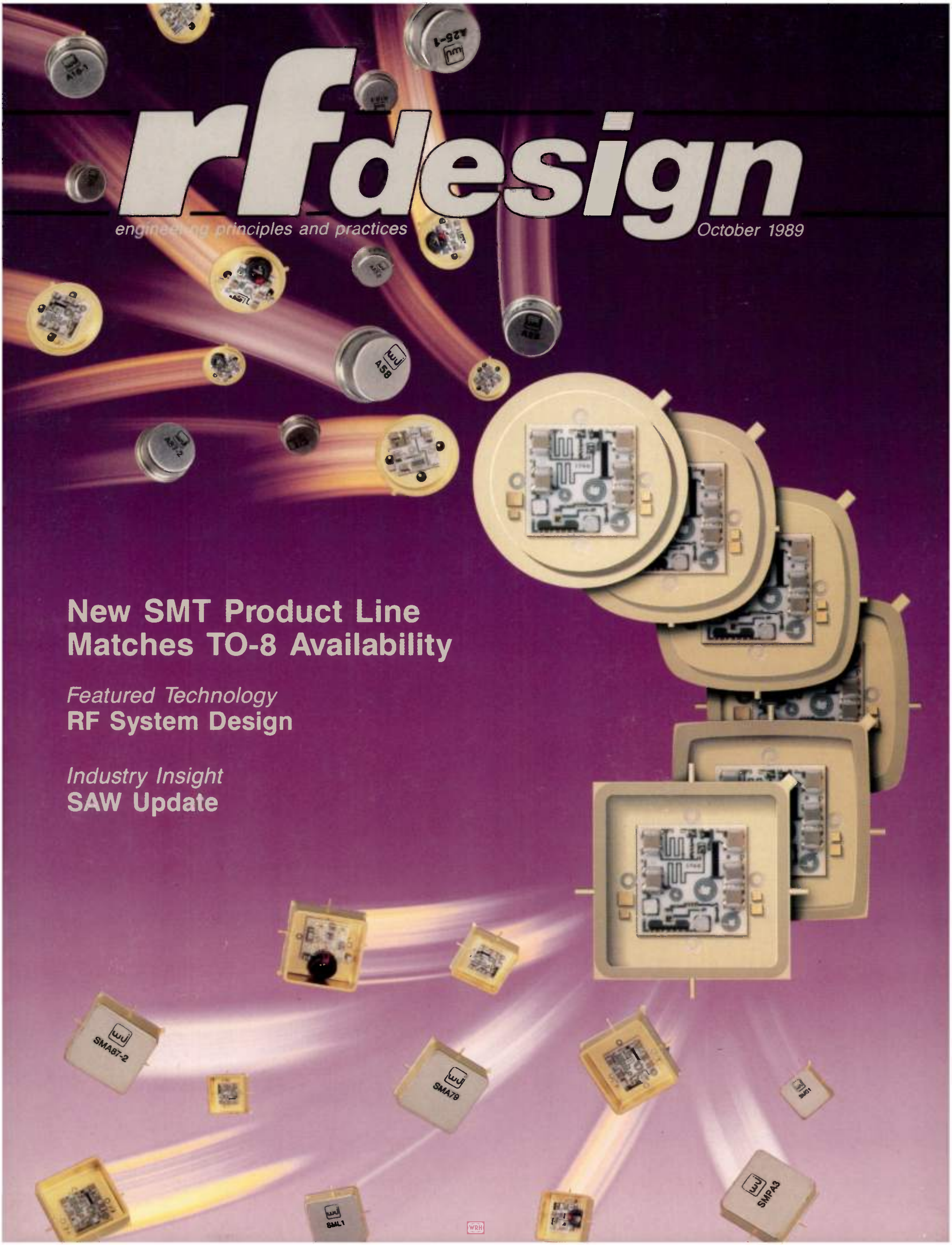
rf design

engineering principles and practices

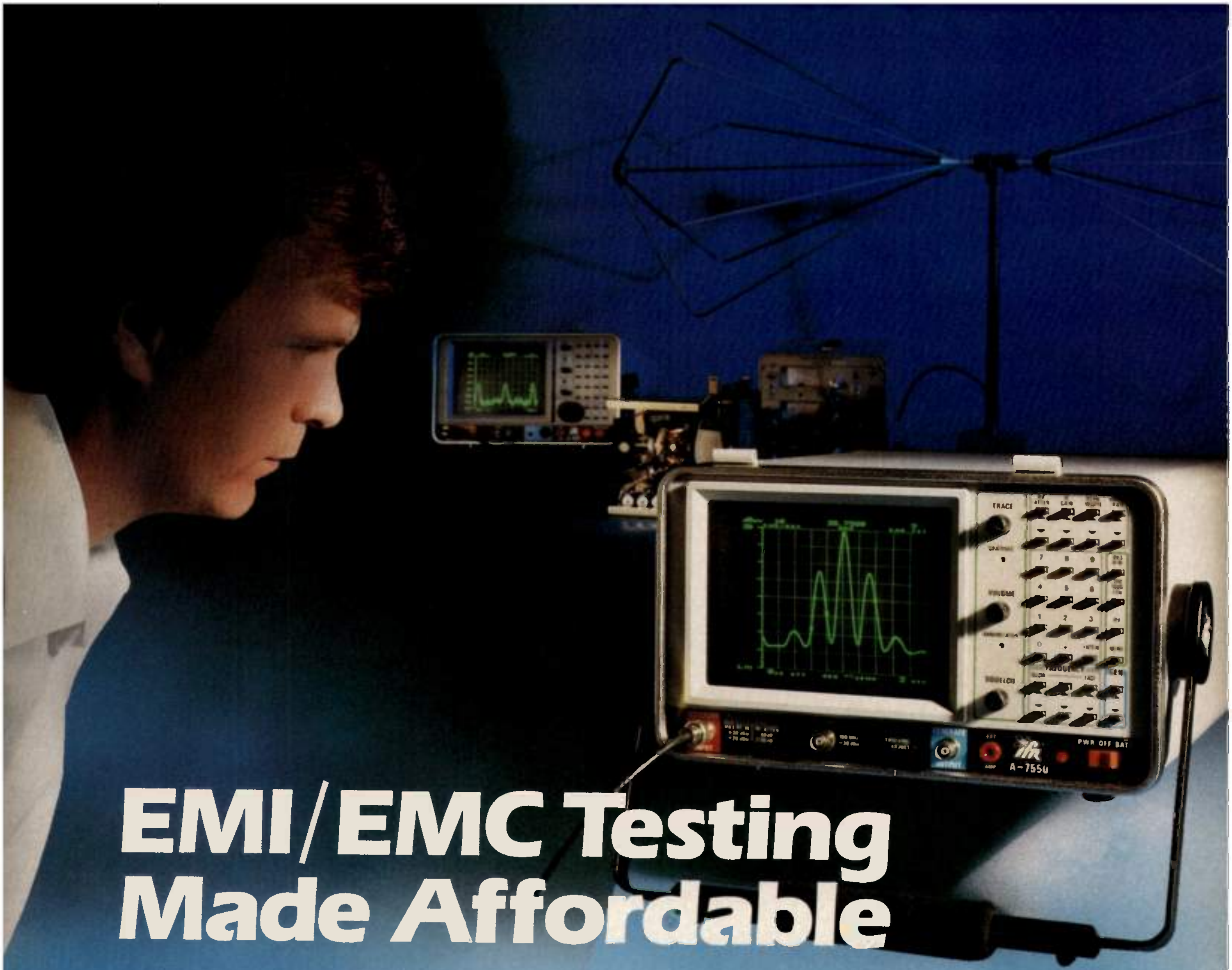
October 1989



New SMT Product Line Matches TO-8 Availability

Featured Technology
RF System Design

Industry Insight
SAW Update



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INFO/CARD 3

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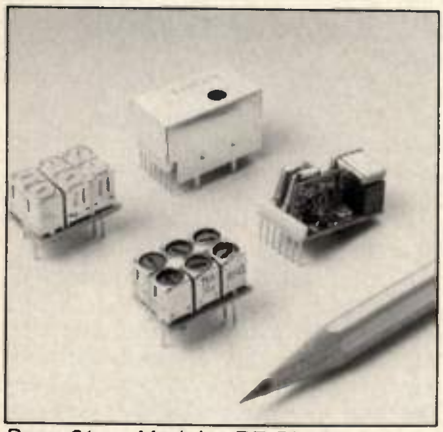
October 1989



Page 31 — Modular RF Blocks

Page 35 — Varactor Dividers

Page 50 — RF Expo East Program

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rf editorial

Plan to Attend RF Expo East

By Gary A. Breed
Editor

I know the title of this month's column isn't exactly subtle, but if you pass up an opportunity to go to RF Expo East, you will miss the outstanding papers, the design courses, and the chance to see key RF companies face-to-face.

I just finished reviewing the papers which make up the technical program, and realized that there are some real groundbreaking developments being discussed. Four of our 1989 contest entries will be presented, including the grand prize winner. All four of them represent pioneering work in PLL, filter and phase shifter development.

Applications of high-speed op amps and analog multipliers are covered in three papers, recent developments in acoustic charge transport (ACT) technology are presented, and new information on RF performance of reed relays and chip capacitors is ready for you to absorb. Excellent RF system design information will be covered, including HF system considerations, interference in collocated facilities, antenna tuners, and power combining. Two sessions on PLLs and frequency synthesis will examine this important design topic.

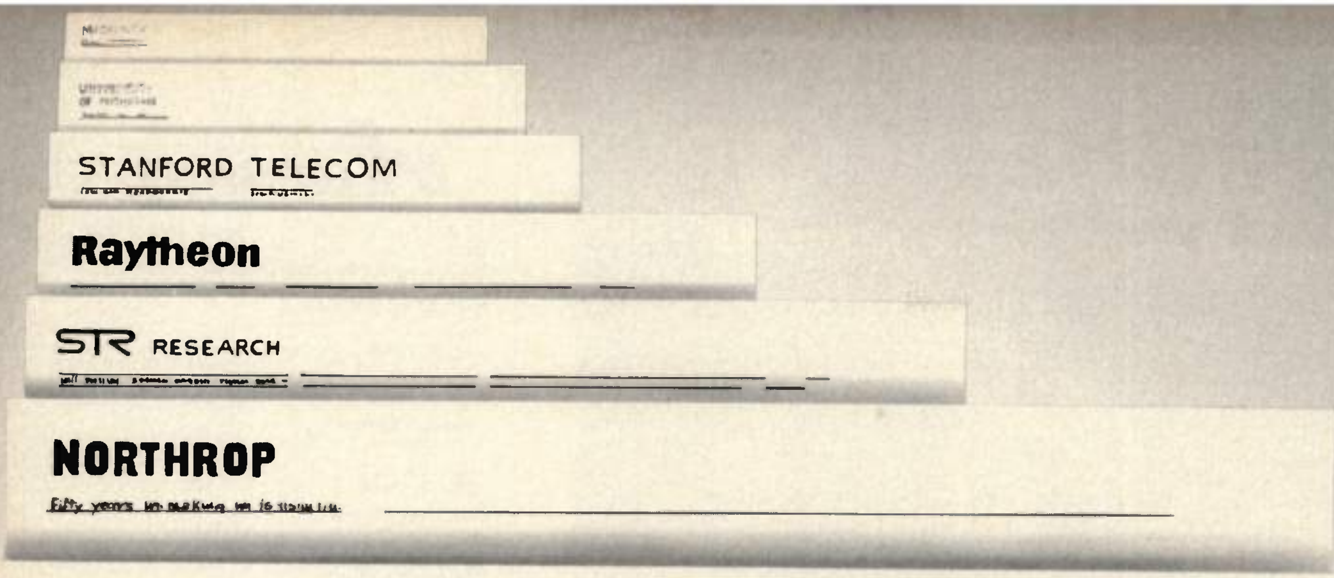
A three-hour segment of Hewlett-Packard's two-day EMC design course is another exceptional presentation. This is a design course, not the rehash of rules and regulations and test methodology usually found elsewhere. You can *use* this information. Another all-morning tutorial covers the basics of antennas, presented by Dr. Benjamin Rulf of Lockheed. Along with the three special courses, Fundamentals of RF Circuit Design (2 parts) and Computer-Aided Filter Design, these extended tutorials offer an in-depth look at essential RF principles.

It would be wise to plan to stay until the very end, too. Developments in crystal oscillators will be described on Thursday morning, including landmark microprocessor-controlled oscillator work by the U.S. Army LABCOM. Their work promises 10- to 100-times improvement in performance. Other papers on Thursday's schedule feature oven-controlled oscillator development, antenna tuner design for HF, and active receive antennas. A complete summary of the program starts on page 50.

I see a lot of engineering developments — as proposed articles, conference technical papers, and press information from various companies. But I have never seen as much new information in one place as you will find at RF Expo East.

See you there!

Gary A. Breed



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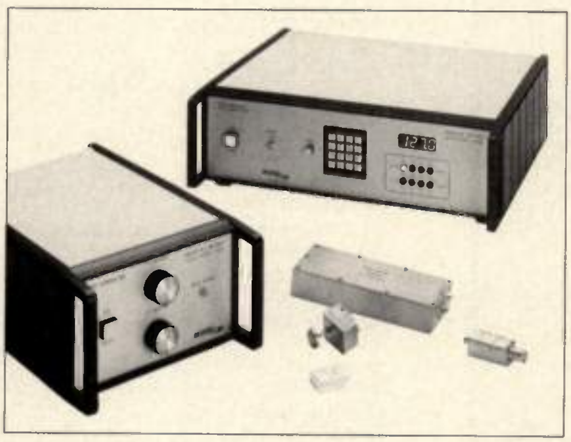

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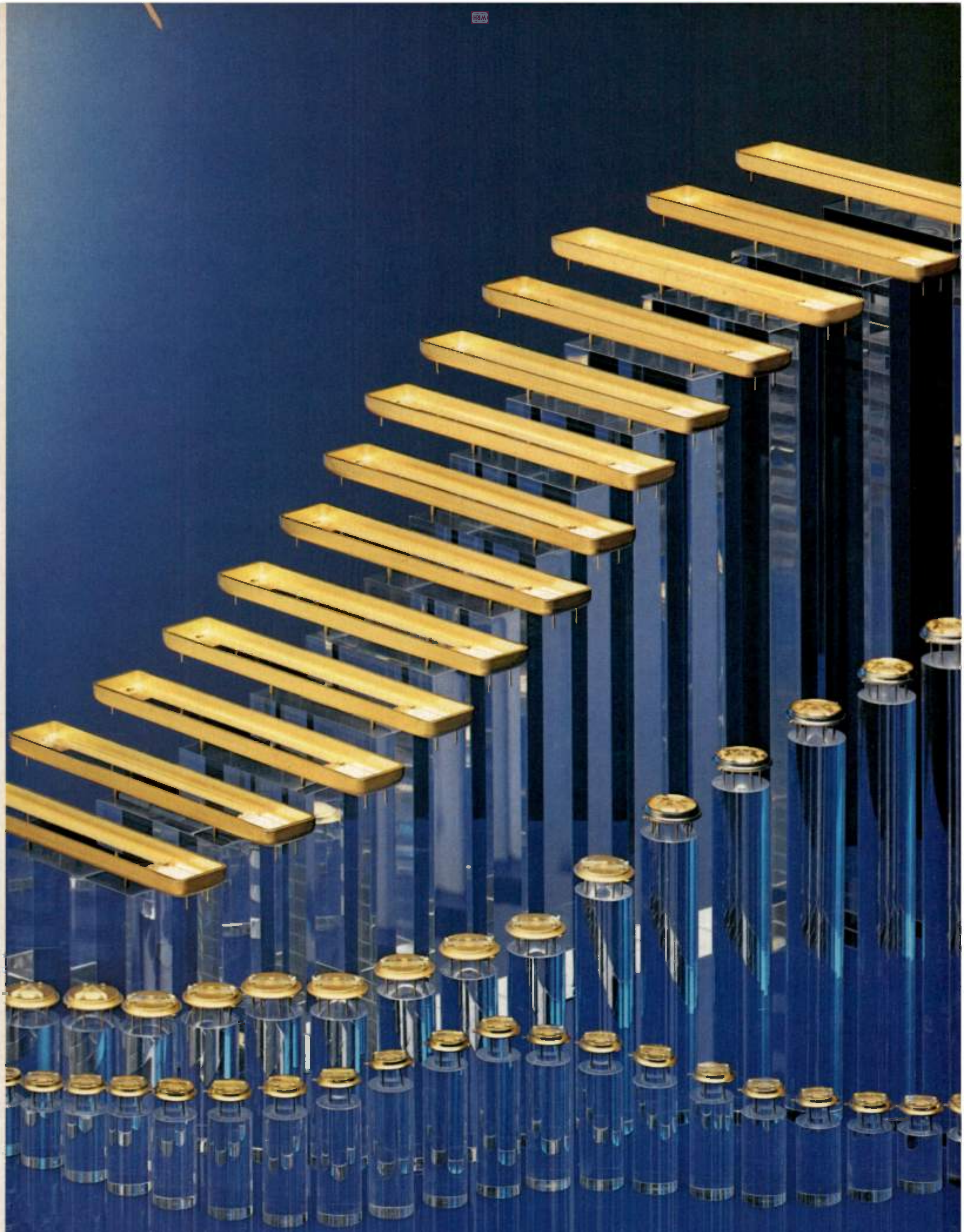


INFO/CARD 8

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

Filter Comments

Editor:

Jack Porter's article "Chebyshev Filters With Arbitrary Source and Load Resistances" (*RF Design*, August 1989) is quite thorough and useful, but I do have two comments. First, a question: In this modern-day world of elliptic and other synthesized pole-zero filters, is it really important to be able to design a variety of all-pole Butterworth and Chebyshev filters? On a practical percentage basis, what types of filters are really efficient in size, parts count and cost? Consider a test case with a 1.2:1 shape factor to 60 dB; would it *ever* be built with a Butterworth or Chebyshev?

Second, Mr. Porter says, "Bandpass filter designs are always based on doubly terminated, minimum insertion loss prototypes." However, bandpass filters are frequently not based on that type of prototype, and in fact rarely are unless symmetrical stopbands are specified. The word "always" is especially inappropriate; one very notable exception is seen in the modern method of designing multiplexer filters, frequently bandpass, consisting of paralleled filters all designed as one-end terminated bandpass filters. See Christian and Eisemann's *Tables* and the *S/FILSYN User's Manual.*

William B. Lurie
Boynton Beach, Florida

Propagation Corrections

Editor:

Past articles relevant to RF propagation in buildings by Dr. Rappaport (*RF Design*, January 1989) and Dr. Ishii (*RF Design*, July 1989) were welcome and informative. The numerous references provided by both authors are appreciated, especially on a subject such as RF propagation. After careful reading, study, and comparison of the results presented, it is clear that continued research on RF propagation within buildings is required, and I look forward to seeing this subject treated in future issues.

I did notice some errors in the article by Dr. Ishii. First, the numerical value in the denominator of equation 7 should read as 4.343. Also, $-10n_c$ in equation 16 should be $+10n_c$ instead. Another error I noticed was that the line preceding equation 18 should read: "Substituting these into equation 7..." The line preceding equation 19 should read: "Substituting the values in (17) into equation 13..." Finally, the values given in (17) do not appear to agree with those shown in Figure 2, nor do they agree with the loss number α calculated in equation 18.

Again, thank you for the articles in this subject area. I look forward to additional contributions on this subject in *RF Design*.

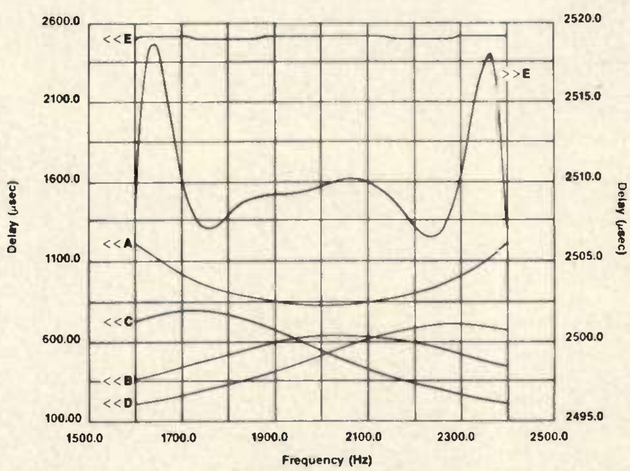
Alan Victor
Monicor Electronic Corp.
Fort Lauderdale, Florida

After conferring with the author, the following additional correction was determined: The value given in (17) for P_r should be −97 dBm, instead of −79 dBm. With this change, the values in (17) correspond to those in Figure 2 and equation 18. The author regrets any inconvenience caused. —Editor

Corrections

1. In "An Analysis of Inverter Crystal Oscillators" (*RF Design*, August 1989), the author's employer was given incorrectly. Leonard Kleinberg is an electronic engineer at the NASA Goddard Space Flight Center, Greenbelt, Md.

2. An incorrect phone number was given for the author of "Crystal Delay Equalizers" (*RF Design*, August 1989). Mr. Lurie's phone number is (407) 369-3218. Also, the figure below should be substituted for Figure 2 as it appeared in the article.



rf calendar

October 9-12, 1989
Annual Old Crows Meeting
Sheraton Washington Hotel, Washington, DC
Information: Association of Old Crows, 1000 N. Payne Street, Alexandria, VA 22314. Tel: (703) 549-1600

October 9-13, 1989
Antenna Measurement Techniques Association 11th Annual Meeting and Symposium
Doubletree Inn, Monterey, CA
Information: Cheryl Komer, 1989 AMTA Symposium, Lockheed Missiles and Space Co., 1111 Lockheed Way, O/62-42 B/076, Sunnyvale, CA 94089-3504.

October 15-18, 1989
22nd Annual IICIT Connectors and Interconnection Technology Symposium
Wyndham Franklin Plaza Hotel, Philadelphia, PA
Information: Janice MacDonald, IICIT, 104 Wilmot Road, Suite 201, Deerfield, IL 60015-5195. Tel: (312) 940-7218

October 16-17, 1989
Interface '89 Rhode Island Conference
Sheraton Islander Inn, Newport, RI
Information: Michael P. Lauro, c/o Tanury Industries, 6 New England Way, Lincoln, RI 02865. Tel: (401) 333-9400

October 16-19, 1989
SCAN-TECH 89
New San Jose Convention Center, San Jose, CA
Information: AIM USA, 1326 Freeport Road, Pittsburgh, PA 15238. Tel: (800) 338-0206; (412) 963-8588

October 17-19, 1989
Northcon/89
Portland Memorial Coliseum, Portland, OR
Information: Northcon/89, 8110 Airport Boulevard, Los Angeles, CA 90045-3194. Tel: (213) 772-2965

October 22-25, 1989
1989 IEEE GaAs IC Symposium
Sheraton Harbor Island Hotel, San Diego, CA
Information: IEEE GaAs IC Symposium, 655 15th Street, N.W., Suite 300, Washington, DC 20005. Tel: (202) 347-5900

October 22-27, 1989
ISA/89
Philadelphia Civic Center, Philadelphia, PA
Information: Instrument Society of America, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709. Tel: (215) 922-2612; (919) 549-8411

October 24-26, 1989
RF Expo East 89
TropWorld, Atlantic City, NJ
Information: Kristin Hohn, Cardiff Publishing Company, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111. Tel: (303) 220-2600; (800) 525-9154

October 26, 1989
4th Annual EMC Event
Minneapolis Hilton Inn, Minneapolis, MN
Information: Diane Swenson, Amador Corporation, Taylors Falls, MN 55084-0270. Tel: (612) 465-3911

rf courses

Georgia Tech Education Extension

Principles of Modern Radar
October 30-November 3, 1989, Atlanta, GA

Information: Education Extension, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel: (404) 894-2547

The George Washington University

Grounding, Bonding, Shielding and Transient Protection
October 30-November 2, 1989, Orlando, FL
Frequency-Hopping Signals and Systems
November 6-8, 1989, Washington, DC
Electromagnetic Interference and Control
November 13-17, 1989, Washington, DC
Modern Receiver Design
November 13-17, 1989, London, England

Information: Misael Rodriguez, Continuing Engineering Education, George Washington University, Washington, DC 20052. Tel: (800) 424-9773; (202) 994-6106

University of Wisconsin-Madison

Surge Protection for Telecommunications
October 23-25, 1989, Madison, WI

Information: University of Wisconsin-Madison, College of Engineering, 432 N. Lake Street, Madison, WI 53706. Tel: (800) 262-6243; (800) 362-3020

Learning Tree International

Introduction to Fiber Optic Communications
November 14-17, 1989, Boston, MA
November 14-17, 1989, San Diego, CA
December 5-8, 1989, Los Angeles, CA

Information: John Valenti, Learning Tree International, 6053 W. Century Boulevard, P.O. Box 45974, Los Angeles, CA 90045-0974. Tel: (800) 421-8166; (213) 417-8888

EEsof, Inc.

MMIC Design Workstation (MMIC)
October 23-27, 1989, Westlake Village, CA
Computer-Aided Engineering for Nonlinear Microwave Circuits (mwSpice)
November 9-10, 1989, Westlake Village, CA

Information: Sande Scoredos, Training Coordinator, EEsof, Inc., 5795 Lindero Canyon Road, Westlake Village, CA 91362. Tel: (818) 991-7530, ext. 197

Hewlett-Packard Co.

Designing for Electromagnetic Compatibility (EMC)
October 16-17, 1989, Andover, MA
October 19-20, 1989, Rockville, MD
November 14-15, 1989, Las Colinas, TX
December 4-5, 1989, Santa Clara, CA
December 11-12, 1989, Mountain View, CA
December 14-15, 1989, Mountain View, CA

Information: Hewlett-Packard Co., 3000 Hanover Street, Palo Alto, CA 94304. Tel: (800) 2HP-EDUC

Interference Control Technologies, Inc.

EMC in Medical Electronics
October 17-20, 1989, San Francisco, CA
TEMPEST Design and Measurement
November 7-10, 1989, San Francisco, CA
Practical EMI Fixes
November 6-10, 1989, Atlanta, GA

Information: Penny Caran, Registrar, Interference Control Technologies, Inc., State Route 625, P.O. Box D, Gainesville, VA 22065. Tel: (703) 347-0030

EMC Services

Filter Design for Switching Supplies
November 6-7, 1989, Tampa, FL
EMI Control for Switching Supplies
November 8-10, 1989, Tampa, FL

Information: Sonya Nave, EMC Services, 11833 93rd Avenue North, Seminole, FL 34642. Tel: (813) 397-5854

National Semiconductor

Linear Applications Seminar
October 17, 1989, Portland, OR
October 18, 1989, Oakland, CA
October 19, 1989, Santa Clara, CA
October 20, 1989, Palo Alto, CA
October 23, 1989, Boston, MA
October 24, 1989, Boston, MA
October 25, 1989, Trumbull, CT
October 26, 1989, Long Island, NY
October 27, 1989, Paramus, NJ
October 30, 1989, Philadelphia, PA
October 31, 1989, Baltimore, MD

Information: National Semiconductor, 2900 Semiconductor Drive, P.O. Box 58090, Santa Clara, CA 95052-8090. Tel: (800) 548-4529; (408) 721-5000

Praxis International, Inc.

Managing the EMI Function
November 15-16, 1989, Washington, DC
Facility Grounding, Shielding and Lightning Protection
November 15-17, 1989, Washington, DC

Information: Praxis International, Inc., Exton Professional Building, Suite 103, 319 N. Pottstown Pike, Exton, PA 19341. Tel: (215) 524-0304

R & B Enterprises

Prominent E^3 Standards
October 23, 1989, Philadelphia, PA
E^3 Detailed Design Course
October 24-27, 1989, Philadelphia, PA
Grounding, Bonding and Shielding
October 25-26, 1989, Philadelphia, PA
Real Life Solutions to EMI Problems
November 1-2, 1989, Philadelphia, PA

Information: Registrar, R & B Enterprises, 20 Clipper Road, West Conshohocken, PA 19428. Tel: (215) 825-1966

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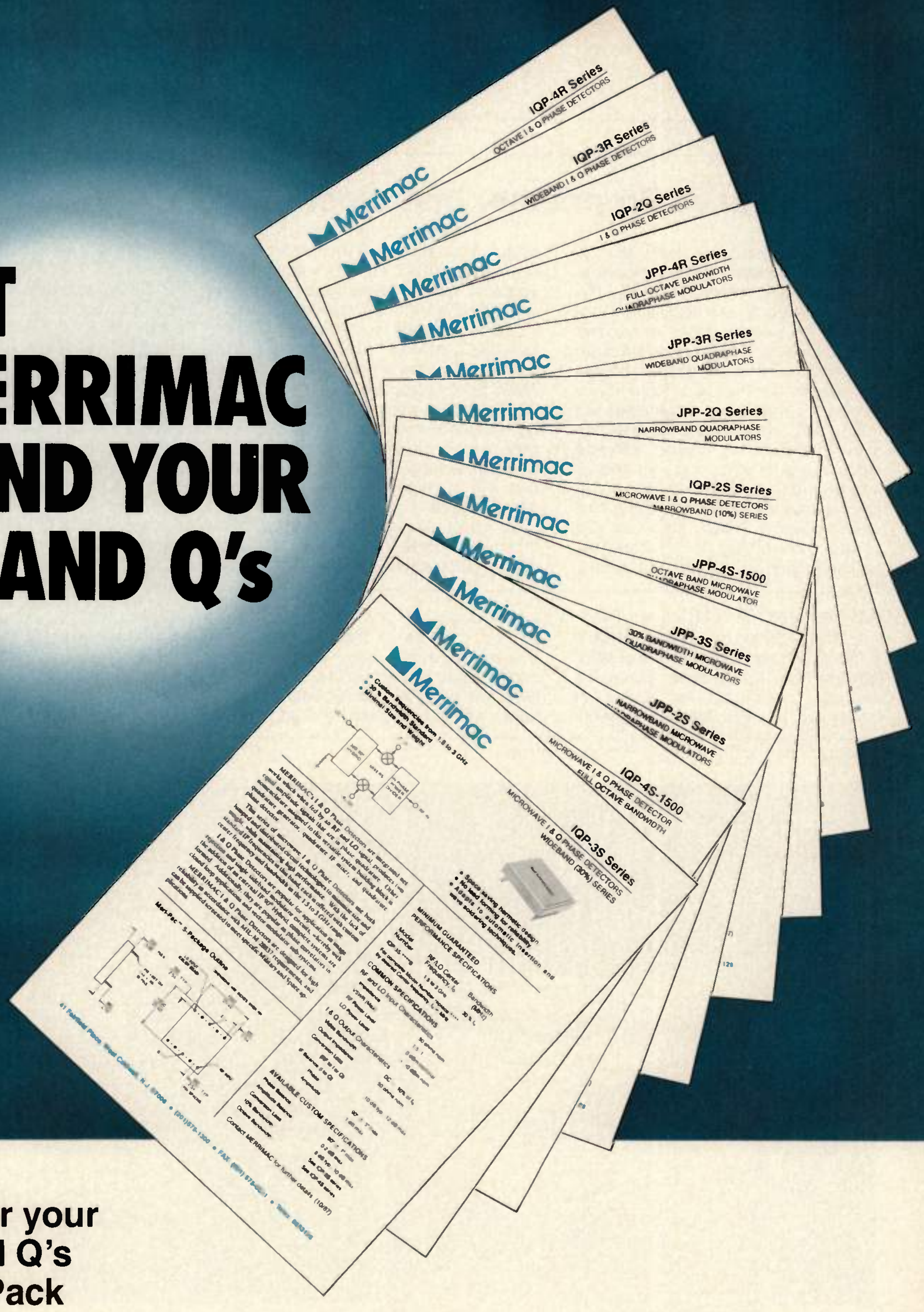

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INFO/CARD 11

HP Releases Proprietary Instrument Language

Hewlett-Packard Co. (HP) has released its proprietary test and measurement systems language (TMSL), formerly referred to as HP systems language, for use by other instrument manufacturers. TMSL is a standard instrument-control language, providing generic commands not tied to any particular instrument. It enables an instrument programmer to use the same command to instruct different types of instruments (e.g., an oscilloscope and a spectrum analyzer) to carry out an instruction (e.g., to measure frequency). TMSL also provides vertical compatibility. That is, a particular instruction is carried out with a single command for all instruments of a certain type. This allows for equipment upgrades without rewriting software.

All of HP's VXIbus products and other instrument-system products will incorporate TMSL. At least 14 products supporting the language are already available. TMSL is fully compatible with IEEE-STD-488.2, and is designed to support all types of instruments. Existing standards organizations are being evaluated by Hewlett-Packard in an effort to find one that will manage the TMSL enhancement process.

To assist manufacturers who want to incorporate TMSL (and IEEE-488.2) into their instruments, HP is offering an optional training course. A technical data book, *TMSL Syntactic and Semantic Requirements,* is also available. To participate in the course or to obtain the book, implementors will be required to sign a license agreement. Cost of the course (and license) is $1500, and cost of the book (and license) is $100. Another book, *A Beginner's Guide to TMSL,* instructs instrument programmers on the structure and syntax of TMSL. To order this book, call 1-800-538-8787. Further information on TMSL can be obtained by contacting: TMSL Manager, Hewlett-Packard Co. P.O. Box 301, Loveland, CO 80539-0301.

GEC-Siemens Win in Plessey Takeover Bid—Britain's General Electric Co. plc (GEC) and Siemens AG of West Germany have successfully completed their $3.1 billion bid for control of Plessey Co. plc. The fight for Plessey, which began in late 1988, has been marked by fierce resistance from Plessey at every step. The takeover comes after many months of negotiations and hearings, ending with a green light from the European Economic Commission, the U.K. Monopolies and Mergers Commission and the British Ministry of Defense.

Control of Plessey's various businesses will be distributed between GEC and Siemens according to a proposal announced previously. According to the plan, Plessey's North American defense electronics subsidiaries Sippican Inc. and Leigh Instruments Ltd. will be wholly owned by GEC. Plessey's avionics and naval systems will be 100 percent owned by GEC, while ownership of the radar and defense systems will go to Siemens. GEC will have a 75 percent share in Plessey Electronic Systems Corp., with the remaining 25 percent controlled by Siemens. GEC Plessey Telecommunications Ltd. will be split on a 60/40 basis between the two companies. These arrangements were agreed upon in part to satisfy concerns at the Ministry of Defense regarding competition and national security.

SGS-Thomson to Acquire Microwave Semiconductor Corp.—Siemens and SGS-Thomson have signed a letter-of-intent covering the proposed acquisition of the non-gallium arsenide activities of Microwave Semiconductor Corporation (MSC) by the SGS-Thomson Microelectronics Group. Under terms of the agreement, SGS-Thomson will acquire the MSC silicon product line, which consists of RF/microwave devices, amplifiers, subsystem components and assemblies. MSC's GaAs operation, which was shut down late last year, is not included in the deal with SGS-Thomson. Microwave Semiconductor Corp. was founded in 1968 and acquired by Siemens in 1979. It was the subject of an unsuccessful acquisition attempt by Phoenix Monolithics Corp. of Telford, Pa., in late 1988.

EEsof Users to Meet at RF Expo East—The ninth meeting of the EEsof Users' Group will take place on Wednesday, October 25, 1989, from 4:00 to 6:00 p.m., in conjunction with RF Expo East in Atlantic City, N.J. The meeting, to be held at TropWorld, will be chaired by President Weiming Ou of Varian III-V and Technical Program Chair Chuck McLaughlin of KDI/triangle Microwave. The EEsof Users' Group serves as a forum for RF and microwave engineers who use EEsof software. For more information about the group, contact Maxine Surks, Users' Group Coordinator, EEsof, Inc., 5795 Lindero Canyon Road, Westlake Village, CA 91362. Tel: (818) 991-7530, ext. 131

Grumman to Close Tachonics—Grumman Corp. has announced that it will close its Tachonics subsidiary by the end of this year. Tachonics Corp., of Plainsboro, N.J., manufactures gallium arsenide (GaAs) components for sale to the commercial electronics industry. Tachonics will complete all existing contracts, but is accepting no new orders. Grumman Electronics Systems Division will continue to design GaAs circuits for Grumman's defense and space requirements. Tachonics was formed in 1985 to design and manufacture integrated circuits from GaAs for high-speed electronics applications. The company markets multi-application switches and amplifier circuits to subsystem manufacturers and distributors, for both standard and semicustom microwave and digital applications.

Burr-Brown Offers Bulletin Board Service—Burr-Brown Corp. has announced the availability of an electronic bulletin board service (BBS) offering information about Burr-Brown's products and services via personal computer. The electronic BBS, which debuted August 7, is operated and maintained in the company's Customer Service Center by the Applications Engineering Group. The service covers all of Burr-Brown's systems products as well as its components (linear ICs). Information available through the BBS includes: new product announcements, tips and application notes, software utilities and updates, a technical support message section (public), and private E-mail. Service is available 24 hours a day, with information updated daily.

Common PC-based programs which can be used to access the BBS are Procomm™, XTALK, Red Ryder and others. Files are transferred using the industry standard XMODEM Protocol. The BBS phone number is (602) 741-3978. Communications settings are 300/1200/2400 8-N-1. Further information about the bulletin board service is available by contacting: Ed George, Manager, Applications Engineering, Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734. Tel: (602) 741-4378

Ericsson and GE in Mobile Communications Joint Venture—Ericsson of Sweden and the General Electric Co. (GE) have announced an agreement to form a joint venture in mobile communications. Ericsson-GE Mobile Communications will be owned 60 percent by Ericsson and 40 percent by GE. It will produce cellular telephones, mobile radio products and systems, and "Mobitex" mobile data communication systems for the international market. The joint venture will also serve the U.S. and Canadian market for cellular telephone systems. It will be formed by merging existing company units.

Gamma Microwave Forms Satcom Division—Gamma Microwave Inc. has formed a new division, Satcom Products Operations, for development and manufacture of new RF transceivers and terminals for data communications. The new operation will supply RF transmission components for the high-speed Small Earth Terminal marketplace. Two new products under development for this market are microwave transceivers for use in C- and Ku-Band earth stations. First delivery of four units is scheduled by the end of 1989.

Tektronix Forms Test and Measurement Group—Tektronix Inc. has merged its Instrument and Systems Groups to form the new Test and Measurement Group. The new group represents the core of Tektronix' traditional business, with such products as oscilloscopes, logic analyzers, semiconductor test systems and spectrum analyzers. The Test and Measurement

Group will be headed by Richard I. Knight, vice-president and general manager of the Systems Group since January 1988.

Toko Launches R&D Division—Toko America Inc. has established a Research and Development Division at its Mount Prospect, Ill., headquarters. Mark Sullivan has been named to the additional post of Director of Research and Development, and Michael Woo to the post of Research and Development Engineering Manager. The new division will concentrate on board and system level products. Discrete and IC component research and development from the Japan headquarters of the parent company, Toko Inc., will support the U.S. operations. According to Sullivan, "The creation of the R&D Division effectively shifts our North American operations from an 'adapt products to fit' mode to a 'develop products for' mode." The R&D division will be working to develop new products targeted specifically for Toko America's North American markets.

M/A-COM and Filtronics Components in Joint Venture—M/A-COM Inc. and Filtronics Components Ltd. have finalized an agreement to form a joint venture company, FILCOM Microwave Inc. The new company will design, develop and manufacture microwave subsystem components primarily for electronic warfare applications under a technology transfer and licensing arrangement with Filtronics Components Ltd. Products will include switched multiplexers, detector log video amplifiers, digital frequency discriminators and frequency memory loops. These products will be sold and marketed through M/A-COM's field sales organization. FILCOM Microwave has already begun operations in Chelmsford, Mass.

TRW and FEI Microwave to Market GaAs MMIC Devices—TRW's Electronics and Technology Division and FEI Microwave Inc. have announced an agreement according to which FEI Microwave will market and distribute TRW's line of advanced millimeter/microwave monolithic integrated circuits commercially. The original equipment manufacturer (OEM) distribution licensing agreement extends for five years and covers circuits designed and fabricated by TRW on the Department of Defense's MMIC program, as well as those designed and fabricated by TRW as part of its own internal MMIC effort. The agreement between the two companies is a response to DOD requirements that GaAs MMIC technology be spread widely throughout the defense contractor community, and eventually be made available to companies serving the commercial sector.

INFO/CARD 15

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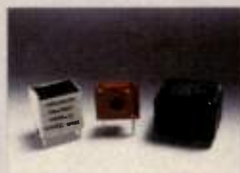

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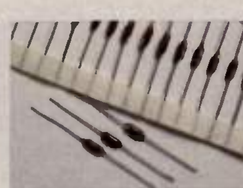

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INFO/CARD 16

The Outlook for SAW Technology

By Mark Gomez
Technical Editor

The Surface Acoustic Wave (SAW) industry can be divided into three segments: the military, commercial and consumer. In the United States, the biggest segment is definitely the military. However, commercial and consumer applications for SAW devices are seeing growing use. While the markets are catered to by local vendors, foreign competitors such as the Japanese and Europeans seem to have their niche established in the SAW consumer arena.

There are many reasons for designing with SAW technology. These include higher performance levels, better reproducibility, simpler architecture and smaller packaging size. "Performance is a very important reason for using SAW devices," says Frank Perkins, vice-president of marketing at RF Monolithics. "It also aids in reproducibility," he adds. Gary Monetti, director of sales and marketing at Sawtek, remarks, "In bandpass filters, we have seen a great deal of emphasis on filters that track or channel-match each other." He explains that SAW filters, since they are produced photolithographically, can be manufactured essentially identical to one another.

SAW consumers are beginning to see products with better capabilities. These include devices that are easier to use through higher integration levels, products with lower loss, and higher frequencies. "In general, the trend is toward higher frequencies and lower loss," comments Dick Fraley, vice-president of marketing at Phonon Corporation. Monetti reflects some trends by saying the radar and EW people are looking for filters with lower insertion loss and better triple transit suppression. "There is a trend towards higher frequencies," says Mitch Koga, an applications engineer at Kyocera Northwest.

As with other RF segments, packaging is a very important issue in the SAW industry. The biggest issue here is surface-mount packaging. Even though the bulk of the military business is for older programs that did not incorporate surface-mount, this new form of packaging is seeing growing use. "We supply a significant number of our products in surface-mount packaging," says Perkins. "In the medium and long term, I see a move towards surface-mount packaging," says Dr. Emmanuel Sang, general manager of SAW devices for Tektronix.

According to Monetti, there are various problems associated with surface-mount packaging. "Since plastic is essentially not hermetic, plastic surface-mount packages are not suitable for many SAW applications," he explains. "There are other surface-mount packages that are hermetically sealable," he adds. "However, they usually require very hot temperatures to reflow glass." He goes on to say that Sawtek has developed a method of producing a leadless chip carrier surface-mount package that is bondable and solderable and can be sealed by a one-shot electronic discharge process.

In the United States, the SAW industry seems to be shifting to subsystems. While this is primarily seen in the military sector, some commercial subsystems are being introduced. This obviously translates into higher levels of integration, where vendors are providing modules and subsystems such as SAW filter banks and frequency sources as opposed to individual filters and resonators. "The growth in this industry could potentially be in the SAW-based subsystem area," says Monetti. Bob King, product applications manager at Andersen Laboratories, says that he has anticipated the trend towards subsystems over the years and is seeing it now. "The demand for integrated SAW assemblies is certainly on the rise," he comments.

There are many advantages associated with this shift to subsystems. These include improved cost-effectiveness, smaller overall system packages, and products that are easier to use. "We are delivering SAW technology in an easier-to-use form," say Frank Perkins. "For example, we are providing filters with integrated matching," he explains.

Even though the military market is shrinking, there is a certain amount of commercial and consumer related activity. "In general, there are a significant number of commercial applications that are picking up some of the slack in the SAW industry," says Dr. Sang. Dick Fraley shares this opinion by saying that the market is growing because more SAW components are being used. Although there is activity here, it does not seem to be large enough to support all the companies involved. "The growth in the commercial segment of the professional SAW market is not yet large enough to support all the competitors in it," comments Dr. Albert Comparini, vice-president of sales and marketing at Crystal Technology. Dr. Sang says, "There seems to be a shake-out gradually taking place and some poor companies do not seem to be making it."

A key problem facing the SAW vendors is hiring qualified engineers. "It is tough to find talented, qualified people who know how to design SAW components," comments Monetti. Dr. Sang agrees with this viewpoint. He says, "Since very few people train in SAW, you either have to hire an old-timer or a new recruit that could be groomed."

As this industry matures, more and more commercial applications are emerging. About five years ago, education played a rather big part. Now, as other industries have begun to accept SAW, the level of education has shifted from conveying the benefits of SAW to keeping the community informed of new capabilities. "Education is not as badly needed as it was a few years ago," says Dick Fraley. King from Andersen Laboratories feels that SAW technology has established itself as a viable technology.

Surface Acoustic Wave products appear to have overcome their educational barrier. Having crossed this hurdle, these devices have found new commercial and consumer activity. This dynamic industry is even showing up in areas such as lightwave systems and undersea cable systems where companies like AT&T Network Systems are gearing up their efforts. Also, as frequencies of SAW devices increase, other potential applications such as ISDN are emerging. With continued research and development in both applications and product designs, this industry should be able to see growth in all areas.

Surface-Mount Products Match TO-8 Performance and Availability

By Louis M. Seieroe, Kenneth S. Ledford, Timothy J. Blaney, and Louis Hsiao
Watkins-Johnson Company

The emphasis on improving system performance by adding new features, while simultaneously reducing overall system cost, continues to be an industry trend. Part of this emphasis has resulted in increased use of MMICs. However, a large gap still exists when it comes to RF and microwave hybrid components which are often needed to attain the required system performance.

Watkins-Johnson Company continues its support of industry requirements by introducing an extensive line of surface-mount RF and microwave amplifiers, attenuators and limiters. This new line of surface-mount products is a mirror image of their entire TO-8 (0.5 in. diameter) product line, covering a frequency range of 0.001 to 6.0 GHz.

The advance of surface-mount technology has enabled manufacturers to reduce system size and cost. The typical board size can be reduced by as much as 40 percent by replacing conventional TO-8, TO-5, dual in-line and flat-pack packages with surface-mount components. Conventional packages require very elaborate circuit boards and manual assembly techniques, but surface-mounted RF and microwave components are directly compatible with current automated assembly equipment.

Watkins-Johnson's new SMTO-8 line of surface-mount products allows system designers to make the transition into surface-mounted system design without being hampered by the lack of availability of various products. The performance of TO-8 products, already familiar to the system designer, can also be achieved with the new surface-mount products.

The SMTO-8 advantages include: excellent RF and microwave performance to 6 GHz, high reliability, wide product selection, and compatibility with automated assembly techniques.

The SMTO-8 package evolved from the identification and subsequent implementation of several requirements

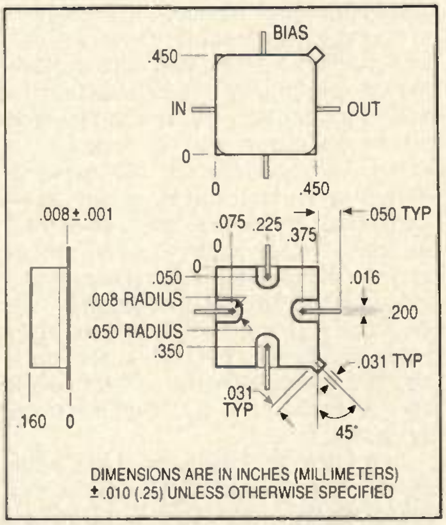

Figure 1. SMTO-8 package dimensions.

essential for a successful surface-mount RF product. Attention was focused on size, performance, structural integrity for mechanical mounting, inspectable solder connections, and hermeticity.

The size of the SMTO-8 was held to a minimum while still accommodating all of the company's TO-8 products, including RF and microwave amplifiers, attenuators, and limiters. The SMTO-8 package, shown in Figure 1, allows the use of ferrite chokes and transformers while maintaining a height of 0.160 inches.

The internal-to-external RF feedthrough design has resulted in RF performance virtually identical to existing TO-8 products. In addition, the bonding-pad pattern on the floor of the package is identical to the pin pattern on a TO-8 header. In fact, the exact circuit layout and component orientation found in a TO-8 may be placed directly into an SMTO-8 package. This compatibility allows the use of proven manufacturing techniques, thereby maintaining high manufacturing yields.

Built from the ground up, the SMTO-8

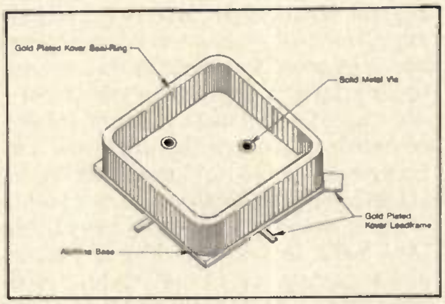

Figure 2. Pictorial view of package.

utilizes a Kovar leadframe, an alumina base, and a Kovar seal-ring, respectively (Figure 2). When the three pieces are brazed together and electrically connected using solid metal vias in the alumina, a mechanically strong, temperature-resistant package is created. Along with mechanical strength, a square outline offers the benefit of easier handling by automated pick-and-place equipment.

The SMTO-8 package construction also provides improved thermal performance compared to its TO-8 counterpart. The TO-8 header is made of Kovar (0.061 in. thick), which has poor thermal conductivity. However, the SMTO-8 package uses a ceramic base and a Kovar (0.008 in. thick) leadframe that lowers the thermal resistance by 15 percent.

For high-reliability markets, the package must meet military specifications for visual criteria on soldered connections. For this reason, the SMTO-8 leads protrude 0.050 in. so that solder fillets may be easily inspected. If visible solder joints are not a requirement, the leads may be sheared flush with the base of the package in order to achieve a greater component density on the board. The thickness of the leadframe along with the channel around each lead (Figure 1) allows flux to be easily washed away using flux removers.

Major concerns for package compliance with MIL-STD-883 are hermeticity, salt spray, and humidity. Failure in any

Material	Board Thickness (In)	Dielectric Constant	Coefficient of Thermal Expansion ($\times 10^{-6}/^{\circ}C$)	Thermal Conductivity (W/M/°C)
96% Al_2O_3	0.015	9.6	6.2	25
RT/Duroid* 6010	0.025	10.5	X = 24 Y = 24 Z = 24	0.41
RT/Duroid* 5880	0.031	2.2	X = 31 Y = 48 Z = 237	0.26
FR4/G-10	0.062	5.2	10-15	0.29

*RT/Duroid is a registered trademark of Rogers Corporation, Microwave Materials Division, Box 3000, Chandler, AZ 85224, (602) 961-1382

Table 1. Material properties of selected printed wiring boards.

of these three requirements can quite often be associated with damaged glass-to-metal seals. Since the SMTO-8 does not utilize glass-to-metal seals, compliance with MIL-STD-883 becomes much more consistent. Seam welding a solid nickel cover to the package yields a leak rate of less than 5×10^{-8} atm-cc/s.

Mounting Considerations

Watkins-Johnson Company's SMTO-8 products can be mounted on a number of printed-wiring-board materials, including etched-copper board materials and thin/thick-film on ceramic materials. Ceramic materials, such as alumina, closely match the package's thermal expansion coefficient with good electrical performance. However, most systems today are designed using etched copper-backed boards, such as G10/FR4 and Duroid[R].

The use of surface-mount products places additional constraints on the system designer in the areas of thermal coefficient of expansion (TCE) mismatches and thermal conductivity of the board material selected. Table 1 compares the significant electrical, mechanical and thermal properties of various printed-wiring-board materials.

The metallization scheme must be carefully selected to prevent the phenomenon known as "scavenging." This occurs when gold migrates into the solder joint during reflow, which may cause embrittlement of the joint. However, several techniques can be used to minimize the effects of scavenging. By pretinning the package/leads with 63Sn/37Pb solder paste with RMA flux, the gold concentration is reduced, thereby producing a stronger solder joint. Alternately, indium alloy solder pastes, which have a low tendency to dissolve gold, may also be used.

Watkins-Johnson has done extensive work in the area of surface-mount products in both the Systems and Devices groups of the company. The outcome of this work has been a universal printed-wiring-board (PWB) layout suitable for convection, IR, IR/Convection, vapor phase and wave solder reflow processes. Although the company's recommended PWB layout was optimized for its IR/Convection process, it is suitable for most manufacturing environments.

The PWB layout is designed such that the package aligns itself due to surface-tension effects during solder reflow. The layout has the same width as the package to maintain proper alignment in the X-direction. The Y-dimension on the layout is made larger to allow for an inspectable solder fillet. The lead pads serve to align the device in the Y-direction. Figure 3 shows the

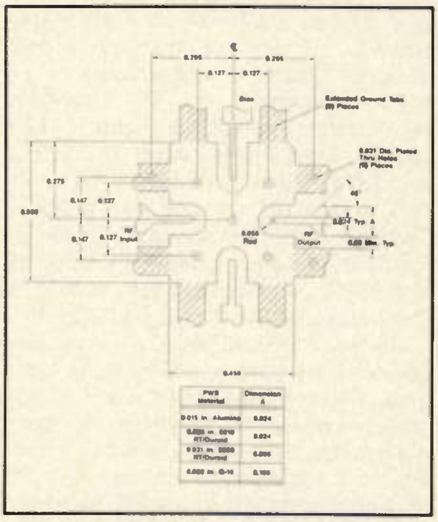

Figure 3. Printed-wiring-board layout: 9-hole configuration.

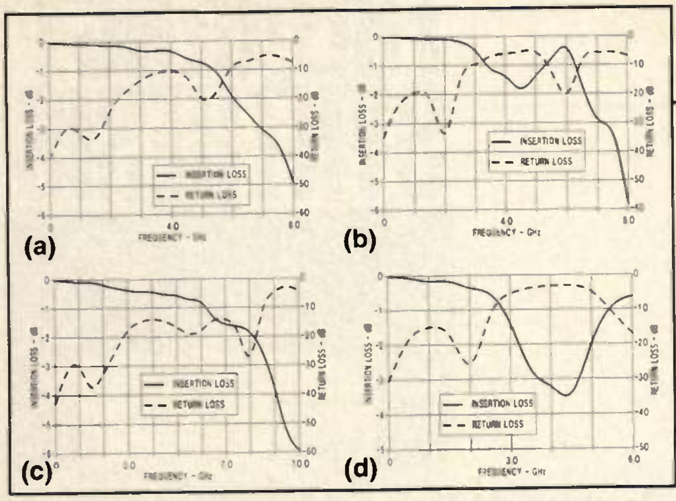

Figure 4. Performance of the SMTO-8 package mounted on the 9-hole PWB configuration on: a) 0.062 in. G-10, b) 0.025 in. 6010 RT/Duroid, c) 0.031 in. 5880 RT/Duroid, and d) 0.015 in. 96 percent alumina.

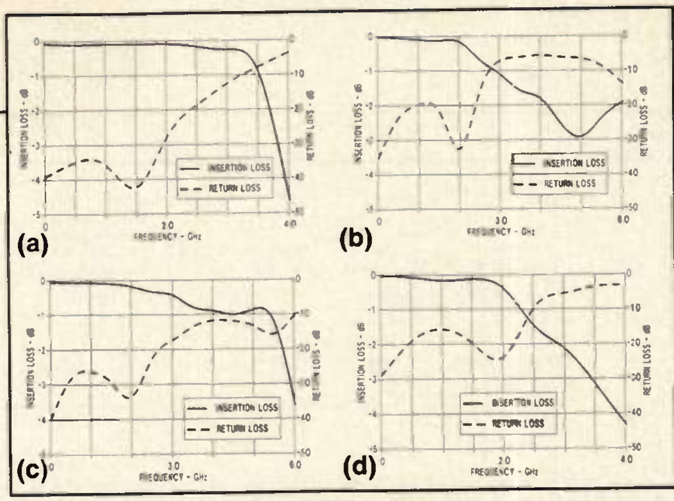

Figure 6. Performance of the SMTO-8 package mounted on the 4-hole PWB configuration on: a) 0.062 in. G-10, b) 0.025 in. 6010 RT/Duroid, c) 0.031 in. 5880 RT/Duroid, and d) 0.015 in. 96 percent alumina.

layout for a typical printed-wiring-board material. The input/output transmission lines vary in width as different dielectric materials are used.

The electrical performance of Watkins-Johnson Company's SMTO-8 package (containing a 50-ohm feed-through) using this printed-wiring-board layout on various microstrip materials is shown in Figure 4. These layouts use a number of plated-through holes directly underneath the package to minimize the ground inductance, which limits the upper frequency performance of the device.

The use of plated-through holes underneath the package does present some difficulties. First is a reduction in the solder fillet, since solder flows into the plated-through holes during reflow. Also, rework is more difficult due to thick solder plugs formed in the plated-through holes.

An alternate printed-wiring-board layout with plated-through holes located

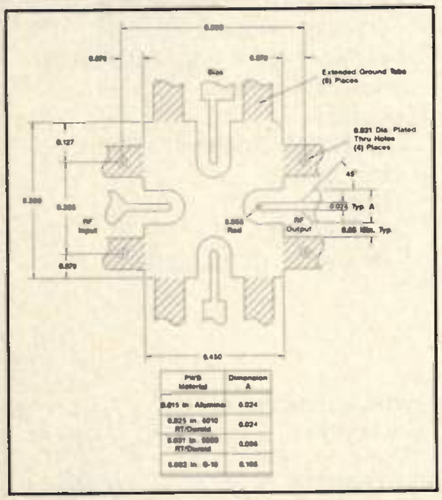

Figure 5. Printed-wiring-board layout: 4-hole configuration.

adjacent to the package is shown in Figure 5. Electrical performance is degraded slightly when the ground vias are not located underneath the package, as shown in Figure 6. This degradation is caused by the increased ground inductance which, in turn, lowers the upper cut-off frequency.

Electrical Considerations

As with most new concepts, the SMTO-8 package evolved from its predecessors, in this case, the flat pack and TO-8 package. The new SMTO-8 leads do not extend from the bottom of the package as do those of the TO-8, eliminating the need for through-hole mounting to the PWB. Nor do the leads extend from the middle of the wall of the package, like those of the flat pack, which eliminates the need to recess the package into the PWB and/or bend the leads for mounting. All of these features, coupled with the performance of 1.0 dB insertion loss at 5.5 GHz, 18.0 dB return loss (shown previously in Figure 4(a)) and 54.0 dB isolation, give the system designer a significant advantage.

For comparison, the TO-8 package performance is shown in Figure 7. This design allows operation up to 5.5 GHz with 1.0 dB insertion loss, 13.0 dB return loss, and 28 dB isolation. The flat-pack package, with performance shown in Figure 8, has an insertion loss of 1.0 dB at 2.0 GHz, and a return loss of 8.0 dB. The measured isolation is 50.0 dB.

Surface-mount digital ICs and passive devices have been in use for quite some time. However, the introduction of surface-mount RF components has been more difficult. The transmission medium and device interconnection behavior are of greater concern to the RF engineer, as these can limit the system performance. The SMTO-8 package, like all devices, can be modeled as a combination of series and shunt reactive elements. The construction of the package as illustrated in Figure 9(a) can be modeled as in Figure 9(b).

The inductance associated with the via hole (L_{via}) is directly related to its diameter and is a limiting factor in the upper cut-off frequency of the package. As the diameter is increased, the inductance is lowered and the package will exhibit less loss. However, the diameter is constrained by the size of the overall bonding area and the manufacturability of the part. In addition, the substrate capacitance (C_{sub}) needs to be minimized for the same basic reason. This is accomplished by the use of ground vias located as close as possible to the interconnect via. This approach decreases the capacitance by moving the ground plane on the bottom of the package closer to the one inside the base of the package. Finally, the lead inductance (L_{lead}) will have the same effect as the via inductance but can be minimized with a good impedance match between the package and the mounting surface.

With the current dimensions and overall structure of the package, a self-resonance is produced at 10.4 GHz, as shown in Figure 10.

In summary, the insertion loss of the package is improved by reducing the shunt capacitance and series inductance, which cause high frequency roll-off. By maintaining a good impedance match between the package and its mounting surface and the package interconnections, the return loss will be improved. Finally, the use of many ground vias inside the package and plated-through holes connecting the package to ground on the printed-wiring-board ensures good RF connection,

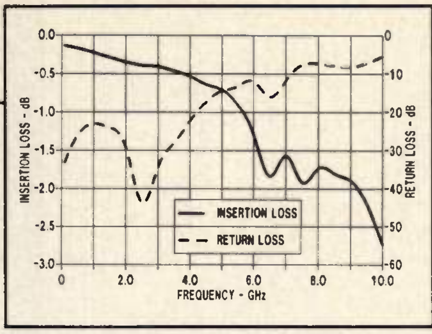

Figure 7. Performance of the TO-8 package mounted on 0.062 in. G-10.

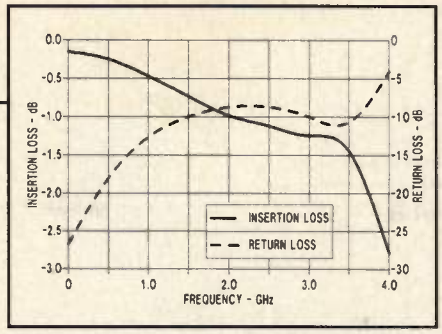

Figure 8. Performance of the flatpack package mounted on 0.062 in. G-10.

improves isolation, and reduces the possibility of oscillations in amplifiers.

Test Fixture

Once the internal capacitances and inductances of the package have been minimized, the problem of testing this new device becomes an issue. As with most devices, mismatches between the device and the test set-up need to be minimized in order to achieve good electrical response. The test fixture, shown in Figure 11, has two main areas of concern. The first is the interconnection between the test set and the fixture, accomplished as is usually done, with a transition from coax to microstrip.

The second and most important interconnection is between the fixture and the package itself. This connection is accomplished by the transition of microstrip (the filler substrate) to stripline (a combination of the package and filler substrate). This microstrip-to-stripline transition is probably the most difficult to make and is the main factor in determining the upper cut-off frequency of the test fixture. Mismatch loss is caused by shunt capacitance, because the ground plane is too close to the conductor directly under the package. This loss is minimized by introducing a

ground step, or cavity, directly after the filler substrate. The filler substrate should not extend past the lead as this will produce more ground-plane coupling and loss. This test fixture design operates up to 7.0 GHz with only 1.0 dB of loss.

With the use of proper calibration techniques and standards, the performance of the SMTO-8 package in this fixture is that shown in Figure 12. As can been seen from the graph, the operational goal of 6.0 GHz was achieved.

Electrical Comparison

The electrical performance of the new SMTO-8 package has been tested and compared to the performance of the existing TO-8 products using the same alignment configuration. The results obtained show that the TO-8 version and SMTO-8 counterpart are identical, thus making this package a drop-in replacement to any existing TO-8 and next generation surface-mount board. The design and development of the package has allowed the placement of Watkins-Johnson's entire TO-8 product line in the SMTO-8 package with no degradation in performance. With TO-8 performance well established in the industry, the reliability of the SMTO-8 is at zero risk to the user.

The components tested in the new package included a low-noise amplifier, limiter, attenuator, power amplifier and limiting amplifier that cover the 5.0 MHz to 6.0 GHz frequency range. The data in Figure 13 and Table 2 show a performance comparison of gain, VSWR, output power and noise figure of a few SMTO-8 models and the equivalent TO-8 version.

Reliability and Screening

Watkins-Johnson Company's thin-film hybrid surface-mount products are designed and manufactured with the same materials and assembly techniques already proven in its line of TO-8 products. This similarity in design and construction allows the system designer the same level of confidence of system integrity. The SMTO-8 line is designed and manufactured to meet the stringent performance and quality requirements of MIL-STD-883, Method 5008.

All of the new surface-mount products are offered with a standardized environmental screening option, designated "S" series. The "S" series provides a cost- and time-effective approach to meeting the requirements commonly found on many airborne, ground mobile, shipboard, and missile applications. The screening is per MIL-STD-883, Method 5008. Customized reliability screening options and applications are also offered.

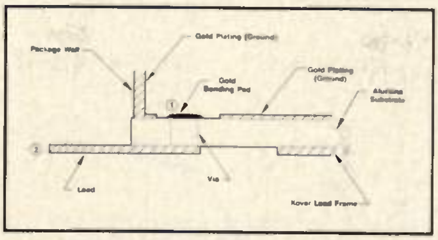

Figure 9(a). A cross-section of the SMTO-8 package showing the lead-frame, ceramic base, metal via and Kovar wall.

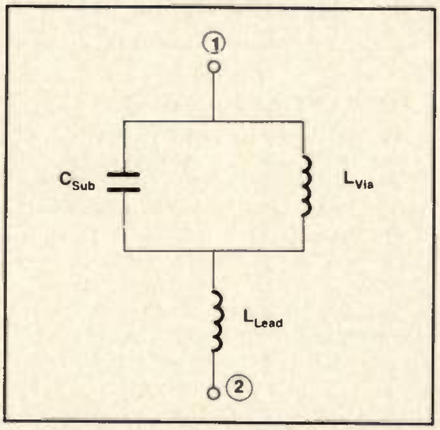

Figure 9(b). An electrical model of the metal via, ceramic base and Kovar leadframe.

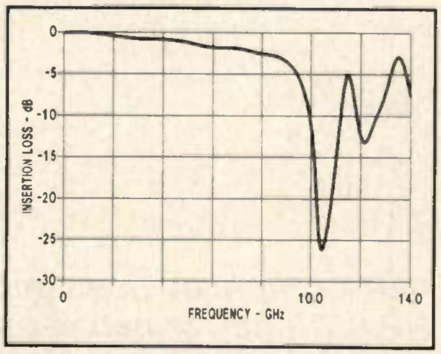

Figure 10. The self-resonance of the SMTO-8 package is at 10.4 GHz.

Conclusion

Watkins-Johnson Company continues to support the industry's needs by introducing a complete line of surface-mounted RF and microwave components. In designing the package, special attention was placed on RF perform-

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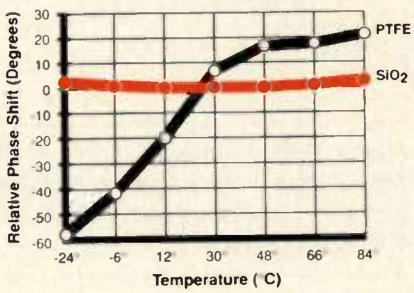

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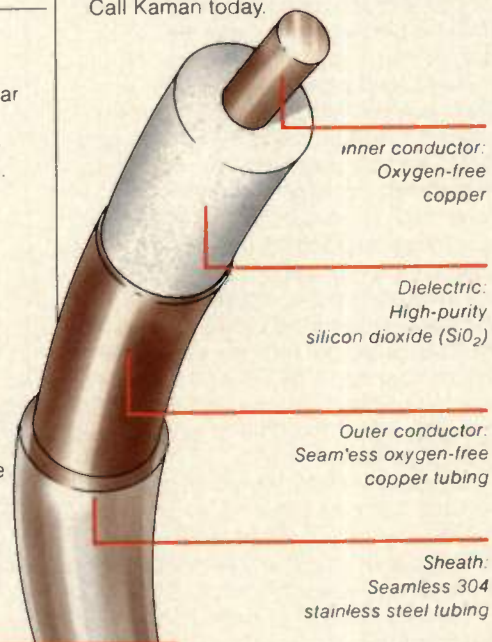

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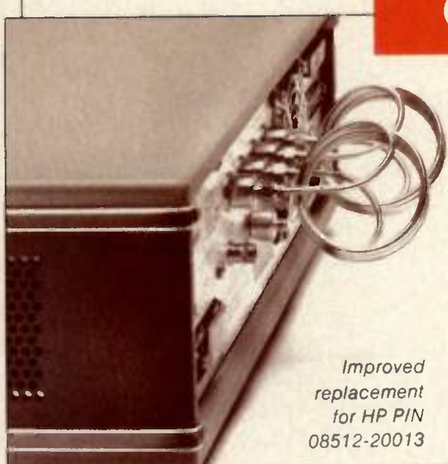

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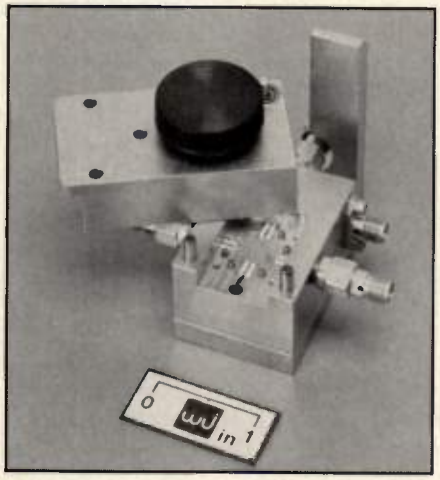

Figure 11. Photograph of the compression loaded test fixture for the SMTO-8 package.

ance, size, structural integrity for mounting, inspectable solder connections, and hermeticity. This package allows system designers the freedom to choose from a wide variety of previously available TO-8 components.

Typical Performance at 25°C

SMA36	100 - 2000 MHz	
Specification	TO-8	SMTO-8
Gain	16.5 dB (min.)	16.7 dB (min.)
Noise Figure	5.5 dB (max.)	5.3 dB (max.)
Output Power	12.0 dB (min.)	12.5 dBm (min.)
IP3	23.0 dBm	22.0 dBm
SMA70	**10 - 250 MHz**	
Specification	TO-8	SMTO-8
Gain	8.0 dB (min.)	8.0 dB (min.)
Noise Figure	1.8 dB (max.)	1.8 dB (max.)
Output Power	8.5 dBm (min.)	8.5 dBm (min.)
IP3	21.0 dBm	23.0 dBm
SMA61	**2.0 - 6.0 GHz**	
Specification	TO-8	SMTO-8
Gain	7.0 dB (min.)	7.0 dB (min.)
Noise Figure	3.4 dB (max.)	3.5 dB (max.)
Output Power	12.0 dBm (min.)	12.2 dBm (min.)
SMA81-2	**20 - 500 MHz**	
Specification	TO-8	SMTO-8
Gain	22.0 dB (min.)	22.8 dB (min.)
Noise Figure	4.0 dB (max.)	4.0 dB (max.)
Output Power	14.5 dBm (min.)	14.5 dBm (min.)
IP3	28.0 dBm	28.0 dBm
SMLA7	**50 - 500 MHz**	
Specification	TO-8	SMTO-8
Gain	12.8 dB (min.)	13.2 dB (min.)
Noise Figure	7.0 dB (max.)	6.6 dB (max.)
Output Power	13.5 dBm (min.)	14.0 dBm (min.)
Maximum Limiting	17.0 dBm (max.)	16.0 dBm (max.)

Table 2. Comparison of typical performance of various products.

The SMTO-8 advantages include: excellent RF and microwave performance to 6 GHz, high reliability, wide product selection, and compatibility with automated assembly techniques.

The authors would like to acknowledge the contributions of the following people in the preparation of this article: Scott Frager, Milo Flores, Dawn M. Perry, Kathy A. Johnson, Diane Bridges, Susie Gaines, and Nguyen Trintt.

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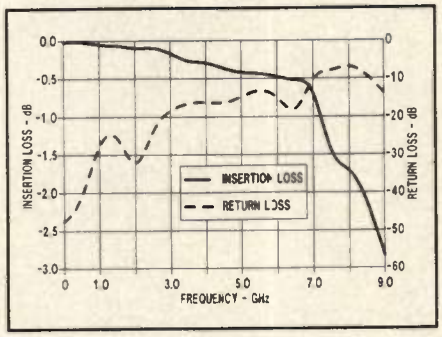

Figure 12. Performance of the SMTO-8 package measured in the test fixture of Figure 11.

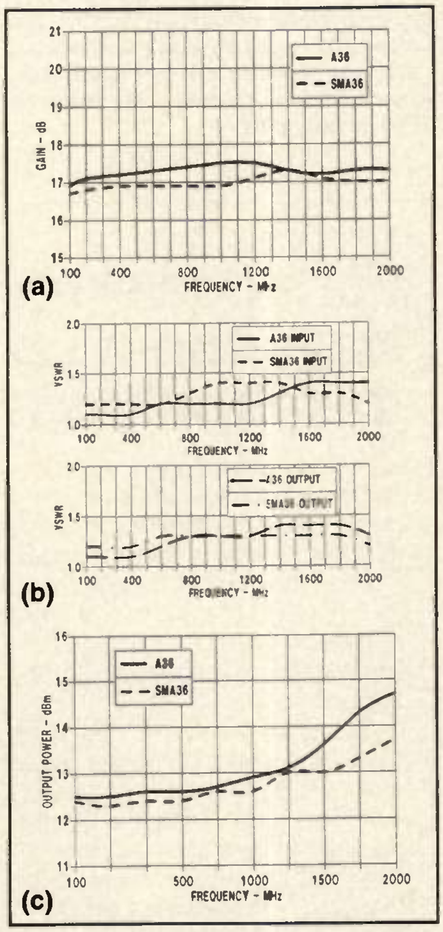

Figure 13. Electrical test results of a standard TO-8 A36 amplifier with the SMTO-8 version comparing: a) gain, b) VSWR, and c) output power at the 1 dB gain compression point.

Modular RF Systems Shorten Design-to-Product Time

By Alan Victor
RF Consultants, Inc.

Manufacturers are now providing the RF design engineer with complete functional systems. These capabilities are found integrated in chip forms such as phase-locked loops or complete frequency synthesizers. Other functions are found in MMIC (monolithic microwave integrated circuit) products using silicon or GaAs as the substrate material and containing microwave front-ends or high performance broadband amplifiers. In addition to these integrated devices, functional RF blocks for building RF receivers are also available.

Complete functional RF blocks are the subject of this article. These devices include selectivity, amplification and mixing — all the necessary ingredients to produce a good performing RF receiver. These building blocks allow RF engineers to put together moderate performance VHF and UHF receivers without all of the time and effort required to integrate a functional system from scratch. The time saved can be used to investigate other aspects of the RF system.

One example of the capabilities afforded the RF engineer today comes from Toko America. A family of FM RF system blocks covering the frequency range of 130 MHz through 512 MHz is available. The series of RF modules are available as band-split units with guaranteed RF performance to ±4 MHz about the UHF center frequency or ±3 MHz about the VHF center frequency. Included in this family is a dual conversion IF amplifier block at 21.4 MHz/455 kHz (TMX 235B) containing a 4 pole crystal filter for selectivity, ceramic filters, second LO, squelch, broadband discriminator data output and audio output. Audio or data muting is accomplished by applying an external voltage or using the internal squelch illustrated in Figure 6.

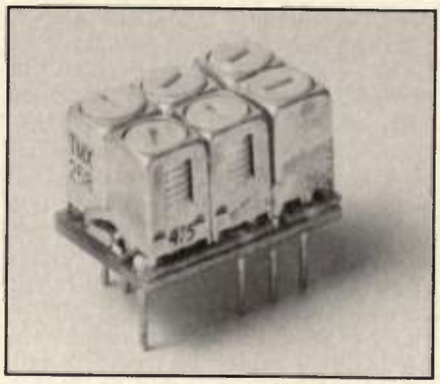

Figure 1. The Toko UHF module.

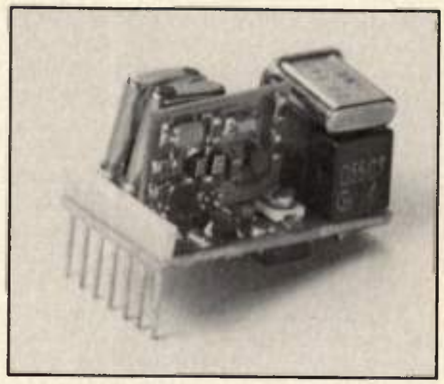

Figure 2. The 21.4 MHz IF module.

The front-end RF module contains helical filters for RF selectivity, bipolar RF preamp and bipolar RF mixer. The VHF modules use lumped element 5 mm coils which are C-top coupled. The module block diagram is similar to Figure 5, but two pole RF selectivity is used before and after a bipolar RF preamplifier. The entire series of RF modules uses identical pin out and the same IF at 21.4 MHz. Other support modules in this series are frequency synthesizers and voltage tuned filters. One interesting aspect of the front-end modules is the use of high side LO injection, which has several benefits, including reduced mixer spurious responses (1). If a companion transmit lowpass filter is available, this will provide additional protection to receiver spurious since the major spurious products lie above the desired receive frequency.

Measurement Procedures/Characterization and Testing

Photos of the RF and IF modules as well as the evaluation test fixture design are shown in Figures 1 through 3. The test fixture breadboard is constructed to evaluate the RF performance of the modules. Block diagrams covering the series of modules and the test set are shown in Figures 4 through 6. Measurements are based on EIA standard RS-204C (2) for land mobile radio. An EIA specified audio de-emphasis lowpass filter is used at the FM discriminator output of the IF module and most measurements are based on a reference sensitivity of 12 dB SINAD (a ratio of signal plus noise and distortion to noise and distortion present at the audio port). A simple highpass pi match is used to interface any of the series of RF front-end modules to the common IF at 21.4 MHz. A minimum number of discrete components are required for RF bypassing and bias.

Measurements of the modules include the following:

- RF sensitivity, 12 dB SINAD
- First stage mixer RF image rejection
- Second stage mixer RF image rejection
- First mixer half IF rejection
- RF intermodulation or 3rd order intercept
- Adjacent channel selectivity

The measurements represent a fair

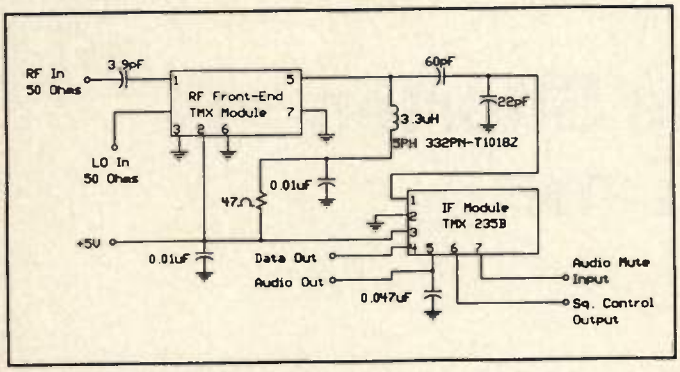

Figure 3. Toko module test fixture.

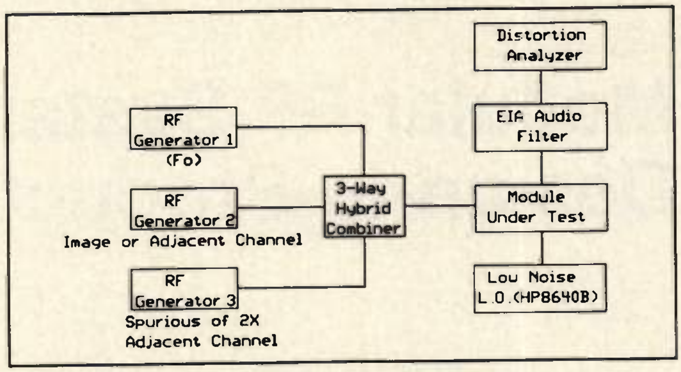

Figure 4. Test set for RF module evaluation.

assessment of the performance and capability expected in using these modules. In addition to these RF performance measurements, additional evaluations are made on the power drain, audio recovery, audio distortion and squelch performance.

Receiver measurements follow the procedures outlined in EIA docket RS-204C. These measurements consider that the receiver is in use receiving a desired on-channel signal. The desired signal level is defined as 12 dB SINAD, and is considered the minimum acceptable signal level for intelligible voice communication. The RF level for 12 dB SINAD is then increased 3 dB (producing approximately a 20 dB SINAD level). An interfering signal is introduced by coupling a second or third RF signal generator into the input of the RF module under test. The interfering signal(s) is increased in level until a 12 dB SINAD level is established again. The difference (in dB) between the desired on-channel signal and the interfering signal is the measurement parameter.

First and second image rejection levels are a function of the front-end selectivity and the 4 pole crystal filter ultimate attenuation, respectively. Since the Toko modules use high side first LOs, the image frequency lies above the filter center frequency. Low side injection is used for the second LO and is 910 kHz below the RF filter center frequency.

Optimum first LO injection level was determined by measuring sensitivity and intermodulation distortion ratio (IMR), and by consideration of the excess current drain required to achieve a higher LO drive level. Zero dBm was found acceptable and a reasonably flat level in IMR was found across the entire frequency range. Another measure for IMR is given by some manufacturers and is labeled as the third order intercept (TOI) (3). Obtaining this value from the IMR level is straightforward. This is given by:

$$\text{TOI (dBm)} = (3/2)(\text{IMR}) - \text{Sensitivity (dBm)}$$

Finally, a swept measurement of the RF front-end bandwidth was conducted. This measurement along with sensitivity measurements made without retuning the front-end helical filters indicated a 1 dB bandwidth (1 dB receiver sensitivity degradation BW) of 7 MHz.

Audio tests of the IF module with an RF front-end in place indicated proper squelch operation. The IF modules use noise-activated squelch. One of the major problems with FM squelch operation is squelch clamping. To observe this problem the EIA specified method of measurement is used. The squelch is set to open on a signal which is at a strong level relative to SINAD, and the FM deviation is set to the maximum specified at 5 kHz. The modulation frequency is then swept from 300 Hz to 3000 Hz and the squelch operation is monitored. If no appreciable distortion is generated in the receiver IF, then the squelch should remain open (no reduction of audio output). An improperly operating squelch will clamp, and no matter how large a signal is presented to the receive input, the squelch will remain activated (no audio output). These modules exhibited no clamping with the modulation frequency as high as 3800 Hz. For voice modulation this is probably adequate. But if data were passed at rates above 4800 bps, for example, the use of a noise squelch to sense carrier would be dificult and other techniques would be required.

Audio recovery and data output recovery are quite adequate for most applications — for 3 kHz deviation, these are measured as 300 mV p-p and 1.5 V p-p, respectively. In addition, discriminator audio distortion was less than 2 percent.

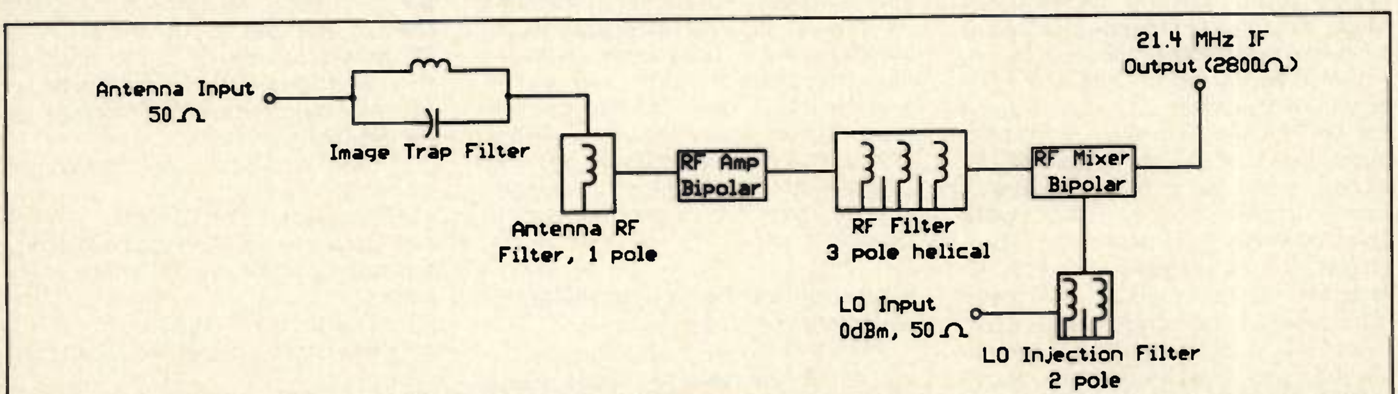

Figure 5. Block diagram for the RF modules.

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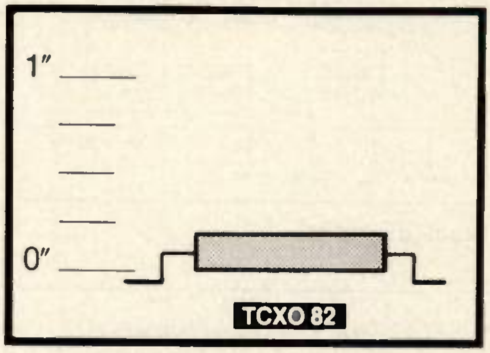

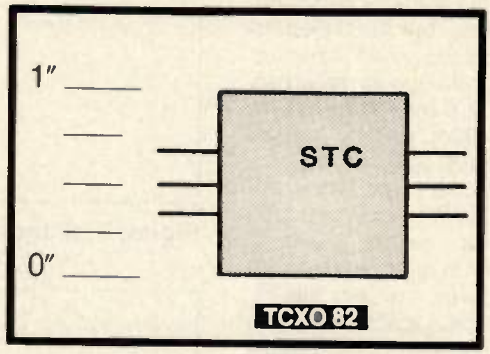

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Measurement Benchmarks

A number of private companies and federal agencies have established parameter standards which are deemed as the minimum accepted level of performance for reliable two-way communication. For example, the U.S. Department of Justice has published minimum performance requirements for receivers used in mobile FM transceivers (4). In addition to the EIA 204C for land mobile, there is also EIA 316B which addresses portable performance standards. Although the particular RF modules tested were probably not designed with a mobile environment in mind, some of the parameters measured are not too far out of line for mobile applications (note the low current drain and power supply voltage).

Some of these measured benchmarks, along with actual data obtained from VHF and UHF Toko modules, and the test set conditions, are tabulated in Tables 1 to 3.

Applications and Conclusions

Besides their obvious use in voice communications, the modules provide non-deemphasis output for data recovery. They can be used as a high IF in downconversion requirements such as microwave counters, spectrum analyzers or high performance HF receivers and data links. In many circumstances, the cost and time of re-engineering these functions may not make sense. Certainly if the desired "dB's" provided by modules such as Toko's TMX Series are not in line with the application and goals, then other appropriate designs are in order. Clearly, as RF engineers define their system block requirements, manufacturers will strive to meet these goals and provide the improved performance. rf

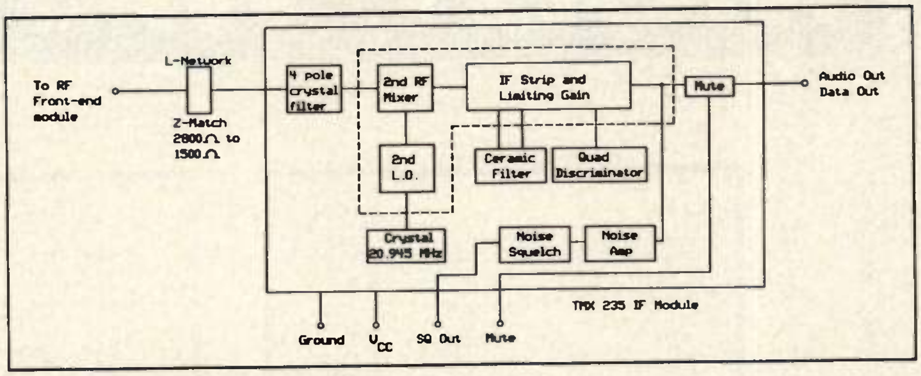

Figure 6. IF module block diagram.

	NIJ 0210	EIA 204C	EIA 316B
Sensitivity:	0.4uV	0.5uV/1uV (UHF)	0.5uV
Spurious:	95dB	85dB	50dB
Intermodulation:	75dB	60dB	50dB
Selectivity:	80dB	85dB	50dB

Table 1. Minimum performance requirements (EIA and NIJ Standard).

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1. Alan Victor, "A Computer Algorithm for Mixer Spurious Analysis," *RF Design*, July 1985, pp 42.
2. Engineering Department, Electronic Industries Association, 2001 Eye St., NW, Washington, DC 20006, 1979 May, RS-204-C, Minimum Standards for Land Mobile Communication FM or PM Receivers, 25-947 MHz.
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4. National Institute of Justice Technology Assessment Program, "Mobile FM Transceivers," NIJ Standard-0210.00, May 1986.
5. Engineering Department Electronic Industries Association, 2001 Eye St., NW, Washington, DC 20006, 1979 May, RS-316-B, Minimum Standards for portable/personal radio transmitters, receiver and transmitter/receiver combination land mobile FM or PM equipment, 25-1000 MHz.
6. Hewlett-Packard Application Notes, AN 170-2, "The 8640A/B Third Order Intermodulation Product Characteristics."
7. Further information on the products discussed here can be obtained directly from Toko America, 1250 Feehanville Dr., Mt. Prospect, IL 60056. Tel: (312) 297-0070.

About the Author

Alan Victor is president of RF Consultants, Inc., 8758 S.W. 51st Place, Cooper City, FL 33328. He can be reached by phone at (305) 979-1907.

Frequency	Sensitivity	Image	(1/2)IF	Intermodulation Distortion Ratio
450 MHz	−122dBm (0.17uV)	82dB	61dB	65dB (−24dBm TOI)
460 MHz	−121dBm (0.2uV)	70dB	66dB	70dB (−16dBm TOI)
470 MHz	−119dBm (0.2uV)	65dB	86dB	65dB (−23dBm TOI)

Adjacent Channel Selectivity: ±25 kHz 75dB
2nd Image +910 kHz: 70dB
First local oscillator injection level: 0 dBm
Power Supply: 5 volts at 7.4 mA

Table 2. Toko UHF module TMX 258A (450-470 MHz).

Frequency	Sensitivity	Image	(1/2)IF	Intermodulation Distortion Ratio
150 MHz	−122dBm (0.17uV)	71dB	83dB	65dB (−24dBm TOI)
160 MHz	−121dBm (0.2uV)	69dB	76dB	59dB (−32dBm TOI)
170 MHz	−121dBm (0.2uV)	58dB	80dB	66dB (−22dBm TOI)

Adjacent Channel Selectivity: ±20 kHz 72dB
First local oscillator injection level: 0 dBm
Power Supply: 5 volts at 10.5 mA

Table 3. Toko VHF module TMX 314A (150-162 MHz).

Frequency Division With Varactor Diodes

By William J. Hoffert
Los Alamos National Laboratory

A runner-up in the Fourth Annual RF Design Awards Contest, this article briefly reviews the theory of frequency division with varactor diodes and describes a practical divide-by-six device that has very good efficiency and phase stability.

Frequency multiplication with varactor diodes is a well-known technique with distinct advantages of simplicity, efficiency and phase stability. Not so well known is the technique of frequency division using varactors. By proper circuit design, frequency division can be accomplished using varactors with the same degree of simplicity, efficiency and stability as in multiplication.

Although this may be an oversimplification, in a varactor multiplier, the input signal is distorted by the nonlinear characteristic of the varactor, resulting in the generation of harmonics. The output circuit selects the desired harmonic and, along with the idler circuits, concentrates the energy in the desired frequency. The harmonics, and therefore the output frequency, are always integral multiples of the input frequency.

In the multiplier, it should be apparent that the output energy also produces distortion in the varactor and generates its own family of harmonics. This phenomenon is the basis for the frequency divider. In the divider, the idler circuit responds to a harmonic of the output frequency. The idler harmonic energy combines with the input frequency to enhance the output frequency. This is a bootstrap operation, but no more so than a self-excited oscillator.

The following basic divide-by-three circuit (Figure 1) is an example of a frequency divider. In this circuit, the frequency f is to be divided by three to produce f/3. Initially, there is no subharmonic at f/3; however, as in a self-excited oscillator, some noise-generated energy at f/3 will appear in the C_4L_4 output circuit, which will generate a second harmonic. This second harmonic energy at 2f/3 excites the idler circuit, L_3C_3; the 2f/3 energy and the input power at f combine in D_1 to produce a difference frequency at f/3.

Any division by more than three follows the same reasoning. Dividing by two is not so straightforward because there is no harmonic of the output frequency that falls between the input at f and the output at f/2. In the divide-by-two case, the idler is tuned above the input frequency to resonate at 3f/2, which combines with the input frequency at f to produce a difference of f/2. Experimental circuits have been built and tested for division by two, three and four. Efficiency, phase stability and spectral purity were about the same as for multipliers.

The Divide-by Six Unit

A divide-by-six unit was built for use in a particle accelerator radio-frequency (RF) system to divide 410 MHz to 68.3 MHz, which used two sections in cascade: one divide-by-three section followed by a divide-by-two section. A single transistor amplifier was used between stages for isolation and to make up losses in the first section. The divide-by-three section had an efficiency of 35 percent, and the divide-by-two section was over 50 percent.

Figure 2 shows a schematic of the unit, and Table 1 lists the parts used in the circuit. The first tuned section in each part is a matching section; the last two are a matching section and a band-pass filter. Note that C_{13} to C_{18} are coupling capacitors.

Figure 3 shows the spectral purity of the input signal, the output of the divide-by-three section, and the output of the divide-by-two section. These photos show the 68.3 MHz output to be somewhat cleaner than the 410 MHz input except for a slight second harmonic at 136.6 MHz, which is about 45 dB below the 68.3 MHz. This second harmonic seems to be the feedthrough of the drive signal because it was not evident at reduced drive.

Diode selection for frequency dividers follows the same rules as for multipliers. The C swing diodes are preferable for orders of division less than five. Above that, step-recovery diodes are recommended. The diode capacitance should have a reactance of 75 to 100 ohms at the output frequency and at the operating bias. Minority-carrier lifetime should be 10 to 20 times the time period for one cycle at the output frequency, and snap time should be less than one cycle at the input frequency.

Tuning the Resonant Circuits

Initial tune-up of these devices is tedious. The best approach is to tune each resonant circuit to the approximate frequency with a grid dip oscillator with all coupling capacitors at minimum. During this procedure, the diode should be biased to the approximate operating voltage from an external voltage source because the resonant frequency of some of the circuits depends on diode capacitance. Diode bias can be approximated from the estimated power at the diode, about two-thirds of the drive power, and the diode reactance.

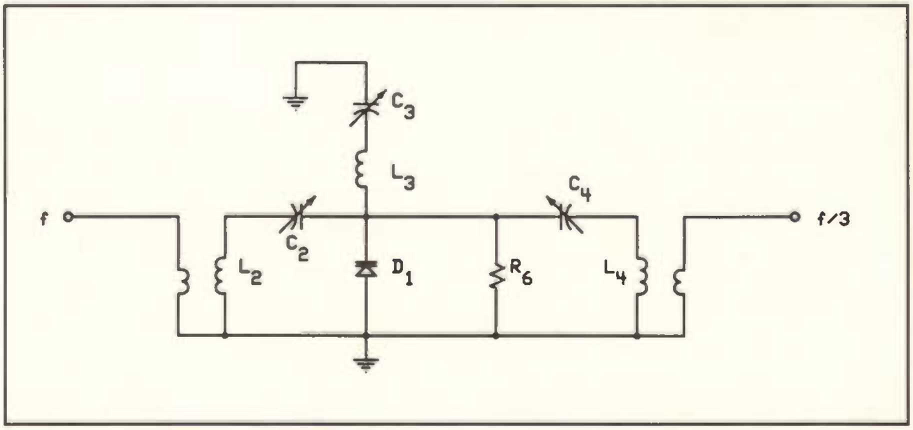

Figure 1. A divide-by-three circuit.

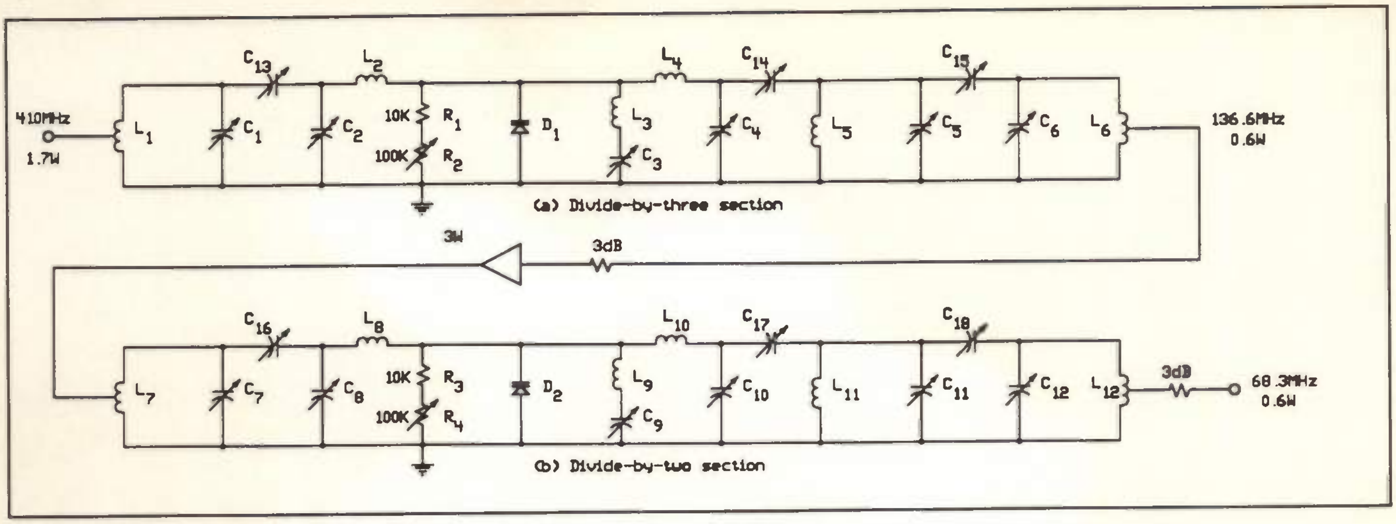

Figure 2. The divide-by-six circuit.

After this approximate tuning, apply RF power to the input at the operating frequency and tune the input circuits for maximum diode voltage with R_2 at maximum. With a 1 watt input, the diode voltage should be 6 to 8 V. Then, tune the idler and output circuits for maximum output, best spectral response, and stability. The idler tuning may be critical and exhibit a sharp break in power output in one direction of tuning. Tune away from this breakpoint until the power begins to decrease. This snap action can be made less critical by adjusting the biasing resistor. Finally, increase the coupling capacitors and retune for maximum output for each change of coupling capacitance until there is no further increase in power output. Overcoupling will cause double tuning and erratic behavior. It should be noted that all tuning adjustments, especially in the circuits connected to the diode, are interdependent so that iterative tuning is necessary.

R_1 — 10K 1/2 watt
R_2 — 10K variable
R_3 — 10K 1/2 watt
R_4 — 10K variable
L_1 — 2 1/2 turns, tap at 1st (all coils wound on phenolic standoff, 1/4 inch diameter and 1/2 inch long)
L_2 — 4 turns
L_3 — 9 turns
L_4 — 5 turns
L_5 — 9 turns
L_6 — 8 turns, tap at 3rd turn
L_7 — 8 turns, tap at 3rd turn
L_8 — 9 turns
L_9 — 5 turns
L_{10} — 15 turns
L_{11} — 11 turns
L_{12} — 13 turns, tap at 3rd turn
C_1 to C_{12} Johanson type 5520Q, 1 to 20 pF
C_{13} to C_{16} Trimtronics type 60-408, 0.3 to 3.5 pF
C_{17} and C_{18} Trimtronics type 10-805, 1.1 to 5.8 pF
D_1 Microwave Associates MA44712 (C_{j6} = 4.5 pF)
D_2 Microwave Associates MA44720 (C_{j6} = 19 pF)

Table 1. Parts list for the divide-by-six circuit.

Final tuning can best be accomplished using a power meter and a spectrum analyzer. In fact, spectral purity can be positively determined only with a spectrum analyzer. When properly tuned, spurious components should be at least 40 dB below the carrier. However, 50 dB is not unusual.

Phase stability on the order of one or two degrees is typical. Though not easy to gauge, phase stability can be measured using a balanced mixer-detector or by building two identical units and comparing their output. In the latter example, it is customary to take the worst case and assume all phase error occurs in one unit. Fast phase jitter is caused primarily by phase and amplitude noise on the input signal. Slow phase drift usually results from thermal effects and changes in the average level of input power.

As a final check, change the power level and frequency while observing the spectrum analyzer display. There should be no change in spectrum for a 25 percent change in power or a 4 MHz change in frequency. If there is change, readjust bias resistance and the three circuits connected to the varactor for best stability.

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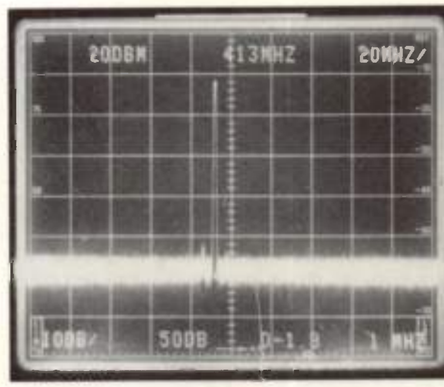

Figure 3(a). Spectrum analyzer display for the 410 MHz drive.

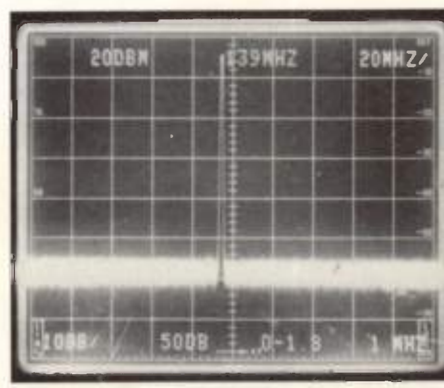

Figure 3(b). The output of the divide-by-three circuit (136.5 MHz).

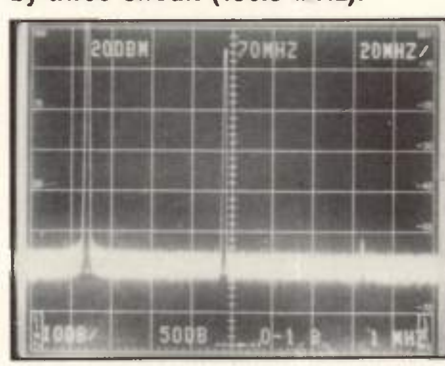

Figure 3(c). The final output of the circuit (68.3 MHz).

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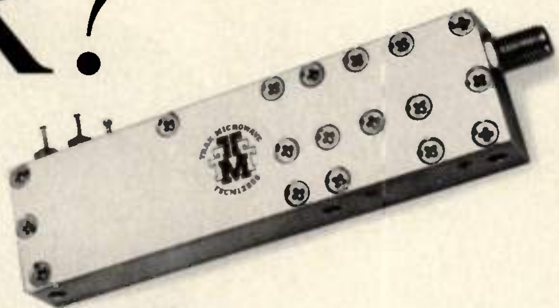

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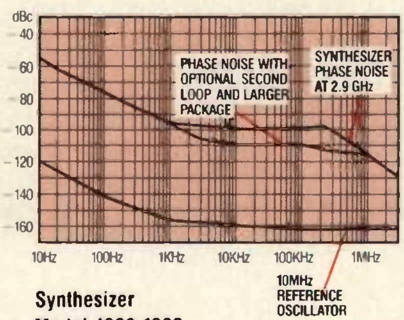

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Model 4002-1320
Typical Phase Noise (dBc/Hz)

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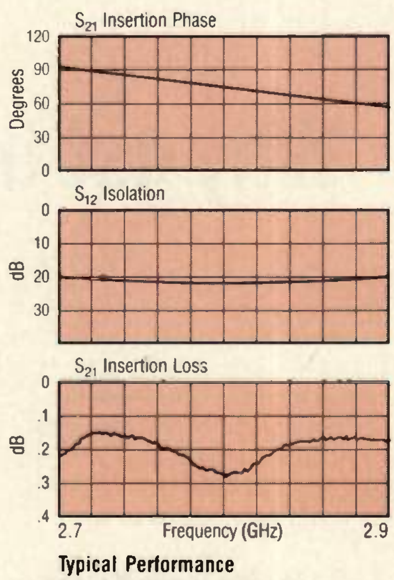

Typical Performance
2.7–2.9 GHz Drop-In Isolator

Synthesizer
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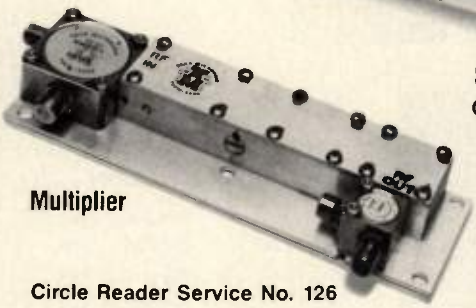

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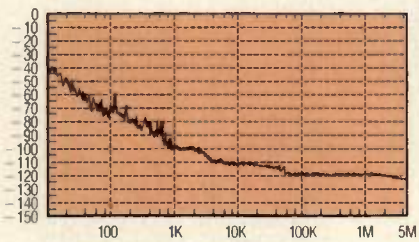

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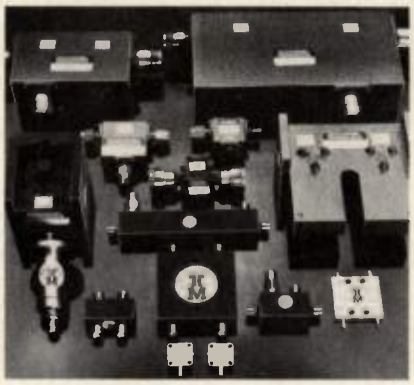

INFO/CARD 30

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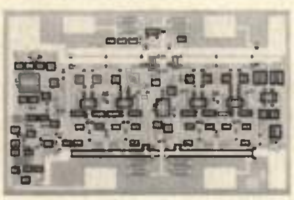

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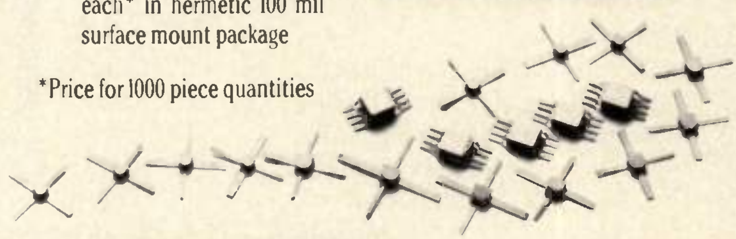

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INFO/CARD 38

A Spurious Response Program for Wideband Mixer Circuits

By William E. Sabin
Rockwell-Collins Co.

Certain kinds of surveillance receivers employ mixers which have a wideband RF input followed by a wideband IF, usually of a different bandwidth. The entire IF spectrum is monitored visually on a CRT. If a strong signal anywhere in the RF band causes a spurious response due to harmonic intermodulation, anywhere in the IF, it is observable instantly and constitutes an interference. This article describes a computer program specialized for this kind of application.

The MS-DOS program WIDEMIX.EXE, written in Microsoft Pascal and using special graphics UNITs, gives a graphical display of the spurious responses which can be hardcopied on an Epson dot matrix printer. The manner of display is especially suited to the particular problem described above. A companion program, WDMXPLOT.EXE, plots the graph on an HP 7475A/7470A pen plotter as shown in Figure 1.

Graph Description

Figure 1 presents a typical result illustrating all of the program's features. The diagonal dashed line (−1 −1) relates the input frequency (horizontal axis) to the "desired" output frequency (vertical axis). The solid lines relate the frequency of a strong input signal to its IF output frequency due to harmonic intermodulation. For example, a desired signal at 212 MHz produces a desired output at 58 MHz, and a strong signal at 217 MHz produces a seventh-order spur at the same output frequency. Also, the 14th-order spur crosses over the desired signal at 210 MHz and produces an output at 60 MHz. The other lines do not cross over the desired signal, but a fifth-order (3 2) at the low end is unfavorable.

On this graph, the top (or left) number is the harmonic of the signal (M) and the lower (or right) number the local oscillator (LO) harmonic (N). The equation solved is:

$$F_{IF} = |M(F_{SIG}) - N(F_{LO})|$$

Note that the RF bandwidth is greater than the IF band, due perhaps to the much higher frequency of the RF band. But signals in the greater RF band still cause interference in the narrower IF band and must be accounted for. The graph shows this very clearly.

The dashed horizontal and vertical lines represent the bandwidths of RF and IF filters, respectively. These lines are used to estimate the effects of selectivity in the RF and IF channels on spurious products. That is, strong signals outside these passbands can cause interference, depending on the filter transition band response. For example, the fifth-order (3 2) response can be greatly improved by these filters.

Figure 2 shows the format of the input data and is self-explanatory. Figure 3 gives the block diagram, with the frequency values, which the program presents on the screen.

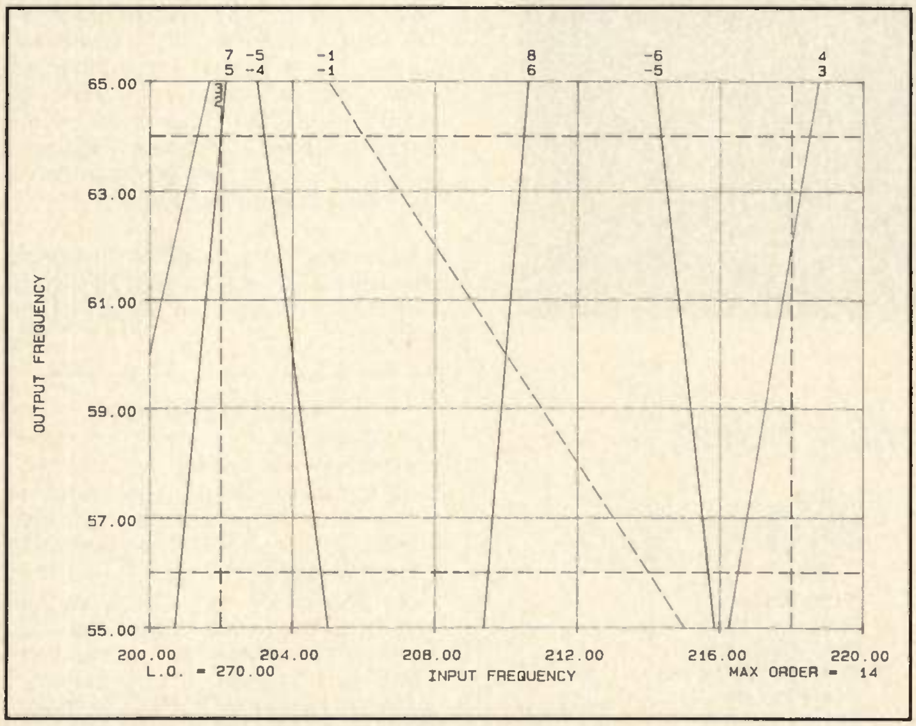

Figure 1. Graphical display of spurious responses.

```
                 INPUT FREQUENCY VALUES:
                 MAX INPUT FREQUENCY = 220
                 MIN INPUT FREQUENCY = 200
                         L.O. FREQUENCY = 270
                MAX OUTPUT FREQUENCY = 65
                MIN OUTPUT FREQUENCY = 55
                             MAX ORDER = 15
     INPUT FREQUENCY AXIS TIC SPACING = 4
    OUTPUT FREQUENCY AXIS TIC SPACING = 2
                   DRAW GRIDS (Y/N) ? Y
  ADD I/O FILTER BOUNDARY LINES (Y/N) ? Y
          ADD INPUT BOUNDARIES (Y/N) ? Y
                 UPPER INPUT VALUE = 218
                 LOWER INPUT VALUE = 202
         ADD OUTPUT BOUNDARIES (Y/N) ? Y
                UPPER OUTPUT VALUE = 64
                LOWER OUTPUT VALUE = 56
       EPSON PRINTOUT OF GRAPH (Y/N) ?
```

Figure 2. Input data format.

Figure 4 illustrates how the spurious responses are calculated. The line "A" is the locus of all IF frequencies which lie between IF_{min} and IF_{max} at the minimum value of RF frequency. "B" is a similar line at the maximum value of RF frequency. "C" and "D" are the loci of signal frequencies which are at IF_{min} and IF_{max}, respectively. The four equations at the bottom are solved for I1, I2, S1 and S2. "L" is oscillator frequency. If, for a particular pair of values of M and N, one of these values lies on the four boundaries A, B, C or D (respectively), then that point is one end of a spur line. If, for a particular pair of M and N values, two points are found, a line is drawn between them. The desired signal, or the image signal, appears on the plot as some combination (±1 ±1), and is drawn as a dashed line. This method proceeds very quickly.

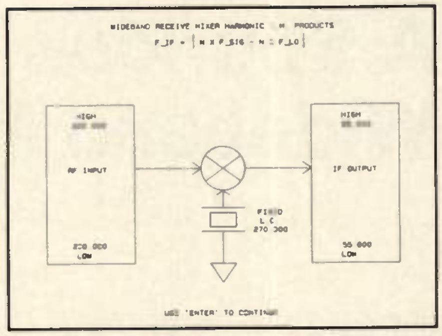

Figure 3. Screen presentation of block diagram.

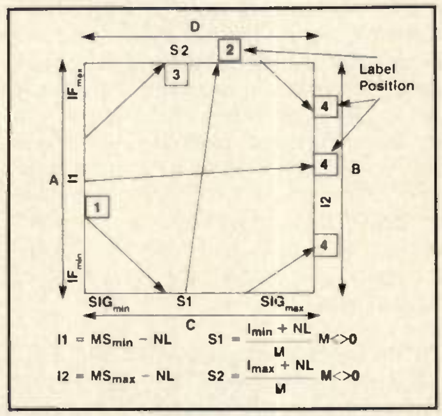

Figure 4. Method of spurious response calculation.

The spur lines are drawn in the directions indicated, and the labels, such as (−2 2), are placed as shown by the small rectangles. Often, labels land on top of one another and are unreadable. This can usually be fixed by modifying the frequency limits of the graph to separate the labels. The added dashed boundary lines can then define the intended frequency limits.

The programs described in this article are available on disk from the RF Design Software Service. See Page 74 for details.

About the Author

William Sabin is a design engineer with Rockwell-Collins. He designs RF and digital circuitry used in radio communications equipment, and holds BSEE and MSEE degrees from the University of Iowa. He is the co-editor of the recent McGraw-Hill book, *Single-Sideband Systems and Circuits*. Mr. Sabin can be reached at Collins Defense Communications, MS 137-154, Cedar Rapids, IA 52498. Tel: (319) 395-3145.

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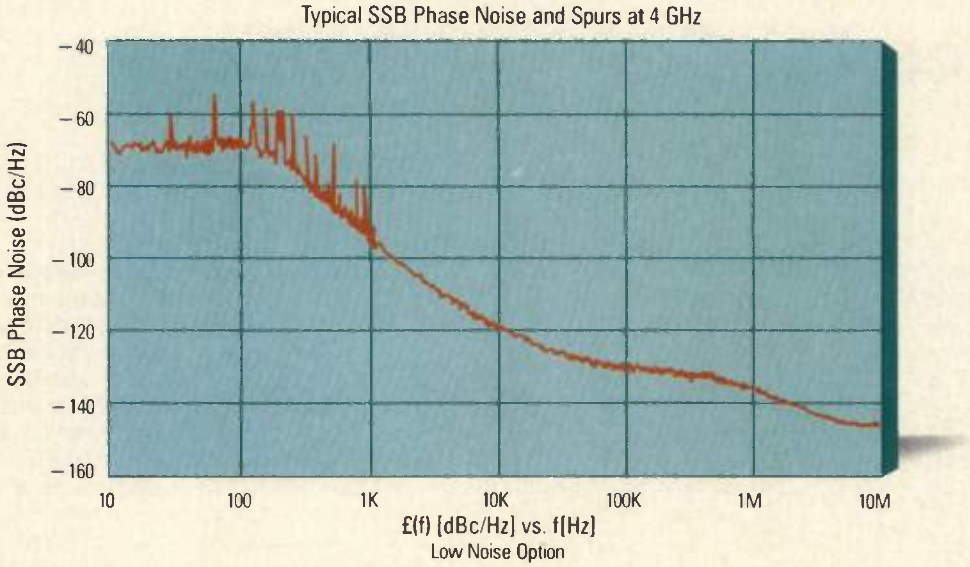

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INFO/CARD 32

Noise Power Ratio Characterizes A/D Performance for Communications

By Michael Johnson
ILC Data Device Corporation

Noise power ratio (NPR) is a common unit of measurement in multichannel communications systems. NPR is defined as the decibel ratio of the noise level in a measuring channel. The baseband should be fully loaded to the level in that channel with all of the baseband noise loaded except the measuring channel. In a frequency division multiplexed system where all channels are processed by the same analog/digital (A/D) converter, any nonlinearity will cause intermodulation within the broadband signal. Where the broadband signal-to-noise ratio (SNR) of the A/D is a function of randomly distributed noise (white noise), it may be characterized as per-channel noise power ratio.

The concept of RMS error is essential to the understanding of signal-to-noise ratio and noise power ratio. In analyzing the output of an A/D converter, there is an error for each sample point. To quantify this performance as one number, one examines the RMS error (defined as the square root of the sum of the errors squared) to describe the average deviation over the array of sample points. This results in a signal-to-noise ratio "R", where R is the RMS amplitude of the measured signal divided by the RMS error. The dB equivalent SNR is then calculated by:

SNR (in dB) = 20 log R

For an A/D converter, a means of analyzing the array of sample points is a fast fourier transform (FFT) analysis.

FFT Test Description

In order to analyze the signal-to-noise ratio of a 12-bit 2 MHz track/hold (T/H) and A/D converter, such as the ADC-00300 from ILC Data Device Corp., specialized hardware on an FFT software analysis program is used. The hardware consists of a high-speed 4096 x 16 bit RAM buffer and a digital data acquisition unit for front-end processing.

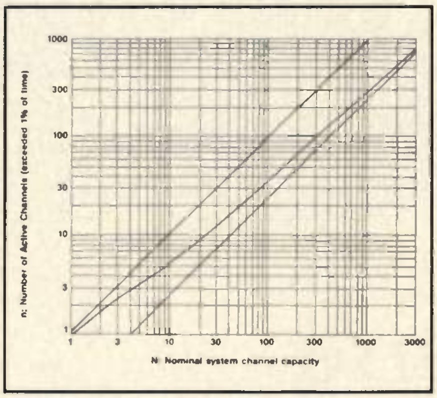

Figure 1. Number of active channels as a function of system channel capacity.

The FFT contains 512 points. The extra points that are taken can be used for increasing the spectral resolution or for averaging a number of records to minimize the run-to-run variation in readings. A single 512-point record typically gives run-to-run variations of as much as 1 dB in signal-to-noise ratio. An eight-record average can decrease this to about 0.2 dB. The 512 data samples are windowed using Hanning weighting. An FFT is then performed on the weighted bins.

The frequency bins are scanned for the bin with the largest amplitude. This is defined as the fundamental frequency. The amplitude of the fundamental is determined by computing the RMS sum of the bin below the fundamental, the fundamental and the bin above the fundamental. This three-cell summation yields an amplitude accurate to less than 0.01 dB. This summation minimizes the effect of spreading the spectral energy due to the window function. The amplitude for each harmonic is calculated by summing the three bins around 2*F fundamental for the second harmonic, 3*F fundamental for the third harmonic, and so on. This yields the harmonic distortion.

The signal-to-noise ratio is calculated by taking the RMS sum of the frequency bins up to bin 255 (the Nyquist rate), except for the DC term (bins 1, 2 and 3), the fundamental frequency (10 bins below the fundamental to 10 bins above the fundamental), and plus or minus two bins around each harmonic. These bins are eliminated because they relate to harmonic distortion and would otherwise give a false reading of signal-to-noise. The number of bins eliminated in each case is due to the leakage of the windowing function, causing spillover into the area around the frequency terms. The summed frequency bins are then compared with the normalized fundamental for calculation of the broadband signal-to-noise ratio.

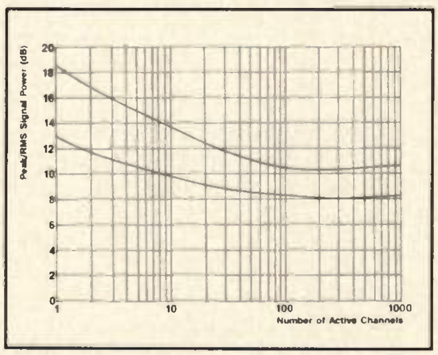

Figure 2. Variation of peak factor with number of active channels.

Per-Channel RMS Error

The device used in this example, the ADC-00300, is configured for a 5 $V_{p\text{-}p}$ analog input, which translates into a 1.76775 V RMS FSR signal. With R = (RMS signal)/(RMS error) and SNR (65 dB in this case) = 20 log R, the RMS noise is calculated as 994 uV broadband. Selecting the input signal bandwidth at the Nyquist rate of 1 MHz with noise randomly distributed broadband, the noise floor is 994 nV/ $\sqrt{Hz}$. For a multichannel application with a 4.1 kHz channel bandwidth, the noise is 55.4 uV RMS per channel.

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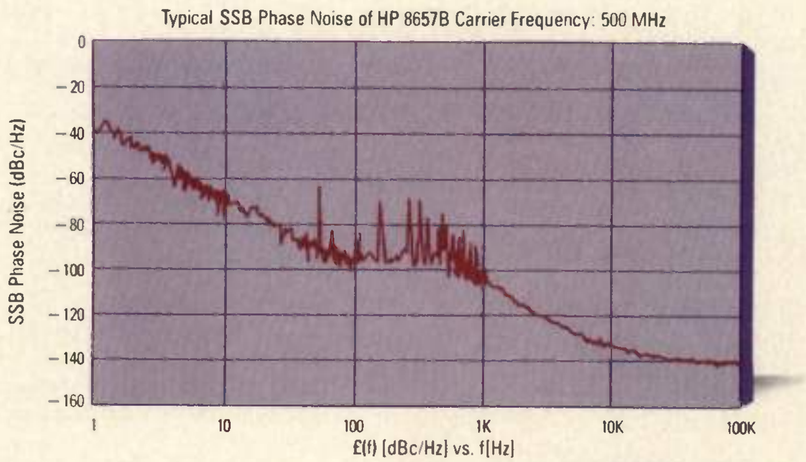

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SNR to NPR

For examining NPR, it is important to consider the system channel capacity and the peak factor, a somewhat complex function of the number of active channels (since all channels will rarely be loaded simultaneously). With a 1 MHz system bandwidth and a 3.1 kHz per-channel bandwidth, and allowing 3 kHz stopband around each channel, a 160-channel system is conservatively selected. Figure 1 allows an estimation of the number of active channels not exceeded more than 1 percent of the time on the basis of an activity factor of a single channel for 0.25. From Figure 2, which illustrates variation of peak factor with a number of active channels (approximated at 50 channels from Figure 1), the total peak factor can be calculated.

Fifty active channels out of 160 channels that do not exceed more than 1 percent of the time yields 10 log 50 or 17 dB. Peak/RMS signal power is 11 dB, not exceeding more than 0.1 percent of the time for 50 channels. Each channel RMS voltage is calculated by:

$$11\text{ dB} + 17\text{ dB} = 28\text{ dB} = 20\log(2.5\text{ V peak})/(\text{V RMS/channel})$$

Solving for V RMS/channel yields:

$$\text{V RMS/channel} = 2.5/\log^{-1}(1.4) = 100\text{mV}$$

The noise power density in a 3.1 kHz channel due to the conventional load is given by:

$$\text{P per channel} = \text{P} - 10\log(\Delta f/3.1)\ \text{dBmO/channel}$$

where P is the conventional load in dBmO, and f is the bandwidth of baseband in kHz.

Since channel noise in dBmO is the negative of SNR:

$$\text{SNR (unweighted)} = \text{NPR} + 10\log(\Delta f/3.1) - \text{P}$$

For N (number of channels) equal to 240, it can be approximated that:

$$\text{P} = -1 + 4\log \text{N and}$$

$$10\log(\Delta f/3.1) = 10\log \text{N} - 1.1$$

Combining the equations yields the following:

$$\text{SNR} = \text{NPR} + 6\log \text{N} + 2.1$$

SNR/channel is 65 dB min and NPR = SNR − 6 log N − 2.1 dB, where N is the number of channels (160), and NPR is 50 dB worst case. rf

References

1. David C. Pinkowitz, "Fast Fourier Transform Speeds Signal-to-Noise Analysis for A/D Converters," *Digital Design*, Vol. 16, No. 6, 1986.
2. M.J. Tant, *Multichannel Communications Systems and Testing*, White Crescent Press Ltd., Luton, England, 1974.

About the Author

Michael Johnson is an applications engineer at ILC Data Device Corp., 105 Wilbur Place, Bohemia, NY 11716. Tel: (516) 567-5600, ext. 384

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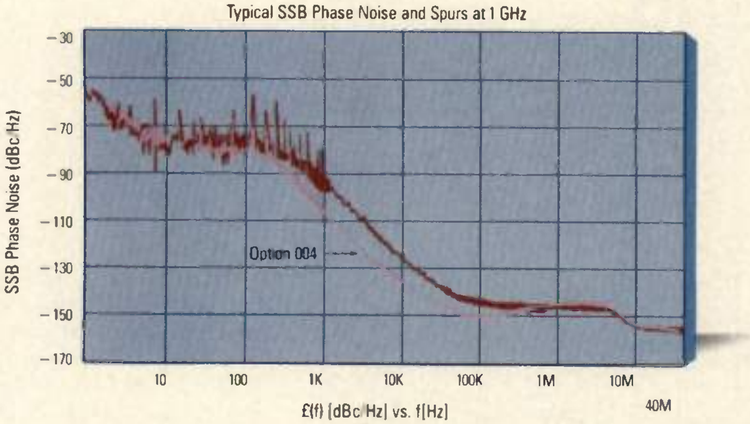

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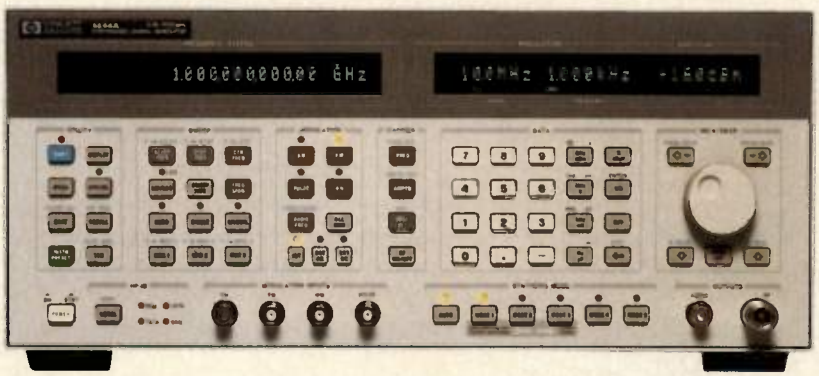

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INFO/CARD 35

Fiber Optic Current Sensing for EMC Testing

By Jon Tobelmann
MetriCor

Many aircraft and space vehicles use electro-explosive devices (EEDs) to perform functions such as firing rockets, jettisoning external stores, activating fire bottles, etc. It is possible to subject these devices to electromagnetic fields that induce sufficient current flow to inadvertently detonate the device. Tests are required to measure the amount of energy developed in the EED circuits to insure against spontaneous detonation while exercising the vehicle's electrical systems and/or operating in strong electrical fields.

Hazardous Electromagnetic Radiation Ordnance (HERO) testing of electrical shielding and electromagnetic compatibility (EMC) testing have been difficult with traditional thermocouples because of their metallic and electrical nature. Measurements with thermocouples are often difficult to make during normal operation of the vehicle, due to the interference caused by external fields and the vehicle's electrical systems. Measurements then must be made immediately following a power-down of the systems producing electromagnetic interference (EMI) and RF interference. The validity of the result can be questionable with this procedure.

A fiber-optic-based EMC test system has been developed that can be used to monitor induced currents while the vehicle's systems are fully operational. Its optical-fiber, light-actuated, current-sensing probes are immune to EMI and RF interference. The system has a current sensitivity of 10 mA with an update rate of 0.7 to 2.3 ms and a system response of 10 ms. Measurements can be made up to 2500 feet from the instrument without accuracy or response degradation. The sensor's response is electronically flat from DC to gigahertz frequencies.

Figure 1 shows a current sensor incorporated in a Mark 1 Squib which is used for EMC testing in typical aerospace applications. The sensor probe assembly consists of: 1) a sensing device mounted directly within the EED replacing the standard squib wire; 2) the optical fiber cable (1 to 6 feet with optional extension cables of up to 2500 feet in length); 3) an optical connector; and 4) a personality key. The personality key contains a solid-state memory device with calibration data that will automatically calibrate the current sensor in the instrument.

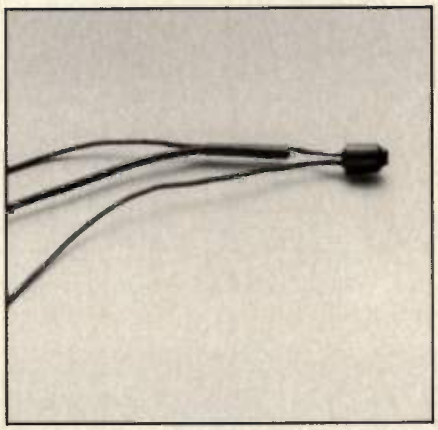


Figure 1. Optical fiber sensor mounted in Mark 1 Squib.

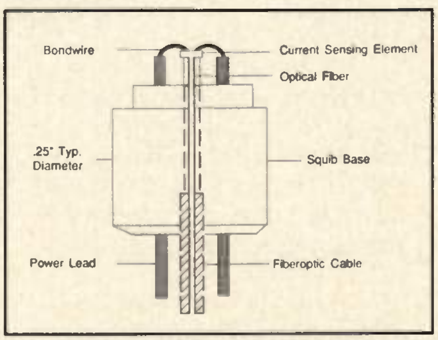


Figure 2. Mark 1 Squib and sensor assembly.

The EMC Test System is capable of acquiring low currents with a resolution of 1 mA at 100 mA levels without disturbing the normal operation of the squib circuit. The sensor has an operating range from 0 to 200 mA, with a standard impedance of 1 ohm which is the same as the Mark 1 Squib. The current sensor can be adapted to any squib with resistance ranges from 1 ohm to 1000 ohms. The instrument obtains and outputs data at rates of up to 0.7 ms for one channel, and as fast as 2.3 ms for four-channel operation.

The instrument is simple to operate. English language prompts guide the user through menu selections so that all available configurations can be selected without confusing codes or numbers. The Model 1420 EMC Test System is the most recent development in a family of optical sensing instruments and probes. MetriCor has developed a family of sensors using Fabre-Perct etalon models to characterize the behavior of the optical cavity resonators that shift the wavelength of the light in proportion to the parameter being measured. When this light is reflected back to the instrument, a ratiometric evaluation of the amount of shift is performed and output in the form of an electrical signal. Products based on this technology are presently available for measuring pressure, temperature, refractive index and current. The EMC current probe is a thermo-optic concept that uses the same optical resonator design to measure and monitor electric current flow. Consequently, all standard sensors may also be used in the 1420.

Sensor Description

Figure 2 illustrates construction of the current sensor. The squib bond wires are connected to an electrically resistive microdot that is bonded onto a temperature-sensitive optical resonator. The re-

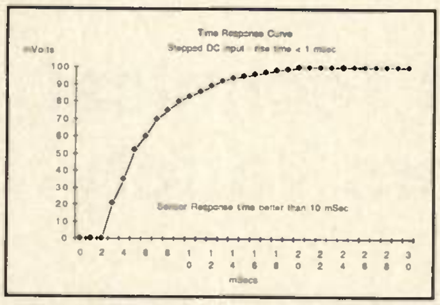


Figure 3. Typical sensor response curve.

sistor/resonator combination is in turn mounted on a transparent glass substrate. An optical fiber is mounted directly under the substrate connecting the sensor to the instrument.

As current flows across the microdot, there is a rapid increase in temperature. This temperature increase modifies the resonator's spectral properties, leading to a color shift in reflected light. This change in return light is transmitted by the fiber to the receiver. The instrument evaluates the amount of shift using ratiometric techniques and converts it to an electrical signal proportional to the current flowing through the squib. The EMC Test System provides a variety of digital and analog outputs. Up to four sensors can be monitored simultaneously.

Preliminary testing with a Navy EED simulation system indicates that the EMC Test System has excellent response time. Figure 3 presents a typical sensor response curve. The system's sensitivity (10 mA) was judged acceptable, while its ability to sense remotely over extended distances between the EED simulator and the electronics unit was considered excellent. A typical sensitivity curve is shown in Figure 4.

The optical resonator cavity technology described here was originally developed for applications in the medical industry. The temperature, pressure and refractive index sensors have been successfully used in the industrial process control, pharmaceutical, food processing and chemical processing industries. As further development work is completed, it is expected that the current sensor can be adapted to accommodate many other EMI and RF testing applications. These include sensors for measuring electromagnetic fields and clamp-on sensors for measuring current flowing through a conductor. rf

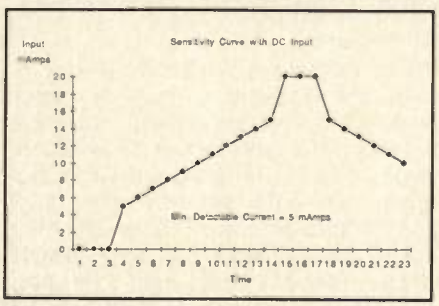


Figure 4. Typical sensor sensitivity curve.

About the Author

Jon Tobelmann is senior vice-president, operations for MetriCor, a Corning affiliate. He is responsible for the development, manufacturing and marketing of industrial fiber optic sensors and sensor instrumentation. He can be reached at MetriCor, 18800 142nd Avenue N.E., Woodinville, WA 98072. Tel: (206) 483-5577

rf expo program

RF Expo East Technical Program Offers Variety and Depth

RF Expo East will be held October 24-26, 1989 at TropWorld in Atlantic City, New Jersey. Under the direction of Program Chairman Andy Przedpelski, a technical program has been developed that presents outstanding developments in current RF technology. In addition to the three courses that have become essential for the continuing education of RF engineers, these papers offer engineer-to-engineer descriptions and analyses of some truly state-of-the-art engineering achievements.

Tuesday, October 24 — 8:30 to 11:30 a.m.

Session A-1: Filter Design

Disk-Rod Filter Design
Douglas K. Linkhart and Andrew W. Owens, Micon, Inc.

Lowpass filters are used in transmitters, for reduction of harmonic and spurious outputs, as well as in other applications. At high frequencies and high power levels, lumped element designs are impractical. This paper describes the design of distributed coaxial transmission line lowpass filters suitable for up to megawatts of power at VHF.

An RF Active Elliptic Filter
Eric Kushnick, LTX Corporation

Sharp cutoff filters in the 1 to 10 MHz region are often required for anti-aliasing and reconstruction purposes in digital signal processing applications. These filters have typically been passive L-C types, with the disadvantages of high cost and large physical size and weight. Newly developed wideband operational amplifiers now make it practical and economical to consider active filters for RF applications. This paper describes some initial work in this area, a 7th-order elliptic-function lowpass filter with a 1 MHz cutoff frequency.

An Unconventional Varactor Tuned Filter
Gary Thomas, G.E. Mobile Communications

A novel approach to the design of an electrically-tuned bandpass filter is presented in this paper. The design uses a directive device, such as a hybrid splitter or VSWR bridge, in conjunction with a varactor-tuned bandstop filter. This implementation is shown to have several advantages over conventional varactor-tuned coupled-resonator bandpass filters. Also discussed are refinements in the structure that can further improve performance.

Session A-2: EMC Design Tutorial (3 hours)

Designing for Electromagnetic Compatibility
Tom Jerse, Hewlett-Packard Co.

Portions of a two-day course currently offered by Hewlett-Packard's Signal Analysis Division are included in this three-hour presentation. The tutorial includes fundamental EMC concepts, such as electric and magnetic field coupling, grounding and shielding. The presentation will address solutions for conducted and radiated emissions from boards, cables and enclosures.

Session A-3: IC Applications

Op Amps Simplify Design of RF Systems
Steve Millaway, Burr-Brown Corp.

Recent development in semiconductor IC processes are making it possible for monolithic operational amplifiers to play a role in the design of RF equipment. Low-cost devices with gain-bandwidth products of 200 to 500 MHz are readily available. Op amp designs which replace discrete amplifiers, passive filters, and other circuits can be developed using SPICE modeling techniques described in the paper.

50 MHz Analog Multiplier Replaces Arrays in Video Mixer and AGC Circuits
Brian D. Mathews and Robert W. Huckabee, Harris Semiconductor
Wideband analog multipliers have been complex arrangements of discrete devices, with many adjustments, level-shifters, and current-to-voltage conversion stages. Described in this paper is a new monolithic IC and applications circuits, including a video mixer, a 100 MHz voltage-controlled amplifier, and a 50 MHz AGC system.

Recent Applications of ACT Technology
Dan Fleisch, G. Peters, and B. Hunsinger, Electronic Decisions, Inc.
Acoustic charge transport (ACT) technology holds the promise of high-performance applications in filtering and other signal processing applications. Basically a high-frequency tapped analog delay line structure, the ACT can operate on a signal using digital algorithms. Since the taps do not load the delayed signal path, the device can also provide programmable response for adaptive systems.

Tuesday, October 24 — 1:30 to 4:30 p.m.

Session B-1: Frequency Synthesis

Introduction to Direct Digital Synthesis
Tzafrir (Tee) Sheffer, John Fluke
Increased performance demands for RF systems require greater stability, accuracy, and modulation capability from RF signal sources. Programmable phase-locked divide-by-N synthesizers have been employed, but have reached their theoretical limits in some applications. This paper is a fundamental tutorial on direct digital synthesis (DDS), which offers many of the performance characteristics required for current RF applications.

Frequency Modulation Design for Direct Digital Synthesizers
Earl W. McCune, Jr., Digital RF Solutions
DDS is now an important technology for the RF synthesizer engineer. For communications systems using frequency modulation, both frequency control and modulation can be combined in the DDS block. Performance advantages over PLL designs include improved linearity, and a modulation bandwidth that includes DC. A review of FM is included, and the characteristics of DDS-FM are examined.

Selection of Frequency Dividers for Microwave PLL Applications
Mark Bomford, Telemus Electronic Systems, Inc.
A low noise, ultra stable, agile microwave PLL source is described, which uses direct division of a fundamental GaAs FET VCO. The single loop PLL uses a combination analog and bipolar digital frequency division, along with a high speed GaAs digital phase/frequency detector. The design process and the design options evaluated for the project are presented in this comprehensive case history.

Session B-2: Component Applications

Reed Relays Designed to Handle Fast Pulses and RF Applications
John Fullem and John Bateman, Coto Corporation
A comprehensive analysis of reed relay performance in fast pulse and RF signal applications is presented. Transmission and time-domain reflectometry (TDR) performance have been examined, with results presented for frequency response, characteristic impedance, pulse rise time, VSWR, insertion loss and isolation.

Theory and Applications of PIN Diodes
Peter Sahjani, SDI Microwave, Inc.
This paper presents a comprehensive review of PIN diode operation, performance and applications. The fundamentals of PIN diode behavior are reviewed, including structure, and charge injection and minority carrier lifetime. Performance is examined, including ON resistance, power dissipation and switching speed. Basic applications in attenuators and switches are also presented.

Perspectives on Ceramic Chip Capacitors
Mark Ingalls, Dielectric Laboratories
Theoretical and practical aspects of capacitors for RF applications are presented. Acoustics, optics and electromagnetics all play a part in capacitor performance, altering behavior from "perfect" models. Characteristics discussed include series resistance and induc-

tance, resonance, transmission line effects, and piezoelectric effects.

Session B-3: Power Amplifiers

Computer-Aided Design of High-Efficiency RF Power Amplifiers and Resonant DC/DC Power Converters
Nathan Sokal, Design Automation

The efficiency of an RF power amplifier can be improved considerably over that obtained in conventional Class B or Class C circuits, by operating the output device as a switch, and designing the load network to provide Class-E operation. The same circuit, with a rectifier at its output, can be used as a high-efficiency DC/DC power converter. The paper describes basic switch-mode operational data, and describes software which can be used to design high-efficiency RF amplifiers, and to examine design tradeoffs.

A High Power FET For RF Applications: The Solid State Triode
Adrian Cogan, Microwave Technology, Inc.

The development of power transistors using solid state triode technology is updated in this paper, including performance capabilities of currently available products.

Wednesday, October 25 — 8:30 to 11:30 a.m.

Session C-1: Antenna Tutorial (3 hours)

Antenna Principles
Benjamin Rulf, Lockheed Electronics

This three-hour tutorial is intended to explain basic concepts and facts of antenna theory. It assumes that the attending engineers have had some exposure to electromagnetics, and have a working knowledge of transmission lines and engineering mathematics. Wave theory, constructive and destructive interference, vector analysis and spherical surface analysis are included in the introductory material. Following sections include wire antennas, small aperture antennas, reflector antennas, and antenna arrays.

Session C-2: Receiver Design

Logarithmic Amplification Used in EW Receivers
D. Johnson, E. Gertel, R. Kopski, and M. Kumar, AE L, Inc.

The input signal to a radar or communications receiver has a wide dynamic range that can vary from volts to microvolts, often exceeding the dynamic range of the processing circuitry. Logarithmic amplification solves this problem by transforming a large input dynamic range which increases logarithmically, to a small output dynamic range which increases linearly. Since the compression ratio is known, the input signal amplitude information is preserved.

Design, Implementation, and Test of a Wideband HF Receiving Subsystem
John Link, AT&T Technologies, and Harry Lenzing, AT&T Bell Labs

The high frequency (HF) part of the RF spectrum has increased in popularity in recent years. Present receive subsystems designs are capable of covering the entire band, often collocated with HF transmitters. Because of the high levels of atmospheric and galactic noise encountered at HF, proper subsystem design does not necessarily attempt to provide the lowest noise figure, as is the case for most UHF or SHF systems. This paper discusses the tradeoffs of system noise figure, external noise levels, and other performance factors in HF receive system design.

LNA Measurement Techniques
Albert Wu, Allied-Signal Aerospace, Bendix Field Engineering

In many areas of microwave communications, we are seeking the highest sensitivity, or signal-to-noise ratio. One effective method of evaluating a receiving system's performance is the noise temperature measurement. This is commonly used for commercial and home TVRO systems, radar systems, radio astronomy receive systems, and point-to-point communications systems. The theory and techniques for noise temperature measurement are presented.

Session C-3: Analysis and Modeling

Arithmetically Symmetrical Bandpass Filters
Randall Rhea, Circuit Busters, Inc.

The classic approach of transforming lowpass or highpass prototype filters into bandpass configurations results in geometric symmetry, but often arithmetic symmetry is required. Furthermore, group delay symmetry is achieved with arithmetic response symmetry. This paper describes a lowpass to bandpass transform for designing bandpass filters with excellent response symmetry up to approximately 50 percent bandwidth.

Software Assists Characterization of Large-Signal Device Models
Jeremy Bunting, EEsof, Inc.

Circuit simulation programs require accurate device models in order to achieve maximum accuracy. Large-signal devices are sufficiently non-linear to require models based on measured data. This paper describes software products which make it possible to extract MESFET device parameters from automated measurements.

Automated Microwave Transistor Test Jig
Harvey Horowitz, B & H Electronics

Wednesday, October 25 — 1:30 to 4:30 p.m.

Session D-1: Phase-Locked Loops

A Reference-Cancelling Phase/ Frequency Detector
Dan Baker, Tektronix, Inc. (2 hours)

The design described in this paper is the Grand Prize winner in the 1989 RF Design Awards Contest. The author will discuss his analysis of digital phase detector phase-locked loop behavior, and describe the circuit that was developed to demonstrate the theory. The circuit uses a double-quadrature phase detector to mathematically cancel the reference frequency, reducing normally troublesome PLL reference sidebands to 50 dB or more below the carrier. The circuit also demonstrates that a PLL can be optimized to settle in the theoretical minimum period of two samples.

An Exclusive-OR Phase/Frequency Detector
Perry Jordan, Analog Devices, Inc., CLD Division

Modern frequency synthesizers require fast settling times, which can be achieved using phase/frequency detectors. Some common phase and frequency detectors are reviewed, and an enhanced exclusive OR gate phase/ frequency detector is described. The internal logic of this detector, the IC process used, and a design example are also included.

Session D-2: Transmission Systems

A High Performance Hybrid Phase Shifter
Gary K. Montress, Raytheon Company, Research Division

A new TO-8 packaged phase shifter is described, which has 60 degree phase variation over a 0-12 volt control range, with low loss, low noise, and a minimal variation in phase shift linearity and insertion loss versus control voltage over its 435-535 MHz operating range.

Applications of Power Combining in Communications Systems
Robert P. Gilmore, QUALCOMM Inc.

This paper addresses the issues of combining sinusoidal signals with unequal amplitude or phase, uncorrelated signals or noise sources, and systems with two antennas combined for increased gain or circular polarization. New applications for combiners as phase detectors or synchronous detectors are also presented.

Interference Investigations of Collocated Radio Terminals
John L. Ramsey and Louis L. Taylor, The MITRE Corporation

Frequency hopping and/or single channel radios operating in close physical proximity can generate significant mutual interference, even if most energy is radiated in widely separated bands. The mechanisms by which different radio terminals can interfere with one another are described, as well as the potential effects of this mutual interference. A testing program for determining the

H-P Offers 3-Hour EMC Tutorial

On Tuesday morning (October 24), an entire three-hour technical session, Designing for Electromagnetic Compatibility, will be presented by Tom Jerse of H-P's Signal Analysis Division. The session will cover the basic principles of EMC: electric and magnetic field radiation, grounding and shielding principles, coupling modes, conducted and radiated emissions, and susceptibility. The class emphasis is on design, presenting solutions not only for dealing with existing EMC problems, but for minimizing EMC problems by proper design and layout of circuits.

The session consists of highlights from H-P's two-day course on EMC design, which is currently being offered in a number of locations around the country. Information on the course can be obtained from Hewlett-Packard. See the Courses column on page 14 of this issue for upcoming dates and registration information.

amount of isolation required is given as an example, and methods of achieving the necessary isolation are presented.

Thursday, October 26 — 8:30 to 11:30 a.m.

Session E-1: Antenna Topics

HF Antenna Tuners
Nick Long, Great Circle Design, Melting Highways Ltd.
Despite the existence of wideband antennas, there is still a need for an antenna tuning unit (ATU) in many HF installations, particularly mobile systems with electrically short (capacitive) antennas. Frequency hopping, direct-sequence spread-spectrum, and multiple simultaneous carriers are currently used for anti-jamming communications, placing new requirements on ATU design. Broadband ATUs and other possible alternative feed systems are discussed.

Active Receive Antenna Technology
Brian Shreve, Defense Systems Inc.
Engineers are not often familiar with active receive antenna technology and may have difficulty interpreting performance parameters published by manufacturers. This paper provides an overview of active receive antennas, intended as a reference for RF systems designers, discussing active antennas versus antenna/preamplifier combinations and passive antennas.

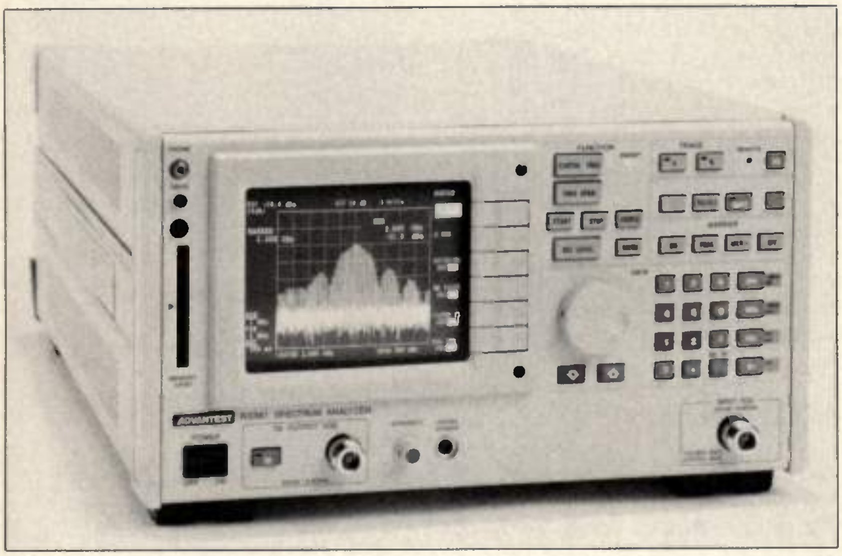
Session E-2: Oscillators

Several New Design Techniques for OCXOs
Arik Hertz, David Pincu, Isaac Edri, Time and Frequency Ltd.
An intensive effort has recently been made to develop new design techniques for oven-controlled crystal oscillators (OCXOs), with the objective of producing a low-cost, small device with low current consumption, short warm-up time and good frequency stability.

Microcomputer-Compensated Crystal Oscillator With Self-Temperature-Sensing
S.S. Schodowski, R.L. Filler, V.J. Rosati, and J.R. Vig, U.S. Army LABCOM
The best overall accuracy in a wide temperature range (−55C to +85C) TCXO has remained at about 1 ppm for the last 30 years, due to basic limitations relating to thermal hysteresis, the trim effect, and thermometry inaccuracies. A new microcomputer-compensated crystal oscillator (MCXO) is described which is capable of providing 10- to 100-times improvement in overall frequency accuracy compared to a conventional TCXO.

ANNOUNCING
THE FIFTH ANNUAL

RF Design Awards Contest



The Grand Prize:
Advantest R3261A
Spectrum Analyzer

Second Prize:
Software from
Circuit Busters, Inc.

Third Prize:
SMT Test Fixture
from Coilcraft,
plus Design Kits
and Tool Set

And 11 more Honorable Mention Prizes

From Sprague-Goodman Electronics — A set of eight specialized trimmer adjustment tools.

From Coilcraft — A set of five Designer's Kits, including fixed and adjustable inductors, chokes, and SMT inductors.

Contest Entry Rules

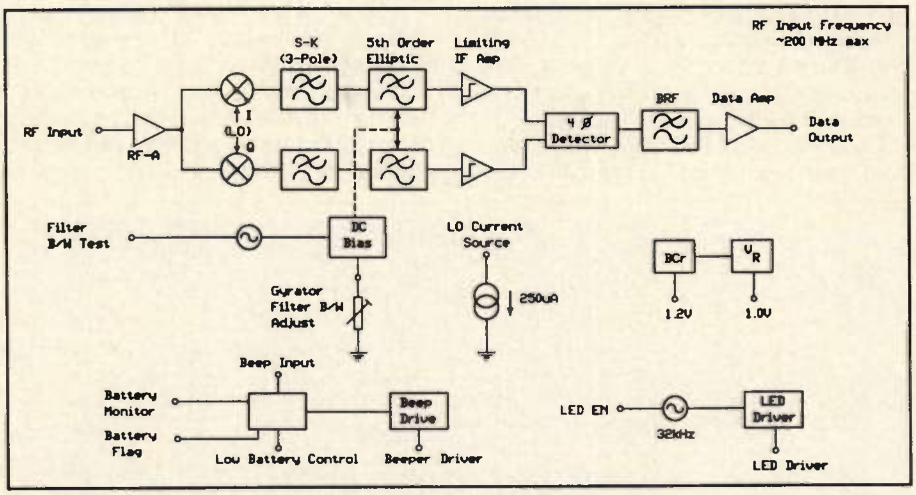
1. Entries shall be RF circuits containing no more than eight single active devices, or six integrated circuits, or be passive circuits of comparable complexity.
2. The circuit must have an obvious RF function and operate in the below-3 GHz frequency range.
3. Circuits must be the original work of the entrant, not previously published. If developed as part of the entrant's employment, entries must have the employer's approval for submission.
4. Components used must be generally available, not obsolete or proprietary.
5. Submission of an entry implies permission for *RF Design* to publish the material. All prize-winning designs will be published, plus additional entries of merit.
6. Winners shall assume responsibility for any taxes, duties, or other assessments which result from the receipt of their prizes.
7. Entry must be postmarked no later than March 31, 1990, and received no later than April 10, 1990.

Send entries to: **RF Design Awards Contest**
RF Design Magazine
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111

Direct Conversion FSK Data Receiver From Plessey

The SL6639 is a low-power direct conversion RF data receiver requiring minimum external components for the detection of FSK modulated data. The IC contains a low-noise RF cascode amplifier, direct conversion mixers, baseband amplifiers, filters and data demodulator. Frequencies in excess of 200 MHz with data rates exceeding 1200 BPS are supported.

One of the major features of the IC is the inclusion of on-chip channel filters. Baseband filtering utilizes both Sallen-key active filters and unique gyrator filters. The gyrator technique provides adjacent channel rejection in excess of 70 dB at 25 kHz channel spacing. Only one external resistor is required to adjust the tunable filters.



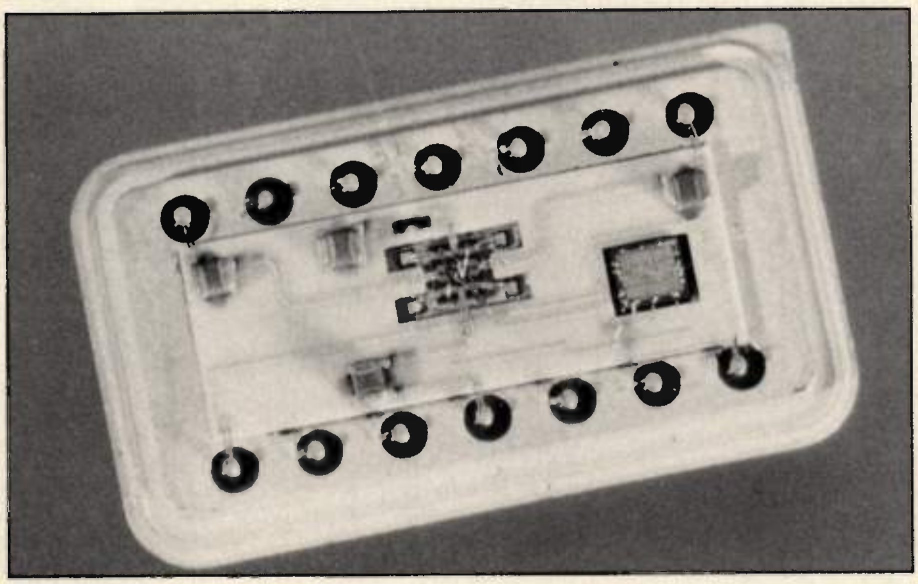
Sensitivity is typically −124 dBm (0.14 uV) at 150 MHz from a 50 ohm source. Typical third-order intermodulation for the receiver is 55 dB. Adjacent channel rejection is 70 dB. The device comes with a high current beeper drive, high current LED driver and low battery flag indicator.

Typical applications for the SL6639 include use in low-power radio data receivers, radio paging including wrist watch or credit card pagers, ultrasonic direction indication and security systems. In quantities of 100,000, the device is priced at $6.80 each. **Plessey Semiconductor Corp., Scotts Valley, CA. For more information please circle INFO/CARD #230.**

New RF Switches from M/A-COM

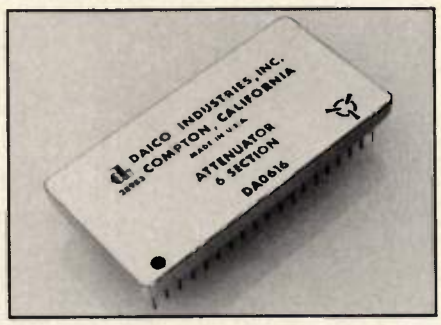
The MA4GM201T GaAs MMIC SPST reflective switch features 3 ns switching speeds. The circuit topology consists of two shunt connected FETs and a single series FET. The second-order intermodulation product is 77 dBm and the third-order intermodulation product is 45 dBm per tone.

Also available is the MA4GM202MD-2009S SPDT GaAs MMIC switch with matched ports. At 4 GHz, isolation is 38 dB and minimum isolation is 1.7 dB. Input VSWR ranges from 1.4 to 2.0 over the full bandwidth. Typical switching time is 50 ns and maximum input power rating is 30 dB. **M/A-COM Advanced Semiconductor Div., Burlington, MA. INFO/CARD #229.**



Constant Insertion Phase Attenuator

The Daico DA0616 is a high-speed, balanced, constant insertion phase, digital attenuator. The DA0616 has less than 1 degree of phase variation from 70 MHz to 100 MHz, 0.5 dB LSB with 31.5 dB of range (6-bits), and 5 dB of insertion loss at 100 MHz. Second-order



intercept point is +82 dBm and third-order intercept point is +29 dBm. It switches from 50 percent TTL to 90 percent/10 percent RF in 20 ns and 10 percent/90 percent RF in 5 ns. The switching elements are arranged in a bridge topology that cancels most of the switching transients. **Daico Industries, Inc., Compton, CA. INFO/CARD #228.**

Narrowband SAW Filter

Centered at 400 MHz with a 1.5 MHz bandwidth, the FB400-1 SAW filter exceeds 50 dB of ultimate rejection. It features Gaussian shape with linear tracking. Amplitude tracking is ±1.5 dB and phase tracking is ±5 degrees. The internally matched filter is housed in a 6-pin dual-inline hermetic package.

Phonon also introduces a hybrid SAW delay/filter module with selectable bandwidths and delays. This eight-path switching GaAs FET hybrid easily integrates with SAW filters or delay chips to allow selectable frequency passbands, bandwidths or delay times. The eight SAW designs are realized on a single substrate and packaged in a hermetic DIP with input and output hybrid switch networks. The module offers unity gain. Switch, amplifiers and other electronics operate to 1 GHz. For filtering requirements, two modules can be cascaded to achieve 80 to 100 dB rejection. The module measures 3 in. X 2.5 in. X 0.55 in. **Phonon Corp., Simsbury, CT. Circle INFO/CARD #227.**

Modular Receivers

Apcom unveils a compact receiver designed for signal monitoring in the 20 to 520 MHz band. All receivers share a common reference oscillator and tuning control interface, yet may be individually set for the desired operating mode. Each receiver is tuned through the 500 MHz operating band in 1 kHz increments with the IEEE-488 bus. Front panel controls on each receiver are used to select AM or narrow band FM detection, input and output levels, and the squelch/COR threshold. Available outputs include audio, pre-detection IF and COR status. The standard IF bandwidth is 15 kHz; bandwidths up to 300 kHz are available. Overall noise figure is 12 dB and internally generated spurs are less than −100 dBm. **Apcom, Inc., Gaithersburg, MD. INFO/CARD #226.**

Highpass Filters

The F-95 Series of filters are rated at 50 watts continuous and are available for cutoff frequencies from 500 to 3000 MHz. A typical filter, Model F-95-1000-5-N provides a passband insertion loss of less than 0.5 dB from 1000 to 2000 MHz while rejecting 700 MHz and below at 40 dB min. In unit quantities, price is $230. **RLC Electronics, Inc., Mount Kisco, NY. INFO/CARD #225.**

Multi-Channel FSK Receiver

The Model DCRX covers from 136 to 174 MHz to provide 1520 narrowband FM channels. Operating frequency is selected digitally by programming the on-board multi-loop frequency synthe-

sizer over a serial interface or directly from thumbwheel switches. It is based on a quadrature local oscillator technique. Sensitivity is 0.5 uV, spurious rejection is 70 dB and data rate is 12 kbits. **Zubiel RF Systems, Inc., Manhattan Beach, CA. INFO/CARD #224.**

One-Piece Plastic Cases for Split Beads

Fair-Rite introduces Nylon 6/6 one-piece hinged cases designed to clamp pairs of split round cable beads securely over cable. The case design ensures the proper mating of pairs. A hinge and latch feature permits the separation of the pairs as needed. **Fair-Rite Products Corporation, Wallkill, NY. Please circle INFO/CARD #223.**

Surface Mountable Reed Relay

The 9200 Series surface mountable relay features a coaxial shield which has a 50 to 75 ohm characteristic impedance. The design provides approximately 1.4 pF of capacitance from the open reed to the shield and coil tied together. It is available in axial, radial, gull wing and J terminal configurations. Isolation is greater than 10^{13} ohms. **Coto Corp., Providence, RI. Please circle INFO/CARD #222.**

Vector Modulation Signal Generator

The HP 8782A vector-modulation signal generator features a wide range of built-in modulation formats — from BPSK to 256 QAM plus 9 to 81 PRS. The 1 MHz to 250 MHz output range (+ 7 to −100 dBm) covers most commercially used receiver IFs. An internal pseudo-random bit-sequence generator with a 2^{23}-1 sequence length makes standard digital formats available without requiring an external modulation source. The unit also handles parallel-modulation inputs with data rates to 100 MHz and serial rates to 200 MHz. Data-input lines are compatible with ECL and TTL. Burst-modulation rates to 50 MHz with on/off ratios of > 50 dB are typical for time division multiple-access applications. AM and scalar modulations are available with rates from DC to 50 kHz. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #221.**

Voltage-Controlled Oscillator

Z-Communications introduces a line of VCOs based upon coaxial resonator technology. The D-900 Series covers from 700 to 1000 MHz. Phase noise is −95 dBc/Hz at 1 kHz, −105 dBc/Hz at 5 kHz and −120 dBc/Hz at 25 kHz. Sample units are priced at $85. **Z-Communications, Inc., Ft. Lauderdale, FL. Circle INFO/CARD #220.**

Shielded Inductors

The RL1123 and RL1124 zero radiation inductors use ferrite shields and end caps to enclose inductor winding. Almost 200 standard values from 1.0 uH to 47,000,000 uH are available. These axial leaded devices are replacements for pot core inductors. Prices start at $1.00 each in quantities of 1000. **Renco Electronics, Inc., Deer Park, NY. Circle INFO/CARD #219.**

Portable Broadband Antenna

The FD-288 antenna is designed as an RF test instrument (transmit and receive) from 2 to 88 MHz. It is capable of transmitting up to 25 watts. VSWR is 3:1. The 16 foot whip breaks down to 8.6 feet in length and 5 inches in diameter. **Astron, Herndon, VA. Please circle INFO/CARD #218.**

EMC Type Absorber

Rantec introduces an EMC Series absorber that is optimized for operation from 30 MHz to 120 MHz. It features a somewhat thicker base over Rantec's standard absorbers and an altered geometrical shape. This allows for optimum impedance matching at frequencies where the absorber is a fraction of a wavelength in thickness. **Rantec Microwave and Electronics, Inc., Canoga Park, CA. INFO/CARD #217.**

Cold Weld Crystals

These high-stability precision crystals offer good aging and Q characteristics. They are available from 1.0 MHz to 250 MHz and are calibrated within ±0.0005 percent. **K & L Quartztek, Phoenix, AZ. INFO/CARD #216.**

Antenna Measurement System

HP introduces a system that performs automated far-field antenna-pattern measurements from 1 GHz to 26.5 GHz, with optional coverage up to 110 GHz. The HP 85301A is an integrated system that includes all RF measurement instrumentation, a workstation controller, system software and accessories. The system tests gain, beamwidth, side-lobe levels, polarization, axial ratio and beam symmetry of antennas under far-field conditions. Measurements are managed by the workstation controller and system software. **Hewlett-Packard Company, Palo Alto, CA. INFO/CARD #215.**

Chip Capacitors

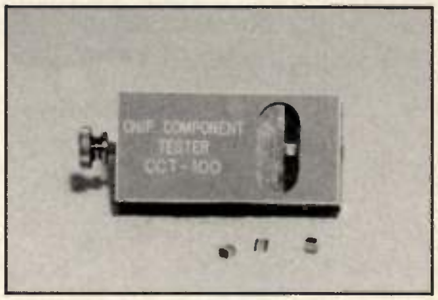
Designated the A3S00 Series, these chip capacitors are thin film devices which feature small size and high Q. Specifications include a loss of 0.04 dB in a 50 ohm system, 50 ppm/degree C typical temperature stability, and typical insulation resistance of 10^6 ohms. Units are available with capacitance ranging from 1.0 to 25 pF (±20 percent). **FEI Microwave, Inc., Sunnyvale, CA. Circle INFO/CARD #214.**

A/D Converter

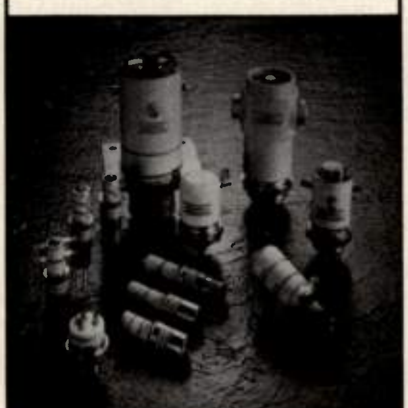
The DCS101CR is a complex output analog-to-digital converter intended for use in pulse Doppler radar and digital radio systems. It accepts as input an IF signal and produces the baseband signal in quadrature at its digital output. Image rejection is better than 55 dB over a ±5 MHz bandwidth relative to the local oscillator frequency. Other specifications include an LO from 60 to 80 MHz, sampling rate from 1 to 10 megasamples per second and dynamic range better than 65 dB. **Data Conversion Systems Ltd., Castle Park, Cambridge, England. For more information circle INFO/CARD #213.**

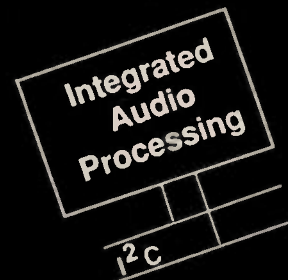
Chip Capacitor Test Fixture

This chip capacitor test fixture is spring loaded to hold the capacitor and make measurement contact. An enclosed phenolic cavity makes chip placement easy and contacts are nickel



plated. The unit holds capacitors with widths from 0.01 to 0.375 inches. It plugs into the standard banana jack and is priced at $79.95. **Lark Engineering Company, San Juan Capistrano, CA. INFO/CARD #212.**



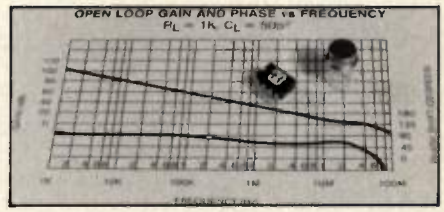


Miniature Active Filters

Toko America introduces the THB series of filters which are available in both bandpass and lowpass designs. The filters use an operational amplifier to eliminate the need for inductance. The filters simplify equipment design by treating the audio filtering requirement as a module rather than as a series of components. The bandpass filters have a passband of 300 to 3000 Hz, while the lowpass units are available with cutoff frequencies of either 3 kHz, 14 kHz, 18 kHz, 20 kHz or 22 kHz. Stopband attenuation is in excess of 30 dB for the bandpass filters, and greater than 36 dB for the lowpass type. In 500-piece quantities, price ranges from $6 to $12. **Toko America, Inc., Mt. Prospect, IL. INFO/CARD #211.**

Precision Op Amps

The HA-5221 and HA-5222 (a dual version of the 5221) feature 100 MHz bandwidth at frequencies below 100 kHz and are internally compensated to achieve 30 MHz unity-gain bandwidth. Offset voltage is 750 uV and open loop



gain is 128 dB. Noise is 3.4 nV/Hz and output current is ±30 mA. The HA7-5221-5 CERDIP, rated for commercial temperatures, is priced at $6.68 when purchased in 100-piece quantity. Can packaging is also available. Other available temperature options include industrial and military (883). **Harris Semiconductor, Melbourne, FL. Please circle INFO/CARD #210.**

70-140 MHz Oscillator

Model 1850031 is an oscillator with a 70 to 140 MHz frequency range. Stability over the −20 to +60 degree C range is $\pm 7 \times 10^{-6}$. It has a sinewave output with a minimum of +3 dBm. In small quantities, price ranges from $300 to $350. **Piezo Crystal Company, Carlisle, PA. INFO/CARD #209.**

rf software

Synthesis and Analysis Program for Transistors

Compact Software introduces Version 1.1 of SONATA. This version has the added capability of predicting single sideband (SSB) phase noise. SONATA is a software package that is designed for the synthesis and analysis of microwave and RF field-effect and bipolar transistors. The program supports IBM PC/XT/AT/386/PS-2 and compatible computers. **Compact Software, Inc., Paterson, NJ. INFO/CARD #195.**

Oscilloscope Driver Software

The PM 2235 oscilloscope driver PC software package from John Fluke Mfg. Co. eases GPIB/IEEE-488 programming and use with features such as self-documenting routines and an auto-configuration utility. It supports the Fluke PM 3320A, PM 3350 and PM 3365 analog/digital storage oscilloscopes. The software is priced at $399 and includes an interface card. **John Fluke Mfg. Co., Inc., Everett, WA. Please circle INFO/CARD #194.**

Active Filter Design Software

RLM introduces AFDPLUS, an active filter design software package that provides analysis capabilities and the ability to design filters including custom structures. It features an integrated simulator compiler that can be customized to generate simulator compatible files. Schematics can be generated on the screen or directed to a printer. Plots of zero and pole locations can also be displayed. Butterworth, elliptic, Chebyshev, inverse Chebyshev and Bessel configurations are supported. AFDPLUS is priced at $850. **RLM Research, Boulder, CO. INFO/CARD #193.**

Analog System Simulator

EEsof introduces Version 1.1 of OmniSys, a microwave and high-frequency analog simulator that combines linear and nonlinear characteristics to form a representation of systems and subsystems. Depending on platform and options, the software is priced between $14,000 and $16,800. **EEsof, Inc. Westlake Village, CA. INFO/CARD #192.**

RFI/EMI Testing Brochure

Instrument Specialties introduces a brochure on its radio frequency and electromagnetic interference testing capabilities. It covers the company's certified testing program to determine compliance with current commercial and military EMC specifications. The testing is calibrated to NIST standards. These RF, ESD and EMP tests are conducted over the 20 Hz to 18 GHz range with radiated susceptibility levels to 200 V/m. **Instrument Specialties Co., Inc., Delaware Water Gap, PA. Please circle INFO/CARD #191.**

New Components Brochure

RF and microwave components from Anzac, RHG and SDI Microwave covering from DC to 26 GHz are featured in the new Adams-Russell RF & microwave signal processing components catalog. It includes over 150 products such as GaAs MMICs, log amplifiers, surface-mount devices, RF and microwave control devices, mixers, hybrids, passives, and subsystems. Other features include complete design/selection guides, application notes and technical articles. **Adams-Russell Components Group, Burlington, MA. INFO/CARD #190.**

Materials Datasheet

Xtalonix announces the availability of their materials datasheet that gives specifications on garnet materials, ferrite materials and dielectric materials. Also included are brief descriptions. **Xtalonix, Columbus, OH. Please circle INFO/CARD #189.**

Capabilities Brochure

This brochure from Microwave Solutions describes the facilities and capabilities for custom design and fabrication of microwave amplifiers and related components used to control, filter and switch RF and microwave signals from 10 MHz to 26 GHz. Computer-aided-design capabilities and design modifications to provide solutions are discussed. **Microwave Solutions, Inc., National City, CA. INFO/CARD #188.**

High Frequency Probing Bulletin

Cascade Microtech introduces a bulletin that features the MTF26 microstrip test fixture, which provides microstrip measurements that repeat within 0.1 percent. Also included is a discussion on the advantages of probe absorbers, a software description, and an article on using the test fixture and the NPT18 noise parameter test set. **Cascade Microtech, Inc., Beaverton, OR. Please circle INFO/CARD #187.**

Brochure Describes Anechoic Chambers and Shielded Enclosures

This brochure discusses RF shielded enclosures and anechoic chambers including complete turnkey systems. It outlines specifications and performance charts and graphs from 120 MHz to millimeter-wave. **Rantec Microwave and Electronic Systems, Inc., Canoga Park, CA. INFO/CARD #186.**

Crystals and Oscillators Guide

User's Guide to Quartz Crystals and Oscillators features Valpey-Fisher's line of related products. Crystals from 14 kHz to 300 MHz are featured in more than 35 package styles. Also included are TTL, ECL, CMOS and HCMOS hybrid clock oscillators in full size, half size, through hole and surface mount packages. Other information presented includes cross-references and ordering information. **Valpey-Fisher Corp., Hopkinton, MA. INFO/CARD #185.**

ASIC Short Form Catalog

The Custom ASIC Products Short Form Catalog from Stanford Telecom contains information on frequency synthesizer products, forward error correction products, coding products, demodulation products and radiation hardened products. A section that discusses upcoming products is included. The final section of this catalog describes the company's technical support services. **Stanford Telecommunications, Inc., Santa Clara, CA. INFO/CARD #184.**

Application Note Describes Digital-Microwave Radio Fading Tests

Measuring Digital-Microwave Radio M-Curves/Signatures (AN 379-1) is an application note for engineers who work on digital communications. The M-curve, sometimes called a radio's signature, is a measure of a radio's resistance to fading effects of multipath transmissions. Multipath fading results in bit-error rate (BER) increases and loss of performance. This note reviews the basic theory of the three-ray model of fading simulation and shows the measurement procedures using the HP 11757A multipath fading simulator and an HP BER test set. **Hewlett-Packard Company, Palo Alto, CA. Please circle INFO/CARD #183.**

Precision Trimmer Capacitors Catalog

Voltronics has published a catalog on its line of precision trimmer capacitors. A product selection guide is highlighted together with product descriptions on capacitors, DRO and magnetic tuners, and non-magnetic trimmers for NMR and MRI including non-magnetic slip clutches. The final section details engineering prototype kits and tuning tools. **Voltronics Corp., Hanover, NJ. INFO/CARD #182.**

RF Power Semiconductors Data Book

Mitsubishi announces the availability of its RF power semiconductors data book. Specifications are provided on RF power modules, high-frequency high-power transistors, antenna switches and hybrid antenna switches. A section on applications is included. Basic applications for the RF power modules include use in mobile and portable radio. **Mitsubishi Electronics America, Inc., Sunnyvale, CA. INFO/CARD #181.**

Conductive Thermoplastics Brochure

This brochure describes the uses of Electrafil^{R}, an electrically conductive reinforced thermoplastic. Featured is a section on the properties of Electrafil thermoplastic materials that incorporate conductive additives and fibers in a range of base resins including nylon, polycarbonate, polypropylene, ABS and high-temperature thermoplastics. Also illustrated are typical applications. **Akzo Engineering Plastics, Inc., Evansville, IN. INFO/CARD #180.**

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ELECTRICAL/COMPUTER: BSEE/MSEE/BSCE/BSCS or equivalent. Seeking experience in any of the following areas: analog and RF circuit design, receiver or transmitter RF circuits; LCD display technology, acoustics, and 8-bit microprocessor software; infrared and fiber optics; low speed data; digital modulation; 900 Mhz RF power amplifier design with hybrid or microstrip circuitry; RF device development; parallel and/or push-pull RF amplifier design at 900 Mhz or UHF; A/D and D/A convertors; RF propagation; passive/active filter theory; microwave antenna design; UL, EMI and RFI requirements; HP 3062 test system; HP 9000; digital hardware, microprocessor applications and interfaces; digital switching technology; firmware development methodology; PCM and digital telephony; digital signal processing; ASIC design; LAN systems, PSTN standards, ISDN standards, processor architectures, high speed logic; 16-bit MPU design practices, programmable logic; digital modulation, synchronization, adaptive signal processing, viterbi algorithm and MLSE, decision feedback equalizer; convolutional code and linear block code, speed coding, echo cancellation, encryption; CAE techniques for digital hardware design using Mentor Graphics, etc.; data communications protocols (CCITT #7, OSI, X.25, X.75, PAD, LAPB, LAPD, Ethernet, ISDN, CCITT V Series modem, group 3 fax); computer network management/administration (Apollo, Sun, Mentor Graphics, AppleTalk). **Refer to Dept. #EC/RFD.**

SYSTEMS: BSEE/BSCE/BSCS or equivalent. We are seeking persons with experience in any of the following technologies: radio/cellular communication systems engineering; RF propagation prediction methods; PSTN traffic planning; telephone network, interconnection and telecommunication industry standards; microwave system design and equipment engineering; telephone switching systems; software programming skills. **Refer to Dept. #SY/RFD.**

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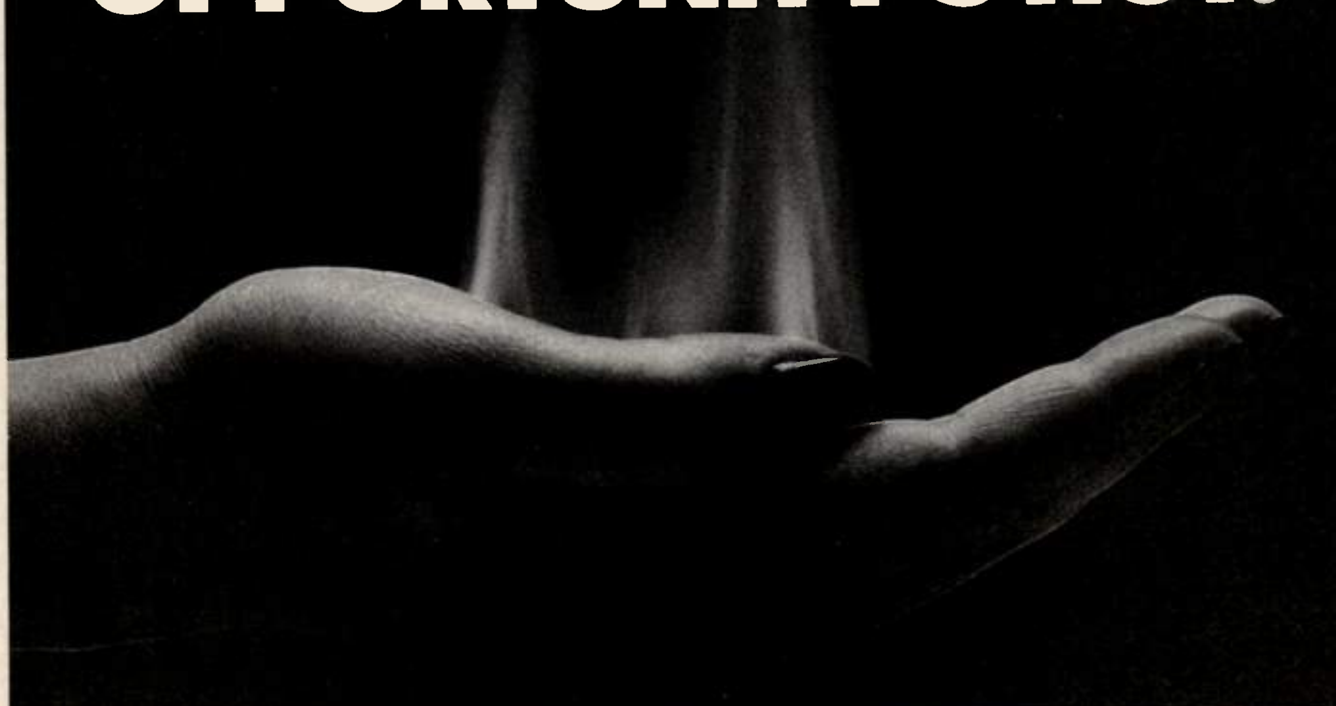

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Computer programs from *RF Design*, provided on disk for your convenience.

This month's disk (RFD-1089)
"A Spurious Response Program for Wideband Mixer Circuits," by William Sabin of Rockwell-Collins. Computes and plots intermodulation products for wide bandwidth frequency conversions. (Pascal, compiled, executable file)

Disk RFD-0989: September 1989
"Calculating S-Parameters from Nodal Analysis," by Bert Erickson of G.E.
Two programs: SPAR, described in this issue's article (BASIC), and NTWK (Compiled, executable) an updated version of the author's nodal analysis program published in December 1986 *RF Design*.

Disk RFD-0889: August 1989
1. "Chebyshev Filters with Arbitrary Source and Load Resistances," by Jack Porter of Cubic Corp. (BASIC).
2. "A General Purpose Oscillator," by Dr. Y.C. Cheah of Hughes Network Systems. From June 1989 issue—Mathcad files for S-parameter conversions.

Programs have been available on disk since February 1989. Send for a complete listing of available programs.

Disks are $9.00 each (5¼ in.) or $10.00 (3½ in.). Outside U.S. and Canada, add $8.00 per order. Foreign checks must be in U.S. funds, drawn on banks with U.S. offices or agents. Prices include postage and handling.
Annual subscriptions are available, providing 13 disks for $90 (5¼ in.) or $100 (3½ in.). For subscribers outside the U.S. and Canada: add $50.
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