6.8	60	48	7.95
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Note: *10-49 qty.

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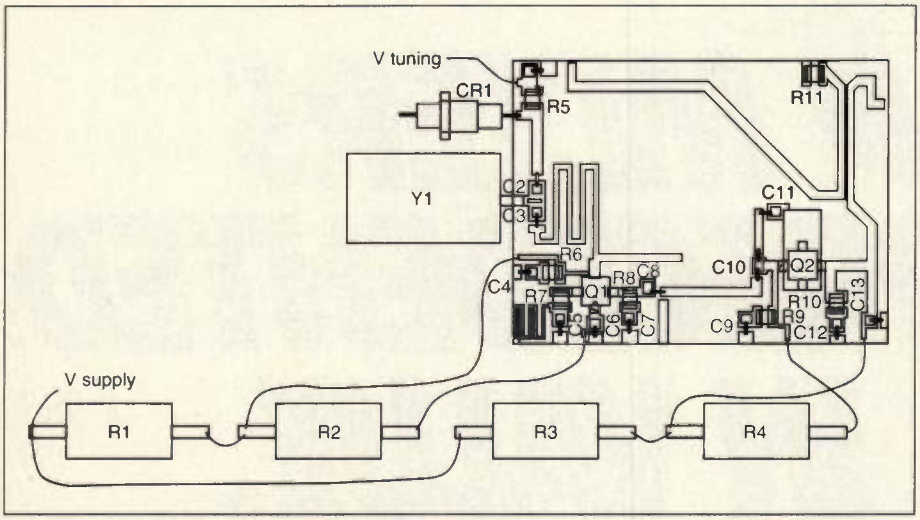

Figure 2. Physical layout of oscillator printed circuit board, showing location of coaxial resonator and external bias resistors.

bines the "active" circuit and the "resonator." The circuit file can then be optimized to get "active" S11 < –10 dB, "active" S22 > 10 dB, and "oscillator" S11 > 10 dB. The circuit can then be built on an alumina substrate using packaged parts. Once assembled, tuning can be added to the high-impedance, 1/2-wave, transmission line to tune the circuit to the center frequency, f_0.

A 2.3 GHz Example

As a practical example, a CRO was designed using the above method using an NPN bipolar transistor in a MICRO-X package that has two emitter leads. The circuit was built on a 25-mil alumina substrate with $\varepsilon_r = 9.9$. All simulations were done using a linear analysis program. A 2.3 GHz coaxial-resonator was chosen. For the transistor, the simulations indicated the best starting point would be a common-base configuration. Ideally, it is desirable to have a transistor with $0 < K < 1$ for $f_0 \pm 20\%$, $K < 1$ for all other frequencies, and $G_{max} = 12$ dB at f_0.

To optimize the K for the "active" circuit, a series resistor and capacitor from the emitter to ground and a capacitor from the base to ground were added to the transistor. Later, the resistor value was doubled and one was put on each emitter lead for balance. On one emitter lead, a high-impedance, 1/4-wave stub to ground-was added for biasing purposes. The other emitter lead is the output of the CRO. To the collector were added matching stubs, a capacitor C3, the resonator port, a capacitor C2, and a capacitor to ground for the varactor, (see Figure 1). The capacitor C3 was chosen sufficiently small so as to not over-couple the resonator to the circuit and pull it off frequency. The capacitor C2 was chosen sufficiently large to allow for enough tuning range to compensate for temperature variation and aging effects, yet small enough to have an acceptable amount of phase noise. The "resonator" was simulated as a one-port, low-impedance, 1/2-wave transmission line. The "oscillator" combined the "active" and "resonator" circuit files and was then optimized to get "active" S11 < –10 dB, "active" S22 > 10 dB, and "oscillator" S11 > 10 dB. For my purposes, I needed more output power and two outputs, so I added an amplifier using the same transistor and a coupler. I used externally mounted, leaded resistors for the bias so that bias changes could be made without disturbing the circuit. The existing DRO cavity dimensions were approximately 1 × 2 inches. The CRO was made on a 1 × 0.75 inch substrate. It was made this size to accommodate the inputs and outputs. Had this not been the case, the substrate could have fit in roughly half that space.

The layout of the substrate was done using a CAD program and the mask was made directly from the CAD file. The circuit design and the layout are shown in Figure 2.

The completed oscillator was assembled without the resonator and measured using a network analyzer. Once the two-port parameters had been measured and verified, the resonator was installed and the oscillator was measured on a spectrum analyzer as well as a microwave frequency counter. The frequency of oscillation was low, but by shorting across the 1/2-wave line the frequency was increased to 2.3 GHz. It was determined that the tuning bandwidth was too broad, so C2 was decreased. The result was that it worked right at 2.3 GHz after it was tuned in. Table 1 displays measured performance of the oscillator.

Frequency	2.3 GHz
Voltage Controlled Bandwidth	32 MHz
Output Power Port 1	12.9 dBm
Output Power Port 2	2.9 dBm
Output Return Loss	–30 dBm
Harmonics	–20 dBc
Supply Voltage	12 V
Tuning Voltage	0 -12V
Supply Current	62 mA
Substrate Size	1 in. × 0.75 in.
Phase Noise at 10 kHz	–84 dBc
Phase Noise at 100 kHz	–114 dBc

Table 1. Measured performance of the 2.3 GHz oscillator.

Conclusion

The design method works quickly and easily. The only change I would make in future designs of this type would be to substitute board-mounted chip resistors for the externally-mounted biasing resistors used in this design. Because of its smaller dimensions and ease of tuning, I feel a coaxial-resonator oscillator is a good alternative to using DROs at low frequencies.

Acknowledgments

The author would like to thank his colleagues Dr. Ming Yung and Mr. Thomas J. Holden. The author also thanks Mrs. Johnna M. Polidi for all her support and encouragement. *RF*

About the Author

Danny I. Polidi received his BS and MS in Electronic Engineering from California Polytechnic State University, San Luis Obispo, in 1989 and 1991, respectively. In 1991, he joined Space Systems/Loral, where he is responsible for the design and development of new circuits for space communication applications. He can be reached at 1635 Wyndham Dr., San Jose, CA 95124, or by phone at (408) 264-7819.

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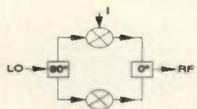
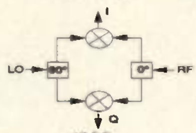


I/Q MODULATORS

MODEL	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	106	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-38M	34	38	5.6	0.10	48	37	54	65	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
Surface Mount Models									
☐ JCIQ-88M	52	88	5.6	0.1	40	35	45	65	49.95
☐ JCIQ-176M	104	176	5.6	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

MODEL	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
MIQA-70D	66	73	6.2	0.10	0.15	0.7	56	58	49.95
MIQC-38D	34	38	5.5	0.10	0.10	0.5	60	65	49.95
MIQC-60WD	20	60	5.3	0.10	0.15	1.0	55	67	79.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	65	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
Surface Mount Models									
☐ JCIQ-176D	104	176	5.5	0.1	0.15	2	52	65	54.95
☐ JCIQ-895D	868	895	8.8	0.1	0.2	1	45	65	99.95
☐ JCIQ-1785D	1710	1785	8	0.2	0.2	2	50	65	99.95
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An EMI Noise Reduction Technique

By Kevin P. Slattery and James Garrison
FF Developments

This article describes a method developed for reducing conducted noise seen at the I/O of an automotive electronic engine controller. Conducted noise at open I/O pins have been seen to closely correlate with radiated emissions from the vehicle. Therefore, the reduction of conducted emissions at the module level is a cost effective procedure since the module is typically ready for measurement long before the vehicle.

The complexity and functionality of today's automotive electronics have come a long way in terms of complexity and functionality. It is not unusual to find several processors and ASICs in transmission and engine controllers. Reduction of noise at the source IC can lead to parts reduction in that specialized ferrites and filters are not required at the I/O connector. This paper describes a method of directly measuring the noise density at each pin of the processor/ASIC IC set.

Measuring the Noise Density at the Processor

The technique to be described in this paper grew out of the EMC development process for an engine controller. This controller utilizes several processors and a "glue" ASIC. Many measurements of the conducted emissions at the I/O pins, and preliminary measurements in a vehicle, indicated that there were radiated problems in the range 60-170 MHz, with the peak coming at approximately 128-136 MHz. A means of comparing the effectiveness of various fixes was necessary. One of the methods developed arose from modifications to the actual test software. The test software was originally written to show the maximum measured level, in dB, over a specified limit. Also given was a number called the noise density.

Noise Density (ND) refers to the summation of all measured peaks over a given specified limit level. Typically,

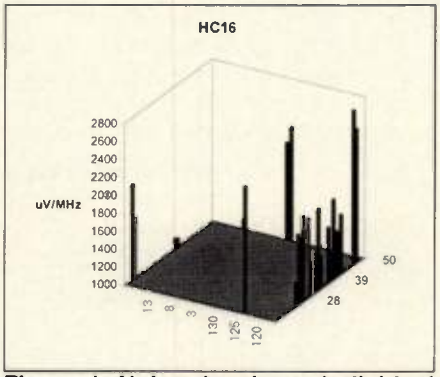


Figure 1. Noise density at individual processor-pins.

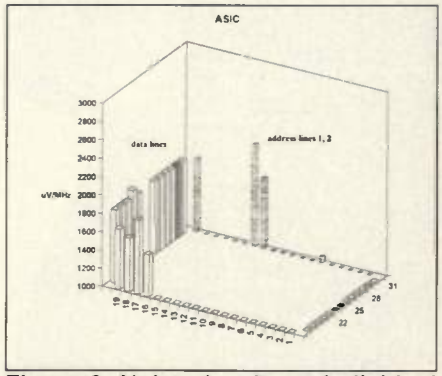


Figure 2. Noise density at individual ASIC-pins.

we will measure these peaks in microvolts. To arrive at the density, we then divide the summed peaks by the frequency span (in this case, 2-200 MHz). The resulting noise density is then given in micro-volts per MHz.

where T_{pks} is the total number of individual peaks over the limit and f is

$$ND = \frac{1}{f_{max} - f_{min}} \cdot \sum_{n=1}^{n=T_{pks}} \text{peaks(in } \mu\text{V)} > \text{limit}$$

given in MHz.

This quantity was modified somewhat, and the frequency range of interest, (in this case 2-200 MHz), was divided into four equal quadrants. The software then gave out a total ND and the ND for each quadrant. This allowed us to compare fixes as a function of what frequency quadrant was affected. In addition to the quadrant ND, we also measured the ND in the band 88-108 MHz, the FM band. An example of the data's form is shown in Table 1.

Table 1 indicates which pin is being measured, the maximum peak over the limit, given as a negative value, the total noise density, the frequency at which the maximum level was seen, the four quadrant ND values and finally, the noise density in the FM band.

Breaking the data down into this form allowed us to concentrate on fixes directed at the frequency ranges considered to be problem areas. As mentioned, this area was 120-140 MHz, which was seen to be due primarily to the processors. This led to measuring the same quantities directly at the IC pins, and implementing fixes aimed at the frequencies indicated.

The equipment used included a Tektronix P6156 wide-band probe(10X), an HP 12 step attenuator set to 40 dB attenuation, an Amplifier Research LN1000 pre-amplifier, and an HP 8568B spectrum analyzer. The resolution bandwidth was set to 10 kHz and the video bandwidth to 30 kHz. The sweep time was set to 10 seconds for a frequency span of 198 MHz. In addition to the hardware, a program developed for conducted emissions was used to take the scans and interpret the data.

Two of the processors in the IC set were seen to have noise numbers below a certain level and were ignored. The processor with the highest measured numbers was a Motorola HC16. The ASIC also showed fairly high levels, but only on the data and two of the address lines. The measured numbers are shown in Figures 1 and 2. The distribution follows the IC pin-out.

The noise density number was derived as a figure of merit when making conducted emissions measurements at the module I/O. As an example, if you measured a single peak over the limit, the ND number would be approximately 0.1 μV per dB over the limit. Typical values for I/O pins with signals over a –80 dBV limit are in the range 1-10 μV/MHz. Because we are making this measurement directly at the processor pins, the ND numbers are going to be much higher. Figure 1 has been modified to show only those pins with noise density levels greater than 1000 μV/MHz. It was decided that this was a reasonable cutoff level. Any pin with lower measured levels was not considered for modification. It should be emphasized that the noise density is a derived number referenced to a specific limit level. The levels measured at the IC pins are referenced to a limit selected for comparison purposes.

Figure 2 shows the levels for the ASIC. Most of the high ND pins were associated with the data and address lines. Certain manufacturing constraints, and layout density, precluded us from modifying the data lines. In the case of the address lines, our measurements showed that only the two lower order lines needed to be modified. Figure 3 shows the measured levels for the address lines. Measurement of the data lines showed that all data lines have approximately the same level at 2100 μV/MHz, which corresponds to the requirement for transfer of information. Figure 4 shows the data lines as measured at the HC16.

After measuring all of the processor pins, we then reviewed the pin functionality. It was found in most cases that the offending pins were either open pin or tied to ground through a resistor. For the open pin instances we inserted a 500 pF capacitor to ground. For those pins tied to ground through a 10k resistor we added a 500 pF capacitor in parallel. The results are shown in Figure 5.

For the two lower order address lines, 220 ohm resistors were placed in series at the ASIC. The ASIC lines were chosen simply because it is not a fine pitch device and was therefore more amenable to modification. CMOS outputs provide virtually no current in the high or low state. However, during the state transition, current can be significant. Add to this the fact that CMOS loads are capacitive, and that the packages have intrinsic inductance, and you can see that there is

pin	max. level (dB over limit)	ND μV/MHz	f_{max} MHz	Q1 2-50 MHz	Q2 50-100 MHz	Q3 100-150 MHz	Q4 150-200 MHz	FM 88-108 MHz
a1	–4.8	2.96	148	0	0.12	1.26	1.57	0.04
a2	–9.8	8.04	168	0	0.62	0.57	6.85	0.1

Table 1. Total noise density and noise density in various frequency ranges for two example pins on the processor.

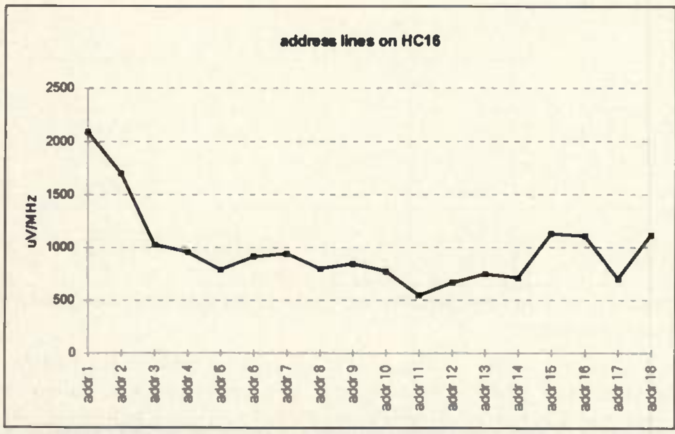


Figure 3. Noise density on the processor's address lines.

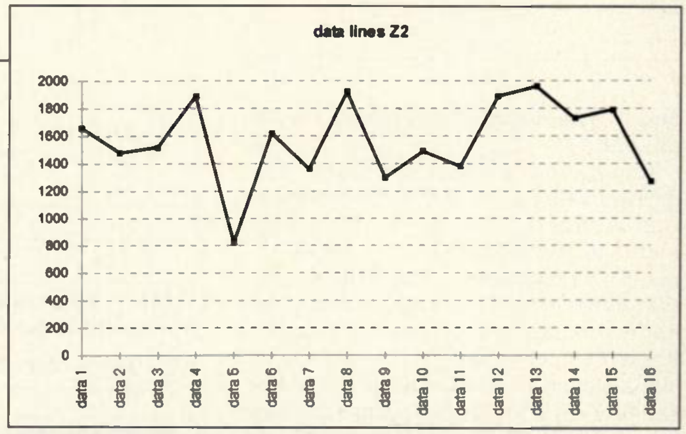


Figure 4. Noise density on the processor's data lines.

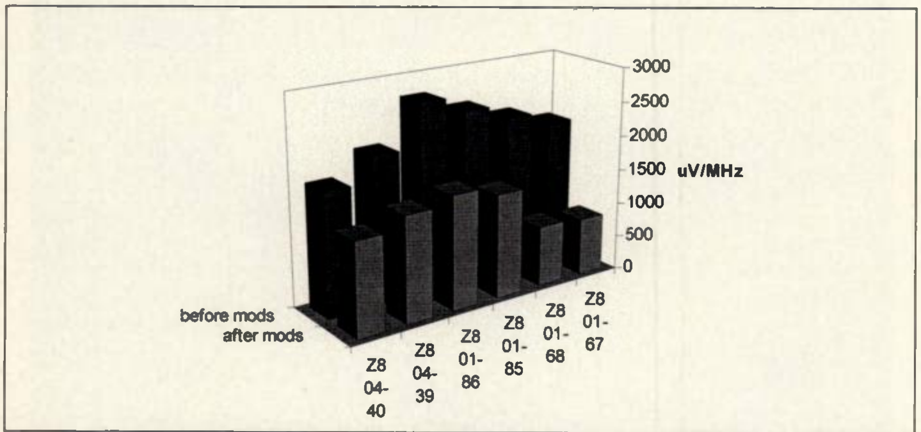


Figure 5: Noise density on six different pins before and after either being tied to ground, capacitively bypassed or both.

the possibility of a resonant condition during transition. This can cause quite high instantaneous current demand. It is precisely these switching currents that provide most of the noise source driving the module power and ground structure. Inserting a series resistor in the address lines (or data lines) reduces the Q of the resonant structure, and therefore reduces the instantaneous switching current. A caveat at this point is necessary: all "fixes" must not affect the functionality!

It can be seen that a significant decrease has been effected in the noise density as measured at the IC pins. Did this translate into an improvement as seen at the I/O pins?

Figure 6 is a plot of the measured conducted emissions at pin A25 of the I/O of the engine controller. As was mentioned, the primary area of interest is the frequency range 60-150 MHz, where several peaks are obvious, and the broadband noise floor is at, or just over, the limit.

Figure 7 shows the same pin after the modifications were made. As is apparent, there has been a significant reduction in the maximum level measured, the overall extent of the noise peaks over the limit, and the noise floor can be seen to have been reduced by several dB.

Figure 8 shows a comparison of the noise density levels measured at each I/O pin before and after the modifications. The REV H P0 is the unmodified module. The data has been sorted in descending order.

Finally, Figure 9 shows a comparison of the FM band, 88-108 MHz, for the first 33 pins of the two modules. It can be seen that the modifications made a quite significant improvement in terms of the noise over the limit.

Summary

This paper has described a relatively simple procedure for measuring and addressing noise sources at the IC level. It has been shown that by making these measurements, and subsequently performing certain modifications, a significant improvement in the EMC performance of the module can be achieved. No degradation in system performance was noted after any of the modifications.

This series of measurements at the ICs showed that the address and data

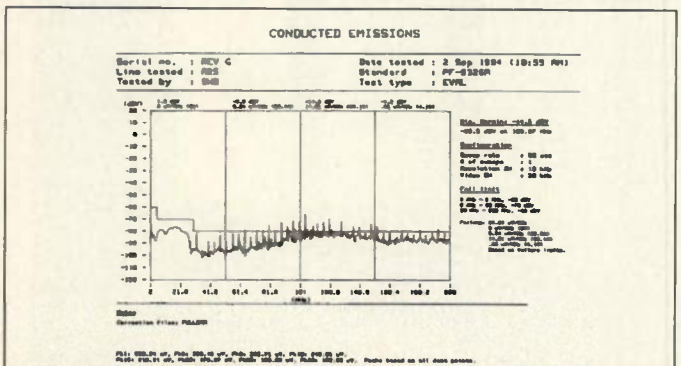


Figure 6. Conducted emmissions at pin A25 of the I/O of the engine controller.

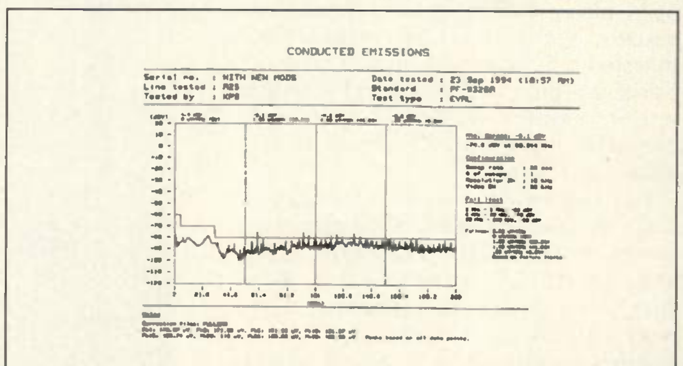


Figure 7. Conducted emmissions at pin A25 of the I/O of the engine controller after modifications.

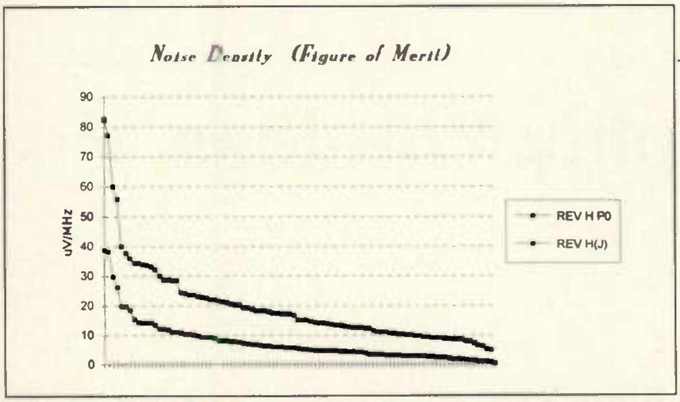


Figure 8. Noise density levels measured at each pin of the engine controller module I/O before and after modifications. Data are sorted from noisiest pin to quietest.

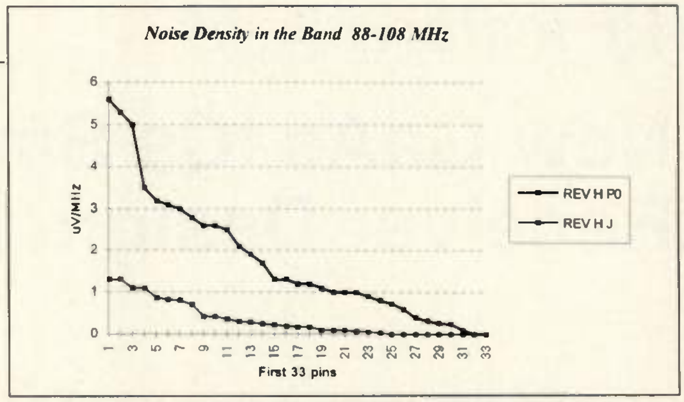


Figure 9. Noise density in the FM broadcast band for the first 32 pins of the engine controller module before and after modifications.

lines were the most serious contributors to source noise. For the address lines, modification of the two lower order bits showed significant improvement. Modifying all the data lines was not possible in a production module at this time. However, measurements were made on a module with modified data lines and a similar reduction in the noise densities was noted and an overall improvement in the conducted emissions at the module I/O was seen. *RF*

About The Authors

Kevin Slattery is an automotive electronics consultant with FF Development USA, Inc. Previously, he worked for CKC Labs, and has also developed high-speed timing systems and particle beam transport systems at the Stanford Linear Accelerator Center. His address is FF Developments USA, Inc., 125 Electronics Blvd., Suite 3-M, Huntsville, AL 35824. Tel.: (205) 464-2864.

James Garrison is an engineer at Chrysler Huntsville Electronics Divison. He designs electronic control and display modules for cars. He received a BSEE from the University of Alabama, Huntsville and an MBA from Alabama A&M. He may be reached at Chrysler Corporation, 100 Electronics Blvd. P.O. Box 240001, Huntsville, AL, 35824-6401. Tel.: 205-464-2761. E-Mail: JamesG6797@aol.com.

New GaAs ICs Simplify Wireless Receiver Design

By Barak Maoz
Anadigics, Inc.

As wireless communication equipment becomes more popular, the demand for smaller and less expensive phones, modems and PDAs becomes increasingly urgent. The importance of time to market has increased as markets grow and revenues explode. Designers of wireless communication systems are called upon to meet these new challenges. Using integrated circuits offers engineers one solution.

Anadigics, which designs and manufactures GaAs monolithic integrated circuits (MMICs), has answered the call for more integration by marketing a new family of ICs that perform the receiving function in wireless communication radios. A number of monolithic receivers that cover applications such as cellular base stations, cellular phones, new PCS hand-sets as well as CDPD modem cards and high frequency cordless phones are available. Their high level of integration often means that additional expensive and large components such as filters or VCO modules can be eliminated. By using the integrated circuits, manufacturers can shorten their time to market while reducing component count, size and cost. The receivers offer consistent performance in a plastic, surface mount package for automatic assembly.

The AWR0900 Reciever

First in the family is the AWR0900, a receiver for hand-held applications operating at 900 MHz, such as cordless phones and their base stations and other applications working under FCC part 15 regulations. The AWR0900 receiver chip is unique in its level of integration. It incorporates a low-noise amplifier, a mixer and an on-chip filter that reduces the contribution of the image frequency to the overall system noise. In addition, the chip includes a VCO and buffer amplifiers connecting the VCO to both the LO port of the mixer and to an output port for use as an upconverter or phase lock loop.

The performance of the chip is outstanding, with a conversion gain of 16 dB, overall RF to IF noise figure of 3.3 dB, third-order intercept point referenced to the RF input of –5 dBm, and current consumption of less than 13 mA from a +4.5 V supply (good performance is maintained at a supply voltage of +3.3V). Additionally, it is possible to shut off the low-noise amplifier and the mixer while the radio is transmitting. With the use of a high-quality external resonator, it is possible to achieve an extremely clean LO signal featuring very low levels of phase noise (–95 dBc/Hz at 10 kHz offset), making the chip suitable for certain cellular telephones. A variation of this chip allows the use of an external VCO in cases where the performance of the integrated oscillator is not sufficient.

The AWR1900 Receiver

Another receiver currently manufactured is the AWR1900. Similar to the AWR0900, this receiver is intended for wireless hand-held applications, particularly phones and data radios working in the 1800 to 2000 MHz band. Such applications exist today in Europe (DCS-1800) and are coming to the United States as the new PCS technology is developed. The AWR1900 includes a low-noise amplifier, a mixer and an image-reject filter that eliminates over 15 dB of the image frequency. Amplifiers on the chip strengthen an external VCO signal and feed it to the LO port of the mixer and to a buffered LO output pin.

The conversion gain of the receiver is

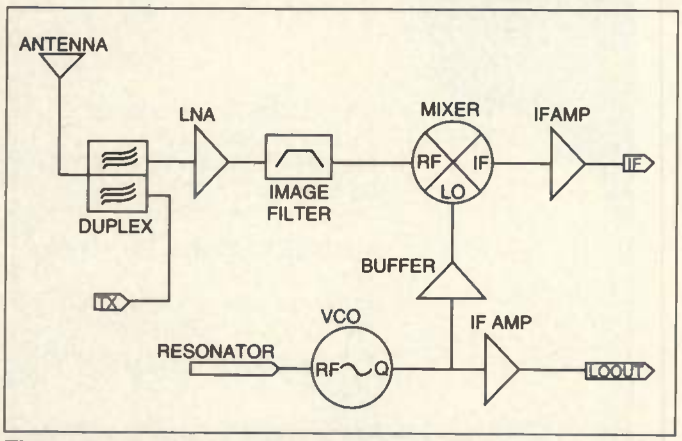


Figure 1: A typical application of an MMIC with receiving function, as used in celluar phones.

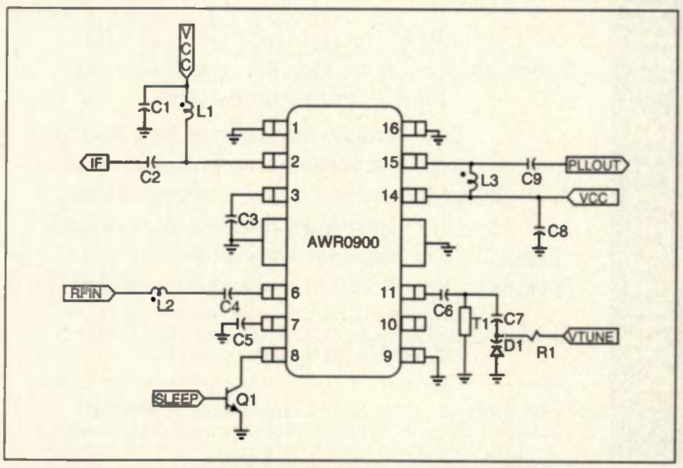


Figure 2: An application circuit for the AWR0900.

	AWR8001	AWR0900	AWR0901	AWR1900
Frequency RF (MHz)	700-1200	800-1000	700-1200	1700-2000
Frequency IF (MHz)	40-150	50-150	40-150	50-220
Gain (dB)	20[1]	16	12[1]	20
IIP_3 (dBm)	–10	–5	+13	–10
NF (dB)	2.5	3.3	2.5	3.5
I_{dd} (mA)	12	13	150	15
On-chip filter		Yes		Yes
On-chip VCO		Yes		

[1] Gain calculated with an image-reject filter of 2 dB loss in place.

Table 1: Performance Summary of Receivers

20 dB and its noise figure is less than 3.5 dB. The third-order intercept point referenced to the input is –10 dBm. The total LO power needed for this performance is less than –5 dBm and the chip consumes less than 17 mA from a +4.5 V supply. An additional feature lets the user shut off the low-noise amplifier while transmitting or when a strong input signal is present.

The AWR0901 Receiver

To complement the product family, the AWR0901 brings an integrated receiver solution to the cellular base station and other wireless applications requiring an extremely high dynamic range. This receiver is unique because of its combination of an extremely low noise figure coupled with a very high linearity, making it an ideal component for a quick and cost-effective design of a high-end radio. These features come in especially handy when considering the small size and low cost constraints on the new micro and pico cell base stations being used to expand the cellular infrastructure (for example, in building wireless PABX and new PCS applications).

The chip includes a low-noise amplifier and a high-performance double balanced mixer as well as LO buffers and bias networks. An external filter placed between the low-noise amplifier and the mixer allows the user to easily re-tune for different frequency bands. The chip is optimized for RF frequencies between 500 and 2000 MHz and IF frequencies of 50 to 250 MHz. The conversion gain of the receiver is +12 dB assuming a filter with 2 dB of passband loss. The receiver features a 2.5 dB noise figure and +13 dBm third-order intercept point referenced to the RF input. The level of external LO drive needed for this performance is a mere –5 dBm and the leakage of LO signal to the RF port is measured at less than –50 dBm. Another unique feature of this chip is its superior response to half-IF interference. Half IF interference is in-band interference due to the 2 x 2 spurious formed by the LO and a signal at the LO plus half the IF frequency. An example of this interference would be seen in a mixer with an LO of 1000 MHz, an IF of 200 MHz and both an 800 MHz signal and an unwanted 1100 MHz signal at the RF input. The desired product is 1000 – 800 = 200 MHz, but the the 2 × 2 spurious {2(1100) – 2(1000)} also falls on the 200 MHz IF frequency. The input intercept point for this interference is +40 dBm. The chip consumes less than 180 mA from a supply of +5 V and less than 5 mA from a supply of –4 V.

These three receivers and their variations form the basis for Anadigic's family of products. These ICs come in 16-pin SOIC packages and are shipped in tape and reel. *RF*

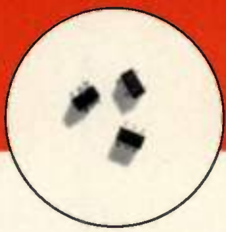
About the Author

Barak Maoz is the manager of the wireless circuits product line at Anandigics. He is responsible for developing radio frequency ICs for wireless communications.

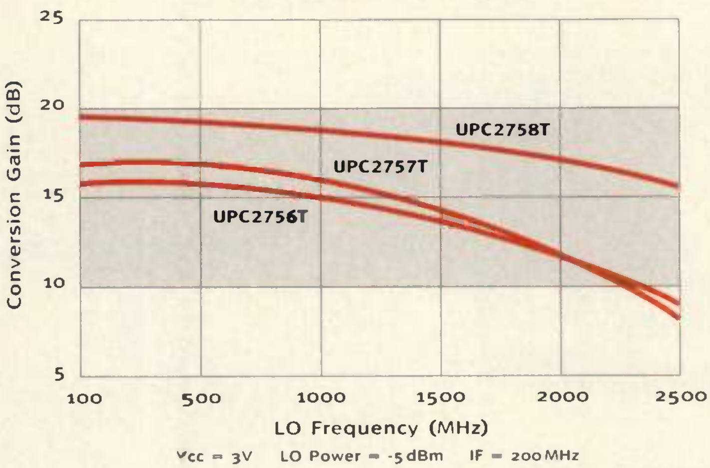
Mr. Maoz has developed products and product lines using GaAs MESFET, GaAs HBT and silicon bipolar technologies.

A senior member of the IEEE, Mr. Maoz received his BSEE from the University of Tel Aviv and MSEE from Rutgers. For more information, please call Jerry Miller or Barak Maoz at (908) 668-5000.

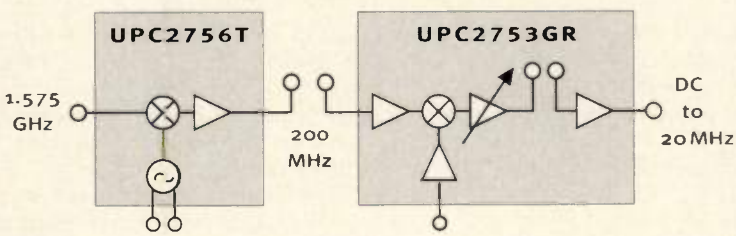
New 3 Volt Downconverters: From RF to IF for 99¢



CONVERSION GAIN



RECEIVER LINEUP



TYPICAL SPECIFICATIONS

PART	OPERATING VOLTAGE	Icc	CONVERSION GAIN	OUTPUT IP3
UPC2758T[1]	3V	11 mA	17 dB	+5 dBm
UPC2757T[1]	3V	5.6 mA	13 dB	0 dBm
UPC2756T[2]	3V	5.9 mA	14 dB	0 dBm

1. Measured at 2.0 GHz 2. Measured at 1.6 GHz

NEC miniature downconverters are the latest addition to CEL's growing family of 3 Volt RF ICs.

Need low distortion? Our new *UPC2758T* delivers +5 dBm output IP3. Low current application? Choose the *UPC2757T*. It provides 13 dB of conversion gain from only 5.6 mA. Both feature a mixer, LO and IF buffer amplifier, and a *Power Down* function to prolong battery life.

Another low current device, the *UPC2756T*, helps simplify your designs by combining mixer, IF amplifier and oscillator — all on a single chip.

All three feature 3 dB RF bandwidth to 2.0 GHz, with 3 dB IF bandwidth of 10 to 300 MHz.

Housed in miniature packages no bigger than a SOT-143, these devices are available now on tape and reel and priced in quantity from only 99¢.

Best of all, they can be combined with CEL's other MMICs and discretes to provide complete GPS, PCN or 2.4 GHz wireless LAN solutions.

Need a higher level of integration? The 3 Volt *UPC2753GR* IF downconverter combines an RF input amplifier, Gilbert cell mixer, LO input buffer, IF amplifier with AGC, external filter port, and IF output limiting amplifier — all in a miniature 20 pin SSOP package. This device features DC to 400 MHz RF response, DC to 20 MHz IF response, and typical overall conversion gain of 79 dB.

For data sheets and a Silicon MMIC Product Selection Guide, call your nearest CEL Sales Office, or circle the number below.

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INFO/CARD 56

RF Filters Shrink While Market Grows

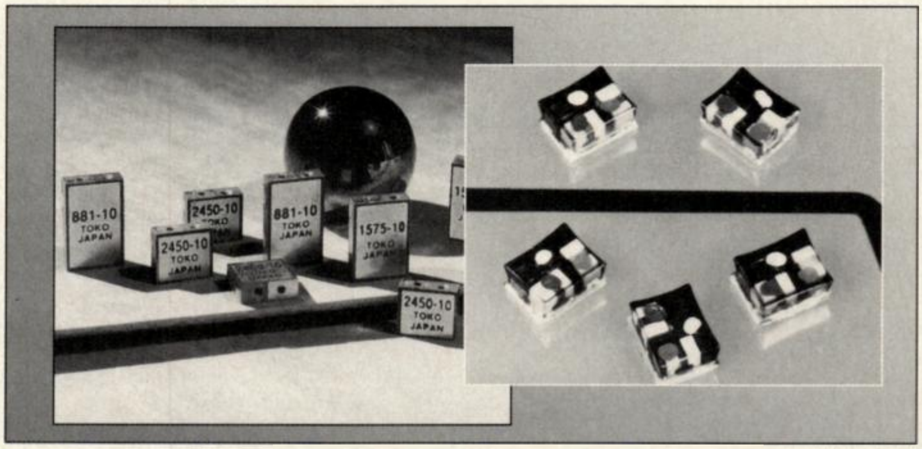
This month we asked filter manufacturers to tell us how filter technology and filter markets are changing. The replys from each company have been only edited for grammar and spelling.

RF Monolithics, Inc.

The market for SAW RF filters has been growing rapidly for several years, and we expect this trend to continue. Wireless telecom applications account for a large part of this growth. SAW filters are used in both RF and IF filtering applications. SAW RF filters exhibit steep skirt rejection compared to other RF filter technologies. This is important to achieving good system performance on a minimum current budget. SAW IF filters feature low group-delay deviation, which is important to systems employing digital modulation. The major challenge for the SAW industry is extending SAW filter technology to 2 GHz to support the RF filtering requirements of PCS and other wireless systems operating above 1 GHz.

Cir-Q-Tel/Div. of Trilithic

The RF and microwave filter market has changed drastically over the last several years, fueled by post-cold war commercial wireless markets. Key markets for filters include cellular, PCS, broadband telecommunications, and point to point data links. Filter manufacturers must provide cost-effective, high performance bandpass, lowpass, highpass, or notch filters to meet new market needs. Gone are the days of heavy boilerplates, eighteen week deliveries, and theoretical design studies; today's marketplace demands fast, on-time deliveries of product built to order but priced for commercial applications. Some filter "manufacturers" appear to have become an importer, offering "their" product for pennies on the dollar. While these devices are needed, others have avoided this low-end market and supply high-end, custom filter for laboratory or research applications. Trilithic, Inc. has taken the middle ground, offering filters designed, built, and shipped from its Indianapolis factory.



Low profiles are important for handheld and portable equipment. The photo on the left shows dielectric filters from Toko, while the photo on the right shows LC filters from Coilcraft encapsulated in a low profile package.

Micro-Coax

The overwhelming growth in commercial communication systems has fueled the expansion of the RF/microwave filter market. In addition, the defense market remains sound with continued advances in electronic warfare technology. The total market for filter products will continue to grow throughout the decade, stunted only by the threat of a U.S. economic recession.

Bandwidth restrictions and the reallocation of spectrum will warrent high-volume applications for filters with new cutoff frequencies and greater selectivity. A similar need for selectivity will extend to military applications, with increased receiver complexity and airwave traffic.

RF and microwave filter manufacturers will continue to face the challenge of miniaturization. Customers will demand smaller, lighter packages without sacrificing performance. Broad lines of standard products will give way to customized designs with reduced development cycles.

Micro-Coax stands poised to meet these demands with space-efficient in-a-cable and cable-integrated filters. When interchanged with pre-existing cable, they provide the smallest solutions available.

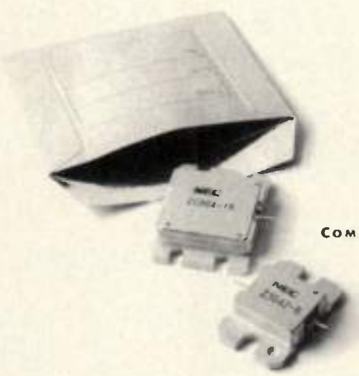
MuRata Electronics North America

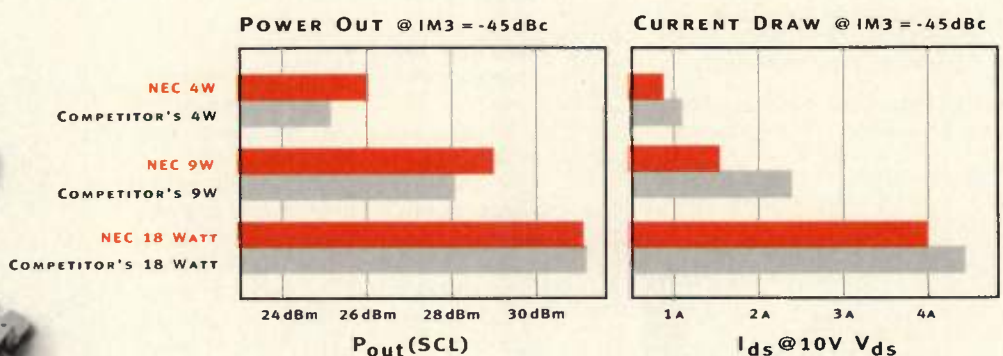
The explosive growth of the wireless market has triggered an avalanche of portable and miniaturized products for both the traveling business executive and the consumer alike. Reductions in size, accompanied by demands for greater performance, point to the need for corresponding improvements in RF filter technology, design and production. MuRata Electronics has answered the market call in this area with the recent introduction of a new line of dielectric ceramic filters manufactured from a single ceramic block of

Specify NEC Power FETs — You'll see the difference overnight

Lead times giving you ulcers? Get relief overnight. CEL stocks Power FETs, including those for your 5.9 to 6.4 GHz C-Band VSAT designs, and we're ready to ship *now*. Available in 4 1/2, 9 and 18 Watt versions, these NEC devices are package compatible with other suppliers' parts — and more: They'll give you more power out, better linearity, higher efficiency, *or all three*. So when you need Power FETs, spec the parts with better specs, and get on-time delivery from onshore stock.

For data sheets, call your nearest CEL Sales Office, or circle the number below.





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INFO/CARD 57

high permittivity. In addition to obvious advantages offered by reduced size and complexity, the filter design suppresses RF leakage without the need for additional external shielding, since the entir outside surface of the filter is a plated, conductive, grounding layer. With prices at approximately half that of filters using earlier technologies, this filter boasts both volumetric and electric performance surpassing those of nearly all dielectric filters available today.

Coilcraft

LC filters continue to play a major role in RF filtering applications. Improvements in inductors make the LC approach attractive especially at high frequencies (900 MHz and up). LCs don't require up-front tooling expense and lead times sometimes encountered for active devices. In high volume applications the end user is most often inclined to use discreet Ls and Cs and design the filter on their own. Smaller end users may be better served by buying LC filters complete, and customs are not prohibitively expensive. Computer aided design (CAD) software has made "real world" design of LC filters easier.

Coilcraft sees growth in the use of tight tolerance (±1% and ±2%), high Q chip inductors used in filters for wireless communications equipment, and substantial growth in LC filter modules. Presently, the 0805 and 1008 body sizes offer the best combination of cost, performance, size, and availability for LC filter design.

Toko America, Inc.

Improvements in size, performance, and cost of RF filters has been one of the forces fueling the market growth of mobile communications devices.

Now communications makers are gearing their products toward the mass consumer market by offering smaller, multifunctional, and lower-cost products which is putting heavy demands on the RF filter component supplier to continually offer smaller and lower profile solutions without sacraficing performance. For example, over the past ten years, RF filters have gone from bulky connectorized devices to miniaturized chip-mountable solutions. The issue today is filter height, not surface-mount. Many packaging layouts require profiles as small as 2-3 mm.

Toko has introduced several flip-chip filters with less than 3 mm profiles. These are designed for common world-wide communications systems. We are continuing development in this area to provide even lower profile with smaller footprints. Over the coming year we anticipate introducing chip multilayer filters which will approach 1 mm profile.

Piezo Technology Inc. (PTI)

PTI is a volume manufacturer of leading-edge products in three RF filter markets: discrete crystal filters, monolithic crystal filters and LC filters. The growth of all three is tied to cellular and PCN/PCS market expansion.

Key ingredients of digital cellular systems are higher frequency, wider bandwidth crystal filters requiring fundamental mode designs. PTI sees continuing rapid growth in this market and has developed the technology to meet current and future demands. the upper frequency limit has been pushed to 250 MHz while maintaining outstanding intermodulation performance.

PCN/PCS systems to transmit data down existing cable TV lines, now under development are being supported by PTI with new, miniaturized products; market growth is six to 12 months away.

Traditional commercial markets for LC and crystal filters remain very healthy, and PTI is committed to continuing to be the quality supplier for all three filter technologies.

RF marketplace

Classified display ads are available at $125 per column inch. Frequency rates available for multiple insertions. Please call for further information, 1-800-443-4969, ask for Shannon Shuman. Or fax your ad copy for a rate quote to (770) 618-0342.

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To develop state of the art commercial wireless communication products which make use of advanced digital spread spectrum technology in one of the most attractive parts in the US. A minimum of 4+ years experience required for **ENGINEER** level posts, 8+ years for **SENIOR** level positions.

RF/ANALOG IC DESIGNERS—for wireless applications up to 2GHz. Silicon bipolar and/or BiCMOS, frequency converters/synthesizers, PAs, LNAs, IF strips.

RF ENGINEERS—digital cellular handset development experience preferred. RF Circuit design experience to include RX/TX sub-systems, VCO/synthesizer design, LNAs, PAs, filters, modulators/demodulators.

ANTENNA DESIGNER—propogation prediction/characterization experience, plus filter design, combiners, multicouplers and RF switches.

RF ENGINEERS

This company develops, manufactures and markets communications systems and seeks several RF Engineers to help develop individual circuit and module designs for satellite receivers, using LIBRA, and operating in the 25MHz to 1200MHz frequency range. Your involvement will range from the block diagram to implementation and test, including design reviews and generation of test procedures. Applicants need BS in Engineering, good communication skills, and a strong desire to design RF circuits.

RF/POWER SUPPLY DESIGNERS

For an expanding Rocky Mountain company, the technical leader in hi-rel plasma, ion and magnetron power processors for the semiconductor/thin film industries. They seek experienced engineers to design RF generators, solid state amplifiers and matching networks; or in high power DC/low frequency AC output SMPS design (30kw-200kw range); or medium power DC SMPS design (300w-10kw range). Candidates require BS/MSEE and a minimum of 5 years relevant design experience, with strong RF skills, knowledge of regulations (UL, VDE, CSA, etc.) and expertise in magnetic, EMI and control loop designs.

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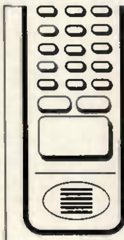

...YOUR CAREER

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

RF Systems Design: Responsible for design of analog and RF systems and circuits for consumer and commercial digital wireless products. Experience with low-cost design techniques for frequency synthesizers, power amplifiers, up/down converters and baseband circuits for digital communications systems. Familiarity with time division duplex or CDMA a plus.

Wireless Consulting Opportunities: Wireless/Cellular, ASIC/DSP/Signal Processing, Algorithm Dev./Distributor Proc., Audio, Speech & Video Compression, Telecommunications/FPGA (XILINX), R.F. Spread-Spectrum/Satellite, Wireless/TDMA/CDMA/CDPD/Freq. Hop., DataCom/TCPIP/Network Management, Full Custom CMOS/Mixed-Signal/VI, SI, Cellular Engs./Hardware & Softweare, Analog IC's/MMIC/Device Modeling, Telecom Software/LPOS/PCN/GUI/OOP/ATM/ LAN/WAN/HUB/Ethernet/ Gateway; located nationally.

Regional Field Sales. Aggressive individuals to create and serve new accounts. Positions are located throughout the U.S.A. An engineer who wants to enter sales world is acceptable. Base salary, commission and car. BSEE.

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 Modulation, Digital Mobile Communications, Channel Equalizers, Transmitter-Receiver-Synthesizer or Audio Design, Digital Signal Processing.

Wireless Engineers
RF Design Engineers: Design of Si RF-ICs for wireless communication applications (AMPS, DAMPS, GSM, DECT, POS). Si RF-IXC design experience in the 400-2400 Mhz; fast RF PLL synthesizer design experience; RF receiver/transmitter/design experience using Si bipolar and MOS technologies.
RF Small Signal and RF Power AMP System Engineers: Requires detailed technical knowledge of cellular and PCS systems with experience designing RF XMTRS and RCVRS. Need 5+ years' related experience in RF.

Design Engineer Communications ICs: Requires B.S E.E. (M.S E.E. preferred) and 5+ years experience. Individual will be responsible for leading the design and characterization of high frequency transceiver ICs for wireless communications applications. Design includes circuit integration of baseband, converter and RF/IF circuitry.

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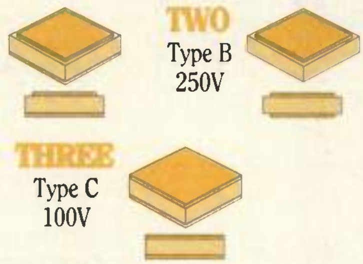

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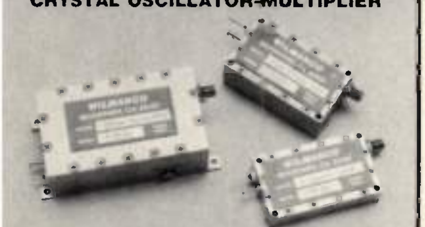

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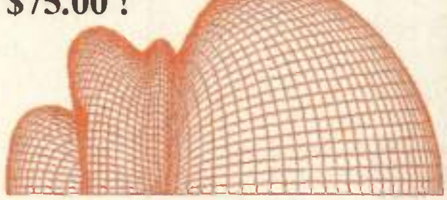

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Dow-Key Microwave Corp., 1667 Walter St., Ventura, CA 93003 ....(805) 650-0260
Matrix Systems corp., 5177 N. Douglas Fir Rd., Calabasas, CA 91302 ....(818) 222-2301
MBF Microwave, Inc., Rt. 2, Box 252A Hardy, AR 72542 ....(501) 856-2685

SYNTHESIZERS
Novatech Instruments,
1530 Eastlake Ave. E., #303, Seattle, WA 98102 ....(206) 322-1562 Fax (206) 328-6904

TELEMETRY

VACUUM CAPACITORS
COMET North America, 11 Belden Ave., Norwalk, CT 06850 ....(203) 852-1231

VACUUM TUBES

DIGITAL SIGNAL PROCESSING

SYSTEMS DEVELOPMENT, REAL TIME
Adaptive Technology, Inc., 309 Curtis St., Syracuse, NY 13208 .(800) 724-6968 Fax (315) 472-3279

MATERIALS AND HARDWARE

COMPONENTS/HYBRID PACKAGES
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013 ....(717) 243-5929

CRYSTAL BLANKS
Reeves-Hoffman, 400 W. North St., Carlisle, PA 17013 ....(717) 243-5929

PC BOARDS
Laminates, Polyester Copper Clad
Glasteel Industrial Laminates, P.O. Box 910, Collierville, TN 38027 ....(901) 853-5070

TEST EQUIPMENT

Racal Instruments, 4 Goodyear St., Irvine, CA 92718 .... (800) 722-2528
Instrument Repair Labs, Inc., 2100 W. 6th Ave., Broomfield, CO 80020 ....(800) 345-6140

RF TEST & MEASUREMENT EQUIPMENT
COAXIAL DYNAMICS, INC.,
15210 Ind. Pkwy., Cleveland, OH 44135....................(216) 267-2233 Fax (216) 267-3142

SPECTRUM ANALYZERS
DC TO LIGHT, P.O. Box 7140, Bozeman, MT 59771 .... (406) 586-5399 Fax (406) 586-6556

SERVICES

ANTENNA DESIGN & MEASUREMENT
Kintronic Labs, 144 Pleasant Grove Rd., Bluff City, TN 37618 (615) 878-3141 Fax (615) 878-4224

CONSULTANTS
Goldman Research, 12705 Monfort, Dallas, TX 75230....................(214) 788-1122
RF Design & Modeling – Spice, EEsof, Wireless ....WNJU80A@PRODIGY.COM

EMC/EMI TESTING
Liberty BEL EMC SVCS., P.O. Box 5431, MS20, Compton, CA 90224 ....(310) 537-4235
Above MS20 represents RF Design
TUV Rheinland of North America, Inc.,
12 Commerce Road, Newtown, CT 06470 ....(203) 426-0888 Fax (203) 270-8883

EQUIPMENT CALIBRATION
Instrument Repair Labs, Inc., 2100 W. 6th Ave., Broomfield, CO 80020 ....(800) 345-6140

OEM PRODUCTS
Locus, Inc., 1842 Hoffman St., Madison WI 53704 ....(608) 244-0500

TELEMETRY SYSTEMS & ENGINEERING
Telemetry Technologies, Inc., 3307 West St., Rosenberg, TX 77471 ....(713) 344-9000

SOFTWARE & SYSTEMS, CAD/CAE

SOFTWARE
Circuit Simulation
COMET North America, 89 Taylor Ave., Norwalk, CT 06854....................(203) 852-1231
Design Automation, Inc., 4 Tyler Rd., Lexington, MA 02173........(617) 862-8998 Fax (617) 862-3769
ingSoft Ltd. – the providers of the RF Designer® Solution ....(416) 730-9611
312 Dunview Ave., North York, ON M2N-4H9, Canada; bbs: 226-9820 .... Fax: 733-3884
Waypoint Software, 1950 Bavaria Drive, #317, Colorado Springs, CO 80918.................... (719) 598-9592

SYSTEM SIMULATION
Tesoft, Inc., 205 Crossing Creek Ct., Roswell, GA 30076 ....(800) 631-1113
Makers of TESLA Com Simulator ....Fax (404) 664-5817 Intl (404) 751-9785

EMC TEST & DESIGN

Products & Services Directory

The Products & Services Directory is a convenient guide to suppliers of products and services for the EMC/ESD industry. Products & Services Directory listings are sold on an annual basis.

For information on rates, closing dates and details on a special Introductory Offer, call 1-800-443-4969. Ask for your yellow page representative.

ELECTRONIC COMPONENTS AND EQUIPMENT

EMI SUPPRESSION COMPONENTS

Cables and Connectors
Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506 .... (814) 835-4000

EMI/RFI Filters
POTTER PRODUCTION CORPORATION, 3004 Hwy. 51 N., Wesson, MS 39191 .... (601) 643-2215
Qualtek Electronics Corp., 7675 Jenther Dr., Mentor, OH. 44060 .... (216) 951-3300
RtroN Corp., P.O. Box 743 Skokie, IL 60076 .... (708) 679-7180
Santek, 9765 Marconi Dr., #205, San Diego, CA 92173 .... (619) 661-8119

Ferrite Beads, Rods, Forms
Fair-Rite Products Corp., P.O. Box J, Wallkil, NY 12589 .... (800) 836-0427
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401 .... (615) 867-4100 Fax (615) 867-4102

Ferrite Suppression Components
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401 .... (615) 867-4100 Fax (615) 867-4102

Filtered Connectors
Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506 .... (814) 835-4000

Transformers/ Filters
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401 .... (615) 867-4100 Fax (615) 867-4102

ESD AND SURGE CONTROL COMPONENTS

Lightning Arrestors
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
Polyphaser Corp., P.O. Box 9000, Minden, NV 89423 .... (800) 325-7170 (703) 782-2511

CABLE AND CONNECTORS

Connectors And Adapters
ADC Telecommunications, 4900 W. 78th St., Minneapolis, MN 55435 .... (800) 366-3891 X3000

Optical Fibers And Connectors
ADC Telecommunications, 4900 W. 78th St., Minneapolis, MN 55435 .... (800) 366-3891 X3000

EMC TEST EQUIPMENT - EMISSIONS

Absorbers
Advanced Electromagnetics, Inc., P.O. Box 711719, Santee, CA. 92072-1719 .... (619) 449-9492
Microsorb Technologies, Inc., 14A Airport Dr. Hopedale, MA 01747 .... (508)634-1900
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

Anechoic Chambers
Advanced Electromagnetics, Inc., P.O. Box 711719, Santee, CA. 92072-1719 .... (619) 449-9492
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

Antennas
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Antennas Above 30 MHz
A.H. Systems Inc., 9710 Cozy Croft Ave, Chatsworth, CA 91311 .... (818) 998-0223 Fax (818) 998-6892

Antennas Above 30 MHz
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Antennas Masts
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888

Current Probes
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
Ion Physics Corp., 11 Industrial Way, Atkinson NH 03811 .... (603) 893-6687

Ferrite Absorber Tiles
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-4684

GTEM Cells
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Line Impedance
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Line Impedance Stabilization Networks
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684
Fischer Custom Communications, 2905 W. Lomita Blvd, Torrence, CA 90505 .... (310) 891-0635
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Near Field Probes
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Shielding Effectiveness Testers
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-8888
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

EMC TEST EQUIPMENT - SUSCEPTIBILITY

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E-Field Probes
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GTEM Cells
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-4684

Power Amplifiers
Applied Systems Engineering, Inc., 8623 Hwy. 377 S., Fort Worth, TX 76126 .... (819) 249-4180

EMC TEST EQUIPMENT - SUSCEPTIBILITY

Pulse Generators
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-468

Sheilded Fiber Optic Links
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-888

ESD TEST EQUIPMENT

ESD Event Detectors
TREK INC., 3932 Salt Works Rd., P.O. Box 728, Medina, NY. 14103 .... (800) FOR-TRE

Field Strength Meters
Antenna Research Associates, Inc., 11317 Fredrick Ave., Beltsville, MD 20705 .... (310) 937-888

ELECTRONIC COMPONENTS AND EQUIPMENT

ESD TEST EQUIPMENT

Surface & Volume Resistivity Meters
TREK INC., 3932 Salt Works Rd., P.O. Box 728, Medina, NY. 14103 .... (800)FOR-TRE

MATERIALS HARDWARE AND PACKAGING

SHIELDING MATERIALS

Antenna Towers
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-468

Architectural Shielding
Specialty Technical Components, Inc., P.O. Box 2106, Southeastern, Pa 19399 .... (610) 647-900

Broadband EMI
Steward, Inc., 1200 E. 36th Street, Chattonooga, TN 37401 .... (615) 867-4100 Fax (615) 867-41

Conductive Adhesives
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-59

Conductive Fiber/Fabric
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-59

Ferrite Absorber Tiles
Fair-Rite Products Corp., P.O. Box J, Wallkil, NY 12589 .... (800) 836-04

Gasketing Materials
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-59

Laminates
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-59

Magnetic Shielding
Ad-Vance Magnetics, Inc., 625 Monroe St., Rochester, IN 46975 .... (219) 223-31

Positioning Controllers
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-46

Sheilding Foils and Tapes
Venture Tape Corp., 30 Commerce Rd., Rockland, MA 02370 .... (617) 331-59

Tripods
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-46

Turntables
EMCO, P.O. Box 1546, Austin, TX. 78767 .... (512) 835-46

SHIELDING EMI/RFI SERVICES

Vacuum Platers, Inc., 115 S. Union Street, Mauston, WI 53948 .... (608) 847-56

SHIELDED ENCLOSURES - EQUIPMENT

Component/Module Cases
Marmin-Hil Plastics, Inc., 101 Roselle St., Linden, NJ 07036 .... **(908) 925-2940 (800) 886-29**

SHIELD ROOMS AND CHAMBERS

Shielded Rooms EMI/RFI/Magnetic
Rantec, P.O. Box 1546, Austin, TX 78767 .... (512) 835-46

ESD PACKAGING

Antistatic and Conductive Polyurethanes
Pad-Tastics, Inc., P.O. Box 50479, Cicero, IL 60650 .... (708) 780-8402 FAX (708) 780-16

ESD ENVIRONMENTAL CONTROL

Antistatic or Conductive Flooring
Freudenberg Building Systems, Inc./Nora Rubber Flooring
94 Glenn St., Lawrence, MA 01843 .... (508) 689-05

TEST LABORATORIES AND CONSULTANTS

TEST LABORATORIES

Spectrum Control, Inc., 6000 West Ridge Rd., Erie, PA 16506 .... (814) 835-40
TUV Product Service, Inc., 1775 Old Hwy. 8, New Brighton, MN 55112 .... (800) 472-79

CONSULTANTS

Kimmel Gerke Assoc. Ltd., 1544 N. Pascal, St. Paul, MN 55108 .... (612) 330-37
EMC Design/Troubleshooting-Medical, Industrial, ITE, Vehicles & More-50+ years exp.

RF software

Multilayer Circuit Design

HP EEsof has introduced a picosecond interconnect-modeling suite that helps designers create more accurate interconnect models in order to better predict how printed circuit boards, multi-chip module substrates, IC packages and ICs will perform. The Picosecond Interconnect Modeling Suite includes schematic entry, model libraries (including multilayer coupled lines and input/output drivers), frequency-domain and transient time-domain simulators, SPICE model generator, and presentation capabilities. U.S. price for the suite is $40,000, individual modules can be purchased separately.
HP EEsof
INFO/CARD #212

DSP Simulation

The MathWorks has announced the availability of SIMULINK with the Digital Signal Processing (DSP) Blockset. The DSP Blockset is an integrated software environment that provides engineers with block diagram simulation and code generation capabilities built on MATLAB®. SIMULINK with the DSP Blockset is available to run on PCs, Macs, and all major UNIX systems. Pricing for the DSP Blockset starts at $395 for PCs and Macs.
The MathWorks, Inc.
INFO/CARD #211

On-Line Site Calculations

Comp Comm has announced its proprietary engineering software is now available on-line. With minimal data entry, users can search CompComm's database of available frequencies; identify co-channels; access the antenna survey branch tower file, terrain and airport databases; develop and store all engineering data and then assemble and print a completed FCC Form 600 with required maps. The sign-up process is simple, and anyone with a PC, modem and HP-compatible laser printer can access the service. Nearly all applications can be completed for well under $100, at a rate of $1.25/minute.
Comp Comm Inc.
INFO/CARD #210

Signal Processing Suite

National Instruments offers a software suite that gives users ready-to-run signal processing capabilities for Windows PCs and Macintosh computers. The Signal Processing Suite includes the Digital Filter Design Toolkit, the Third-Octave Analyzer Toolkit, the newly updated Joint Time-Frequency Analysis (JTFA) Toolkit, and the VirtualBench™-DSA (a dynamic signal analyzer virtual instrument). The Signal Processing Suite will be available in Q4 1995 for $995. Individual parts of the Suite may be purchased separately.
National Instruments
INFO/CARD #209

High-Speed Op-Amp Models

Comlinear Corp. has announced the newest version (MMD.06) of its PSPICE-compatible models. This updated version includes macromodels for 29 of the company's high-performance amplifiers. Available free on a 3-1/2-inch diskette, these models simulate room-temperature performance of 29 DC-coupled, high-speed op-amps with –3 dB bandwidths from 100 MHz to 1 GHz. The SPICE model files are written in ASCII file format and are compatible with PSPICE and other SPICE 2G simulators.
Comlinear Corp.
INFO/CARD #208

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Arthur E. Sweum, Senior Vice President, 9/11/95

Capabilities Brochure
A complete capabilities brochure is now available from Chesapeake Microwave Technologies, Inc. Their eight-page brochure describes the products and outlines the markets in which Chesapeake participates. Also addressed are the extensive commercial and military experience, facilities, and quality assurance of the company.
Chesapeake Microwave Technologies, Inc.
INFO/CARD #207

PCS/PCN Report
Killen & Associates has produced a report, *PCS/PCN: When It Comes to Making Money*, consisting of two parts. U.S. PCS Equipment Markets, Trends, and Opportunities (a 160-page study) and PCS/PCN: Markets, Applications, and Technologies (a 300-page hard-copy report with 22 video presentations/interviews of industry leaders and experts). The report costs $5,000.
Killen & Associates, Inc.
INFO/CARD #206

Switch Catalog
The DMT Division of Jay-El Products announces the release of catalog no. 13, a switch product catalog. The catalog contains information on SPDT, transfer, multi-position and TOH switches for RF and microwave applications. Standard models are featured as well as custom options and specifications.
DMT Div of Jay-El Products
INFO/CARD #205

Mobile Telephony Report
EDS Communications & Electronics Industries Consulting has released a monograph entitled, *An Ice Age is Coming to the Wireless World: A perspective on the Future of Mobile Telephony in the United States*. This report summarizes the substantial change EDS expects in the wireless industry. The paper explains the factors and forces driving these changes and the strategies necessary to stay competitive and profitable. The report is available free-of-charge to professionals in the telecommunications industry.
EDS Communications
INFO/CARD #204

Packaging Forecasts
The Institute for Interconnection and Packaging Electronic Circuits offers *The National Technology Roadmap For Electronic Interconnections 1995*, a six-part report on the future of interconnection product and manufacturing technology. IPC members can purchase the report for $50, while non-members can purchase it for $200.
IPC
INFO/CARD #203

Databooks Online
Motorola has expanded its offering of technical information available on its World Wide Web server. Over a dozen databooks from Motorola Semiconductor Product Sector's Data Library are now available in a full-text search database. The databooks contain application notes and data sheets describing semiconductor devices. Motorola Semiconductor's home page is located at: http://Design-NET.com.
Motorola Semiconductor
INFO/CARD #202

Electronics Catalog
Jameco Electronics has released their latest catalog. The catalog features over 150 new products, including: new ICs, connectors, cables, test equipment, computer products and more. Jameco's product line now includes over 6000 electronic and computer products and more.
Jameco Electronics
INFO/CARD #201

ITU-T Recommendations Online
ITU-T Recommendations constitute the basis for international telecommunications standards developed by the ITU Telecommunication Standardization Sector. A annual subscription service to online electronic versions of these Recommendations is now available. ITU-T Recommendations Online offers over 1000 texts in English, French and Spanish. They are available via network interfaces such as the World Wide Web, Gopher and FTP.
International Telecommunication Union
INFO/CARD #200

Interconnection Industry Electronics Manufacturing Report
The American Electronics Association (AEA) and the Electronic Industries Association (EIA) have announced the availability of the National Electronics Manufacturing Initiative (NEMI) final report titled, "Electronics Manufacturing Technology Roadmaps and Options for Government Action." The report outlines the steps both government and the private sector need to take in the high-volume consumer electronics manufacturing arena. Copies are available at a cost of $35.00 each.
AEA and EIA
INFO/CARD #199

Wireless Test & Measurement
Hewlett-Packard has released a brochure that describes a comprehensive suite of test and measurement products that evaluate wireless communications-systems performance. The 18-page booklet, "Test and Measurement Solutions for Wireless Communications" (Literature 5953-9471E), is available free of charge.
Hewlett-Packard Co.
INFO/CARD #198

Capacitance Meter Literature
Boonton Electronics has released an eight-page brochure on its Model 7200 capacitance meter, which offers accurate and fast characterization of capacitive devices, including semiconductors. The full-color brochure details all pertinent features, functions and applications of the meter, including bias capability, automatic zeroing, bus operation, and versatile plot capability.
Boonton Electronics Corp.
INFO/CARD #197

EMC Desk Reference
International, Science & Technology (I.S.T.) an independent RFI and telephone product compliance test facility has released the *1995 Desk Reference*, Volume 3, issue 1, a booklet containing information explaining the most commonly asked compliance questions and test-proven design fixes. The Desk Reference is available free of charge from I.S.T.
International, Science & Technology, Inc.
INFO/CARD #196

SAW Product Info
The Summer edition of Sawtek's *SAW Scene* contains an article about using a family of SAW filters in CDMA basestation and subscriber unit transmitters and receivers. In the same issue, a new family of low insertion-loss SAW filters at 70 MHz are introduced.
Sawtek, Inc.
INFO/CARD #195

Master Selection Guide
QUALCOMM's VLSI Products has released their newly revised Master Selection Guide, featuring their complete line of synthesizer, forward error correction and voice compression products. The colorful, 37-page Guide details the three product areas with photos, product applications, block diagrams, and tables.
QUALCOMM Inc., VLSI Products
INFO/CARD #194

Technical Brochure
Wandel & Goltermann has released the latest installment of its "bits" series of four-color technical brochures. The new edition, "bits 71," outlines techniques for testing SDH/SONET networks, ISDN access, and base transceiver stations in mobile radio applications.
Wandel & Goltermann, Inc.
INFO/CARD #193

RF DESIGN SEMINAR SERIES

Call for Papers

RF Design Seminar Series — Dallas
January 16-18, 1996 — Sheraton Park Central, Dallas, Texas

Papers are invited for the first RF Design Seminar Series event! Technical presentations on any RF topic are encouraged, with special attention given to papers on recent engineering developments in components and techniques for applications of current interest — Cellular, PCS, WLAN, unlicensed systems, RFID, IVHS, LEO.

Oral Presentations

Oral presentations will be held during the day of January 18. Proposals should indicate whether the paper will require one-half hour or one hour for presentation, including a question-and-answer period. Papers may cover engineering design or analysis, testing, development case histories, or tutorial material.

Poster Session

A special evening Poster Session will be held from 4 to 6 p.m. on January 17. A social reception will be held in conjunction with this session, providing a relaxed atmosphere for the discussion of your work. Indicate your preference for this session in your proposal. Some papers proposed as oral presentations may be invited to participate in the Poster Session. RF companies are encouraged to prepare technical papers or applications notes that can be included in this interactive session.

Presenter Benefits

All speakers and poster session participants receive free admission to the technical papers program and a copy of the Proceedings. In addition, all presenters will be given significant discounts on class fees for the short courses offered at this event. Your contribution to the program is appreciated!

Send a one or two paragraph abstract by October 25, 1995 to:

Gary Breed, Editor
RF Design
6300 S. Syracuse Way
Suite 650
Englewood, CO 80111
Tel: (303) 220-0600
Fax: (303) 267-0234

Future Seminars:
Las Vegas, NV — April 24-26, 1996
Wakefield, MA — October 21-23, 1996

The RF Design Seminar Series — A Unique Learning Environment for RF Engineers

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Coming in the next issue:
(November 1995)

Susceptibility/Immunity Test Equipment and Test Methods

European and FCC Regulatory Update

Product Focus on Ferrites

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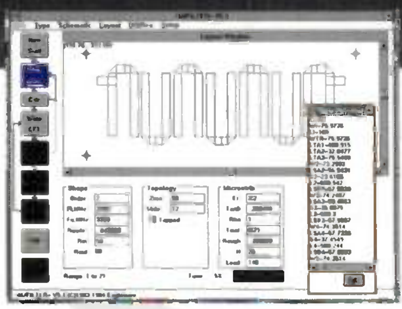
RF guide to editorial coverage

RF advertising index

TURBO-CHARGE TOUCHSTONE



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L-C series mode
L-C Colpitts
L-C Clapp
T-line and L-C VCO
VCO with xformer
Cavity bipolar and hybrid
Dielectric resonator
Terminal SAW bipolar
Port SAW hybrid
Port SAW MOSFET
Pierce and Colpitts crystal
Driscoll crystal
Butler overtone
Overtone with multiplier

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L-C pi and L
L-C tee
T-line quarter wave
T-line single/double stub
General order bandpass
L-C pseudo lowpass
T-line pseudo lowpass
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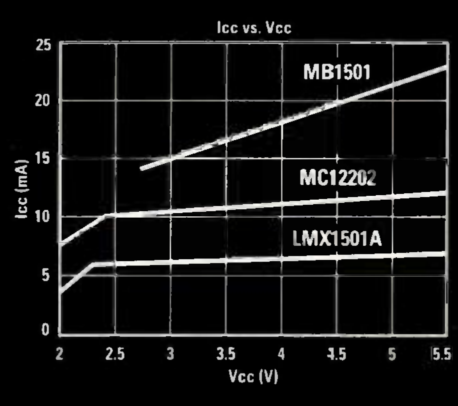

	LMX1501A	LMX1511	LMX2314/15	LMX2320	LMX2325	LMX2330A	LMX2331A	LMX2332A	LMX2335	LMX2336	LMX2337
RF Input-Main PLL	1.1GHz	1.1GHz	1.2GHz	2.0GHz	2.5GHz	2.5GHz	2.0GHz	1.2GHz	1.1GHz	2.0GHz	550MHz
RF Input-Aux PLL						510MHz	510MHz	510MHz	1.1GHz	1.1GHz	550MHz
I_{cc} (typ) @3V	6mA	6mA	6mA	10mA	11mA	15mA	14mA	8mA	9mA	11mA	9mA
Powerdown (typ)	N/A	N/A	30μA	30μA	30μA	1μA	1μA	1μA	1μA	1μA	1μA

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