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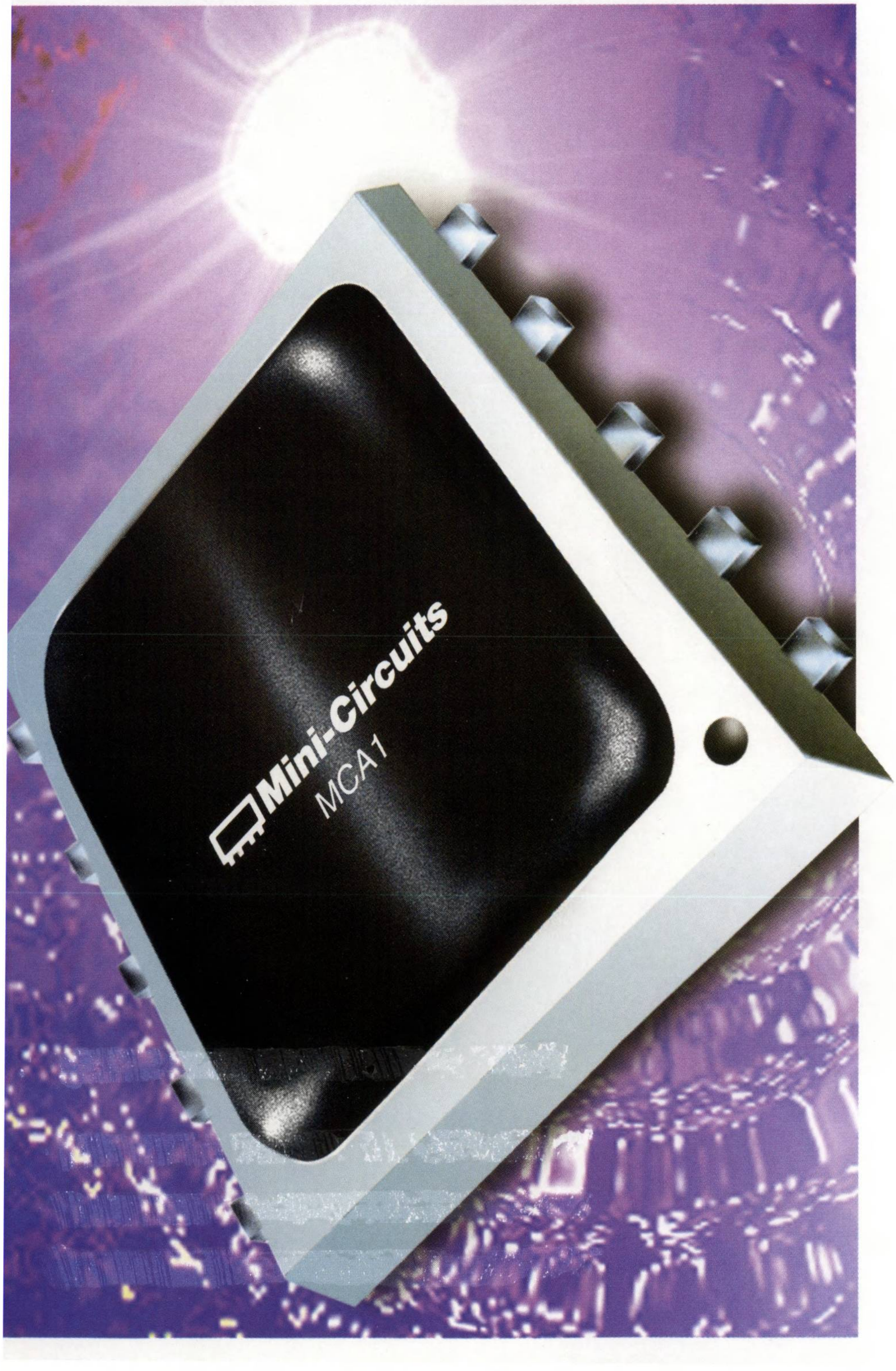

COMMUNICATIONS AND PCNs

QUADRATURE DEMODULATOR SPECIFICATIONS FOR RECEIVER DESIGN

BASICS OF SUSPENDED STRIPLINES

DESIGN ADVANTAGES OF MOSFET CDMA POWER AMPLIFIERS

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good information,
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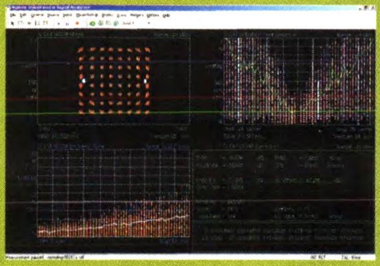
The original idea was simple: use wireless links to give the wired generation more mobility. Of course, turning *Bluetooth* and Wi-Fi into reality—without much time for analysis—has been anything but simple. Perhaps we can help.

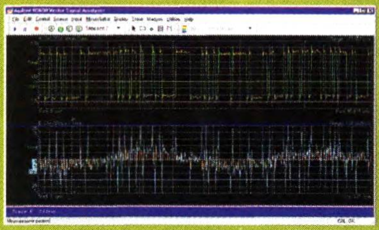
Enhancing interoperability. Many people attribute Wi-Fi's popularity to WECA testing that certifies device interoperability. Those who've passed tell us the roots of success often reach back to early tweaks in their transmitter or receiver designs. For transmitters, error vector magnitude (EVM) versus time or channel is a measure of modulation quality that can highlight underlying problems such as nonlinear distortion, phase noise and spurious signals. Conversely, making receivers more forgiving of nonideal transmitters can come from testing with impaired signals—in hardware, simulation or a system that links both.

Achieving certification. The Agilent Interoperability Certification Labs and Agilent's network of test partners are ready to help, too: they've tested hundreds of Wi-Fi devices and can help you clear the qualification hurdle.

To learn more, please visit www.agilent.com/find/wn, where you can request a FREE CD-ROM packed with articles, solution guides, and application notes such as "RF Testing of Wireless LAN Products" and "Verifying *Bluetooth* Baseband Signals."



For this IEEE 802.11a signal, the overall EVM measurement is acceptable but viewing EVM versus time (lower left) and channel (upper right) shows the effect of a timing error.



The FSK error display can highlight the effects of unwanted frequency modulation, which may indicate the presence of spurious signals in the modulator.

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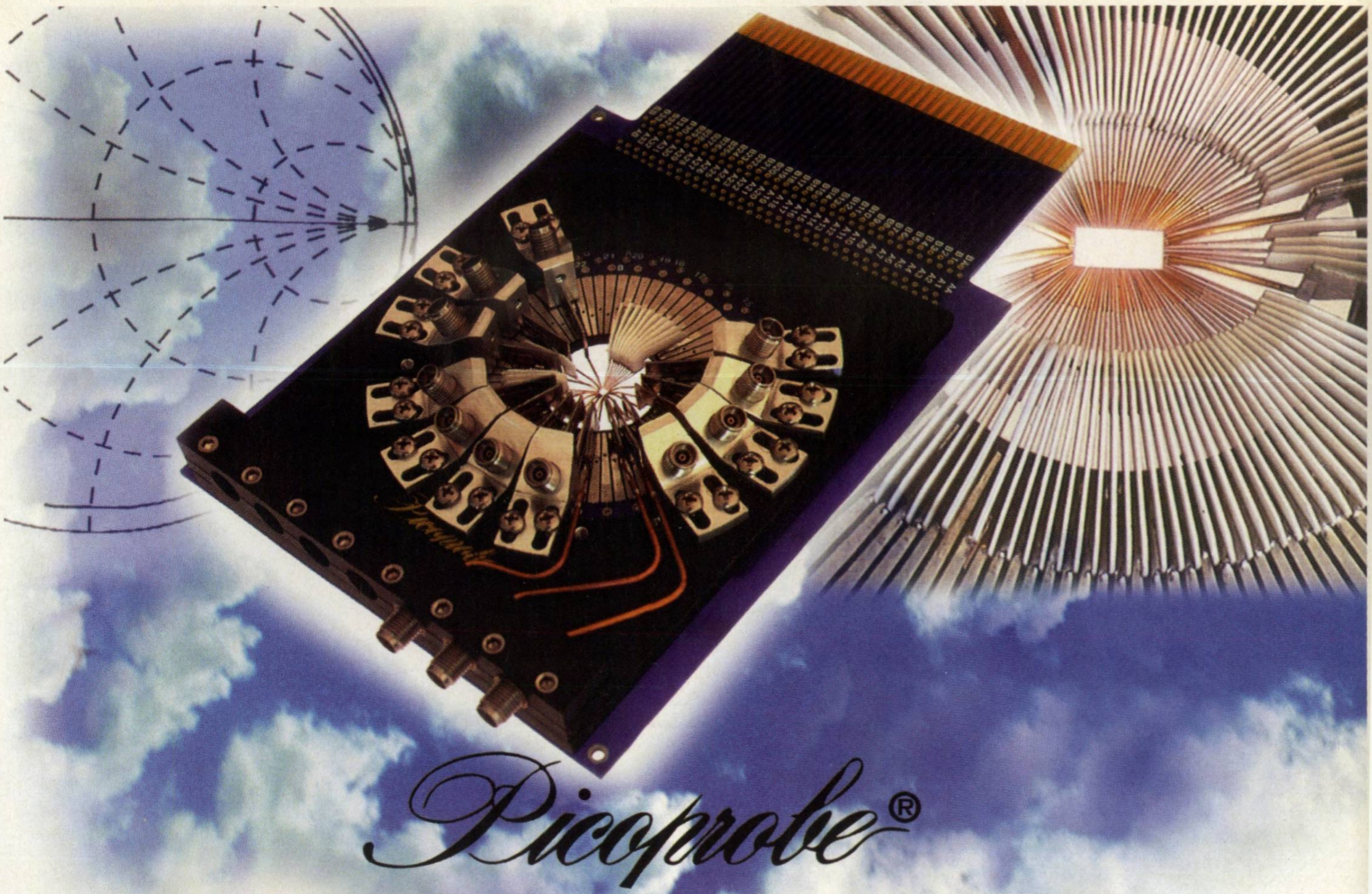

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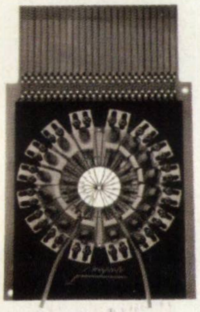

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OCTAVE BAND AMPLIFIERS								
JS2-00500100-045-5A	0.5 – 1	35	1	0.45	2:1	2:1	5	250
JS2-00500100-12-5A	0.5 – 1	35	1.2	1	2:1	2:1	5	250
JS2-01000200-045-5A	1 – 2	33	1	0.45	2:1	2:1	5	250
JS2-02000400-045-5A	2 – 4	28	1.2	0.45	2:1	2:1	5	175
JS2-04000800-08-0A	4 – 8	22	1.2	0.8	2:1	2:1	0	150
JS3-04000800-08-5A	4 – 8	30	1	0.8	2:1	2:1	5	175
JS3-04000800-15-5A	4 – 8	30	1	1.5	2:1	2:1	5	175
JS2-08001200-11-5A	8 – 12	15	1	1.1	2:1	2:1	5	150
JS3-08001200-11-5A	8 – 12	25	1	1.1	2:1	2:1	5	175
JS3-08001200-15-5A	8 – 12	25	1	1.5	2:1	2:1	5	175
JS3-12001800-16-5A	12 – 18	23	1	1.6	2:1	2:1	5	175
JS4-12001800-145-5A	12 – 18	30	1	1.45	2:1	2:1	5	200
JS4-12001800-30-5A	12 – 18	30	1	3	2:1	2:1	5	200
JS2-18002600-20-5A	18 – 26	14	2	2	2.5:1	2.5:1	5	100
JS2-18002600-30-5A	18 – 26	14	2	3	2.5:1	2.5:1	5	100
JS3-18002600-20-5A	18 – 26	22	1.8	2	2.5:1	2.5:1	5	175
JS3-18002600-30-5A	18 – 26	22	1.8	3	2.5:1	2.5:1	5	175
JS4-18002600-19-5A	18 – 26	33	1.5	1.9	2:1	2:1	5	200
JS4-18002600-26-5A	18 – 26	33	1.5	2.6	2:1	2:1	5	200
JS2-26004000-35-5A	26 – 40	10	2	3.5	2.5:1	2.5:1	5	100
JS2-26004000-45-5A	26 – 40	10	2	4.5	2.5:1	2.5:1	5	100
JS3-26004000-35-5A	26 – 40	18	2.5	3.5	2.5:1	2.5:1	5	175
JS3-26004000-45-5A	26 – 40	18	2.5	4.5	2.5:1	2.5:1	5	175
JS4-26004000-40-5A	26 – 40	23	2.5	4	2:1	2:1	5	200
JS4-40006000-65-0A	40 – 60	15	3	6.5	2.75:1	2.75:1	0	175
MULTIOCTAVE BAND AMPLIFIERS								
JS2-00500200-07-5A	0.5 – 2	32	1	0.7	2:1	2:1	5	295
JS2-00500200-15-5A	0.5 – 2	32	1	1.5	2:1	2:1	5	295
JS2-01000400-08-5A	1 – 4	27	1	0.8	2:1	2:1	5	200
JS2-01000400-20-5A	1 – 4	27	1	2	2:1	2:1	5	200
JS2-02000600-08-5A	2 – 6	22	1	0.8	2:1	2:1	5	125
JS2-02000600-20-5A	2 – 6	22	1	2	2:1	2:1	5	125
JS2-02000800-08-0A	2 – 8	22	1.25	0.8	2:1	2:1	0	125
JS2-02000800-20-0A	2 – 8	18	1.25	2	2:1	2:1	0	125
JS3-02001800-25-5A	2 – 18	23	1.8	2.5	2.5:1	2.5:1	5	150
JS3-02001800-50-5A	2 – 18	23	1.8	5	2.5:1	2.5:1	5	150
JS4-02001800-22-5A	2 – 18	30	2	2.2	2.5:1	2.5:1	5	200
JS4-02001800-50-5A	2 – 18	30	2	5	2.5:1	2.5:1	5	200
JS3-02002600-33-5A	2 – 26	21	2.5	3.3	2.5:1	2.5:1	5	150
JS3-02002600-40-5A	2 – 26	21	2.5	4	2.5:1	2.5:1	5	150
JS3-06001800-16-5A	6 – 18	23	1.8	1.6	2:1	2:1	5	125
JS3-06001800-30-5A	6 – 18	23	1.8	3	2:1	2:1	5	125
JS4-06001800-145-5A	6 – 18	31	2	1.45	2:1	2:1	5	200
JS4-06001800-30-5A	6 – 18	31	2	3	2:1	2:1	5	200


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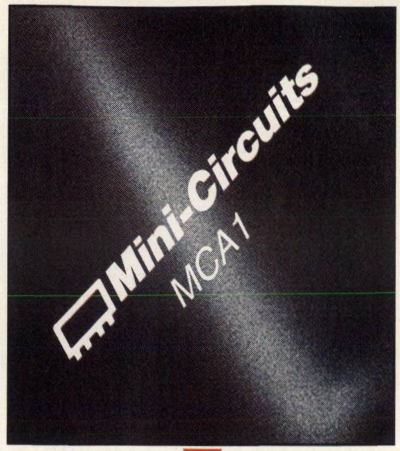

ON THE COVER

A low temperature co-fired ceramic double-balanced mixer covering the 300 to 6000 MHz frequency range is featured on this month's cover

Cover art designed by Frank Andriella, A1 Advertising Inc.; courtesy of Mini-Circuits

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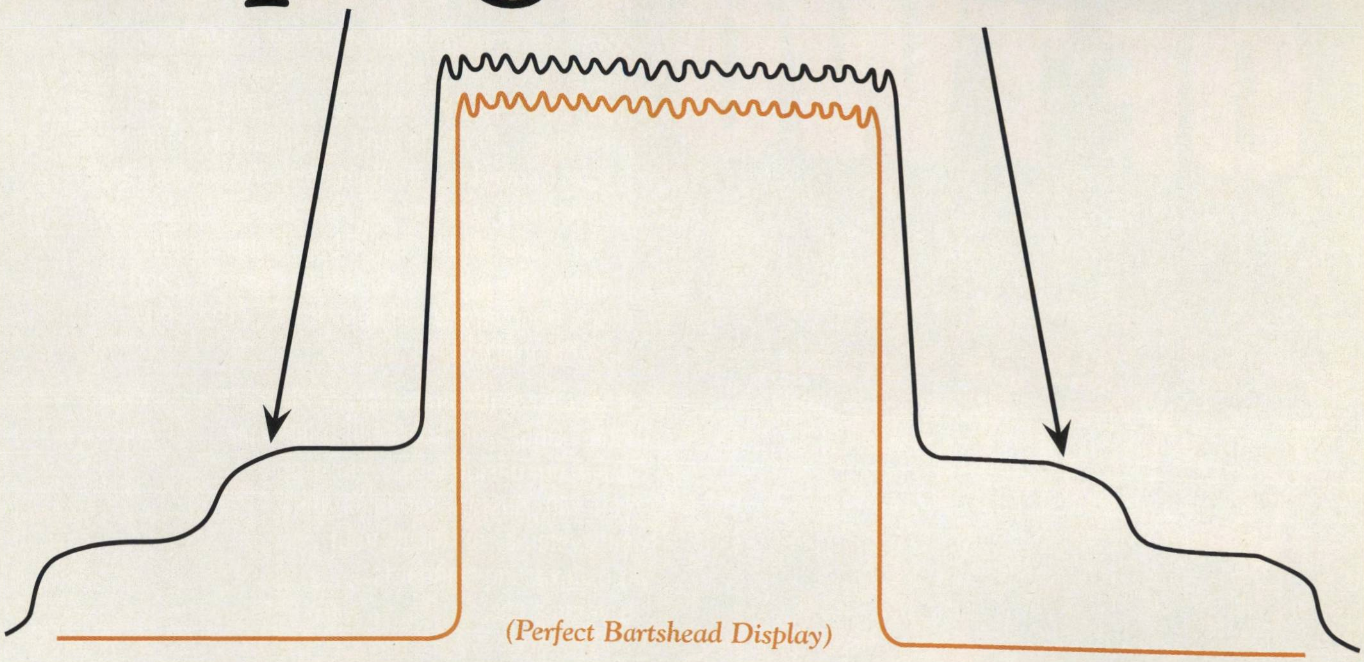
Danger. Sloping Shoulders.



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2002 Asia-Pacific Microwave Conference
November 19–22, 2002
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This conference will be organized and sponsored by the Institute of Electronics, Information and Communication Engineers of Japan, and is cooperatively sponsored by IEEE MTT-S, URSI and IEEE MTT-S Japan Chapter. Topics: active devices and circuits, passive components, systems, basic theory and techniques, and emerging technologies. An International Microwave Exhibition, in association with the conference, will be held concurrently. For further information, contact: Shozo Komaki, Chair, Steering Committee, c/o SIPEC Corp., 4-1-4 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan +81-3-3815-8590, fax +81-3-3815-8529 or e-mail: mweapmc@blue.ocn.ne.jp. Information can also be found online at www.apmc.mwe.org.

23rd Army Science Conference
December 2–5, 2002
Orlando, FL

Sponsor: Assistant Secretary of the Army (Acquisition, Logistics and Technology). The conference theme is "Transformational Science and Technology for the Army...a Race for Speed and Precision." The conference will feature presentations of papers and posters judged as best among those submitted by scientists and engineers from government, industry and academia. Topics: advanced materials and manufacturing, microelectronics and photonics, lethality technologies, biomedical, environmental and geosciences, power and energy, force protection/survivability, advanced computing and simulation, behavioral sciences and human performance, sensors and signal processing, biotechnology, nanotechnology, immersive technology, robotics, and IT/C4ISR. For additional information, visit: http://www.asc2002.com.

60th Microwave Measurement Conference
December 5–6, 2002
Washington, DC

Sponsor: Automatic RF Techniques Group (ARFTG). This conference will explore cutting edge microwave measurements for the industrial, academic, and government-related engineering communities. Original papers demonstrating approaches to the characterization of microwave devices, circuits and systems will be presented. Topics: test challenges for high power on-wafer devices, measurements for emerging technologies, nonlinear measurement, new developments in measurement instrumentation and other areas of automated RF measurements. The conference will also feature an exhibition, for information contact: Leonard Hayden, exhibits chair, Cascade Microtech (503) 601-1580, fax (503) 601-1601 or e-mail: leonard@cmicro.com. For more information on the conference, contact: J. Gregory Burns, conference chair, Northrop Grumman (410) 765-7331, fax (410) 981-4874 or e-mail: john_g_burns@mail.northgrum.com.

IEEE International Electric Devices Meetings (IEDM)
December 8–11, 2002
San Francisco, CA

IEDM is a forum for reporting breakthrough in the technology, design and manufacturing of semiconductors and other electron devices. Additional information is available on the meeting's Web site at www.ieee.org/conference/iedm or, contact: Phyllis Mahoney, conference manager, Widerkehr & Associates, 16220 S. Frederick Ave., Suite 312, Gaithersburge, MD 20877 (302) 527-0900 or e-mail: phyllism@widerkehr.com.

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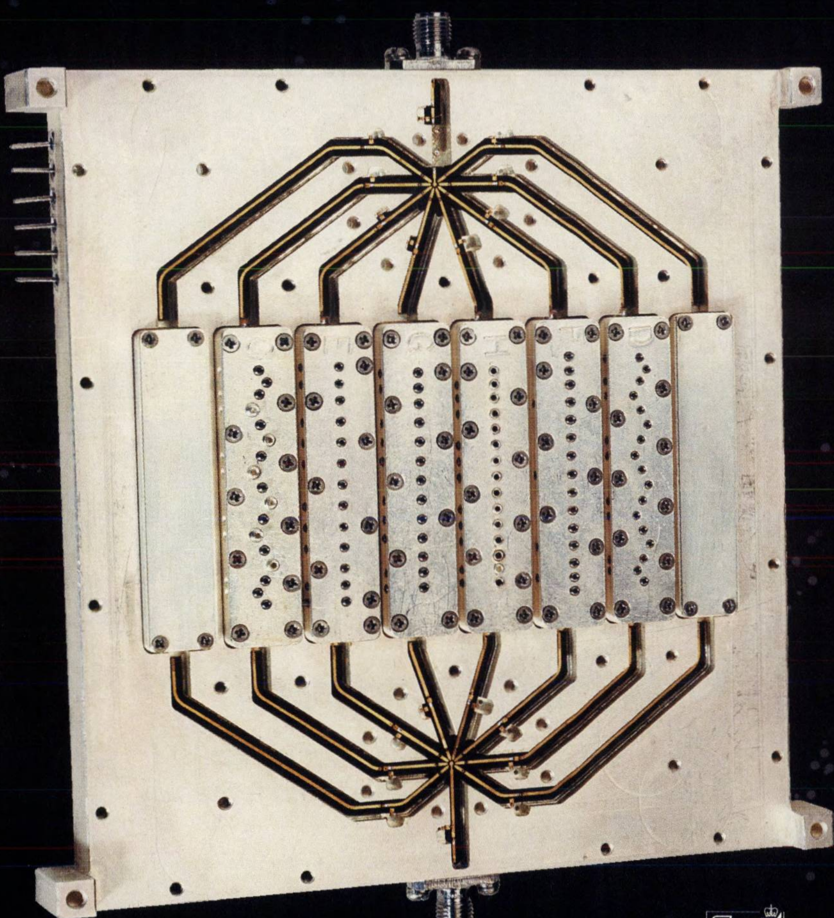

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7th International Commercialization of Military and Space Electronics Conference and Exhibition (CMSE)
February 10–13, 2003
Los Angeles, CA

This conference is organized by Components Technology Institute Inc. in cooperation with EIA/ECA, IEEE/CPMT and IMAPS. It will specialize in COTS systems, subsystems, circuit boards and components while also emphasizing new technology, processes and design practices. Emphasis will be placed on practical solutions, new techniques and how to assess the risks of COTS and make cost-effective decisions that meet the mission requirements. Working groups and discussion sessions are planned on specific topics of concern to the industry. New issues identified by the delegates to the previous year's conference will also be addressed. Topics: design practices, technology trends, applications, case studies/history, obsolescence management, radiation hardness, risk mitigation, selecting COTS and commercial suppliers, testing requirements and results, and constructive and destructive physical analysis. For further information, contact: Dale Stamps or Leon Hamiter at (256) 536-1304 or e-mail: dale@cti-us.com or lhamiter @cti.us.com. Information can also be accessed online at www.cti.us.com.

International Conference on Subsurface and Surface Sensing and Imaging IV
March 2–6, 2003
San Diego, CA

This conference reports advances and progress in the research and development of subsurface and surface sensing and imaging techniques, sensors and applications, and addresses the technical barriers encountered in multiple domains of subsurface and surface sensing and imaging. Topics: surface and ground penetrating sensors, signal and data processing and propagation and modeling, material properties and characterizations, and cross-cutting commonalities across subsurface and surface sensing applications. Additional information is available at http://ee.tamu.edu/subsurface-sensing-conference. For further information, contact: Cam Nguyen, Department of Electrical Engineering, Texas A&M University, College Station, TX 77843 (979) 845-6259 or e-mail: cam@ee.tamu.edu.

IEEE International Symposium on Electromagnetic Compatibility
May 11–16, 2003
Tel-Aviv, Israel

This symposium will provide opportunities for EMC researchers, scientists, engineers and vendors to present the latest research results, discuss problems of current and mutual interest and exchange views and experience related to new EMC components, materials and equipment. For further information, contact: ORTRA Ltd., 1 Nirim Street, PO Box 9352, 61092 Tel-Aviv, Israel +972-3-63844, fax +972-3-6384455 or e-mail: emc2003@ortra.co.il.

IEEE MTT-S International Microwave Symposium and Exhibition
June 8–13, 2003
Philadelphia, PA

This symposium will serve as the centerpiece of Microwave Week 2003. Topics: research, development and application of RF and microwave theory and techniques. In addition to IMS2003, a microwave exhibition, a historical exhibit, the RFIC symposium and the ARFTG conference will be held during Microwave Week 2003. The technical sessions will run Tuesday through Thursday of the Microwave Week. Workshops will be held Sunday through Tuesday, and the ARFTG Microwave Measurements Conference will be held on Thursday and Friday. For information, contact: Richard V. Snyder, general chair, RS Microwave Co. Inc. (973) 492-1207, e-mail: r.snyder@ieee.org. For exhibition information, contact: Kristen Dednah, Horizon House Publications, 685 Canton St., Norwood, MA 02062 (781) 769-9750 or e-mail: kdednah@ mwjournal.com.

WORKSHOPS & COURSES

RF & Microwave Fundamentals

■ **Topics:** Understand the principles of RF/microwave engineering, and undertake RF measurements using power meters, spectrum analyzers and network analyzers. Introduction to noise figure and phase noise is also included.
■ **Site:** Winnersh, UK
■ **Dates:** October 22–25, 2002
■ **Contact:** Tracey Bull, +44 118 9276741, fax +44 118 9276862 or e-mail: tracey_bull@agilent.com.

Introductory RF/Microwaves

■ **Topics:** Intended for engineers, managers and technicians who are new to RF/microwave and need an overview of the field so that they can become productive immediately. Course participants receive a full set of seminar notes and a copy of the course text.
■ **Site:** Baltimore, MD
■ **Dates:** November 7–8, 2002
■ **Contact:** R.A. Wood Associates, 1001 Broad St., Suite 450, Utica, NY 13501 (315) 735-4217.

Wireless Engineering

■ **Topics:** Fundamentals are covered and applied using a hands-on design approach. Course principles are explored by the design of practical filters, diplexers and transistor amplifiers, giving participants a wide range of design experience. Fee: $2045.
■ **Site:** Baltimore, MD
■ **Dates:** November 11–15, 2002
■ **Contact:** R.A. Wood Associates, 1001 Broad St., Suite 450, Utica, NY 13501 (315) 735-4217.

RF Microwave Receiver Design

■ **Topics:** Overview of receiver applications, receiver system requirements, receiver types and architectures, receiver system characteristics, receiver interference considerations, sample receiver design, receiver components and parameters, LO design requirements, statistical design techniques, wireless system design considerations, system analysis.
■ **Site:** Baltimore, MD
■ **Dates:** November 18–20, 2002
■ **Contact:** R.A. Wood Associates, 1001 Broad St., Suite 450, Utica, NY 13501 (315) 735-4217.

RF Wireless System Design Fundamentals

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■ **Site:** Sunnyvale, CA
■ **Dates:** November 20–22, 2002
■ **Contact:** Besser Associates, 201 San Antonio Circle, Building E, Suite 280, Mountain View, CA 94040 (650) 949-3300.

NIST/ARFTG Microwave Measurements Short Course

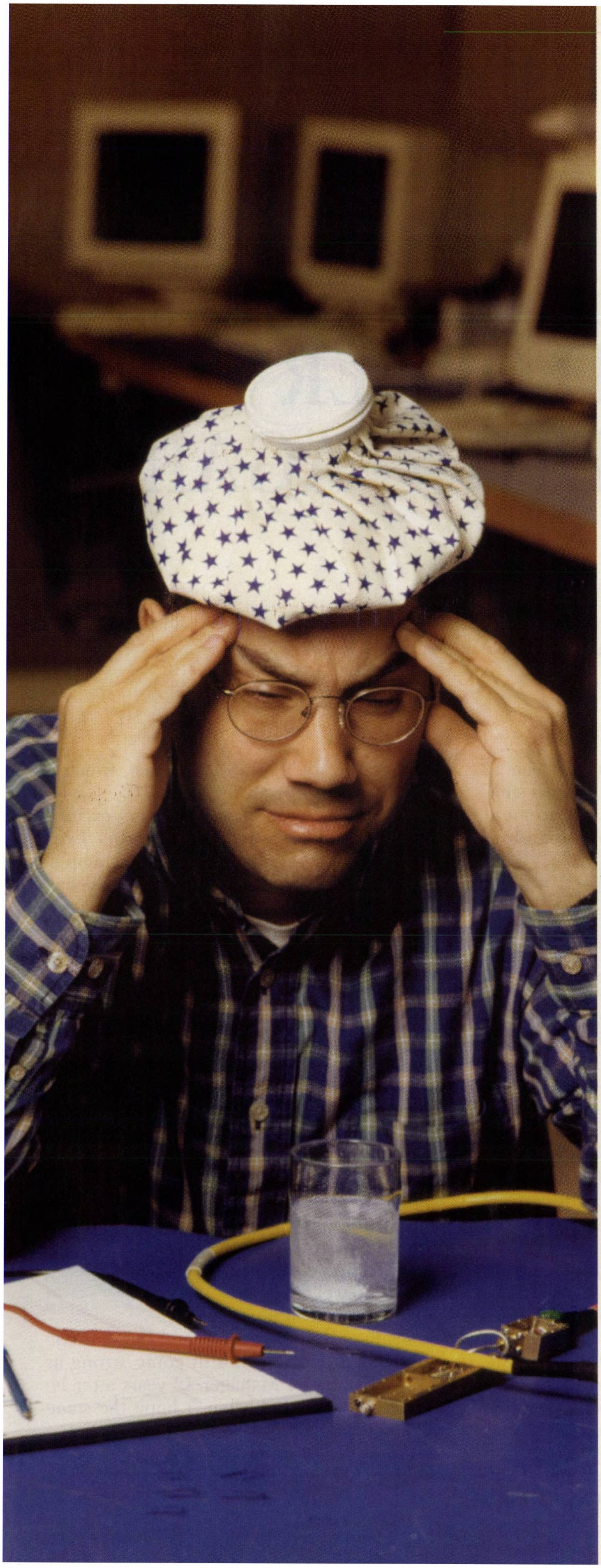
■ **Topics:** Microwave measurement fundamentals, practical issues such as cables, fixtures, probes and on-wafer measurements, as well as more advanced measurement topics.
■ **Site:** Washington, DC
■ **Dates:** December 3–4, 2002
■ **Contact:** Dave Walker, NIST, e-mail: dwalker@boulder.nist.gov or visit www.arftg.org.

Advanced Wireless and Microwave Techniques

■ **Topics:** Antennas and filters are covered briefly, followed by a detailed discussion of figures of merit. Mixers and oscillator designs are evaluated, as well as defining, classifying and improving the efficiency and linearity of power amplifiers.
■ **Site:** Sunnyvale, CA
■ **Dates:** December 9–13, 2002
■ **Contact:** Besser Associates, 201 San Antonio Circle, Building E, Suite 280, Mountain View, CA 94040 (650) 949-3300.

RF Wireless System Design Fundamentals

■ **Topics:** Digital wireless communication systems concepts and performance limitations, system degradation due to RF components, wireless communication system budget profiles, propagation losses and link budgets, cost vs. performance issues, and performance of differing RF wireless system architecture.
■ **Site:** Los Angeles, CA
■ **Dates:** December 11–13, 2002
■ **Contact:** Besser Associates, 201 San Antonio Circle, Building E, Suite 280, Mountain View, CA 94040 (650) 949-3300.



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EDITORIAL

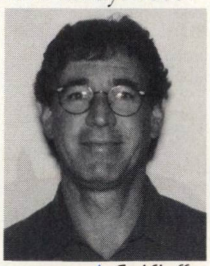
THE OLD ORDER CHANGETH — AGAIN!

I find it hard to believe that it has been 12 years since Howard Ellowitz wrote a similar message announcing his retirement and introducing me as the new Publisher/Editor of *Microwave Journal.* Now it is my turn to slow down a little and find some breathing room. With this issue, I am retiring as Publisher of *Microwave Journal.* Like Howard before me, I plan to continue to work part time for Horizon House. I will still be the Editor of *Microwave Journal* and I will continue to share in the management of the MTT-S Exhibition.

▲ Harlan Howe, Jr.

The new Publisher is Carl Sheffres, who is well known to our advertisers but who may not be as well known to our readers. Carl earned a BS degree in Journalism from the University of Colorado. He has worked in publishing for over 20 years, beginning his career as a sales representative for Beacon Publications, where he advanced to Sales Manager for the company. Later, he founded Battle Green Publications, serving as Publisher. He has worked for *Microwave Journal* for the past 14 years, first as Regional Sales Manager, then National Sales Manager and, most recently, as Associate Publisher. He is well experienced in publication management. I expect that the transition will be seamless and that Carl will maintain the tradition of excellence, which is the hallmark of *Microwave Journal.*

The past 12 years have been very exciting ones for our industry and for *Microwave Journal.* We started the '90s with a severe slump in the industry as the military market that had been our mainstay, dried up. Both the *Journal* and the industry shifted gears to commercial markets, which resulted in the largest growth and prosperity that we have ever seen. Now, once again, the markets have slowed and adjustments need to be made. I have been through more of these cycles than I care to remember since starting as a microwave engineer in 1957. However, we have always recovered with growth and I expect that we will again. Right now, as overextended companies are cutting back, new microwave companies are being formed at a rapid rate. The entrepreneurial spirit is alive and well.



▲ Carl Sheffres

I expect to continue to see many of you at meetings and shows in the years ahead. Howard is still going strong as MTT-S Exhibition Manager 12 years after he stepped down as Publisher. I hope the same will be said of me. ■

HARLAN HOWE, JR.
Microwave Journal *staff*

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TECHNICAL FEATURE

SPECIFICATIONS AND DEFINITIONS FOR QUADRATURE DEMODULATORS AND RECEIVER DESIGN MEASUREMENTS

This article discusses the common and questionable definitions of the specifications for quadrature demodulators, including gain, intercept point and noise figure. Emphasis is on the mapping between single-tone measurement data and the modulated signal specifications for the receiver design. Problems such as the intercept point with post device filtering and the measurement aspect of the IQ signal, noise splitting and combination are discussed in detail. The definitions and reasoning have been clarified to provide correct receiver system analysis and design.

The quadrature demodulator is used in either heterodyne or homodyne receivers. In commercial communication receivers, the local oscillator frequency ranges from a few kilohertz to a few gigahertz. It is usual to test the individual part with a single tone to avoid the complexity of the baseband waveform. The local oscillator could be non-coherent when the measurement is performed. This approach simplifies the tests to normal RF and IF measurements. However, the measured results should be applicable to signals occurring in normal receiver operation — the modulated passband signal and the demodulated baseband signal. In this signal processing issue, using the measured results without considering their accurate definitions would lead to errors. The correct approach is to go from baseband and passband signal processing concepts to simple RF and IF measurement approaches, which will correlate correctly the performance of the demodulator for real world signals.

Fig. 1 A typical quadrature demodulator and measurement set-up.

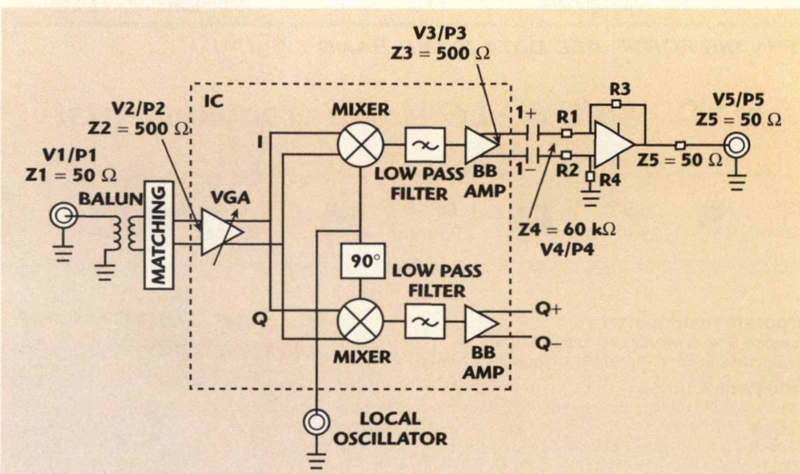

Figure 1 shows the block diagram of a typical quadrature demodulator. It consists of a

[Continued on page 24]

PING YIN
RF Micro Devices Inc.
Greensboro, NC

variable gain amplifier (VGA), mixers and baseband filters. To provide a receiver design with the demodulator performance, or to set the required demodulator specifications based on the required receiver performance, the specifications need to be made and a measurement method should be proposed. The dash line refers to the IC boundary. A number of external components are used for the test.

RECEIVER DESIGN

In receiver design, the final bit error rate (BER) requirement determines the symbol carrier to interference ratio (C/I) at the demodulator output. For simplicity, it is assumed that I is uncorrelated or Gaussian and white. An example of this can be seen in the third generation WCDMA cellular system. For a BER = 10^{-3}, the required E_b/N_o is 6.8 dB for a QPSK signal.[1] There is 21 dB (spreading factor 128) dispreading processing gain. The convolutional coding gain is assumed to be 4.5 dB for simplicity. The ratio of data channel power to the total received power is –10.3 dB. Therefore, the required bit C/I is 6.8 – 21 – 4.5 + 10.3 = –8.4 dB. Please note that this is the C/I for the bit. The sensitivity required is –106.7 dBm at the symbol power.[1] The QPSK symbol contains two bits and when this sensitivity input level is used, the demodulator output symbol C/I that is required to achieve the BER is also –8.4 dB. The receiver chain from the antenna port to the demodulator I and Q ports is calculated for its signal level, noise level and distortion (intermodulation products) level. There are two ways to define the individual demodulator specifications, either before or after the recombination.

The receiver requirement is calculated for modulated passband and baseband signals, but the measurement is performed with a single tone. The intent of the following discussion is to identify the correlation between modulated and single-tone signals.

MEASUREMENT SET-UP

This section discusses the single-tone measurement. In subsequent sections the single-tone measurement results on the actual receiver will be compared with the modulated signal ones.

The IC demodulator circuits usually begin with a differential pair of transistors as input and usually end with a differential pair of transistors as outputs for both I and Q channels, in the form of closed emitters or collectors. When the IC is used in a receiver, the input needs to be conjugate-matched, due to the noise figure cascade properties.

$$NF = 1 + \frac{NF_1 - 1}{\alpha_{s1}} + \frac{NF_2 - 1}{\alpha_{s1}\alpha_{12}G_1} + \ldots + \frac{NF_n - 1}{\alpha_{s1}\prod_{i=1}^{n-1}\alpha_{i,i+1}G_1} \qquad (1)$$

where

$$\alpha_{ij} = \frac{4\left|Z_i\text{out}\ Z_j^{*}\text{in}\right|}{\left(Z_i\text{out} + Z_j\text{in}\right)^2}, \qquad 0 \le \alpha \le 1$$

Equation 1 is the well-known noise figure cascade formula, which shows that, at the relatively early stages, the mismatch coefficient α will degrade the cascaded noise figure. A simple derivation of this equation is provided in ***Appendix A***. The IC input RF impedance is usually a few kilohms for the differential pair. To reduce the Q of the matching circuit and to have better linearity, a parallel resistor of a few hundred ohms is added. In the receiver chain, the matching occurs between the output of the previous stage (usually filter or mixer) and the IC input impedance with a parallel resistor. For measurement, it is matched to a 50 Ω single-ended terminal. The conjugate matching implies that the power at the IC input is equal to the power at the 50 Ω test input port, whereas the voltage has been transformed between these two reference planes.

On the other hand, when the IC is used in the receiver, its output needs to be severely mismatched to save current for the larger signal and to reduce the absolute noise level in order to increase the signal-to-noise ratio. However, according to Equation 1, with the high gain product of the previous stages, the noise figure contribution of that stage is relatively small

[Continued on page 26]

even with very small mismatch coefficients. This is why the receiver cascade noise figure and sensitivity calculation is usually only done for the parts before the mismatch begins. The excess noise of mixed-signal circuits and the digital signal processing circuits following the demodulator is usually low enough to be neglected in the process of cacading noise figures. For a certain input S_i/N_i at the receiver antenna port, the input noise from the transmitter is usually required to be much lower (at least 10 dB) than the thermal noise level (–174 dBm/Hz) when the input signal level is approaching the sensitivity limit. For a certain NF of the receiver, the output S_0/N_0 at the demodulator IQ ports is equal to $(S_i/N_i) \bullet (1/NF)$, where at worst case the S_i is at sensitivity level and the N_i is at –174 dBm/Hz • BW (bandwidth). The output S_0/N_0 should meet the required symbol C/I.

The IC output RF impedance is typically a few hundred ohms, and the load has a high impedance of a few tens of kilohms. The voltage gain (G_v) of the IC demodulator is specified by the IC manufacturer for certain load conditions. However, a more useful specification for the receiver system analysis is the demodulator power gain for a matched load. There are two reasons for this. First, in the receiver system analysis, it is easy to assume a matched case for each stage when performing power gain, noise and intermodulation distortion (IMD) products cascades. To obtain a mismatched load, use the matched power gain of the demodulator and multiply it by a mismatch coefficient.

Second, it is not necessary to redo the measurement when different loads are used. If the output RF impedance of the demodulator is known, simply apply a different mismatch coefficient to calculate the voltage and power delivered to a different load.

For measurement purposes, the input and output impedances of the demodulator are shown together with the impedance transformation at the demodulator's input and output. The external op-amp is used to simulate the load and transform the high impedance to 50 Ω so the measurement can be made with a spectrum analyzer. The five impedance designators at five reference planes are also used for the rms voltage levels, except for V_3, where a mismatch occurs, referring to the rms voltage when it is matched. In the following, unless otherwise specified, the impedances will always be differential and the voltages will always be the rms values.

The op-amp is designed to have unity gain because it is set to have $R_3/R_1 = R_4/R_2 = 2$. The op-amp gain is 2. The post op-amp R_5 is 50 Ω to divide the voltage by 2 at the test load Z_5. Therefore, $V_5 = V_4$. The op-amp performs an impedance transformation and simplifies the test for the spectrum analyzer.

The single-tone measurement is done the simple and usual way. The set-up can also be used to test the baseband signal waveform when the RF/IF signal is modulated. In some cases, the op-amp's balun function, frequency response and noise may need to be calibrated.

Both the input and output impedances of the IC demodulator are 500 Ω. Remember that when the output impedance is known, the load setting could be slightly different from the setting in the actual receiver. Set $Z_4 = R_1 + R_3 = R_2 + R_4 = 60$ kΩ.

For simplicity, the following derivations assume that all impedances are resistive. Suppose the measured power gain $G_p = P_5/P_1 = 95$ dB, which is referred to as raw gain. The IC voltage and matched power gain are easily obtained. The voltage gain of the IC demodulator is

$$Gv = \frac{V_4}{V_2} = \frac{V_5}{V_2} = \frac{\sqrt{P_5 Z_5}}{\sqrt{P_2 Z_2}} = \sqrt{\frac{P_5}{P_1}}\sqrt{\frac{Z_5}{Z_2}} = \sqrt{G_{pmeasured}}\sqrt{\frac{Z_5}{Z_2}} \quad (2)$$

$$20\log G_v = 10\log G_{pmeasured} + 10\log\left(\frac{Z_5}{Z_2}\right) = 95 + 10\log\left(\frac{50}{500}\right) = 95 - 10 = 85\,\text{dB} \quad (3)$$

The power gain from the input of the IC to the dummy load, which is also the input of the op-amp, is

[Continued on page 28]

Dual and Single Branch Downconverters

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Model Number	Conv Gain	IIP3 (dBm)	Input P1dB	Noise Figure(dB)	RF Frequency (MHz)	IF Frequency (MHz)
Dual Branch Converters						
CV210-1	10 dB	+26 dBm	+11 dBm	11.5 dB	806-915	70-120
CV211-1	10 dB	+27 dBm	+11 dBm	11.5 dB	1710-1910	70-250
CV211-2	10 dB	+27 dBm	+11 dBm	11.5 dB	1900-2200	150-300
CV211-3	10 dB	+27 dBm	+11 dBm	11.5 dB	1900-2200	65-200
Single Branch Converters		OIP3(dBm)	Output P1dB			
CV110-1	24 dB	+33 dBm	+18 dBm	5.5 dB	806-915	70-120
CV111-1	23 dB	+33 dBm	+18 dBm	5.5 dB	1710-1910	70-250
CV111-2	22 dB	+33 dBm	+18 dBm	5.5 dB	1900-2200	150-300
CV111-3	22 dB	+33 dBm	+18 dBm	5.5 dB	1900-2200	65-200

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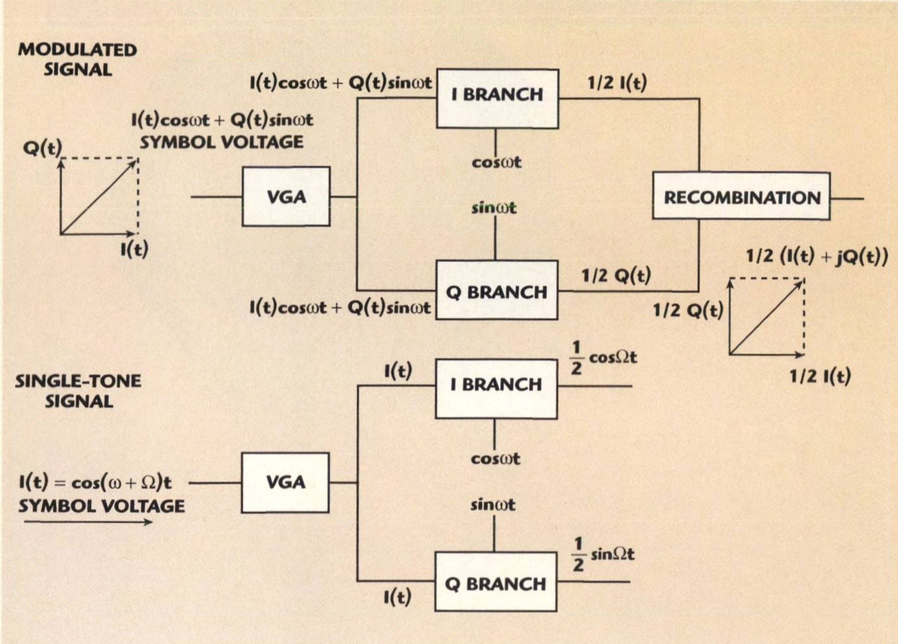


▲ *Fig. 2 Signal representation diagram.*

$$G'_p = \frac{P_4}{P_2} = \frac{P_4}{P_1} = \frac{\frac{V_4^2}{Z_4}}{P_1} = \frac{\frac{V_5^2}{Z_5}}{P_1}\frac{Z_5}{Z_4} = G_{pmeasured}\frac{Z_5}{Z_4} \quad (4)$$

$$10\log G'_p = 10\log G_{pmeasured} + 10\log\left(\frac{50}{60000}\right) = 95 - 30.8 = 64.2\,\text{dB} \quad (5)$$

This mismatch coefficient is

$$10\log\alpha = 10\log\frac{4Z_3Z_4}{(Z_3+Z_4)^2} = 10\log\frac{4\bullet 500\bullet 60000}{(500+60000)^2} = -14.8\,\text{dB} \quad (6)$$

The matched power gain of the IC demodulator is

$$Gp = \frac{G'_p}{\alpha} \quad (7)$$

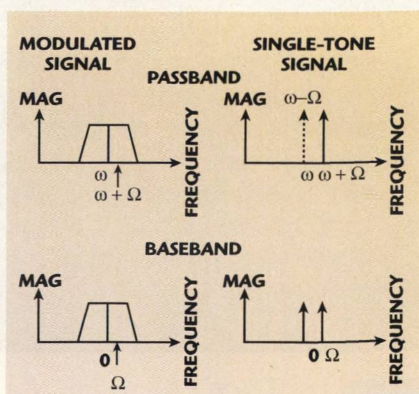
$$10\log G_p = 10\log G'_p - 10\log\alpha = 64.2 + 14.8 = 79\,\text{dB} \quad (8)$$

This number, after the adjustment for the modulated signal, which is explained later, will be used in the receiver chain analysis for the signal, noise and IMD power.

MODULATED SIGNAL GAIN

The modulated signal gain is of interest in receiver design. This section features the mapping between the modulated signal gain and the single-tone measurement. ***Figures* 2** and **3** show the signal representations in the time and frequency domains for the modulated signal and the single-tone signal.

The quadrature demodulator can be used for many different modulation signals. The mapping between the modulation signal and the single-tone measurement is modulation-



▲ *Fig. 3 Spectrum representation.*

[Continued on page 30]


FULL
Wednesday, 1:20 p.m.
Reeling in the big one.

type dependent. The following discussion will focus on and use the QPSK modulation as an example. For this discussion, the analytic form is specifically for QPSK.

To simplify the analysis, it is assumed that the local oscillator is coherent. The result should not lose generality because, in the non-coherent case, although the instantaneous phase has been shifted, the overall integral for the average power is the same as in the coherent case. The signal voltage mapping or the power between modulated signal and single-tone signal is in a continuous time period, which is the average signal voltage or power.

As can be seen, the single-tone signal is at a certain offset Ω from carrier frequency ω. Normalizing the demodulator gain to unity, the single-tone demodulated signal at the I branch after low pass filtering is:

$$\cos(\omega+\Omega)t \bullet \cos\omega t = \frac{1}{2}\cos\Omega t \quad (9)$$

The voltage gain is 1/2 and the power gain is 1/4. The demodulated modulated signal at the I branch after low-pass filtering is

$$\left(I(t)\cos\omega t + Q(t)\sin\omega t\right)\cos\omega t = \frac{1}{2}I(t) \quad (10)$$

where

$$I(t)\cos\omega t + Q(t)\sin\omega t = \sqrt{I(t)^2 + Q(t)^2} \bullet \cos\left(\omega t + \arctan\frac{Q(t)}{I(t)}\right) = A(t)\cos(\omega t + \phi) \quad (11)$$

If the modulation is QPSK with

$$\phi = \frac{\pi}{4}, I(t) = \frac{1}{\sqrt{2}}A(t)$$

The voltage gain is then $1/\sqrt{8}$ and the power gain is 1/8.

Compared to the measured single-tone power gain for the I or Q branch, the actual modulated signal power gain is 3 dB less. The recombination of I and Q QPSK signals will provide 3 dB more power as illustrated in the signal representation diagram. Therefore, the G_p measured by the single tone is equal to the modulated signal power gain after recombination. In many cases, a certain voltage range is required for V_4, which could be the input buffer of an analog-to-digital converter (ADC), making G_p – 3 dB the power gain to be used for the calculation.

QUADRATURE MODULATED SIGNAL

In the spectrum domain, it is obvious that the modulated signal spectrum is symmetric and the single-tone spectrum is asymmetric. Imagine that the modulated signal spectrum consists of multiple tones (the Fourier expansion), or downgrade the modulating baseband signal to a single tone. It is easy to add another tone, at ω – Ω, to the existing single tone, at ω + Ω, as shown by the dashed line in the spectrum representation.

The double tone demodulated signal is then

$$(\cos(\omega+\Omega)t + \cos(\omega-\Omega))\cos\omega t = \cos\Omega t \quad (12)$$

The voltage gain is 1/2, again the same as the single-tone case. Try shifting the tone phase by 90°, it becomes

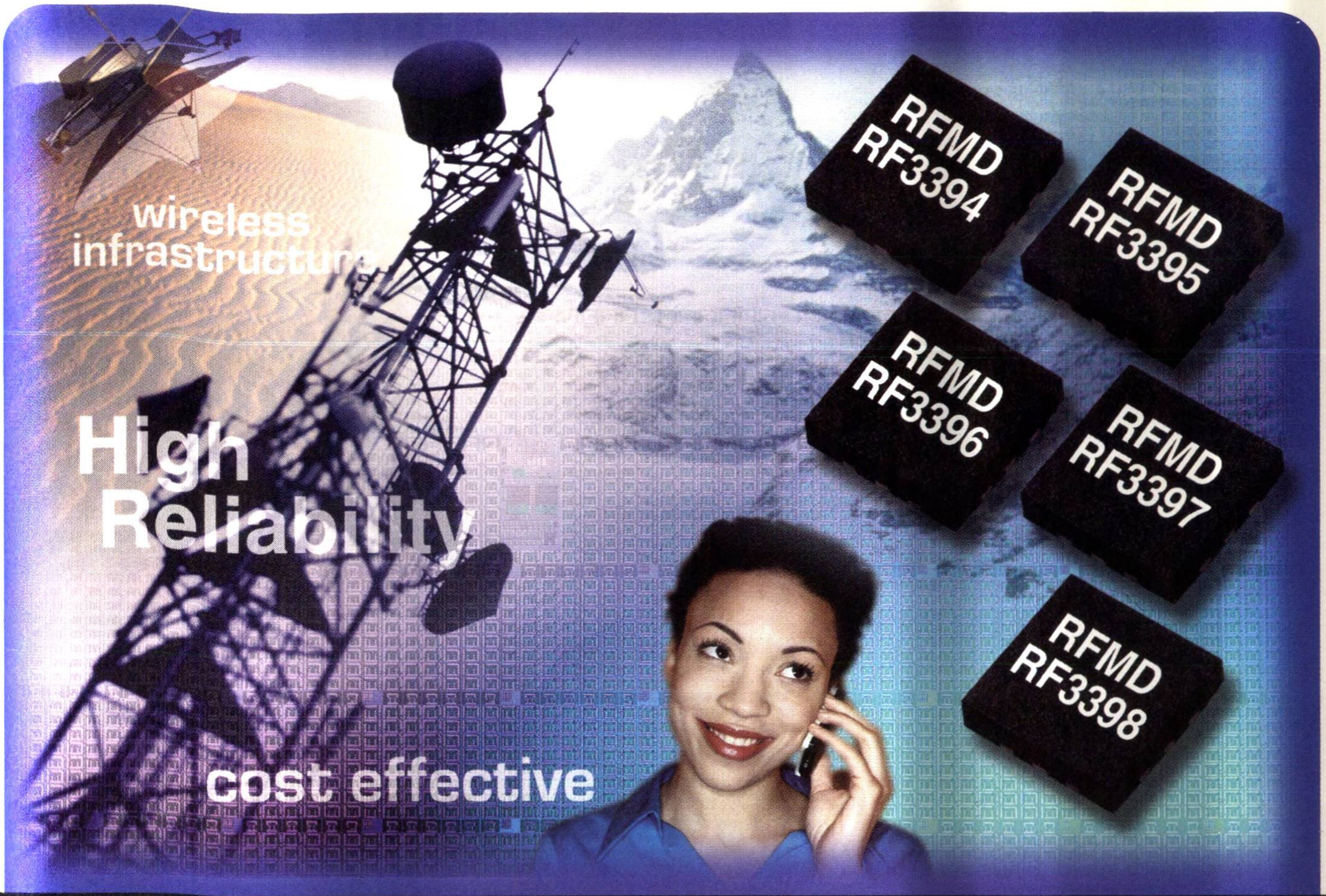
$$\left(\cos(\omega+\Omega)t - \sin(\omega-\Omega)t\right)\cos\omega t = \left(\frac{1}{2}\right)\cos\Omega t + \left(\frac{1}{2}\right)\sin(2\omega-\Omega)t + \left(\frac{1}{2}\right)\sin(\Omega t) = \frac{1}{2\sqrt{2}}\cos\left(\Omega t + \frac{\pi}{4}\right) \quad (13)$$

which is the same as the modulated signal. So far, the mapping between the single tone and modulated signal is clarified for the quadrature nature of the signals.

NOISE

The receiver design example must contain the noise figure of the demodulator for the system C/I after IQ recombination. It is easy to measure the output noise power density $N_{0measured}$ at either the I or Q output of the set-up and to calculate the

[Continued on page 32]



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Output VSWR	1.2: 1	1.5: 1	1.8: 1	1.5: 1	1.5: 1
P1dB Output Power (dBm)	18	14.5	12.2	13.2	12.9
Noise Figure (dB)	4	5	3.8	4.2	5.3
Output IP3 (dBm)	32.0	28.0	24.5	27.5	26.2
Device Volt@Nom Icc (V)	4.6	5	3.5	3.6	3.6
Nominal Current (mA)	65	65	35	40	40

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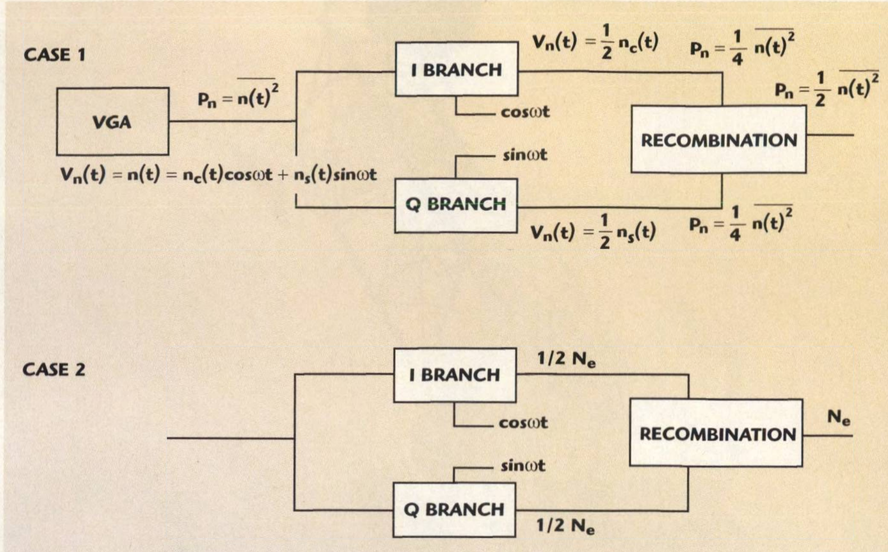


▲ *Fig. 4 Two demodulator architectures in noise analysis.*

noise figure using

$$NF_{measured} = \frac{\overline{N_{0measured}}}{\overline{N_i}G_p} \quad (14\text{-}1)$$

where

$\overline{N_i} = KT = -174$ dBm/Hz

$$NF_{measured} = N_{0measured} + 174 - Gp\ (dB) \quad (14\text{-}2)$$

This section discusses how to map $NF_{measured}$ to the actual noise figure of the demodulator.

Figure 4 shows two different cases for the demodulator and its noise. Case 1 has a VGA in the front, whereas case 2 does not have a noise source before the signal splits. For both cases, the output noise power after IQ recombination is

$$N_0 = N_i G_p^M + (NF - 1)KTBG_p^M \quad (15)$$

where

N_i = input noise power
G_p^M = modulated signal gain

The first part of Equation 15 is not related to the noise figure of the demodulator. The noise figure is defined as

$$NF = \frac{\dfrac{S_i}{N_i}}{\dfrac{S_o}{N_o}} \quad (16)$$

where N_i must be KTB. It is the measure of the additional noise that is generated by the device in the form of a ratio to the thermal noise level. The point of interest in this is the demodulator noise figure. In Equation 16, if the demodulator is treated as a black box and since the gain of the device is known from a previous discussion, the only unknown is the output noise, which is mainly the excess noise of the device.

There are two stage noise contributions in case 1. Recall Equation 1 and simplify the problem by assuming that one stage is dominant in the demodulator output noise. When the noise after the VGA is dominating, case 1 is the same as case 2. Therefore, it is assumed that the VGA is dominating in the case 1 discussion before case 2 is discussed. For case 1, the passband noise voltage at the VGA output is

$$n(t) = n_c \cos\omega t + n_s \sin\omega t \quad (17)$$

where

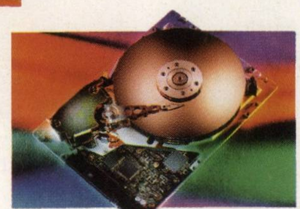
n_c and n_s = bandlimited baseband noise projections

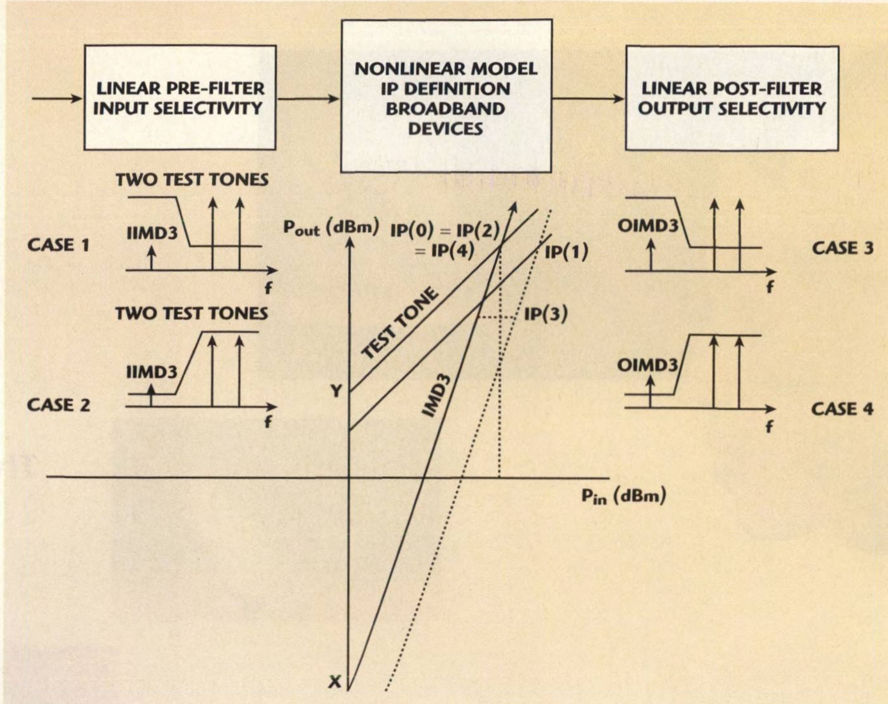
The power of the random noise signal is the mean square value, which is[2]

$$\overline{n^2(t)} = \overline{n_c^2(t)} = \overline{n_s^2(t)} \quad (18)$$

Voltage signal recombination is impossible because the noise is a random signal. The IQ power recombination of the noise and the power gain is 1/2. The noise flow is the same for both modulated signal analysis and single-tone measurement. Compared to the single-tone measurement, the noise level after recombination is doubled. Hence, the demodulator noise figure in case 1,

[Continued on page 34]

▲ *Fig. 5 Intercept point issue with post device filtering.*

compared to Equation 14-1, is

$$NF = \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_o}} = \frac{\overline{N_{0measured}}}{N_i G_p^M} = \frac{2\overline{N_{0measured}}}{N_i G_p} = 2NF_{measured} \quad (19\text{-}1)$$

or

$$NF = NF_{measured} + 3\ dB \quad (19\text{-}2)$$

This number is used in the receiver C/I calculation. So far, the uncorrelated noise and the quadrature signal are combined similarly since the uncorrelated power addition and the quadrature signal addition are both orthogonal additions. However, for the random signal, the passband signal and the noise split in a different way. A possible error is the noise in Equation 17, which is considered a vector like the deterministic signal. There is a correlated recombination, which will lead to the wrong power gain conclusion of 1/8, as shown in Equations 10 and 11.

In contrast to case 1, where the excess noise of the second stage is neglected, the noise in case 2 is mainly contributed by the excess noise N_e of the second stage. The noise components in the I and Q branches are uncorrelated, making the result identical to case 1 with the same Equations 19-1 and 19-2.

INTERCEPT POINT

The quadrature demodulator usually has a filter following the broadband devices such as the mixer and amplifier. Care must be exercised in the measurement plan and use of the measured data for an intercept point measurement performed within the filter attenuation frequencies. The example of a WCDMA demodulator follows.

The WCDMA standard sets a two-tone test for third-order intermodulation at 10 and 20 MHz offsets from the carrier. The demodulator has two tones at 10 MHz and 19 MHz so that one of the output third-order intermodulation distortion (OIMD3) is at 2 • 10–19 = 1 MHz. Using the equation for the input third-order intercept point (IIP3)

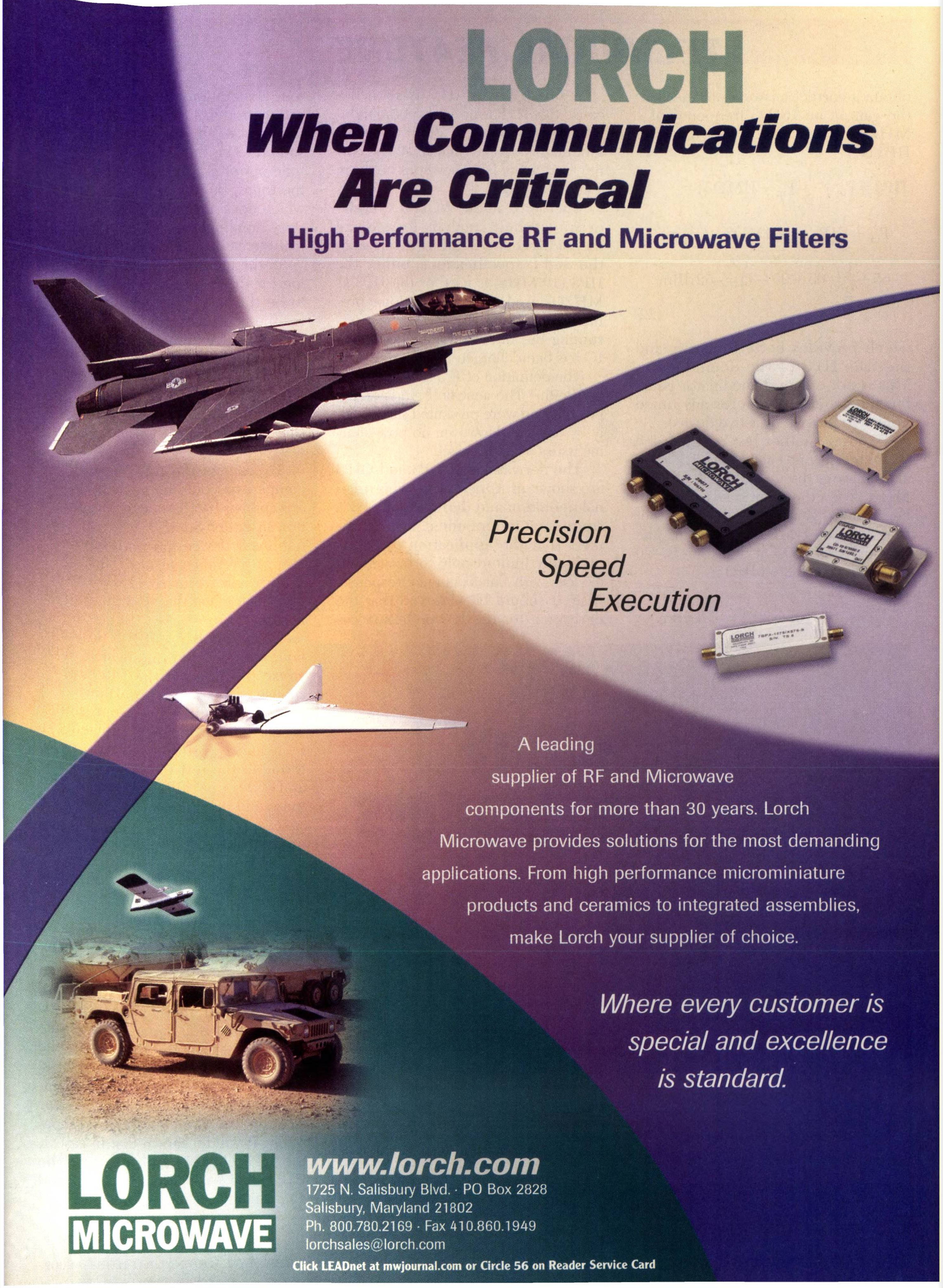
$$IIP3 = P_{in} + \frac{1}{2}\left(P_{out} - OIMD3\right)(dB) \quad (20)$$

with data measured by the setup, P_{in} = –65 dBm, P_{out} = –6 dBm and OIMD3 = 4 dBm, the IIP3 is

$$IIP3 = -65 + \frac{1}{2}\left(-6 - 4\right) = -70\,dBm \quad (21)$$

A wrong answer is obtained since the measured Pout is filtered. This IC has post demodulator low pass filtering. ***Figure 5*** shows the diagram illustrating this issue. The approach to

[Continued on page 36]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obtain a correct answer is to measure the gain at an IMD3 frequency of 1 MHz for G(1 MHz) = 95 dB. The IIP3 is

$$IIP3 = P_{in} + \frac{1}{2}\left(P_{in} - IIMD3\right) =$$

$$P_{in} + \frac{1}{2}\left(P_{in} - \left(OIMD3 - G\right)\right) =$$

$$-65 + \frac{1}{2}\left(-65 + 95 - 4\right) = -52\,dBm \tag{22}$$

which provides better linearity and the true IIP3 of the demodulator. This is not only a demodulator issue, but a general problem for any tuned nonlinear passive or active device.

Perform another test on the same IC with test tones at 1.0 and 1.1 MHz and measure the OIMD3 at 0.9 or 1.2 MHz. When the input is –85 dBm and because the gain is 95 dB, the output tone level at 1 MHz is 10 dBm. The measured OIMD3 at that time is –20 dBm. The calculated IIP3 is

$$IIP3 = -85 + 1/2(10-(-20)) = -70\ dBm$$

A much lower IIP3 is seen because this IC has not only post-modulator low pass filtering but also pre-modulator low pass filtering. The corner frequency is somewhere between 1 and 19 MHz.

Therefore, in the WCDMA receiver spreadsheet analysis for passing the 10 MHz and 20 MHz two tests in the 3GPP specifications, either the IIP3 (10 MHz) is used or the IIP3 (1 MHz) is used with the additional pre-filtering stage in the spreadsheet, assuming the filter response inside the IC has been characterized carefully.

The definition of IP3 is well derived by Smith.[3] The analytical graphics and pre-filtering were presented successfully by Sagers.[4] However, no post-filtering issues were discussed.

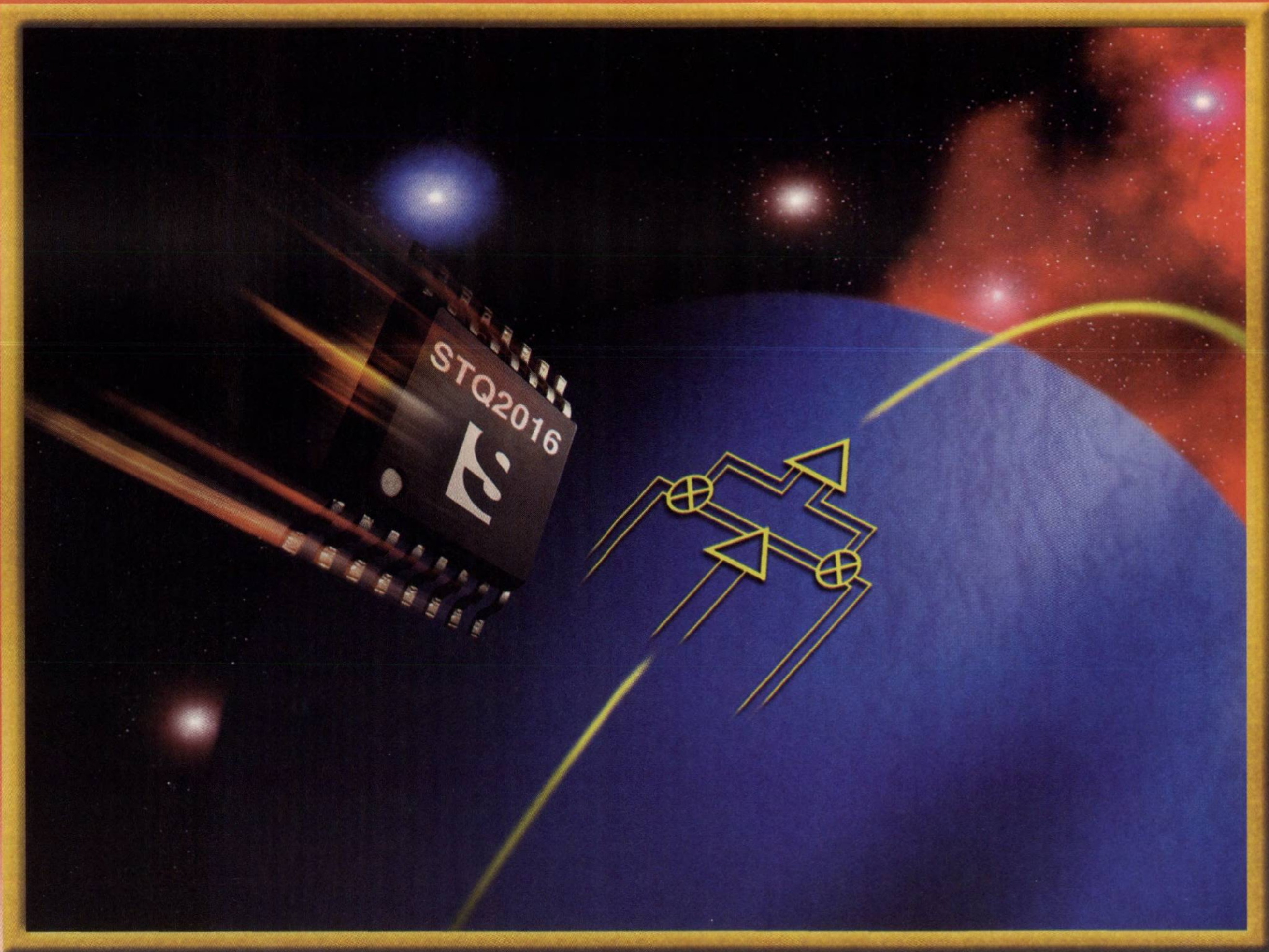
The derivations of IIP3 and OIP3 are shown in ***Appendix B***. This original definition and derivation of IP3 is frequency independent, which implies that the application of IP3 is originally limited only to broadband devices with flat frequency response. Also, it should be observed that the derivation for the IP3 definition has four assumptions: among many third-order products, only one is studied; the level of the two test tones is assumed to be the same; the input test tone power P_{in} is the power of one of the tones; the two tones are in phase which does not mean much in a one-stage nonlinear analysis, but will affect the cascade of nonlinearities.

In the following analysis, the filtering for the two test tones is assumed to be the same. In reality, the filters for the two tones are most likely different and weighting the two test tones should be used, just like in the case where the two input test tones have different power levels. The result with the filtering effect should be the same for both with or without weighting.

To analyze the filtering effect, a comparison could be made by adding a response coefficient to the derivation in either Smith[3] or Sagers.[4] The nonlinear device has both input and output reference planes. The rule of thumb is to refer the IMD3 to the reference plane that is away from the filtering.

Equations B-7 and B-8 no longer hold with any filtering, which might cause problems if the filtering response of the device is unknown. The presence of filtering is represented by the filter response coefficients f_1, f_2, f_3 and f_4, referring to the pre-filtering at the test tones, pre-filtering at IIMD, post-filtering at the test tones and post-filtering at OIMD, respectively, corresponding to the case numbers. The coefficients are normalized, meaning f = 1 for the passband and 0 < f < 1 for the transition and stopband. Remember that the nonlinear effects happen in broadband nonlinear devices only. The filter here is linear. From a signal processing point of view, only nonlinear or time variant linear systems will cause extra frequency components. The filtering is assumed to be a time invariant system. In other words, the operation is linear. Therefore, the IMD products are created in the center block only in the cascade. Four different cases will be discussed separately. It will be shown that in case 1, the IIP3 changes and in case 3 the OIP3 changes, whereas in cases 2 and 4 no change occurs.

[Continued on page 38]



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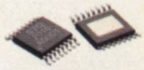

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STQ-2016*	700–2500	+3	-40	40	65	-155	-5	±0.5	±0.05
STQ-3016†	2500–4000	+1	-40	33	50	-153	-6	±2.5	±0.10

*f_{LO} = 2,000 MHz; †f_{LO} = 3,500 MHz

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Case 1: Pre-filtering Test Tones

The input signal to the nonlinear device is

$$x'(t) = Af_1(\cos\omega_1 t + \cos\omega_2 t) \quad (23)$$

Equation B-3 then becomes

$$IMR = OIMR = \frac{OIMD3}{P_0} =$$

$$\left(\frac{3}{4}\right)^2 \frac{k_3^2}{k_1^2}(f_1 A)^4 = \left(\frac{3}{4}\right)^2 \frac{k_3^2}{k_1^2} f_1^4 P_i^2$$

$$= \left(\frac{P_i}{\dfrac{1}{f_1^2}\dfrac{4k_1}{3k_3}}\right)^2 \quad (24)$$

which means that the IIP3 is increased by $1/f_1^2$. The X and Y points refer to the offset of the first- and third-order lines when $P_{in} = 1 = 0$ dBm. The third-order product power is

$$10\log\left(\frac{3}{4}k_3(f_1 A)^3\right)^2 =$$

$$10\log\left(\frac{3}{4}k_3 f_1^3\right)^2 + 30\log A^2 \quad (25)$$

Therefore,

$$X = 10\log\left(\frac{3}{4}k_3\right)^2 + 10\log f_1^6 \quad (26)$$

In the presence of f_1, the point X is shifted down causing the IMD3 line to shift to the right. Also, the first-order output is decreased, the point Y is shifted down and the first order line is shifted down. The device with pre-filtering, to be treated as one device, has its linearity limit in the later stage so that the OIP3 remains the same and the input IIP3 increases. By adding the filter coefficients to the input tones (pre-filtering), the intercept point moves from IP(0) to IP(1) by shifting along the dash lines. The OIP3 does not change but the IIP3 increases.

Case 3: Post-filtering Test Tones

The post-filtering devices are treated as one device and have their linearity limits in the early stage so that the input IP remains the same and the output IP decreases. When f_3 is applied to the output of the test tone in the expansion of Equation B-2, the power output is given by $P_0 = (f_3 k_1 A)^2$. Substituting it into Equation B-3 will result in a wrong definition of IP3 and confuse the problem. The problem can be corrected by knowing and using the filter response. However, it is not suggested because it changes the original definition of IP3 and causes trouble in the receiver IP cascade analysis. From Equation B-8, the input IMR can be used because the IMD3 is not filtered. This is "to refer the IMD products to the reference plane away from filtering."

By deriving the IIMR the same way as Equation B-3, it is easy to prove that the IIP3 stays the same but the OIP3 is decreased by $1/f_3^2$. This is why Equation 20 cannot be used and Equation 22 should be used instead. The post-filtering simply shifts the IP(0) down to IP(3). Using the method "referring the IMD products to the reference plane away from filtering," it is easy to see that cases 2 and 4 have some changes in IIMD3 and OIMD3, but no changes in either IIP3 or OIP3. After all, in a receiver or demodulator, the pre-filtering and post-filtering always exist. Weighting the blocker tone and its filtering are necessary. Because the OIP3 can be calculated from IIP3 with the gain and filtering, the IIP3 can be used as the original parameter. From that point of view, case 1 is the only case that affects the IP3. The IIP3 equation in that case will be

If IMD3 frequency =
2 • first tone frequency
– second tone frequency

IIP3 nonlinear_stage =

$$P_{in} + \frac{1}{2}\Delta = P_{in} - \frac{1}{2}OIMR =$$

$$P_{in} + \frac{1}{2}P_{in} + \frac{1}{2}G - \frac{1}{2}OIMD3 =$$

$$\frac{3}{2}P_{in} + \frac{1}{2}G - \frac{1}{2}OIMD3 =$$

$$\frac{3}{2}\left(\frac{2}{3}P_{in\_first\_tone} + \frac{1}{3}P_{in\_second\_tone}\right)$$

$$+\frac{1}{2}G - \frac{1}{2}OIMD3 =$$

[Continued on page 40]

$$P_{in\_first\_tone} + \frac{1}{2} P_{in\_second\_tone} + \frac{1}{2} G - \frac{1}{2} OIMD3$$

$$\text{IIP3 effective} = \text{IIP3 nonlinear\_stage (no filtering)} + \text{Rejection at first test tone} + \frac{1}{2} \bullet \text{Rejection at second test tone}$$

CONCLUSION

The many "gains," noise figures and IP issues of the demodulator have been discussed to help correct the design of the receiver. Understanding the problems discussed is essential to prevent design and measurement mistakes. ■

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4. R.C. Sagers, "Intercept Point and Undesired Responses," 32nd IEEE Vehicular Technology Conference, May 23-25, 1982, pp. 35–55.

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APPENDIX A

DERIVATION OF CASCADE NOISE FIGURE WITH MISMATCH

This mismatch coefficient is defined as

$$\alpha_{ij} = \frac{\text{transmitted\_power}}{\text{input\_available\_power}} = 1 - |\Gamma|^2 = \frac{4\left|Z_{iout} Z_{jin}^{*}\right|}{\left(Z_{iout} + Z_{jin}\right)^2}$$

where

i and j = numbers of successive stages

Therefore, transmitted_power = α_{ij} • input_available_power.

Consider a two-stage cascade plus an input source stage. The first stage input signal and noise powers are $\alpha_{s1}S_i$ and $\alpha_{s1}N_i$, where S_i and N_i are the available signal and noise power from the source. The signal and noise powers into the second stage are $\alpha_{s1}\alpha_{12}G_1S_i$ and $\alpha_{s1}\alpha_{12}G_1N_i + \alpha_{12}Na_1$, where Na is the excess noise of the stage. The signal and noise powers to the load (stage 3) are $\alpha_{s1}\alpha_{12}\alpha_{23}G_1G_2S_i$ and $\alpha_{s1}\alpha_{12}\alpha_{23}G_1G_2N_i + \alpha_{12}\alpha_{23}G_2Na_1 + \alpha_{23}Na_2$. The cascade noise figure is

$$NF = \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_o}} = \frac{N_o}{GN_i} = \frac{\alpha_{s1}\alpha_{12}\alpha_{23}G_1G_2N_i + \alpha_{12}\alpha_{23}G_2Na_1 + \alpha_{23}Na_2}{\alpha_{s1}\alpha_{12}\alpha_{23}G_1G_2N_i}$$

$$= 1 + \frac{Na_i}{\alpha_{s1}G_1N_i} + \frac{Na_2}{\alpha_{s1}\alpha_{12}G_1G_2N_i} = 1 + \frac{NF_1 - 1}{\alpha_{s1}} + \frac{NF_2 - 1}{\alpha_{s1}\alpha_{12}G_1}$$

This can be extended to N stages.

[Continued on page 42]

APPENDIX B

DERIVATION OF IIP3 AND OIP3

The input signal with two tones is

$$x(t) = A(\cos\omega_1 t + \cos\omega_2 t) \quad \text{(B-1)}$$

The ouptut of a nonlinear broadband device is

$$y(t) = k_1x(t) + k_2x(t)^2 + k_3x(t)^3 \quad \text{(B-2)}$$

Substitute x(t) in Equation B-2 with Equation B-1 and expand it, and the level of any one of the third-order products is

$$\frac{3}{4}k_3A^3$$

The intermodulation power ratio (IMR) is defined as the ratio of the output third-order intermodulation distortion (OIMD3) to the one output test tone power

IMR = OIMR =

$$\frac{OIMD3}{P_o} = \frac{\left(\frac{3}{4}k_3A^3\right)^2}{(k_1A)^2} = \left(\frac{3}{4}\right)^2\frac{k_3^2}{k_1^2}A^4 = \left(\frac{3}{4}\right)^2\frac{k_3^2}{k_1^2}P_i^2 = \left(\frac{P_i}{\frac{4k_1}{3k_3}}\right)^2 \quad \text{(B-3)}$$

The definition of the input third-order intercept point (IIP3) is

$$IIP3 = \frac{4k_1}{3k_3} \quad \text{(B-4)}$$

The equivalent input third-order intermodulation distortion (IIMD3) is defined as

$$IIMD3 = \frac{OIMD3}{k_1^2} = \frac{OIMD3}{G} \quad \text{(B-5)}$$

and the equivalent output third-order intercept point (OIP3) is

$$OIP3 = IIP3k_1^2 = IIP3G \quad \text{(B-6)}$$

The input IMR (IIMR3) and the output IMR (OIMR3) are then

IIMR =

$$\frac{IIMD3}{P_i} = \frac{OIMD3}{P_o} = \quad \text{(B-7)}$$

$$OIMR = IMR$$

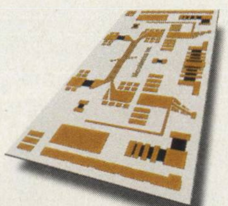
Equation B-4 is extended to

IMR = OIMR = IIMR =

$$\frac{OIMD3}{P_o} = \frac{IIMD3}{P_i} =$$

$$\left(\frac{P_i}{\frac{4k_1}{3k_3}}\right)^2 = \left(\frac{P_i}{IIP3}\right)^2 = \left(\frac{P_o}{OIP3}\right)^2 \quad \text{(B-8)}$$

Fred is thinking thin



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Harris Corp. Selected for Phase 1 of US Army's WIN-T Program

Harris Corp. announced that it anticipates the award of a major subcontract from Lockheed Martin Mission Systems, Gaithersburg, MD, for the design and test of the wireless transmission system architecture as part of the three-year competitive down-select for Phase One of the US Army's Warfighter Information Network-Tactical (WIN-T) program. WIN-T is the next generation of military tactical communications systems, featuring an integrated framework of standards and protocols that will optimize offensive military communications. The production phase of the program, if awarded to the Lockheed Martin team in 2005, could increase the total value of the program for Harris to $1 B over a 15-year period.

Bringing enhanced mobile bandwidth and networking capability to the battlefield, WIN-T will provide modern networking technology to US Army war fighters, enabling battlefield situational awareness on-the-move and giving commanders new capabilities to synchronize combat power. The system will provide a highly secure network backbone for high speed communications for voice, data and video on the battlefield, and ensure interoperability with joint and coalition forces.

During the three-year, competitive, down-select phase of the program, Harris will design the transmission systems architecture for WIN-T, applying the company's proven enabling technologies for wireless, on-the-move communications including phased arrays and SecNet-11™, a revolutionary, Type 1 Secure Wireless Local Area Network (SWLAN) solution. The contract is divided into two phases. Over the 12-month Phase One period, the team will define the architecture for WIN-T, focusing on risk management, technology readiness and coordination with other US Army transformation programs such as Future Combat System. In Phase Two, which runs 23 months, the team will demonstrate modeling and simulation of the WIN-T architecture and develop a prototype system for testing by Army users.

Northrop Grumman and Flarion Promote Scalable Homeland Security Wireless Network

Northrop Grumman Corp.'s Information Technology (IT) sector, a leading provider of advanced IT solutions, engineering and business services for government and commercial customers, and Flarion Technologies, the architect of a mobile broadband network technology for personal computing for data and voice using the industry standard Internet Protocol (IP), announced that the two companies are working together to promote a Homeland Security network communications system based on Flarion's flash-OFDM™ technology (a).

Northrop Grumman IT and Flarion are promoting the network system to government customers wanting the most advanced, secure and flexible broadband network for homeland security and emergency response applications.

The Northrop Grumman IT and Flarion Homeland Security solution provides many significant improvements over existing network solutions, including:

- A packet-switched voice and data airlink technology (flash-OFDM) for nationwide coverage that replicates the wire broadband computing transport experience.
- Flarion RadioRouters™ for wireless coverage and access, deployed at cellular base stations around the country.
- PC cards for personal computing for use with PDA and laptop wireless computing devices.
- Applications access to any standard office and operational system: Operational Database Applications, Customer Specific Applications (IP), Data Mining as well as Instant Messaging.
- Communications support for: "Push to Talk" for mobile voice services and "Always On," fully mobile broadband data access and support for priority access.
- Interoperability with the industry-standard IP network with full support for network and device security (VPN and encryption), Quality of Service (QoS) and seamless handoff to 802.11-based wireless access points.
- Network management tools which allow for Remote Network Management, ad-hoc/Mobile IP Network Design.
- Rapid Deployment Cellular Base Station: Cell-on-light-truck (COLT) is equipped with two base stations and an IP network enables the COLT to offer up to five miles of cellular coverage and access to secure or public networks can be deployed at major disaster scenes to ensure continuous communications capabilities regardless of local carrier problems.

"In our own review for national High Speed Wireless Network for Homeland Security, we determined that a completely new approach would be necessary," said Jim Lindenfelser, Northrop Grumman IT TASC vice president and director, Space and Communications. "Flarion's IP friendly airlink and the business case for flash-OFDM convinced us that the communication network could scale to the demands of a federal network system."

"Along with Northrop Grumman IT, Flarion is pleased to offer help and assistance to the US government with their review of solutions for a secure and spectrum efficient wireless network for voice and data," said Ray Dolan, CEO of Flarion Technologies. "Together, we will demonstrate a highly scalable packet-switched end-to-end network which meets and exceeds the current objectives for a Homeland Security communications system."

Flarion's mobile broadband technology is a packet-switched radio access network, which allows licensed mobile operators to offer customers a seamless, always-on connection to the Internet and private networks, extending the personal computing experience beyond the limits of voice or LAN-based network technologies. The flash-OFDM PC-card modem is plug-and-play compatible with existing IP devices, operating systems and applications and does not require any changes to protocol, settings, devices or content.

Teledyne Wins $22 M Contract from Space and Missile Defense Command

Teledyne Technologies Inc. announced that Teledyne Brown Engineering Inc. has received a five-year, $22 M contract from the US Army's Space and Missile Defense Command, to continue the development of Teledyne's Missile Defense Systems Exerciser (MDSE). The contract contains provisions for five one-year award-term options, which, if exercised, would increase the contract value to $46 M and extend the performance period to ten years. The Missile Defense Agency (MDA) uses MDSE to test tactical hardware and software of a variety of missile defense systems in different locations under realistic battlefield scenarios. For example, controllers in Huntsville, AL, can link MDSE with Patriot and Aegis systems in other locations and then exercise the various software systems. MDSE is the MDA's only accredited tool for assessment of interoperability among its theater missile defense components.

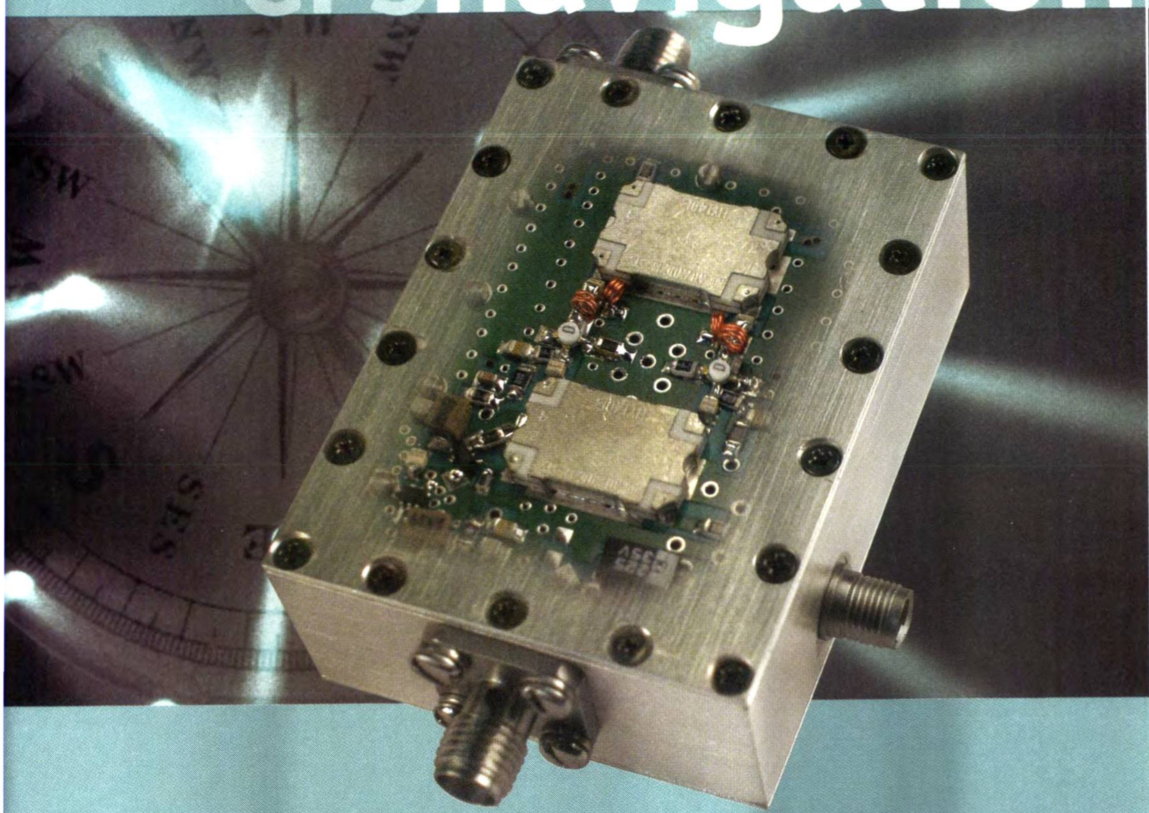
Raytheon Awarded $11.4 M for Light Thermal Weapon Sight Production

Raytheon Co. has been awarded an $11.4 M contract by the US Army's Communications and Electronics Command for the production of the Light Thermal Weapon Sight (LTWS). Deliveries are set to begin in the second quarter of 2003, to be completed within one year. The LTWS is designed and manufactured by Raytheon's Tactical Systems business unit in Dallas, TX.

Additional contract award options in excess of $12 M remain available for future production of the LTWS. Developed by Raytheon and the US Army, the LTWS combines rugged, lightweight construction with Raytheon's advanced thermal imaging technology to give the infantry man the ability to shoot equally well day or night, through battlefield obscurants, adverse weather and zero-illumination situations. Weighing less than three pounds, it features a 2-to-1 electronic zoom, electronically programmable reticles and a liquid crystal display. The LTWS successfully completed the US Army's initial operational testing in December 2001 and is part of proven, fielded weapon sights that include the AN/PAS-13 medium TWS and Heavy TWS configurations. ■

RPV nav
ADSB
cruise missile
ballistic missile

ON TARGET GPSnavigation



cruise missile
surveying
vehicular nav
timebase synch
marine nav
ADSB
telemetry
airborne nav
RPV nav
ballistic missile
airborne nav
surveying
timebase synch

L1/L2 Filtered LNA

The DDX series of Low Noise Amplifiers provides a filtered, low-noise gain solution for GPS applications. A pair of diplexed 3-pole ceramic filters selects only the desired GPS signals while the low-noise gain stage maintains the receiving system's sensitivity. The LNA rejects undesired signals by at least 40dB at 1050, 1410, and 1710 MHz. Plots of return loss, rejection, and insertion gain are available on SEI's website.

The preamplifier is powered by DC voltage applied to the center conductor of the output connector. Optionally, the unit can be powered through an external DC bias connector.

dimensions AND connections

- Antenna Port J1
- Receiver Port J2
- External Bias J3
- 1.50" L x 2.00" W x 0.75" H excluding connectors
- The chassis is machined aluminum with a silver plate finish.

features

- *Low Noise Figure 1.6 dB typical*
- *Double-Diplexed Preamp Filters*
- *Aluminum Housing*
- *SMA type female connectors*
- *Dual Band (L1 and L2) performance*
- *Coaxial and External Bias Options*
- *Environmental Sealing Available*

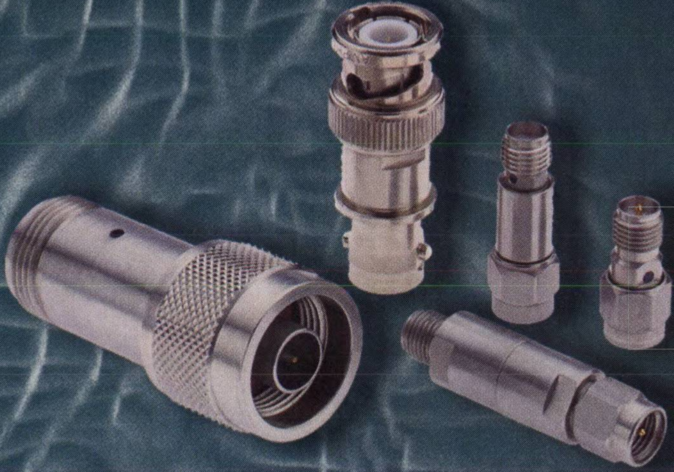
typical specs

All specifications measured at 25°C

Frequency (MHz)	1575.42 (L1) 1227.60 (L2)
Bandwidth (MHz)	30 min.
Noise Figure	2 dB max/1.6 dB typical
VSWR	1.5:1
Gain	14, 26, 34, and 45 dB
Gain Flatness	+/- 0.5 dB
DC Power	5-15V @ 75 mA (max)
Temp Range	-40°C to +71°C

SALISBURY ENGINEERING, INC.
38166 Old Stage Rd.
P.O. Box 480, Delmar, DE 19940-0480
302 846 2750 • fax 302 846 3888
Email: Sales@Salisbury-Engineering.com

800 989 2141
www.salisbury-engineering.com



Martin Streetly, International Correspondent

SEVIRI to Help Nowcasting Meteorology

Successfully launched aboard the European Space Agency/European Meteorological Satellite's (EUMETSAT) Meteosat Second Generation (MSG)-1 satellite on 28 August 2002, the Astrium-sourced Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) payload is set to radically upgrade the accuracy of nowcasting short-term weather forecasting for Europe, Africa and the Atlantic and Indian Oceans. Located at 0° longitude 22,300 miles above the Gulf of Guinea, the SEVIRI instrument is designed to transmit a 12 spectral channel Earth image every 15 minutes. The availability of such imagery is billed as facilitating comprehensive observation of a range of parameters including cloud, land and sea surface temperatures and the composition of particular air masses. Equally, the availability of near real-time imagery is expected to upgrade the accuracy of extreme weather reporting.

Technically, SEVIRI is a combined scan/telescope assembly that weighs 260 kg and incorporates a movable mirror that is positioned in front of its telescope and performs a linear scan of the Earth's surface from north to south. The telescope collects radiation for a focal plane array that divides it into 12 channels of 0.4 to 1.6 μm visible light (four channels including one high resolution) and 3.9 to 13.4 μm IR. The processed data is recorded and passed to a functional control unit that acts as the sensor's interface with the satellite's transmission system. A ground-based, Astrium-sourced image processing facility acts as the link between the space-based sensor and the end user. SEVIRI offers a resolution of 1 km in the visible sector of the spectrum and 3 km in the IR sector and against water vapour. SEVIRI incorporates a total of 42 detectors and has a power consumption requirement of 150 W.

Alongside SEVIRI, the Anglo-European Astrium joint venture is responsible for a range of operational and planned satellite meteorological instrumentation packages that include the Advanced Microwave Sounding Unit (AMSU)-B, the Humidity Sounder for Brazil (HSB), the Advanced Scatterometer (ASCAT), the Microwave Humidity Sounder (MHS) and the Atmospheric Laser Doppler Instrument (ALADIN). Of these, AMSU-B is operational aboard the US's National Oceanographic and Atmospheric Administration's NOAA-M satellite (launched on 24 June 2002) and is used to image cloud cover and precipitation cells together with data gathering on water vapour content in cloud masses. The HSB device is installed aboard the US National Aeronautics and Space Administration's Aqua vehicle and measures the vertical distribution of water vapour in the atmosphere as a means of predicting atmospheric stability.

For its part, ASCAT is a radar instrument that is designed to measure open ocean wind speed and direction together with the distribution of snow and ice on land and sea surfaces. The MHS is intended to establish atmospheric humidity profiles and cloud and precipitation parameters. As currently planned, ASCAT and MHS are to be installed aboard three Metop weather satellites that the ESA plans to have in polar orbit by 2005. The remaining instrument — ALADIN — is planned for use aboard the ESA's Aeolus spacecraft that is scheduled to be in service by 2007. Here, the device will undertake extremely precise wind strength and direction measurements using harmless laser pulses and analysis of laser light reflected by atmospheric cells. Alongside MSG-1, SEVIRI is to be fitted aboard the forthcoming MSG-2 and -3 vehicles.

Austrian and Siberian TETRA Contracts for R & S

German contractor Rohde & Schwarz (R & S) has announced that it has been awarded Terrestrial Trunked Radio (TETRA) system contracts by Russian crude oil supplier SIBNEF and the government of Austria. Taking these in the order given, SIBNEF is to be supplied with a turnkey R & S Bick Mobilfunk Accessnet®-T TETRA mobile radio network to support the security of its trans-Siberian oil pipeline. Commissioned at Nojabr'sk, Siberia during August 2002, the system incorporates TETRA exchanges and base stations that are interconnected by E1 lines and Ethernet connections that use routers supplied by Cisco/ComStore. At the time of going to press, the network was understood to consist of two DMX-521 TETRA exchanges and seven TETRA base stations with over 30 radio-frequency carriers.

In the Austrian context, R & S subsidiary Bick Mobilfunk has been commissioned to supply Austria's new Austrian Digital Operating Network for Integrated Services (ADONIS) which is billed as Europe's largest ever trunked radio system. Valued at €190 million, ADONIS will incorporate in excess of 1200 TETRA transmitters and is compliant with security authority protocols concerning standardised and compatible trunked radio systems that are established as part of the European Union's Schengen open borders agreement.

Korea Selects BAE Systems RWR

South Korea has selected BAE Systems North America's Threat Warning and Defensive Systems business unit (Yonkers, NY) to supply it with 42 AN/ALR-56C(V)1 radar warning receivers (RWR) for use on the country's F-15K combat aircraft. Specifically configured for the F-15K, the ALR-56C(V)1 deal is valued at approximately US$58 M and the equipment is noted as forming part of the platform's integrated Tactical Electronic Warfare Suite (TEWS). Here, the RWR is partnered by BAE Systems' AN/ALE-47 countermeasures dispensing system and the Northrop Grumman AN/ALQ-135 radar jammer. The F-15K is scheduled to make its maiden flight during April 2005, with ALR-56C(V)1 deliveries slated for completion by the end of 2007.

New Start FY2003 FCT Projects Highlight Rest-of-the-World Electronics

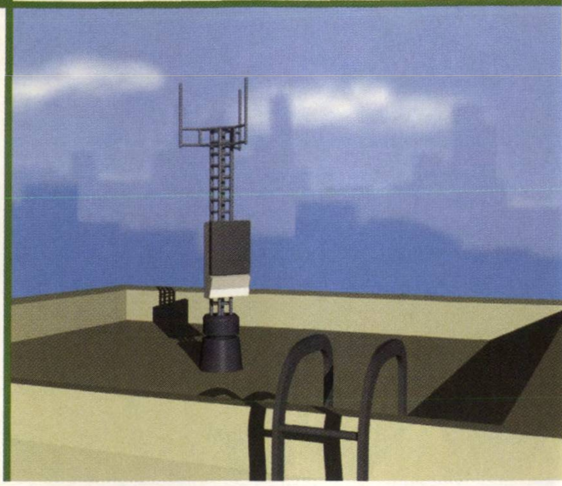
New starts for America's Fiscal Year 2003 Foreign Comparative Testing (FCT) programme highlight a range of rest-of-the-world electronics, the key elements of which are as follows:

- **Anti-jam Global Positioning System (GPS) antenna** A US Navy effort to evaluate a Raytheon Systems Ltd. (UK) developed shipboard anti-jam GPS antenna.
- **Body-worn radar warning receiver** A US Special Operations Command evaluation of a Filtronic Components and Spectrum Solutions (UK) – developed body-worn radar warning receiver.
- **Corona monitoring** A US Navy programme to evaluate corona monitoring cameras from CSIR (South Africa) and OFIL Ltd (Israel) for use in high power Very Low/Low Frequency (3 to 300 kHz) communications systems.
- **Fuel cells** The US Army plans to evaluate electrochemical fuel cells from Advanced Power Sources (UK), Ballard Power Systems (Canada), Hydrogenics (Canada), NoVars (Germany) and Smart Fuel Cells (Germany) as power sources for individual soldier equipment as part of its 'Land Warrior' programme.
- **Intruder detection system** A US Air Force evaluation of a Sensor Electronics Ltd. (UK) wireless-linked, palm-sized, infrared passive intruder sensor.
- **Silverised Kevlar** A US Army programme to evaluate silverised Kevlar from Silverleaf Materials Ltd. (Canada) for use in conductive ground plane, electro-magnetic interference shielding and static discharge applications aboard the RAH-66 Comanche battlefield scout helicopter.
- **Specific emitter identification** A US Navy effort to evaluate QinetiQ (UK) – sourced circuit cards for passive emitter identification and fingerprinting in naval applications.
- **Underwater communications and tracking system** A US Navy programme to evaluate a Nautronix (Australia) digital communications system that is designed to facilitate real-time positional data exchange between submarines participating in open ocean exercises. ■


ITU TELECOM ASIA 2004
ITU TELECOM MIDDLE EAST & ARAB STATES 2005
ITU TELECOM AFRICA 2004
ITU TELECOM AMERICAS 2005
ITU TELECOM ASIA 2002 Hong Kong 2-7 December
ITU TELECOM WORLD 2003 Geneva 12-18 October

SAWTEK OSCILLATORS REALLY DELIVER

Sawtek...Your Supplier of Choice!



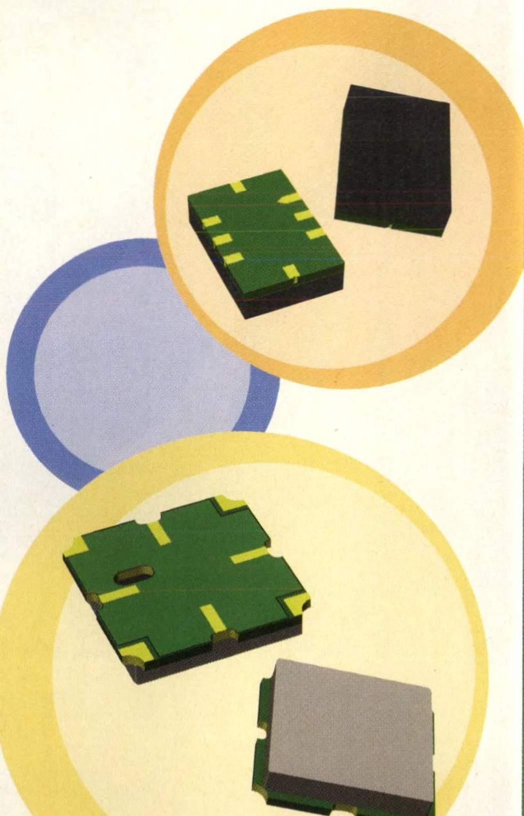
Sawtek's voltage controlled SAW oscillators meet the specs you need with the industry's best phase noise. The differential output Emitter Coupled Logic (ECL) clock is perfect for the low jitter requirements of SONET, Ethernet, and network servers. Sawtek's new single-ended sine wave oscillator is ideal for broadband applications such as SONET, point-to-point and multi-point microwave systems. When your designs demand vibration immunity and aggressive cost-effectiveness, demand oscillators from Sawtek...they deliver.

Differential ECL Clock VCSO

- Frequencies from 600 MHz to just over 1 GHz
- Surface Transverse Wave (STW) technology offers very low jitter at high fundamental frequencies (<.3 pS RMS)

Single-Ended Sine Wave VCSO

- Frequencies from 300 MHz to 2.5 GHz
- STW technology offers low phase noise (-120 dBc/Hz to -135 dBc/Hz at 10 kHz, -165 dBc/Hz at 1 MHz) and exceptional high frequency jitter performance (<5 fS RMS)



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Bluetooth is Steadily Gaining Market

In the midst of the technology downturn, Bluetooth is steadily gaining market traction — evidenced by steady market growth in 2002 — and proving the skeptics wrong. Allied Business Intelligence (ABI) projects Bluetooth chipset shipments to increase to 33.8 M in 2002, up from 11.2 M in 2001. In the longer run, the Bluetooth semiconductor market is forecast to grow to just over 1.1 B chipsets by 2007, with associated revenues of $2.54 B.

The key enablers for moving forward will be the efforts of handset vendors and the Bluetooth IC suppliers. Nokia and Motorola are beginning to catch up with Ericsson's lead in integrating Bluetooth functionality. By the end of 2003, Bluetooth should become a standard checklist feature for handset vendors designing 2.5G and 3G phones.

Bluetooth IC vendors are also in the midst of a competitive frenzy as they look to capture a foothold in the market, with a view to being long term survivors. Particularly impressive has been the chipset ASP declines over the last 12 months, which has been achieved in the absence of a bigger ramp-up in volume. Bluetooth chipset pricing is rapidly shifting from being cited as a market obstacle to becoming a market driver. As pricing becomes more favorable, Bluetooth integration becomes more compelling for a larger set of device vendors.

The ABI report "Bluetooth: the Global Outlook for Bluetooth Component and Equipment Markets" examines the evolution of Bluetooth technology, analyzes potential overlap with other wireless technologies, forecasts the IC market and segments Bluetooth device shipments into 15 categories. While mobile handsets are set to dominate the Bluetooth device market, the report notes that other key Bluetooth device categories will include cordless headsets, computing devices and the automotive market.

For more information on this study, visit http://www.alliedworld.com/servlets/ResearchDetails?productid=BLU02.

Kopin Harness Nanotechnology to Achieve Breakthrough in Solid-state Lighting

Kopin Corp. for the first time has harnessed nanotechnology to produce light-emitting diodes (LED), yielding blue LEDs that are smaller than a grain of sand but are ultra efficient solid-state light sources. The technical breakthrough is revealed and published in the July 29 edition of the prestigious *Applied Physical Letters*.

Using a new patent-pending process that creates "NanoPockets™" and other improvements, Kopin has developed a way to produce blue LED chips as bright as those commercially available and yet are driven by a much lower voltage. Kopin's new CyberLite™ blue LED chips require less than 2.9 V of electricity (for 20 mA of current) — significantly lower than the 3.3 V for commercially available LEDs — and yet have 100 millicandela brightness. "Getting below 3 V has been a scientific hurdle for nearly a decade," said Kopin founder and chairman Dr. John C.C. Fan. "It took a new way of thinking to overcome this challenge. With further development, we can approach the holy grail of using these solid-state sources for general lighting." The blue CyberLite can be combined with a yellow phosphor to create a white LED. These blue and white CyberLite are ideal for compact portable light-using devices, such as wireless phones, games, camcorders, cameras, laptops and PDAs, which operate on battery power. "Today's CyberLites announcement is significant because Kopin has cleverly integrated nanotechnology into the semiconductor process to create LEDs that are extremely low voltage and ultra bright," said Bob Steele, director of optoelectronics at Strategies Unlimited, a market research firm.

"With CyberLites, we have taken a very important first step in the commercialization of nanotechnology," said Fan. "The next step is achieving mass production. Although this is always the toughest part, as we did with our HBT transistors and CyberDisplay™ technologies, we believe we can move CyberLites into large-volume production for the mass-market. We have already begun shipping evaluation samples of CyberLites to prospective customers towards this goal."

Kopin selected LED lighting as its next innovation based on its Wafer Engineering Process™ because it has synergy with its current III-V and CyberDisplays products, and because the high brightness LED market is already large at $1.2 B today and expected to grow rapidly, reaching more than $3 B by 2005, according to Strategies Unlimited.

New Automotive Wireless Networks Study

By way of Chrysler's Uconnect system, 2002 will mark the introduction of an automotive OEM (original equipment manufacturer) Bluetooth offering. However, the question remains: what lies ahead for Bluetooth in automotive and what role is 802-11 expected to take?

Bluetooth's largest automotive driver is the technology's proliferation into mobile handsets. Because the greatest portion of handset use is inside a vehicle, automotive OEMs are looking to link the handset with onboard systems. Since Bluetooth car kits are relatively simple and inexpensive to install, OEMs are proactively installing them, realizing the growing probability they will be federally mandated.

Ultimately, Bluetooth's reach will extend far beyond telephony in the vehicle. Today's telematics systems will soon escape the bonds of cellular networks and will exploit new wireless connectivity options, including 802-11. Potential applications for 802-11a range from electronic toll collection and vehicle-to-vehicle communications to safety applications, navigation, remote diagnostics, etc.

A new ABI study, "Automotive Wireless Networks: Examining the Proliferation of WLAN and PAN Technologies Into the Automotive Platform," discusses the automotive potential for both Bluetooth and 802-11, including business issues and emerging, market-driving applications. In addition to analyses of key market players, the report provides forecasts for automotive-targeted WLANs and PANs nodes, as well as adjunct devices used in the automobile, including PDAs, laptops and headsets.

Active Microwave Modules Market in N. America to Exceed $3.9 B in 2007

In early summer 2002, Engalco released its second issue report on Active Microwave Modules — Markets to 2007 (AMMNA02). This report forecast that the overall total available merchant market for this class of microwave products will grow from the $2.3 B level this current year (2002) to exceed $3.9 B in 2007. The study includes detailed market data on: electronic switches (both PIN- and MMIC-based), VCOs, DROs, YIG oscillators, linear amplifiers, fixed wireless RFICs, frequency synthesizers and other relatively complex function modules.

The first report published by Engalco that provided these data was in 1995 ("Microwaves North America") and this specific product family was first reported upon in 2001. In AMMNA02, a new approach has been adopted: notably the top group of companies addressing various product categories are identified and the end-user segmentation is appropriately adjusted. The radically changed industry dynamics since 2001 are accounted for including the current saturation of the cell phone market and the strengthening of the defense sector. A full supply-side industry directory is included.

Each year, the lead is taken by frequency synthesizers with markets for these types of modules worth over $700 M in 2002 and forecast to exceed $1 B in 2007. Fixed wireless RFICs and linear amplifiers occupy second and third places in the ranking. In contrast to previous years, especially pre-2001 when telecoms, including cell phones, made most of the running, the defense sector is now increasingly important again and this fact is reflected in all the market segmentation. For further information, contact Terry Edwards at terryengalco@compuserve.com. ■

INDUSTRY NEWS

■ **Delta RF Technology Inc.** purchased high power RF amplifier manufacturer **Silicon Valley Power Amplifier Corp. (SVPA)** The purchase will allow Delta RF to offer a broader array of products and gain a step of vertical integration in the commercial FM radio market.

■ **Unitek Miyachi International Ltd.** acquired selected assets of **MicroJoin Inc.** Assets purchased from the **Palomar Companies** include property, all products, systems, equipment and designs, patent rights, trademarks, brand, company and domain names. The former MicroJoin will cease operations.

■ **MEMSCAP** has entered an agreement to acquire substantially all of the business and assets of **JDS Uniphase's Cronos MEMS** business unit. The acquisition provides MEMSCAP with a fully operational unit that is established in MEMS design and foundry services, as well as in optical MEMS.

■ **Peregrine Semiconductor** announced a dedicated company unit specifically targeted at developing products for the stringent quality needs of the space and defense markets. Peregrine's co-founder and CTO, Ronald Reedy, will head the division as VP of space and defense at the company.

■ **Avnet RF & Microwave** has launched **Wavelength Design Solutions (WDS)**, a new business unit that will provide services and products to offer a total solution to customers incorporating wireless technology into their end products. WDS was created to help meet the growing demand from original equipment manufacturers, original design manufacturers and enterprises that plan to incorporate wireless technology into their end products, but do not necessarily have the technical expertise and resources to do the job internally.

■ **Boldt Metronics International Inc. (BMI)** has expanded its manufacturing capabilities to a new location in Shanghai, China. BMI opened the new Asian factory to stay ahead of increased demand, especially from the telecom industry, a very fast growing market in the Far East. From this 15,000 square-foot facility, BMI will manufacture its EMI shield and contacts for the Asian market.

■ **RF Micro Devices Inc.** has opened a new sales and customer support office located at The Imperial Tower, Tokyo, Japan. The Japan sales and customer support team, which will be located in the new office, was first established in January 2001.

■ With a focus on increasing the development of advanced hybrid technology for the automotive and telecom industries, the **TT Electronics BI Technologies Electronic Components Division** recently invested more than $3 M in the expansion of the Fullerton, CA, microcircuits facility. By doubling the size of the factory to include a 5500 square-foot class 10,000 clean room with class 100 operational areas and investing in high speed automated equipment for all microcircuit operations, the company is also positioned to respond to the recent demands for military grade chip and wire hybrids.

■ **Talley Communications Corp.** has purchased a new corporate headquarters facility in Los Angeles, CA, more than doubling the size of the prior building. This 80,000 square-foot warehouse and sales facility will allow the company to better service its customers with wireless communications infrastructure, mobile communications and power products.

■ **Merrimac Industries Inc.** has opened a new 36,000 square-foot Multi-Mix® manufacturing facility in San Jose, CA. This state-of-the-art facility more than doubles the company's existing system in New Jersey, and is optimally organized for high volume production.

■ **Fox Electronics Inc.** has announced a major increase in its worldwide production capacity and a significantly expanded presence in the Asian-Pacific region. The company added a 73,000 square-foot production facility outside of Shanghai to its worldwide manufacturing operations. The facility complements the company's existing design and production capabilities and will serve both international and domestic US market demand. In related news, the company created Fox Electronics–Asia. The Hong Kong headquarters will open this month.

■ **SEMX Corp.** announced that **Polese Co.** and **Talon Composites** have entered into an arrangement for Polese to produce Talbor,® a metal matrix composite consisting of aluminum and boron carbide. This composite will be supplied primarily to the nuclear waste industry for neutron shielding applications.

■ **Actel Corp.** and **Infineon Technologies AG** have entered into a cooperation to develop flash memory field-programmable gate array solutions for production in 0.13-micron chip processes. Building on Actel's flash-based ProASIC FPGA family and Infineon's process technology and manufacturing expertise, the development program will extend the capability of flash-based FPGA technology in both current and new ASIC alternative market segments.

■ **W.L. Gore & Associates Inc.** and **Alvesta** announced a decision to cross-license four-channel parallel optic transceivers as defined by the QuadLink MSA, a multi-source agreement defining small footprint four-channel optical transceivers. The two companies have entered into a technology license agreement that enables both companies to manufacture fully compatible 10-gigabit optical transceivers based on the same underlying optical, electrical and mechanical design.

[Continued on page 58]

■ **Rogers Corp.** was recognized at SEMICON West 2002 in San Jose, CA, with the 2002 Advanced Packaging Award for its ZYVEX™ Liquid Crystalline Polymer laminates. Rogers was one of 14 recipients of the award.

FINANCIAL NEWS

■ **Linear Technology Corp.** reports sales of $140.8 M for the fourth quarter ended June 30, 2002, compared to $200.0 M for the same period in 2001. Net income for the quarter was $55.0 M (17¢/diluted share), compared to $84.8 M (26¢/diluted share) for the fourth quarter of last year.

■ **RF Micro Devices Inc.** reports sales of $103.9 M for the first quarter ended June 30, 2002, compared to $70.1 M for the same period in 2001. Net income was $2.3 M (1¢/diluted share), compared to a net loss of $28.4 M (17¢/share) for the first quarter of last fiscal year.

■ **Ansoft Corp.** reports sales of $9.3 M for the first quarter ended July 31, 2002, compared to $11.2 M for the same period in 2001. Net loss was $3.3 M (28¢/diluted share), compared to a net loss of $498 K (4¢/diluted share) for the first quarter of last year.

■ **Merrimac Industries Inc.** reports sales of $6.46 M for the second quarter ended June 29, 2002, compared to $6.77 M for the same period in 2001. Net loss was $54,000 (2¢/share), compared to a net income of $136,000 (5¢/share) for the second quarter of last year.

■ **Unity Wireless Corp.** reports sales of $273,756 for the second quarter ended June 30, 2002, compared to $570,559 for the same period in 2001. Net loss was $1.39 M (4¢/share), compared to a loss of $611,856 (2¢/share) for the second quarter of last year.

■ **Peregrine Semiconductor** has raised $14 M in the first tranche of its Series A1 round. This investment was led by **Morgenthaler Ventures** and **Wasserstein Ventures**.

CONTRACTS

■ **Lorch Microwave**, Salisbury, MD, has been awarded a multi-year contract to supply RF and microwave filters to a multinational defense contractor. The contract is valued in excess of $6 M.

■ **Eagleware** has been awarded a small business innovation research phase II contract by the Air Force for enhancements to the GENESYS integrated system-synthesis-circuit design environment. This two-year contract will fund the development of synthesis technology not available in the market today.

■ On behalf of the German Armed Forces, the Federal Office for Defense Technology and Procurement has contracted **Rohde & Schwarz** to supply VHF/UHF communications for the TIGER and NH90 military helicopters. The order totals more than Euro 26 M and includes the delivery of M3AR airborne transceivers with the associated control units and several special test systems.

■ **Reynolds Industries** has been awarded a contract from **Bechtel** to provide more than 800 cable assemblies for the US Navy. This award represents Reynolds' fifth configuration of nuclear cable assemblies designed and engineered to meet the US Navy's quality and 20-year life expectancy requirements.

PERSONNEL

■ Apex Microtechnology Corp. has appointed **Debbie Drysdale** as its new president and CEO. Most recently, Drysdale served as VP and general manager of the DSP Standard Product division in the Semiconductor Products Sector at Motorola.

■ Elgar Electronics Corp. has appointed **Joseph A. Budano** president and CEO. Prior to joining the company, Budano spent seven years at Acterna, where he most recently served as group president of the multi-media group.

■ RF Micro Devices Inc. has appointed **Albert E. Paladino** chairman of the board of directors. Paladino has served as an outside director of RF Micro Devices since 1992.

■ Park Electrochemical Corp. has elected **Gary M. Watson** the company's senior VP-engineering. Watson has

[Continued on page 60]

held senior engineering, technology, research, project management and operations positions at various companies. Watson has specialized in, among other things, coating technology.

■ Rockwell Collins has appointed **Ken A. Peterman** VP of business development for government systems. In this role, Peterman will be responsible for worldwide sales and marketing activities for Rockwell Collins Government Systems, which provides defense electronics products and systems for airborne, ground and shipboard applications.

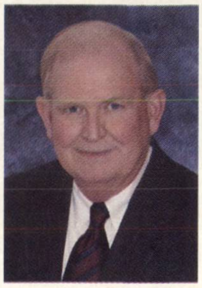
■ SEMX Corp. has named **Pradeep Gandhi** VP and engineering manager for its Polese Company Inc. division. Gandhi brings with him vast experience in the fields of electronic materials and ceramic packaging, including low temperature co-fired ceramics. Gandhi comes to Polese from Ormet Circuits Inc., where he was president.

■ GIL Technologies Inc. has hired **Douglas J. Sober** as its VP, quality assurance. Sober is expected to play an important role in furthering the company's reputation for high manufacturing standards. Sober brings over two decades of base material and printed board expertise to the position. In related news, GIL named **Derrick Neo** as the company's business director of Asia. Neo will manage the company's new Asian sales office in Shenzhen, China, and will direct all of GIL's sales operations throughout the Asian rim.


▲ Sue Guzman

■ Celerity Digital Broadband Test, a division of L-3 Communications, has named **Sue Guzman** VP of sales. Guzman, who was the western regional sales manager at Teradyne Inc. before joining Celerity, will be responsible for worldwide sales and support, customer satisfaction and revenue growth. In related news, the company named **Lucy McGuire** as western regional sales manager. In this position her responsibilities will include sales, customer service and market development. Prior to joining the company, McGuire was employed by Rational Software as an account executive.


▲ Lucy McGuire


▲ Jerry Parsons

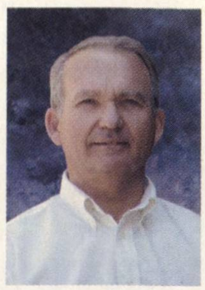
■ Semflex has hired **Jerry Parsons** as eastern regional sales manager. Parsons will service the company's customer base in 23 states east of the Mississippi. He brings more than 30 years of sales experience to the position.

■ Fox Electronics has appointed **Stephen So** managing director of the newly formed Fox Electronics–Asia to its comprehensive sales network and establish a complete, support and logistics center headquartered in Hong Kong. So most recently served as general manager of Bostex Electronics Pte Ltd. in Singapore.


▲ Wai Seng Chew

■ Palomar Technologies has appointed **Wai Seng Chew** as director of the company's Asian office. Chew is responsible for business in China, Taiwan, Japan, Korea, Hong Kong, Thailand, Malaysia, The Philippines, Singapore and Indonesia.

■ Trompeter Electronics has named **Ron Desilets** to the new position of Mil/Aero business development specialist. His responsibilities will include project sales development and customer support to the military and aerospace markets. Desilets brings more than 20 years of RF and microwave experience to the new position, most recently working in a contract capacity with Raytheon Electronic Systems.


▲ Ron Desilets

■ TRU Corp. has named **Nina Lynch** communications coordinator. Lynch, who most recently served as associate producer for New England Cable News, will be responsible for all corporate marketing communications.

[Continued on page 62]

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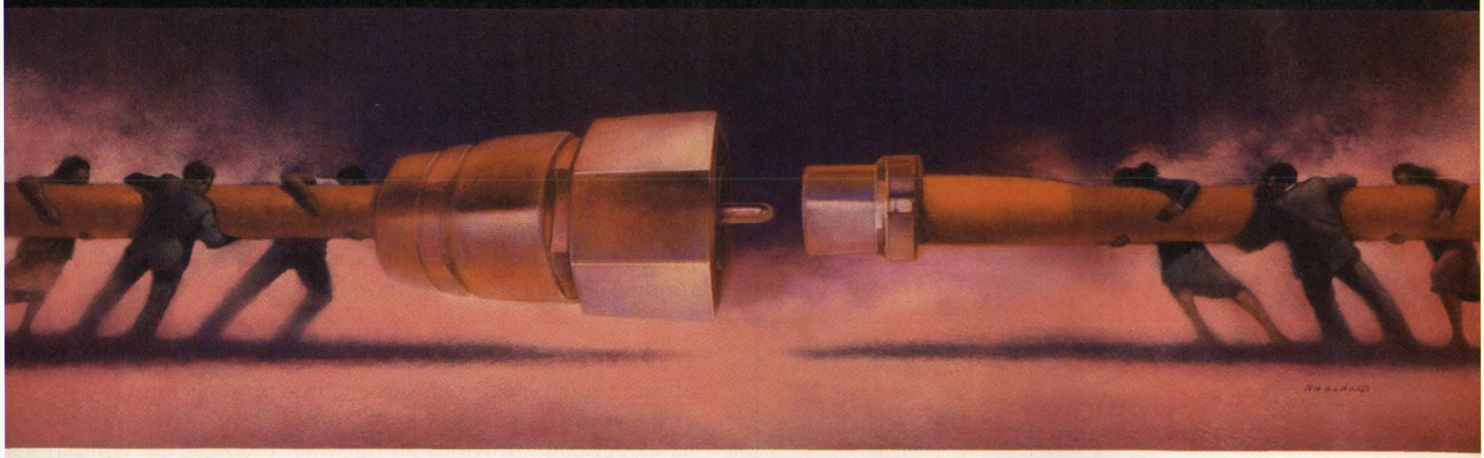

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REP APPOINTMENTS

■ **Hittite Microwave Corp.** appointed **Micro Lambda LLC** as its sales representative firm in Pennsylvania and southern New Jersey.

■ **Powell Electronics Inc.** is now an authorized distributor of **Applied Engineering Products (AEP)**. Powell will provide the value added distribution services of packaging, kitting and materials planning through its 11 US facilities.

■ **Future Electronics** signed an agreement with **ILSI America** to be a worldwide distributor for ILSI America's broad product line of crystals and oscillators.

■ **Advanced Control Components Inc.**, Eatontown, NJ, has made a series of manufacturing representatives appointments. **T&E Repco** will cover Florida, Georgia, South Carolina and Alabama, while **Wavetec** will handle Texas. Internationally, **Elkay International** will be responsible for India, **Giza Technologies SA** for Spain, **SM Engineering Corp.** for Korea and **Univision Technology Inc.** will handle the Republic of China.

■ **AMCOM Communications Inc.**, Clarksburg, MD, has appointed **KJS Marketing** to be the exclusive representatives for Illinois, Missouri, Minnesota, Kansas, Iowa, Nebraska and Wisconsin.

■ **SRI Connector Gage Co.** has announced a number of distribution and representative changes. **Microwave Components Inc.**, Stuart, FL, and **Microtek Inc.**, West Pont, PA, were named franchised distributors. **Comm Tech Sales LLC**, Dallas, TX, was appointed representative for Texas, Oklahoma, Arkansas and Louisiana, while **EG Holmes & Associates Inc.** will be covering most of Florida in addition to the other Southeastern states. Internationally, **Global Overseas Co.** was appointed representative for South Korea, **RF Design** will cover South Africa, **INTELCOM Ltd.** will be responsible for New Zealand and **Microwave & Coaxial Components** will handle Spain.

■ **Littelfuse Inc.** has appointed **TTI Inc.** as an authorized distributor. The agreement, which includes all Littelfuse circuit protection components, enhances the company's ability to serve the growing market for its range of products.

WEB SITES

■ **OPHIR RF** has launched its all new Web site, www.ophirrf.com, which now includes a product search capability, a simple to use 'request for quotation' facility, and a local company representative identifier by selection from a map. Designed for ease of use, visitors to the new site can also request literature, ask for help from an applications engineer and receive new product alerts.

■ **BTC Electronic Components** has added a Live Chat feature to its Web site, www.btcelectronics.com. Customers are now able to inquire about any electronic component need, one-on-one, in real time without having to wait for a response via e-mail. Along with the chat feature, product releases that will inform customers of the diverse product offerings by BTC have been added.

■ **Natel Engineering Co.** has unveiled its new Web site offering microelectronic design tips, product information and manufacturing solutions. The site, www.natelengr.com, provides an illustrated look at the company's comprehensive microelectronics manufacturing capabilities. Highlights include an on-line facility tour, application examples, and free access to design guides and educational materials.

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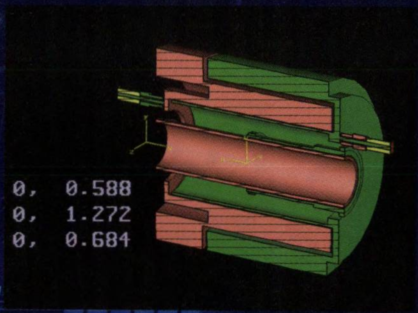
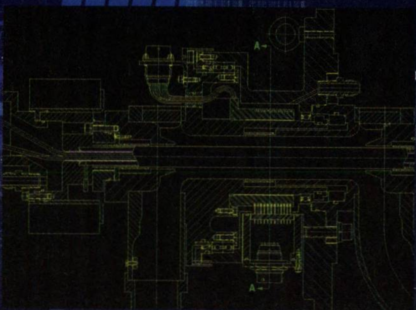
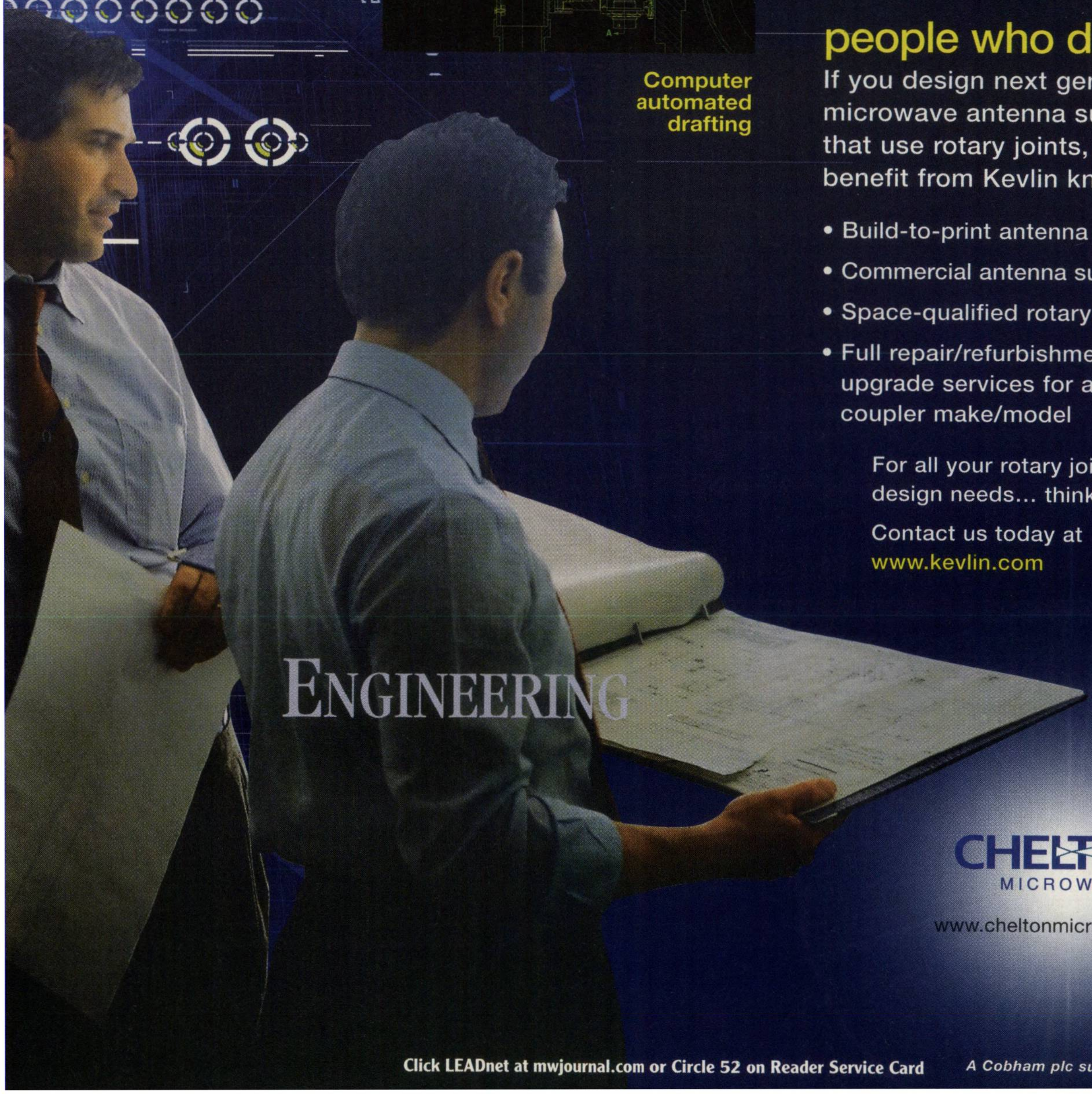





ENGINEERING

DESIGN ADVANTAGES OF CDMA POWER AMPLIFIERS BUILT WITH MOSFET TECHNOLOGY

CDMA power amplifiers are now being produced in volume using MOSFET technology, enabling improvements in amplifier performance and system cost. This article discusses the design characteristics of these very flexible and stable devices and explains how they make it easier to achieve optimal performance for CDMA systems. It also shows how the MOSFET amplifiers facilitate handset designs that operate without isolators, have low RX-band noise generation and achieve high efficiency.

Each of the many process technologies that can be used for RF power amplifiers — GaAs HBT, PHEMT, InGaP HBT and silicon RF MOSFET — have different advantages, such as better frequency characteristics, wider linearity and higher power capability. A fundamental comparison of the different process technologies is shown in ***Table 1***. When designing high power amplifier MMICs and modules, it is essential to use the process best matched to the needs of the application. Semiconductor companies continuously improve their processes to keep pace with evolving design requirements. As a result, there are now CDMA high power amplifier modules in mass production that are built with the MOSFET process rather than GaAs HBT technology. A basic block diagram of a typical amplifier module is shown in ***Figure 1***.

The MOSFET process has many good qualities when applied to CDMA high power amplifiers. MOS devices have excellent stability and ruggedness, characteristics that allow isolator-free operation. They have an excellent noise figure and produce less RX-band noise, enabling improved receiver sensitivity. Also, they use a

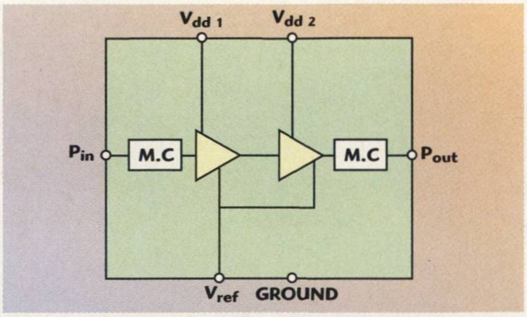
TABLE I

BASIC COMPARISON BETWEEN DIFFERENT PROCESS TECHNOLOGIES

	HBT	PHEMT	E-PHEMT	LDMOS
Knee voltage (V)	~ 1.1	< 1	< 1	< 1
Supply requirements	single	dual	single	single
Manufacturing complexity	high	high	high	low
Stability under extreme SWR	OK	moderate	moderate	excellent
Thermal runaway characteristic	positive	negative	negative	negative
Noise power (relative performance at 2 GHz)	good	excellent	excellent	excellent

E-PHEMT: enhanced mode pseudomorphic high electron mobility transistor
LDMOS: laterally diffused metal-oxide semiconductor

Fig. 1 Block diagram of a typical RF power amplifier module for CDMA systems.



[Continued on page 66]

TETSUO SATO AND CHRIS GRIGOREAN
Hitachi Semiconductor (America) Inc.
San Jose, CA

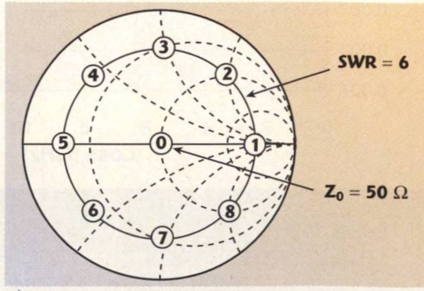
simple bias circuit and have a low saturation resistance, a combination that facilitates the design of CDMA phones that operate at lower voltages.[1]

ISOLATOR-FREE SYSTEMS

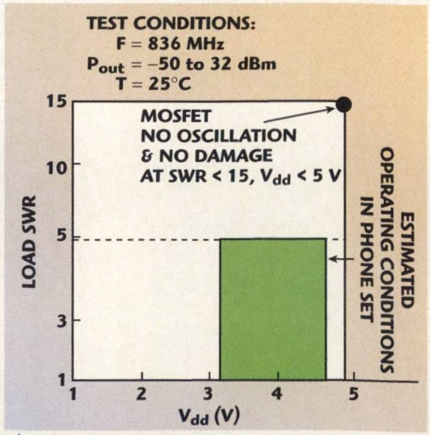
In most CDMA systems today, an isolator is inserted between the high power amplifier and the antenna to help attenuate antenna reflections, thereby protecting the amplifier and helping to suppress intermodulation distortion. Power amplifiers built with the MOSFET process achieve excellent stability under high SWR conditions, so they eliminate the need for an isolator. This improves the signal budget by approximately 0.5 dB, produces a five percent saving in the current budget and yields a 10 percent saving in power. Eliminating the isolator also saves board space and reduces the cost of the handset.

To quantify MOSFET amplifier stability, device measurements were made at the different positions on the Smith chart shown in ***Figure 2***, relating to load SWRs of 1:1 and 6:1. The power amplifiers were operated at V_{dd} = 3.4 V and V_{ref} = 2.8 V. The adjacent channel power rejection (ACPR), which was measured at ±885 kHz for the cellular band and at ±1.25 MHz for the PCS band, was maintained at –45 dBc for these upper and lower frequency limits, controlled by varying P_{in}. The results for the PCS amplifiers, which are summarized in ***Appendices A*** and ***B***, illustrate the consistent performance that CDMA system designers can expect from MOSFET power amplifiers.

MOSFET devices are rugged. They exhibit no degradation when V_{dd} = 5 V, and they can withstand a 15:1 mismatch with no damage. ***Figure 3*** shows that the MOS design has very good quality and reliability characteristics. Silicon has 3.3 times better thermal conductivity at 300 K than GaAs, 1.5 W/cm–°C versus 0.46 W/cm–°C, so it dissipates heat faster. Notably, MOSFETs have a negative temperature coefficient, so the power amplifiers do not experience thermal runaway.



▲ *Fig. 2 Test points used to measure MOSFET amplifier stability.*



▲ *Fig. 3 Acceptable operating conditions for MOSFET amplifiers.*

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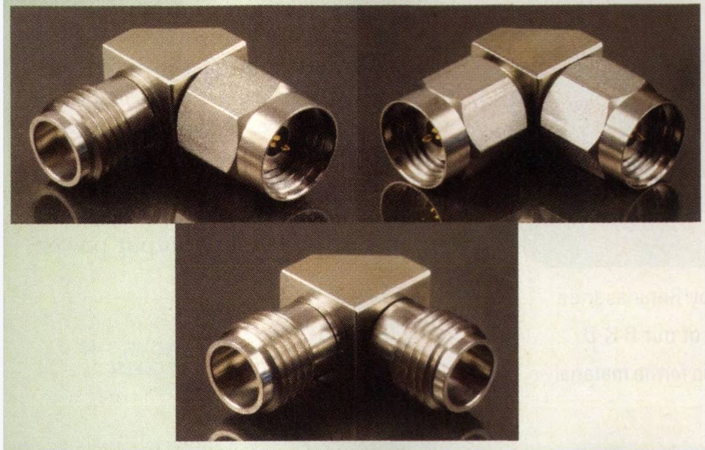

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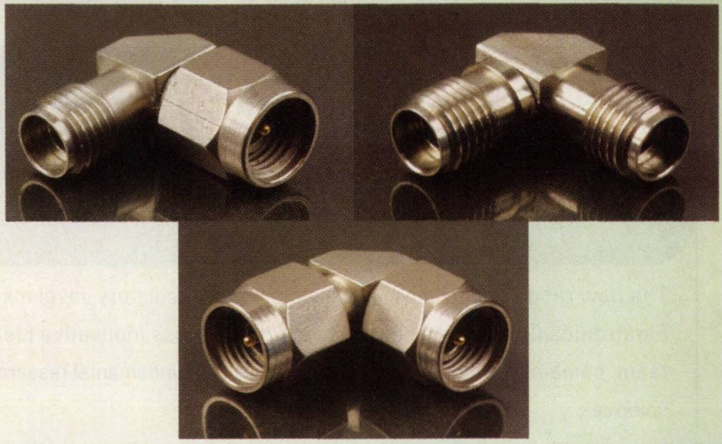

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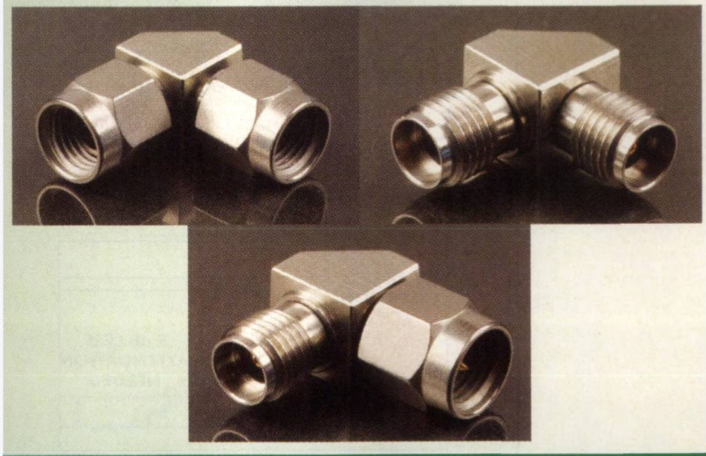

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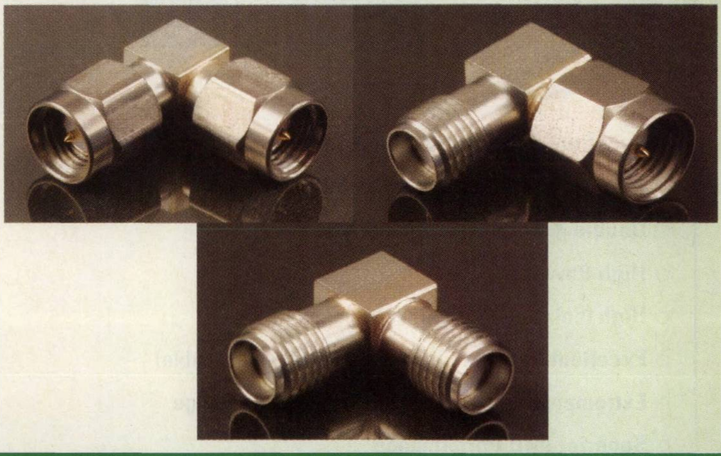

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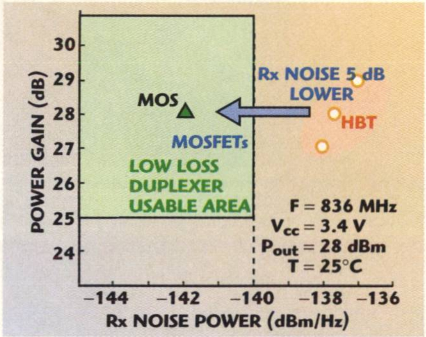
LOW RX-BAND NOISE

In a CDMA system the TX and RX functions operate simultaneously. Therefore, a duplexer with good rejection and compression characteristics is needed to reduce the RX-band noise coming from the TX output signal. This necessitates a design tradeoff between the duplexer's size, insertion loss and rejection specification. MOSFET technology eases this tradeoff because it generates less noise than GaAs HBT technology. In fact, MOSFET amplifiers achieve 5 dB lower RX-band noise than typical HBT devices, approximately –142 dBm/Hz versus –137 dBm/Hz.

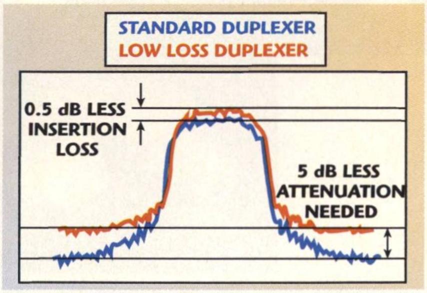
Figure 4 illustrates the RX noise power difference and its beneficial impact on a CDMA system design. The 5 dB improvement in amplifier RX noise level allows the duplexer RX attenuation specifications to be relaxed. In turn, this enables improved insertion loss characteristics. These characteristics are shown in ***Figure 5***. Now a lower insertion loss, lower cost duplexer can be used in the system. The saving on the signal budget is approximately 0.5 dB. This produces another five percent saving in the current budget and achieves another 10 percent saving in power.

HIGH EFFICIENCY

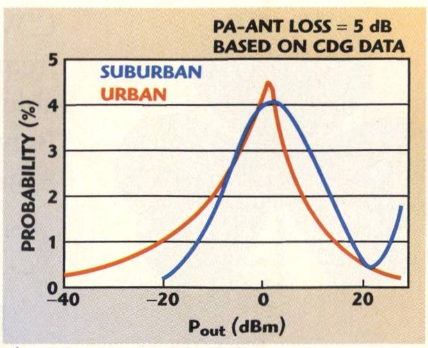
The base station and handset in CDMA systems monitor signal strengths and control the handset's high power amplifier output level accordingly. ***Figure 6*** shows the standard output power level probability of the high power amplifier measured in urban and suburban conditions. The higher probability output power



▲ *Fig. 4 Comparison of RX noise power vs. gain between MOSFETs and HBTs.*



▲ *Fig. 5 MOSFET amplifiers allow the use of low loss duplexers.*



▲ *Fig. 6 Standard output power level probability of the PA measured for urban and suburban conditions.*

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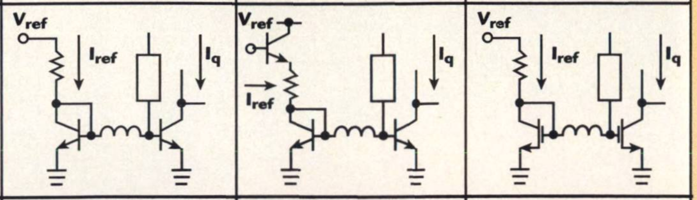
	GaAs HBT		MOS FET
	CURRENT-MIRROR	EMITTER-FOLLOWER	CURRENT-MIRROR
BIAS CIRCUIT			
I_{ref}	TENS mA	LESS 1 mA	LESS 1 mA
$\Delta I_q/\Delta V_{ref}$	6 mA/100 mV	25 mA/100 mV	4.5 mA/100 mV
$\Delta I_q/\Delta T_j$	+1000 ppm/°C	+10000 ppm/°C	+200 ppm/°C

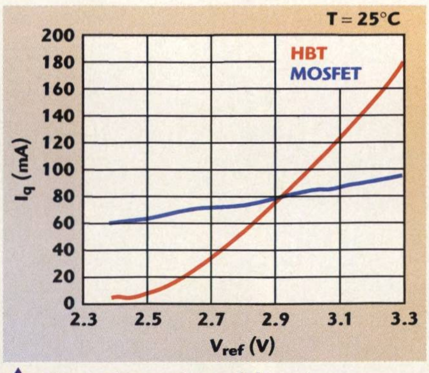
Fig. 7 Comparison of bias control systems.

is found around 0 dBm. These curves show that to obtain long talk times on batteries, the handset's efficiency at low output power levels is much more important than its efficiency at peak output power.[2] A system design that uses a MOSFET amplifier can benefit from this fact.

A well-known technique for improving average system efficiency is to use a bias control system. A key point is that the bias current needed to achieve linearity at the maximum output power level is too large for operating at the smaller output power levels.[3] Many adaptive bias control systems are possible. All of them have three important characteristics: small bias control current, gradual control sensitivity and small temperature dependency. Commonly used bias circuits include the current-mirror and emitter-follower topologies for GaAs HBT amplifiers, and the current-mirror topology for MOSFET devices.

As ***Figure 7*** shows, the current-mirror topology for biasing GaAs HBT power amplifiers requires tens of milliamperes (mA) of control current and has a 6 mA/100 mV control sensitivity and +1000 ppm/°C temperature dependency. The emitter-follower bias control topology for GaAs HBT devices requires less than 1 mA control current, has 25 mA/100 mV control sensitivity and has +10,000 ppm/°C temperature dependency. Even better, the current-mirror for biasing MOSFET devices needs less than 1 mA control current and has 4.5 mA/100 mV sensitivity and only +200 ppm/°C temperature dependency.

Figure 8 plots the quiescent current (I_q) for MOSFET and HBT de-



▲ *Fig. 8 Comparison of the quiescent current vs. V_{ref} between MOSFET and HBT amplifier modules.*

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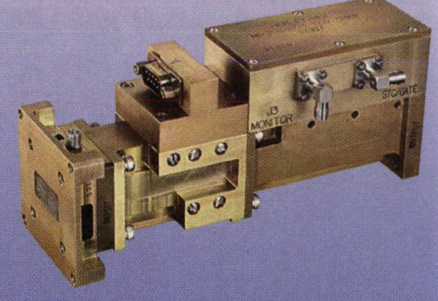

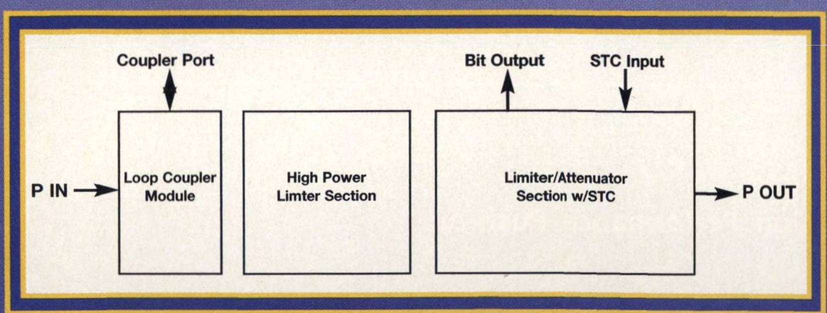

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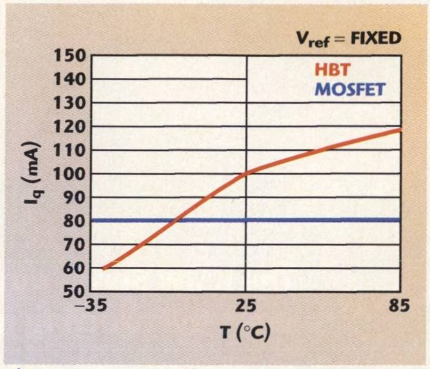
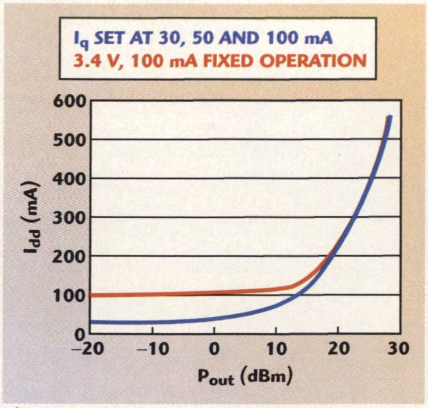
vices versus V_{ref}, while ***Figure 9*** shows I_q for these devices versus temperature. In both cases, the superior performance of the MOSFET device is clearly evident.

For discussion purposes, assume a three-step bias control system for V_{ref} for a MOSFET device. It sets P_{out} < 15 dBm (I_q = 30 mA (Low)), P_{out} = 15 to 20 dBm (I_q = 50 mA (Mid)) and P_{out} > 20 dBm (I_q = 100 mA (Hi)). The operating current (I_{dd}) versus P_{out} for this design is shown in ***Figure 10***. Under these conditions, using the probability data, the average current will be approximately 84.6 mA/55 mA (suburban/urban). Without the bias control system, the average current would be much higher (130.5 mA/109 mA).

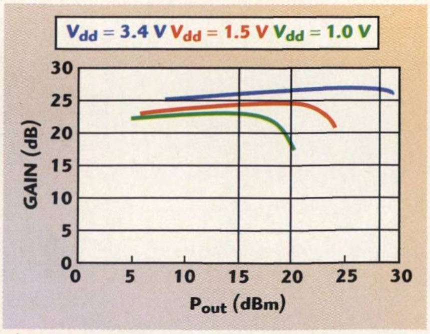
Even higher amplifier efficiency can be achieved with a MOSFET device if a voltage (V_{dd}) control system is used. This control approach benefits from the MOSFET amplifier's low voltage operation, simple bias circuit implementation and low R_{on} device characteristics. Here the three-step control system sets P_{out} < 15 dBm (V_{dd} = 1 V, I_q = 50 mA (Low)), P_{out} = 15 to 20 dBm (V_{dd} = 1.5 V, I_q = 50 mA (Mid)) and P_{out} > 20 dBm (V_{dd} = 3.4 V, I_q = 100 mA (Hi)). Now the average current from the battery is 56.7 mA/32.1 mA (suburban/urban). ***Figure 11*** shows the gain versus P_{out} for this voltage control sys-



▲ *Fig. 9 Comparison of the quiescent current vs. temperature between MOSFET and HBT amplifier modules.*



▲ *Fig. 10 I_{dd} vs. P_{out} showing the effectiveness of the three-step bias control system for V_{ref} of a MOSFET device.*



▲ *Fig. 11 MOSFET amplifier gain vs. output power with a three-step V_{dd} control system.*

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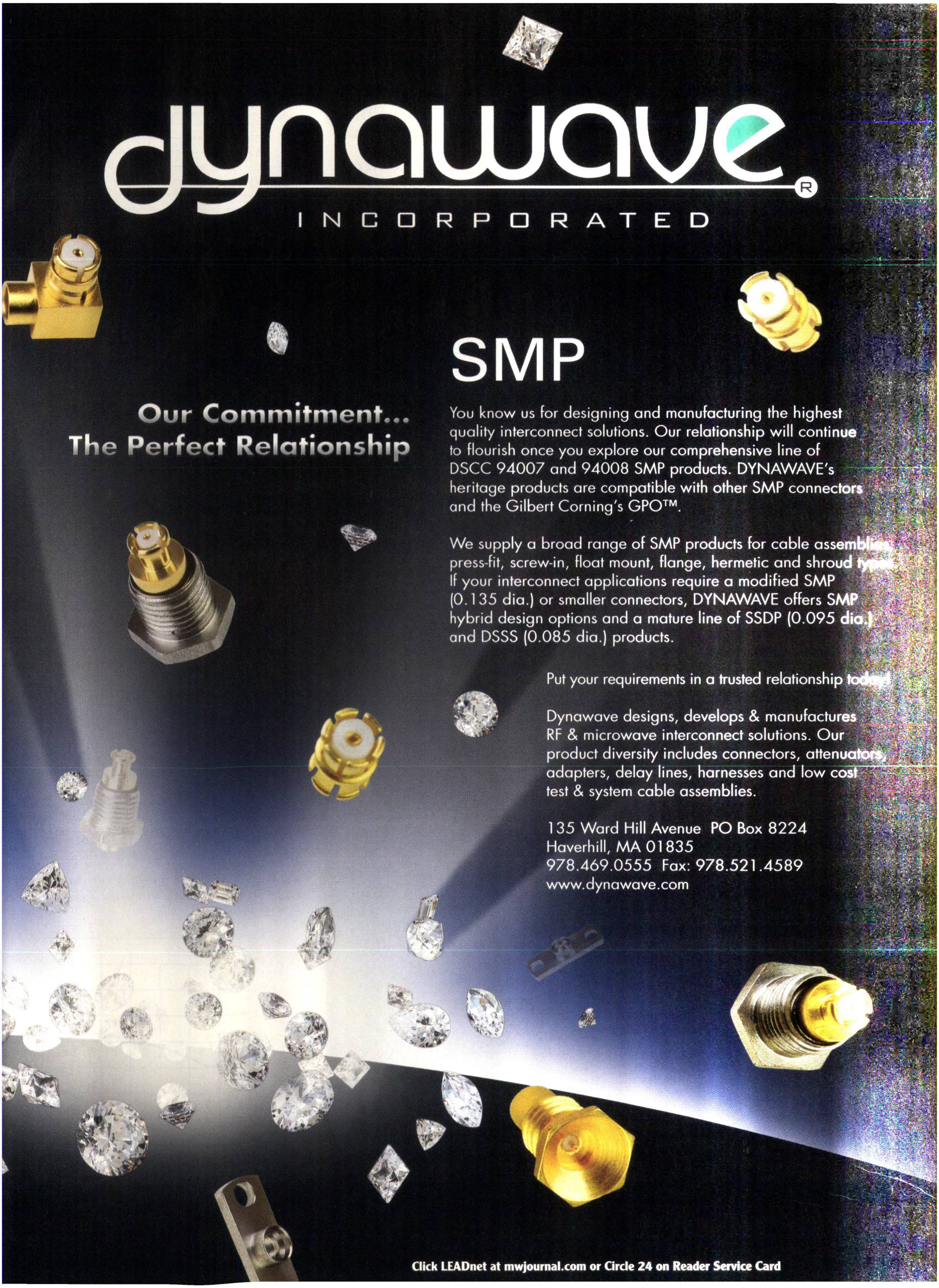
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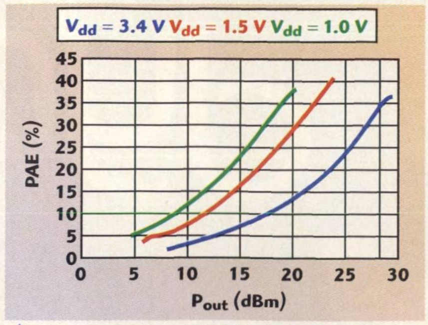
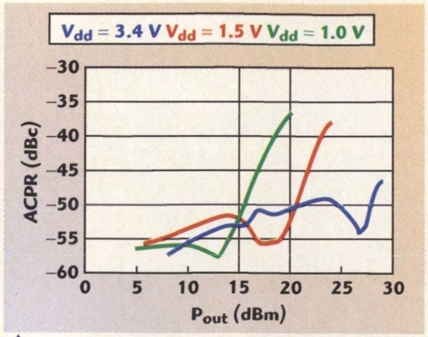
tem design and ***Figure 12*** shows the power-added efficiency (PAE) versus P_{out} data. ***Figure 13*** shows the ACPR vs. P_{out} data.

The efficiency obtained with a MOSFET amplifier and a V_{dd} control system is 2.2 to 3.4 times better than it is without a control system. Moreover, it is 1.5 to 1.7 times better than using the bias control method for V_{ref}. The V_{dd} control approach also works for V_{dd} <1 V operation for the P_{out} < 15 dBm output condition. Data for device current (I_{dd}) are plotted in ***Figure 14***.

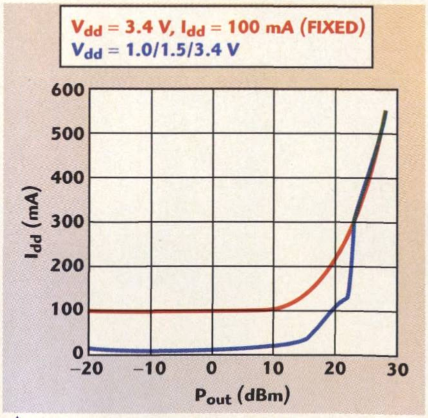
Figure 15 shows that a MOSFET power amplifier can operate at V_{dd} = 1.0 V and maintain a +15 dBm output, while meeting the IS-95 specifications for ACPR. A GaAs HBT device typically needs at least V_{dd} = 1.6 V to meet these specifications, and



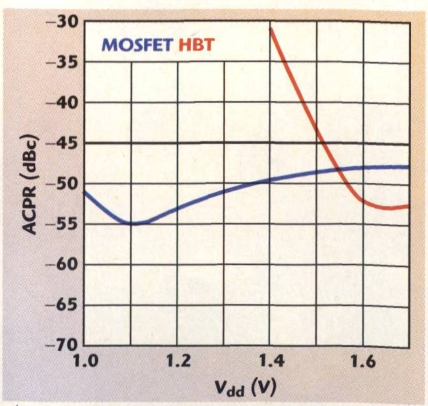
▲ *Fig. 12 Power-added efficiency vs. P_{out} for a MOSFET amplifier with a three-step V_{dd} control system.*



▲ *Fig. 13 ACPR vs. P_{out} for a MOSFET amplifier with a three-step V_{dd} control system.*



▲ *Fig. 14 MOSFET amplifier current vs. P_{out} with and without a three-step V_{dd} control system.*



▲ *Fig. 15 ACPR at +885 kHz vs. V_{dd} for a MOSFET and an HBT amplifier.*

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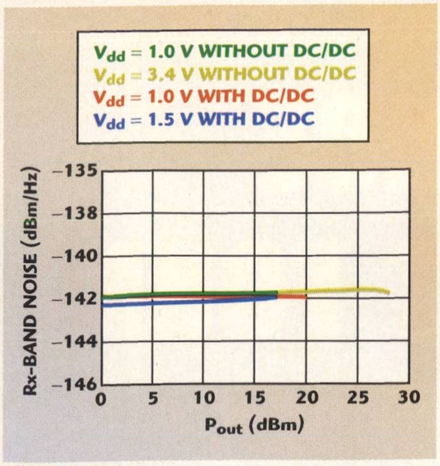
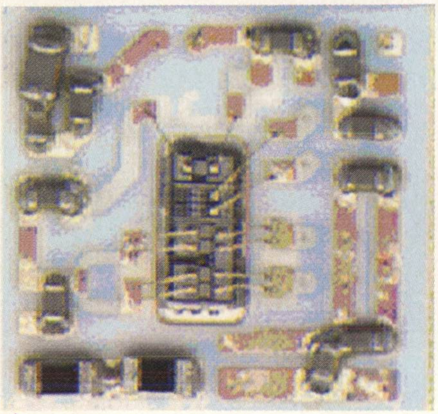
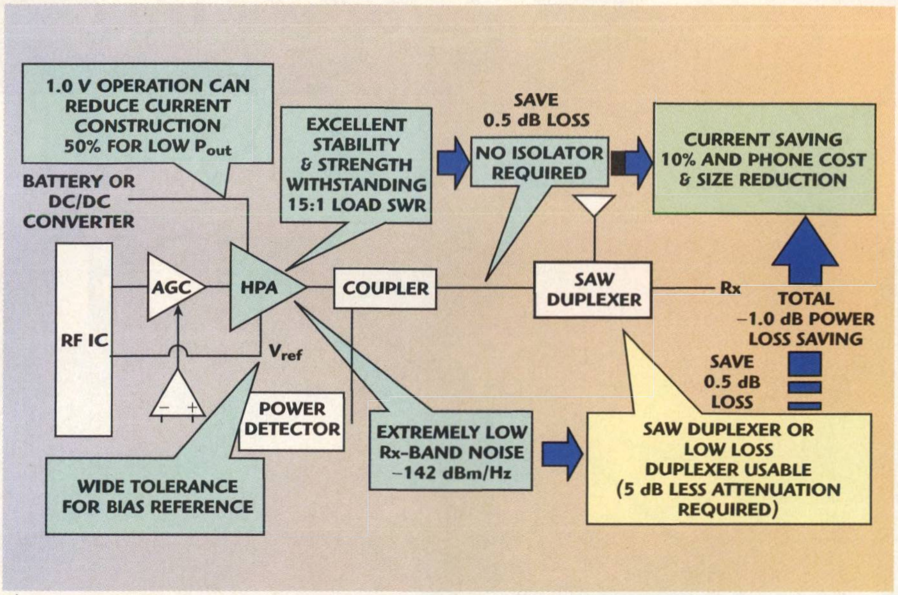


▲ *Fig. 16 Rx-band noise vs. P_{out} with and without the DC/DC converter to generate V_{dd}.*



▲ *Fig. 17 MOSFET RF power amplifier for CDMA systems.*



▲ *Fig. 18 Advantages of a MOSFET power amplifier for a CDMA system.*

usually a few tenths more voltage to account for temperature dependencies. Designers can take advantage of the MOSFET's low voltage operation to extend battery life by controlling the device voltage to obtain optimal output power.[4]

One way to implement the V_{dd} control system is to use a switching DC/DC converter. A key concern regarding this approach is that the converter might add noise to the RX-band. A test was performed which proved that this was not the case. ***Figure 16*** shows the RX-band noise versus output power with and without the DC/DC converter as the power supply for the MOSFET amplifier. It demonstrates that there was no measurable addition of noise to the RX-band as a result of using the DC/DC converter.

GENERAL ADVANTAGES OF MOSFET TECHNOLOGY

With the MOSFET process, low cost, large-diameter silicon wafers can be used in manufacturing. Large production quantities of chips are readily obtained. Also, resistors, capacitors and control devices can be integrated with the RF power transistors, so small-size, low cost MOSFET IC die can be mass produced that reduce the component count of the power amplifier modules. ***Figure 17*** shows a 6 × 6 mm PCS MOSFET module with a MOSFET IC die and discrete components.

MOSFET power amplifiers have one more characteristic that gives them an edge over other types of amplifiers. Silicon is considered an environmentally compatible material, whereas the GaAs in HBT devices, among others, is not. This is a consideration for companies interested in environmentally safer products.

CONCLUSION

The MOSFET process has advanced to the point where it is now a reliable technology for building high power amplifiers for CDMA systems. Designers can take advantage of MOSFET characteristics to develop more efficient, lower cost handsets. In particular, they can use the silicon technology to create systems with isolator-free operation, low RX-band noise generation for better sensitivity and high efficiency operation. ***Figure 18*** summarizes the advantages of using flexible, stable MOSFET high power amplifiers.

The MOSFET devices now commercially available include IS-95 compliant CDMA high power amplifier modules for 0.8 GHz cellular-band dual-mode CDMA/AMPS and 1.9 GHz PCS CDMA applications. These modules have a 6 × 6 mm multi-layer ceramic package with a plastic top that is internally matched to 50 Ω. Standard specifications of the modules are Gain = 24dB (min), P_{out} = 28 dBm, PAE = 32 percent and Rx-band noise = −142 dBm/Hz. These products can also be used for cdma2000 1X RTT systems. ■

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Tetsuo Sato *earned his BS degree in electrical engineering from Iwate University, Iwate, Japan. He joined the Hitachi Semiconductor & Integrated Circuit Division in 1974, dedicating most of his tenure to leading system and circuit designs of analog and digital mixed signal ICs for wireless applications. Sato recently*

[Continued on page 78]

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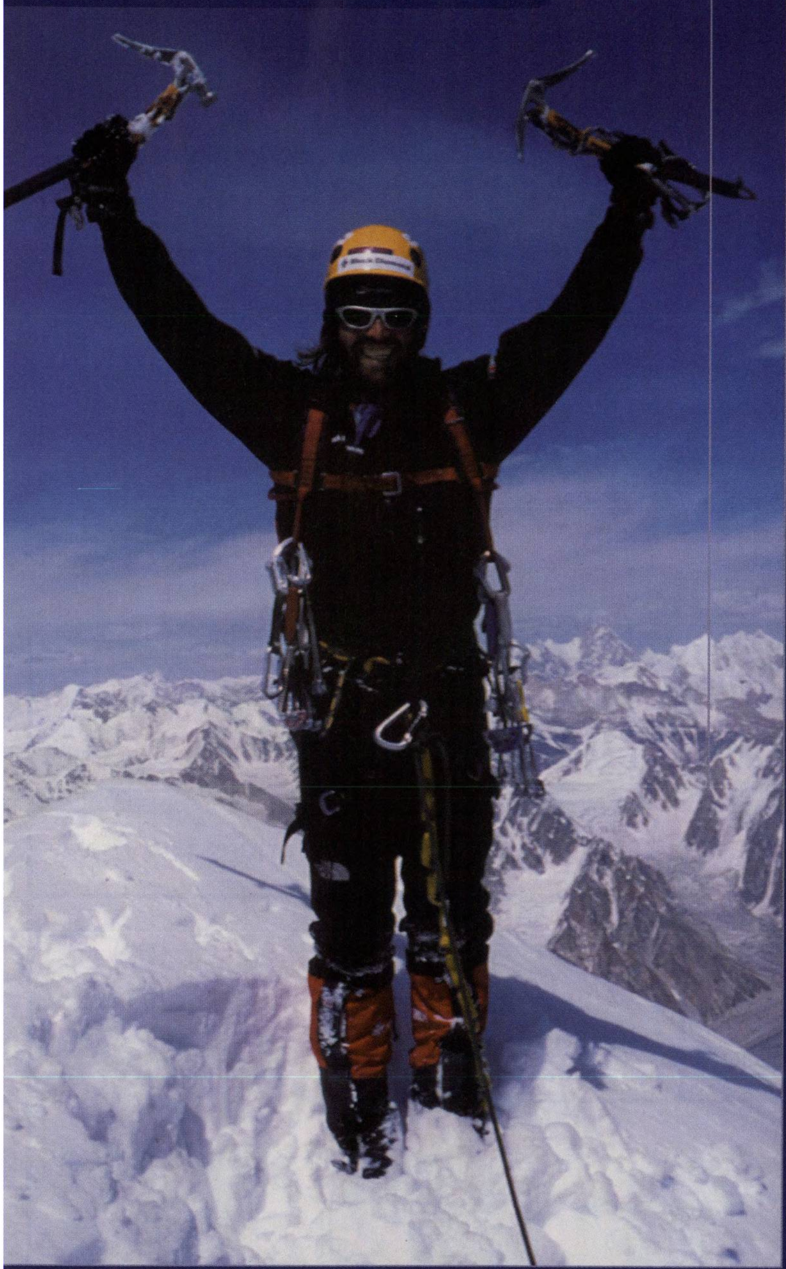

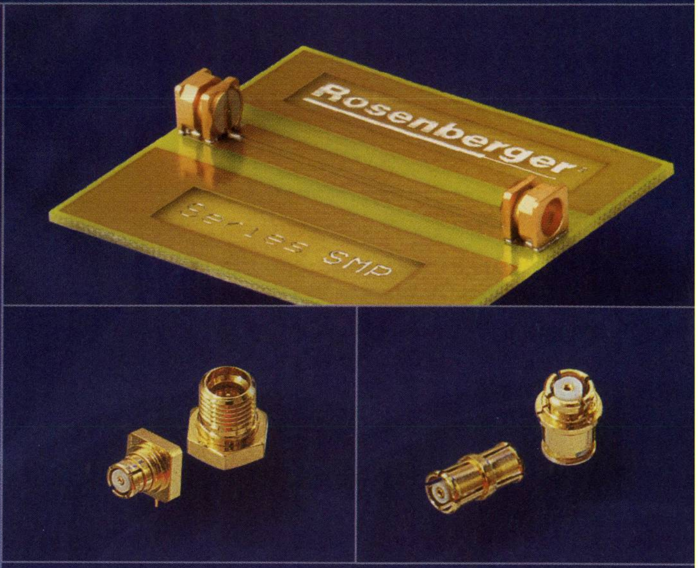

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transferred to Hitachi Semiconductor (America) to maximize his core competence for the US wireless market. He currently oversees the technical support infrastructure for all semiconductor products for wireless systems. His areas of product responsibility include wireless transceiver ICs, RF modules and discrete devices. He is a member of both IEEE Solid-State Circuits and the Institute of Electronics Information and Communication Engineers.

Chris Grigorean *earned his BS degree in electrical engineering from the Florida Institute of Technology, Melbourne, FL. He is currently working on his MBA degree at San Jose State University. He joined Hitachi Semiconductor (America) in June 2001, and currently serves as an application engineer responsible for product testing and technical support for Hitachi's RF products for wireless devices. His areas of expertise include circuit designs of microstrip, stripline, amplifiers, power splitters, couplers, filters and use of various MMICs for subsystem design and system architecture. Prior to joining Hitachi, he worked at SSE Telecom as an electrical engineer and designed a direct conversion RF module and various other RF circuits for the company's new product line. He is a member of the IEEE MTT society.*

APPENDIX A

MOSFET AMPLIFIER CHARACTERISTICS MEASURED AT 1850 MHZ FOR DIFFERENT LOAD MISMATCHES

Load SWR	Position	P_{in} (dBm)	P_{out} (dBm)	Gain (dB)	Idd (mA)	Eff (%)
1:1	0	1.8	28.87	26.5	622	31.7
6:1	1	4.0	28.21	24.2	846	23.0
	2	2.3	28.04	25.8	619	30.2
	3	–0.6	27.34	28.0	329	48.4
	4	–2.1	27.38	29.5	252	63.7
	5	0.0	28.76	28.8	507	43.5
	6	3.0	29.23	26.2	832	29.6
	7	4.2	28.49	24.3	952	21.8
	8	4.5	27.95	23.4	943	19.4

V_{dd} = 3.4 V V_{ref} = 2.8 V ACPR@±1.24 MHz = –45 dBc

APPENDIX B

MOSFET AMPLIFIER CHARACTERISTICS MEASURED AT 1910 MHZ FOR DIFFERENT LOAD MISMATCHES

Load SWR	Position	P_{in} (dBm)	P_{out} (dBm)	Gain (dB)	Idd (mA)	Eff (%)
1:1	0	0.7	28.11	27.4	552	34.4
6:1	1	3.0	28.09	25.1	762	24.8
	2	2.2	28.13	26.0	640	29.8
	3	–0.7	27.12	27.8	415	36.4
	4	–3.2	26.22	29.5	286	43.0
	5	–2.4	27.18	29.6	341	45.0
	6	0.1	28.24	28.1	528	37.1
	7	2.2	28.52	26.3	720	29.0
	8	3.0	28.20	25.2	773	25.1

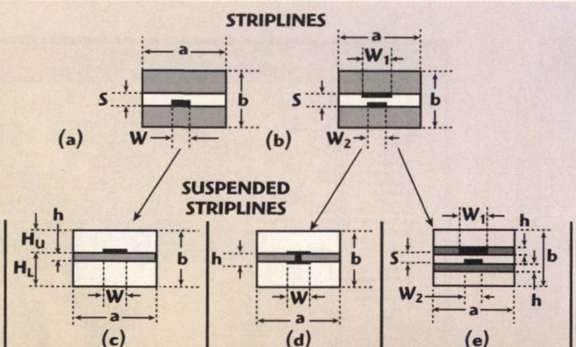
V_{dd} = 3.4 V V_{ref} = 2.8 V ACPR@±1.24 MHz = –45 dBc

REVIEWING THE BASICS OF SUSPENDED STRIPLINES

Suspended striplines are widely used for several reasons. They provide high Q-factor, wide bandwidth and good temperature stability. This tutorial reviews some of the basic principles and new concepts for suspended striplines.

There are several reasons for the wide use of printed transmission lines. They are simple to produce, they operate over a wide bandwidth, and have small weight and dimensions. The earliest form of printed transmission lines was the stripline (***Figure 1a***).[1,2] The printed stripline consists of a strip conductor centered between two parallel ground planes with two identical dielectric substrates. Small air gaps can exist between the two substrates because of fabrication faults. A dominant leaky mode that can exist in such a structure results in undesirable cross-talk and spurious performance.[3] The detrimental effect of such gaps can be eliminated by using mirror image conductors (Figure 1b) on top of the bottom substrate and on the bottom of the top substrate. Due to multiple points of contact along the two conductors, the electric field in the gap is cancelled. In practice, the widths of two center conductors are purposely made slightly different ($W_1 \neq W_2$). The wider conductor is given the width required for the desired characteristic impedance and the other conductor is made slightly smaller. In this way, even if the conductors are

Fig. 1 Stripline configuration.



	(c)	(d)	(e)
ADVANTAGES	SIMPLE CONFIGURATION	HIGHEST Q-FACTOR TEMPERATURE STABILITY	NO SPECIAL REQUIREMENTS FOR PLATING HIGH INTEGRATION INDEX LOW OHMIC LOSSES
DISADVANTAGES	SPECIAL REQUIREMENTS FOR PLATING NON-SYMMETRICAL CONFIGURATION (HIGH MODES) DIELECTRIC LOSSES	ADDITIONAL VIAS SPECIAL REQUIREMENTS FOR PLATING	DIELECTRIC LOSSES

Many RF and microwave components are manufactured using suspended striplines (SS), which yield a higher Q-factor than printed stripline and microstrip lines...

[Continued on page 84]

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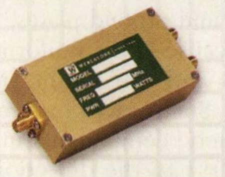

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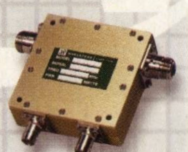

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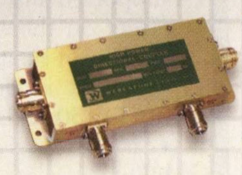

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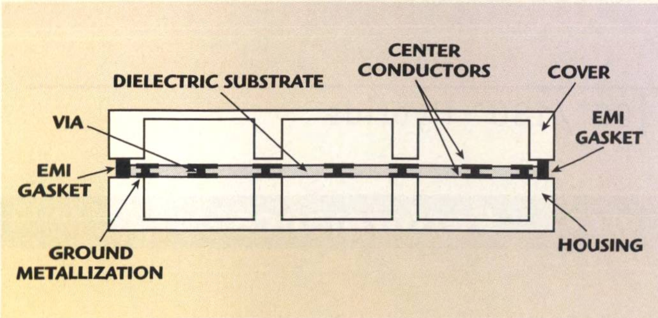

Fig. 2 Suspended stripline three-channel design.

somewhat misaligned, the effective width appears constant with the proper value.

Many RF and microwave components are manufactured using suspended striplines (SS), which yield a higher Q-factor than printed stripline and microstrip lines (ML).[4–7] The SS is a modified version of the stripline. In the SS (Figure 1c to e) the strip conductors are placed on the surfaces of a thin dielectric substrate, and the substrate is then suspended in a metal enclosure. The major portion of the electromagnetic field is confined to the air gaps between dielectric substrate and ground plates. The SS propagation is purely TEM because of the uniform dielectric (air) and the symmetrical configuration. Such waves have electric and magnetic components in the plane transverse to the direction of propagation.

Figure 2 illustrates the cross-sectional view of a suspended stripline three-channel design. A suspended stripline circuit consists of a thin copper clad substrate, photolithographically etched, and suspended in air between identical housing and cover. This substrate is secured with internal and external walls to add further support to the PCB and provide a symmetrical position of the PCB between the housing and cover. Plated through-holes (vias) and electromagnetic interference (EMI) gaskets in the area of the support walls provide grounding connection between the housing and cover, channel-to-channel isolation, RF leakage suppression and moisture sealing. The channel dimensions should be chosen so that the spurious waveguide mode propagation is inhibited.

The suspended stripline has the following advantages:

- it provides low losses and high Q-factor (up to 500) because most of the propagated energy is in the air dielectric
- the air dielectric also helps to increase the integrated circuit dimensions which are crucial for high microwave and millimeter-wave devices, and offers larger fabrication tolerances
- the dielectric characteristics of the supported substrate have a negligible effect on the attenuation and phase velocity of the transmission medium
- a wide range of impedance values (up to 150 Ω) is available
- it possesses good temperature stability
- with good design, it has no waveguide modes

[Continued on page 86]

- it operates over wide bandwidth
- there is no radiation to the outside
- both sides of the suspended substrate are available for circuit patterns enabling broadside strong coupling or combination with microstrip, coplanar or slot line

The disadvantages of the suspended striplines are difficulties in miniaturization and critical housing technology.

In the basic shielded high Q SS (Figure 1d), the parallel strips are printed on both sides of the dielectric substrate in a symmetrical configuration. The top-to-bottom circuit board interconnections are achieved via plated through-holes. This is realized by drilling a hole through the dielectric substrate and then chemically depositing electroless copper inside the walls of the hole in order to bridge the two conductors of the SS. When the dual center conductors in the SS are located symmetrically over each other, they are excited in phase, causing most of the electromagnetic field to propagate in the air dielectric. Therefore, the dielectric loss of the carrier substrate and variation in its dielectric constant have negligible effects on the attenuation and phase velocity of the transmitted waves. An added benefit of the symmetrical positioning of the conductors is that it prevents the launching of parasitic modes. The symmetrical geometry requires tight tolerances on the front-to-back etched pattern alignment and additional vias to connect these strips.

In the one-conductor SS, the transmission characteristics depend on the substrate thickness h, substrate dielectric constant, air-space height and width of the strip conductor. The characteristic impedance dependence on h occurs when the position of the dielectric substrate inside the housing is somewhat asymmetrical, such as when the spacing above the conductor is slightly smaller than that below the dielectric ($H_U < H_L$). This asymmetrical configuration also slightly reduces the losses.

The ohmic losses in the above two suspended striplines are a concern. The RF currents become concentrated near the outer surface of the metal for an approximate skin depth δ.[5] This is usually referred to as the skin effect. The depth δ is the level at which the current I(t) in the conductor decreases to a value of 1/e (37 percent) of its surface value. The skin depth in a conductor is given by

$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}\,(\mathrm{m}) \qquad (1)$$

where

σ = the conductivity of the conductor and the ground plane ($\sigma = 5.813 \times 10^7$ S/m for copper)
μ = the relative magnetic permeability ($\mu = 4\pi \times 10^{-7}$ A/m for copper)
f = the frequency in hertz

In the suspended striplines, currents are concentrated in approximately three skin depths. The highest current density is in the top and bottom plated surfaces that have a lower conductivity than the main copper conductors of PCB.

[Continued on page 88]

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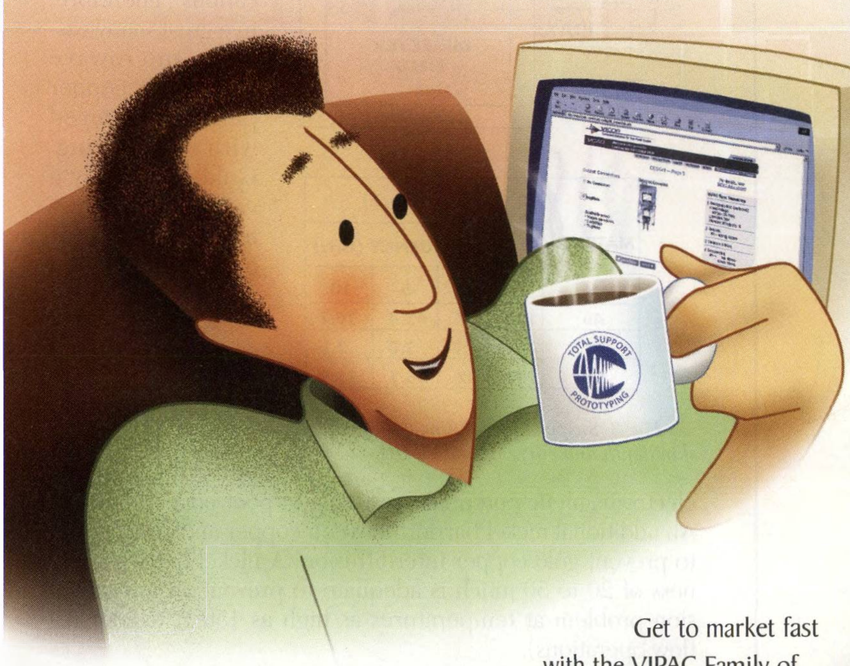

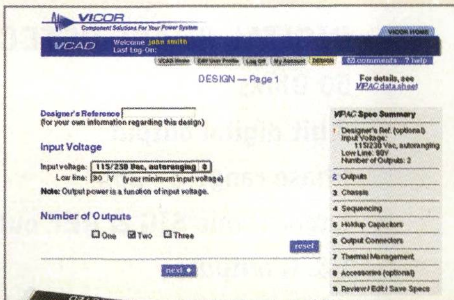

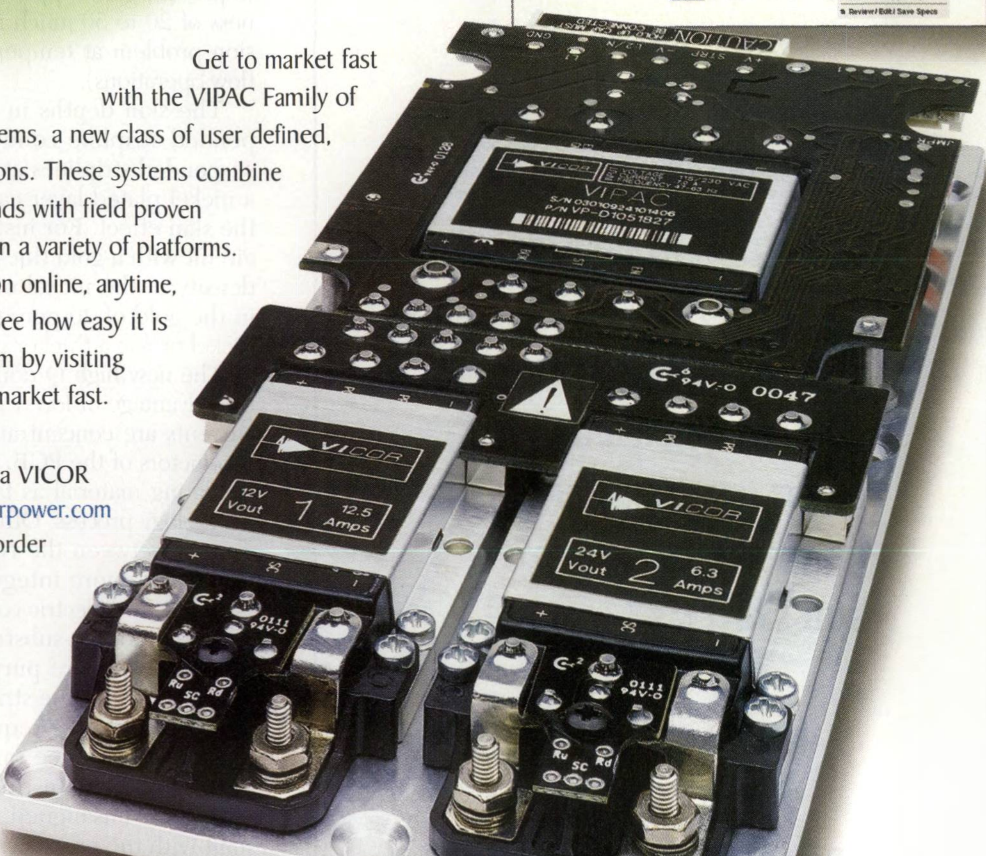

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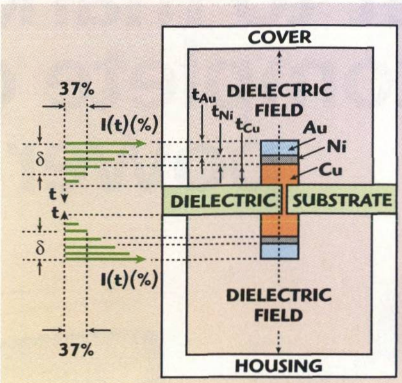


MATERIAL	THICKNESS (μinch)	δ (μinch)		
		FREQUENCY (GHz)		
		1	5	10
Au	100	97	43.4	30.7
Ni	20	6.7	3.0	2.1
Cu	1400	82	36.7	25.9

▲ *Fig. 3 Suspended stripline conductor skin depth and current density I(t).*

While bare copper circuits can be etched to high precision, the poor corrosion properties of the metal make it undesirable for practical applications. Therefore, in a great many cases, a microwave PCB has a copper pattern covered with gold plating. Gold is not only a very good conductor but also has excellent corrosion resistance. However, when the copper-gold combination is etched, accelerated etching takes place on copper because of electromagnetic potentials, resulting in poor edge definition. An additional nickel barrier between copper and gold is used to prevent gold/copper interdiffusion. A nickel barrier thickness of 20 to 50 μinch is adequate to prevent an interdiffusion problem at temperatures as high as 150°C (solder reflow operations).

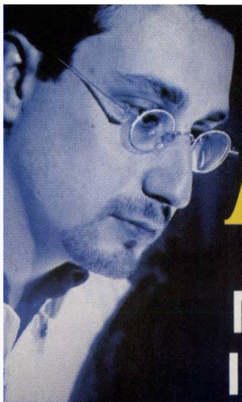
The skin depths in the three metals which form suspended stripline conductors are shown in ***Figure 3***. In suspended striplines at lower frequencies, the presence of a nickel plated layer can produce additional losses due to the skin effect. For instance, a 1 GHz suspended stripline circuit with a gold thickness of 50 μinch leads to a current density in the nickel of 60 percent and a current density in the gold of 40 percent. An alternative is to avoid using nickel or use a thicker gold plating (~100 μinch).

The new high Q double-substrate SS (Figure 1e)[7] offers the advantage of lower ohmic losses because the microwave currents are concentrated in the high conductivity copper conductors of the PCB. This feature also expands the choice of plating material as far as its conductivity, thickness and technology process. Other advantages of this line are simple contact between the two conductors (no plated through-holes) and more integration by increasing the dielectric thickness or dielectric constant of the two substrates.

In the double-substrate SS, the widths of the two center conductors are purposely made slightly different ($W_1 \neq W_2$), similar to the stripline in Figure 1b. The wider conductor is given the required width for the desired characteristic impedance, and the other conductor is made slightly smaller. In this way, even if the conductors are somewhat misaligned, the effective width appears constant with the proper value.

Some recommendations for choosing the physical dimensions of the SS follow. Large height b (the distance between top and bottom ground plates) leads to a higher power capability and Q-factor of the SS. The strip width

[Continued on page 91]



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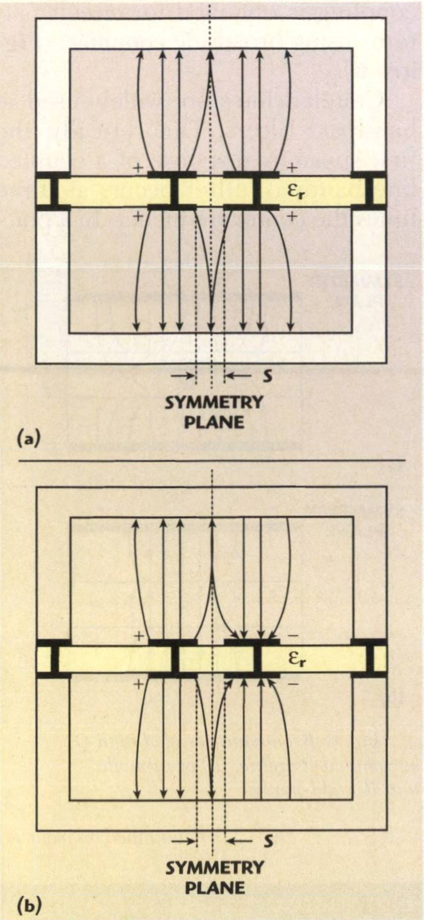

▲ *Fig. 4 Edge-coupled high Q suspended striplines; (a) even-mode and (b) odd-mode.*

should be decreased in order to decrease the overall dimensions, as well as to suppress the high modes. It is important to remember, however, that a smaller strip width leads to higher losses. Also, a smaller strip for the same impedance requires a smaller height. Mechanical tolerances would be more critical for a relatively small height or relatively narrow center conductors. Any vertical asymmetry in the suspended stripline structure could couple to parasitic waveguide-type modes, bounded by the ground planes and the side-walls.

Surface modes cannot propagate at frequencies for which the channel is less than a half-wavelength in width. The dimensions of the suspended stripline channel in which the substrate is supported must be sufficiently small to avoid propagation of waveguide modes. The cutoff frequency at which the TE_{01} mode becomes dominant is

$$f_c = \frac{c}{2a}\sqrt{1-\frac{h}{b}\left(\frac{\varepsilon-1}{\varepsilon}\right)} \qquad (2)$$

where

a = width of the enclosure

The thickness of the dielectric substrate should be minimized for the SS in Figure 1c and d to minimize the losses and the parasitic inductance of vias, and to reduce price. For the new double-substrate SS of Figure 1e, the substrate thickness can be chosen based upon compromise between integration index and dielectric losses.

COUPLED SUSPENDED STRIPLINES

Coupled lines are two or more transmission lines with distributed electromagnetic coupling between them. Coupled lines are a most useful and widely applied structure that provides the basis for directional couplers, filters, coupling elements and phase shifters.

The most convenient method for calculation of coupled suspended striplines with a symmetry plane (see ***Figure 4***) is the method of even- and odd-mode excita-

[Continued on page 92]

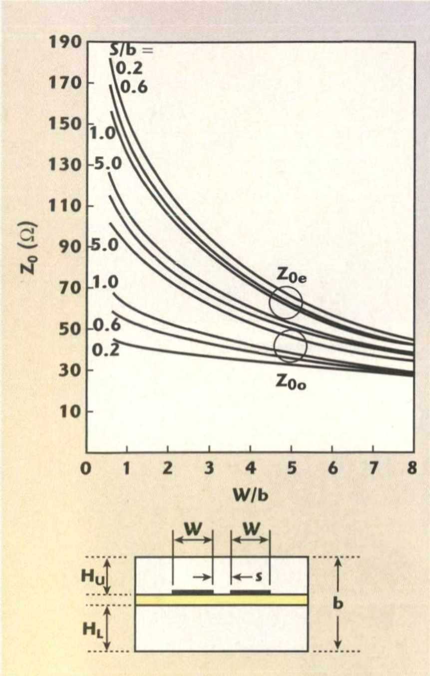

Fig. 5 Even- and odd-mode impedances of edged-coupled suspended striplines.

tion.[8–11] Then the coupled lines can be said to have even-mode and odd-mode characteristic impedances Z_{0e} and Z_{0o} (the last suffix identifies the mode). Z_{0e} corresponds to the strips being at the same potential and carrying equal currents in the same direction. Z_{0o} corresponds to the strips being at equal but opposite potentials and carrying equal currents in opposite directions. The wall at the plane of symmetry acts as an electrical wall for the odd-mode and as a magnetic wall for the even-mode.

When synthesizing suspended coupled lines, the physical dimensions are determined by the even- and odd-mode impedances which are calculated based on the specified electrical characteristics of the coupled line devices (directional couplers, filters, etc). When analyzing coupled line devices, the physical dimensions are given and one must determine the electrical characteristics which depend on Z_{0e} and Z_{0o}. ***Figure 5*** illustrates even- and odd-mode impedances for edge-coupled suspended striplines.

Coupled suspended striplines offer lower insertion loss and the ability to achieve tight coupling. The tight coupling is obtained for circuit patterns using broadside coupling[8] (***Figure 6***).

Coupled lines are widely used in bandpass filters. Theoretically, the first spurious response of a coupled line bandpass filter occurs at three times the center frequency. In a prac-

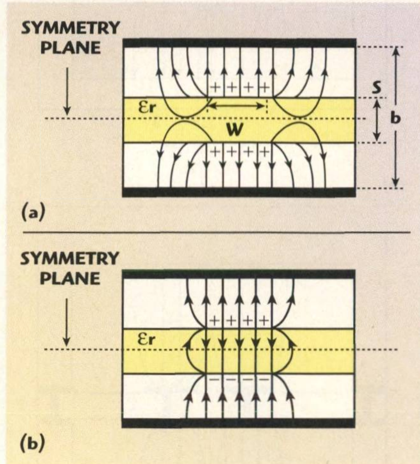

Fig. 6 Broadside-coupled high Q suspended stripline; (a) even-mode and (b) odd-mode.

[Continued on page 94]

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For DLI Associate Fran Weismore, performance is more than a slogan, it's a personal commitment. Her husband, Todd, is a Sergeant in the National Guard Army Reserves, 108th Infantry, based in Rome, N.Y. "Every time a part goes out, I know that people like Todd are counting on it, and that their families want them to come home safe just like I do. That's why I take this work so seriously."

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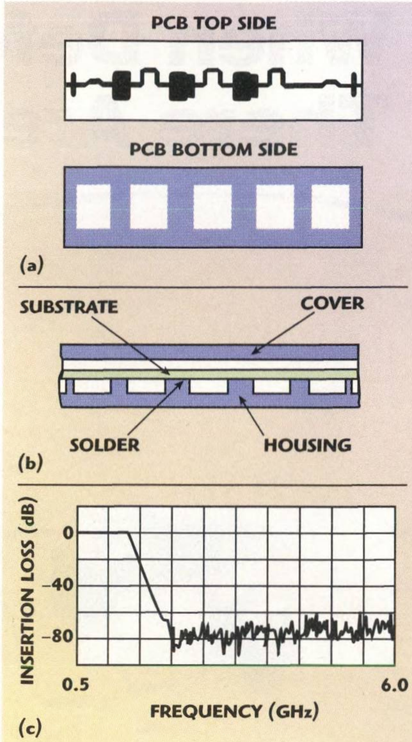
2777 Route 20 East • Cazenovia, New York 13035 • Phone: 315-655-8710 • Fax: 315-655-8179 • www.dilabs.com • ISO 9001 & ISO 14001 Certified tical microstrip parallel-coupled line bandpass filter, a spurious mode occurs at nearly twice the passband frequency because of the different even- and odd-mode propagation velocities of the coupled resonators. In the suspended coupled striplines, electromagnetic fields propagate in an isotropic media, and the phase velocities for even- and odd-modes are equal. This property enables high performance to be achieved in filters and directional couplers. Also, coupled suspended striplines have lower losses and a lower sensitivity to fabrication tolerances than microstrip or stripline coupled lines.



▲ *Fig. 7 Suspended stripline/microstrip line low pass filter; (a) top and bottom PCB sides, (b) side view and (c) LPF insertion loss.*

COMBINATION OF SUSPENDED STRIPLINE AND MICROSTRIP CIRCUITS

Suspended striplines and microstrip lines (ML) offer certain advantageous features with respect to each other.[7] Although the microstrip circuit occupies a smaller area on the substrate, it has high insertion losses (lower Q-factor) and poor temperature stability. For some applications, a combination of these two types of line provides a higher performance. Both sides of the substrate are available for circuit patterns, enabling this combination. This conception is illustrated in the following examples.

A low pass filter (LPF) that uses a combination of SS and ML is shown in ***Figure 7***. This design uses series high impedance suspended stripline inductive elements and low impedance shunt microstrip capacitive elements. This combination of two different lines allows a very large impedance ratio and therefore very good stopband performance in addition to small size. The capacitive element is formed with the ground plane metallization on the PCB bottom side under the low impedance line. The PCB is supported in these areas by a housing pedestal. The PCB bottom side ground plane is soldered to the housing pedestal. Inductor elements are realized by meander suspended striplines in order to minimize losses and size.

The measured insertion loss and rejection characteristics are shown for an 11-section LPF with a 10 mil Duroid™ substrate. This filter provides an insertion loss of less than 0.2 dB, an SWR of less than 1.2 in the frequency range up to 1.2 GHz, and an attenuation of more

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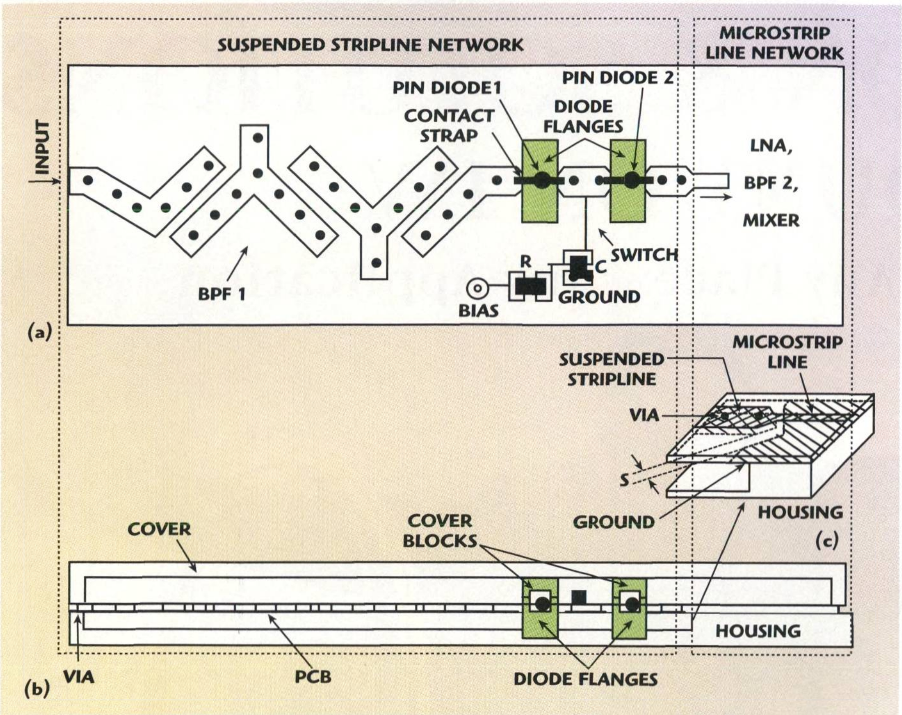

▲ *Fig. 8 Suspended stripline/microstrip receiver block; (a) top PCB view, (b) PCB, housing, cover side view and (c) transition from suspended stripline to microstrip line (without cover).*

than 60 dB in the frequency range between 2 and 10 GHz.

The second example is a C-band receiver using a combination of suspended stripline and microstrip lines (***Figure 8***). To minimize the receiver input noise figure, the input circuit (BPF1 and PIN diode switch) is based on a high Q SS. The low noise amplifier (LNA) and another network are based on ML. The ML offers advantages of size reduction, heat removal and easy ground connection.

The suspended stripline BPF1[12] includes coupled lines and open-ended lines. The half-wavelength resonators are bent in the center and are connected with the open-ended line. The physical length of the open-ended line is equal to a quarter-wavelength at the second harmonic of the input signal for high second harmonic attenuation. The C-band suspended stripline BPF1 shows the following electrical characteristics: insertion losses are less than 0.5 dB, the 3 dB bandwidth is 5.5 percent, the 20 dB bandwidth is 17 percent and the second harmonic attenuation is greater than 40 dB.

The suspended stripline, two-diode, shunt-iterated SPST switch is also shown. For PIN diodes

[Continued on page 98]

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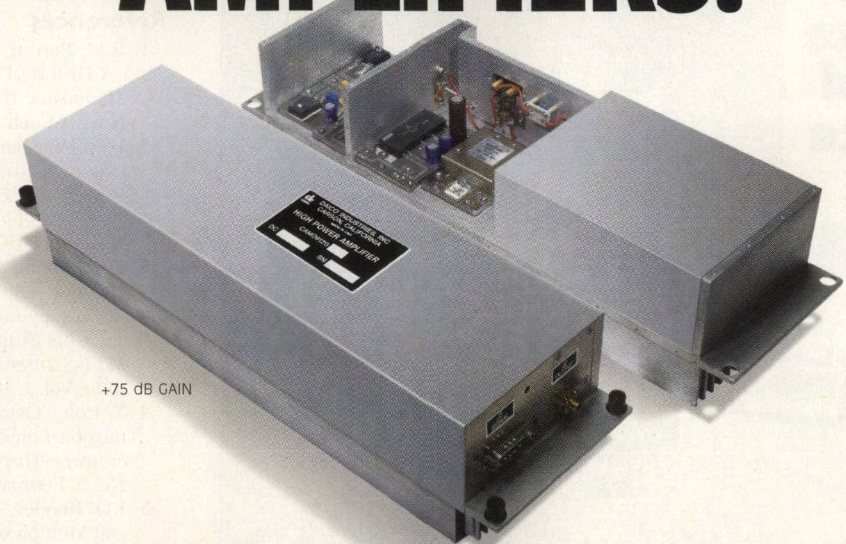

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ELECTRICAL SPECIFICATIONS

Parameter	Min	Typ	Max	Unit	Notes
Frequency	430		470	MHz	50% in band
Small Signal Gain	75		80	dB	
VSWR In/Out			1:2:1		
P1 dB Comp.	63.5	64.0		dBm	
Harmonics Out II, III	60	65		dBc	
Gain Tracking		±0.2	±0.3	dB	Unit-to-unit
Phase Tracking		±2.0	±3.0	degree	Unit-to-unit
VSWR Withstand Under Full Power			∞:1		All phases
Efficiency	52	57		%	
Duty Cycle			15	%	

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M5X3736 (Metelics) with a junction capacitance of 0.12 pF, the optimum spacing between diodes is a little less than a quarter-wavelength (electrical length Θ<90°). The main objectives in the design of the suspended stripline switch are low insertion loss and high isolation. This C-band switch provides isolation greater than 50 dB and loss less than 0.5 dB.

The suspended stripline switch is connected to a microstrip LNA, BPF2 and a mixer. The microstrip design offers advantages for heat removal, a good ground connection and small size for the LNA and output elements. The interconnection between the suspended stripline switch output and microstrip network is shown.[7] The top conductors of the SS and ML are positioned on the same side of a single dielectric substrate, and share the same top ground plate (cover). The bottom conductor of the SS has no connection with the microstrip bottom ground plate (space S), which is connected with the bottom SS ground plate (housing). Improvements in bandwidth and size minimization can be carried out by adjusting the transition line shape (gradually decreasing width) and space S. Experimental results are 0.1 dB insertion loss (max) and 19 dB return loss (min) in the C-band frequency range. This example of a combination of suspended stripline and microstrip elements is effective for simultaneously providing frequency selectivity, low noise figure and small dimensions. ■

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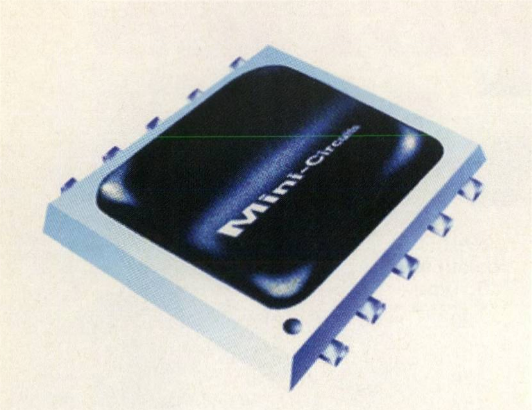


AN LTCC DOUBLE-BALANCED MIXER

Double-balanced mixers are used extensively in transmitters and receivers. For frequencies below 5 GHz, the designs are normally realized using ferrite-based transformers, because they are very compact and their technology is mature. As the operating frequency increases, distributed element baluns become smaller in size and more attractive.

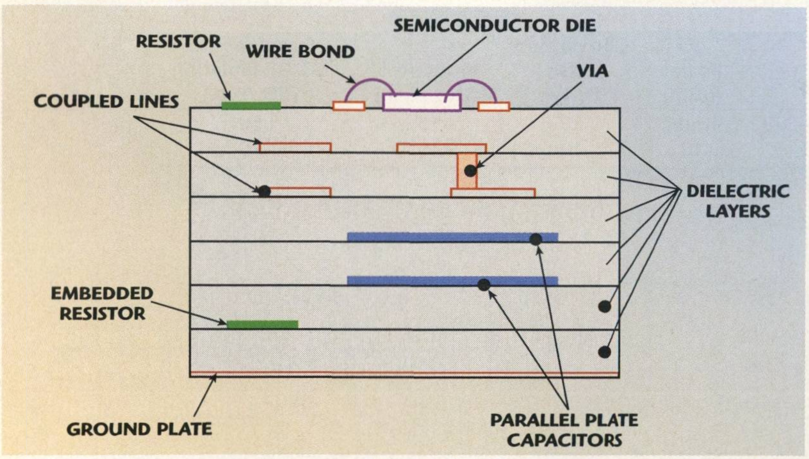
Semiconductor-based mixers are the most compact. However, changing the design is very time consuming and expensive. Therefore, these mixers are generally targeted for high to super-high volume applications.

Blue Cell™ low temperature co-fired ceramic (LTCC)-based mixers are small in size, lower in cost and can be customized to meet various needs. They are easier to customize than semiconductor mixers and are ideal for moderate to high volume applications. A series of Blue Cell™ LTCC-based mixers have been designed and are being offered as standard catalog products.

BLUE CELL LTCC

Blue Cell LTCC technology provides the means to produce multi-layer circuits with ceramic substrate tapes. Conductive, dielectric and resistive pastes are applied on each ceramic sheet or tape, then numerous sheets are laminated together and fired (often in a precisely controlled oven or kiln) in one step. The resulting design is a hermetic, monolithic structure. A typical Blue Cell LTCC structure is illustrated in ***Figure 1*** and consists of multiple dielectric layers, screen-printed or photoimaged low loss conductors, embedded resistors and capacitors, and via holes for interconnecting the multiple layers.

Fig. 1 Typical Blue Cell LTCC structure.



Each layer can be inspected before firing to replace damaged circuits and improve yield. Because firing takes place at low temperatures, typically about +850°C, low resistivity conductor materials, such as silver and gold, can be used instead of the molybdenum and tungsten materials typically used with high temperature co-fired ceramic (HTCC) processes. Since Blue Cell LTCC is a repeatable process, it can reliably produce large quantities of RF and microwave components measuring a fraction of the size of components fabricated with conventional substrate materials. To practically and cost-effectively apply Blue Cell technology, a series of sophisticated three-dimensional computer models have been developed using the latest electromagnetic (EM) simulation tools. These proven computer models allow new and custom LTCC components to be developed quickly, economically and reliably, with a high degree of first-pass design success. Blue Cell LTCC technology yields a highly integrated, surface-mount module that can in turn be used as a platform to mount active components, such as transistors and monolithic amplifiers, to form a miniature multifunction as-

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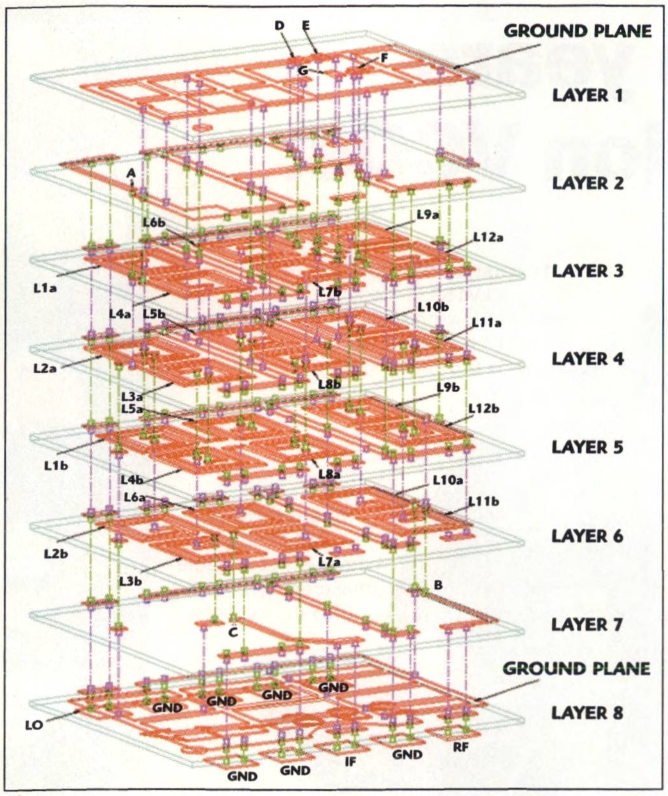


▲ *Fig. 2 A practical LTCC circuit.*

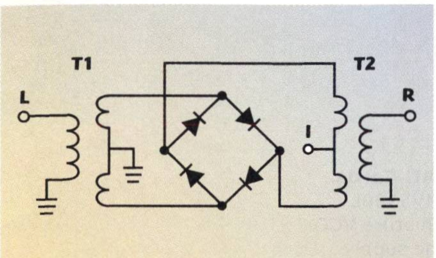
sembly. The resulting Blue Cell LTCC design is a multi-layer, three-dimensional design, such as that shown in ***Figure 2***, that is considerably more compact than a traditional, planar microwave component. High level integration allows Blue Cell LTCC components to be packed within a miniature, surface-mount package, eliminating the need for many external components. In addition, Blue Cell LTCC designs can employ circuit elements in die form for further reductions in size. Since the ceramic materials used in Blue Cell LTCC designs are inherently temperature stable, the need to compensate for variations in temperature is greatly reduced.

CONSTRUCTION

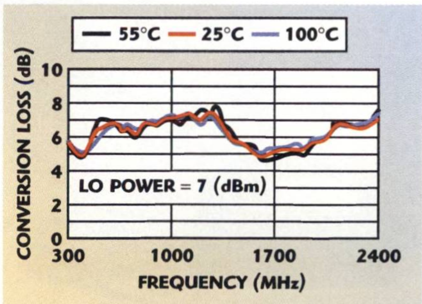
Figure 3 is a schematic of a wide bandwidth double-balanced mixer whose intermediate frequency response extends to DC. The actual mixer design is patent pending. Baluns T1 and T2 are implemented using transmission line baluns distributed over multiple layers. Proven reliability Schottky barrier diodes are used as mixing elements. Solder-plated leads are welded using a patent-pending process to the bottom of the LTCC board to provide interface to the surrounding circuit.

ELECTRICAL PERFORMANCE

The temperature sensitivity of the material used in LTCC generally results in negligible variation of electrical performance. ***Figure 4*** shows the conversion loss of the MCA1-24 mixer as a function of frequency and temperature. These mixers are specified to operate over –55° to 100°C and are suitable for most commercial and military applications. Variation of conversion loss with LO power is basically a property of the semiconductor mixing elements and circuit design.



▲ *Fig. 3 Schematic of the double-balanced mixer.*



◀ *Fig. 4 Conversion loss vs. temperature of a MCA1-24 mixer.*

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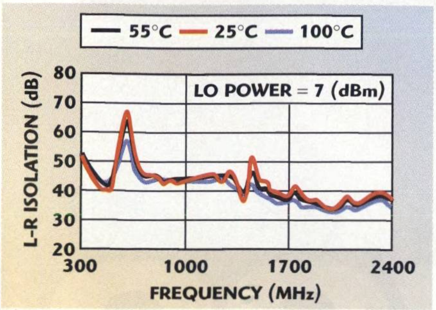
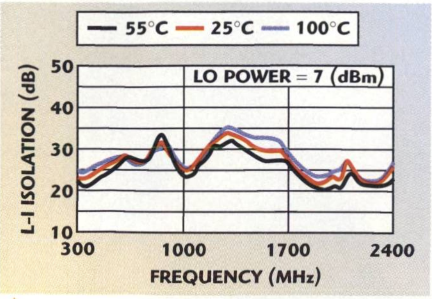
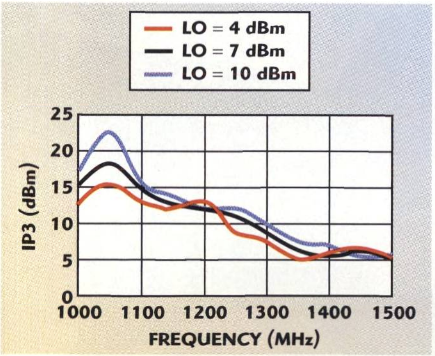


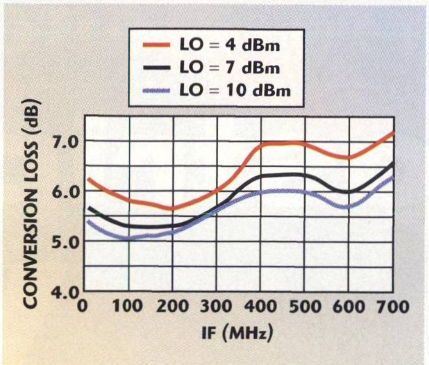
▲ *Fig. 5 L-R isolation vs. temperature of a MCA1-24 mixer.*



▲ *Fig. 6 L-I isolation vs. temperature of a MCA1-24 mixer.*

▼ *Fig. 7 IP3 of a MCA1-24 mixer.*





▲ *Fig. 8 Conversion loss (variable IF) of a MCA1-24 mixer.*

Fig. 9 1 dB compression of a MCA1-24 mixer. ▼

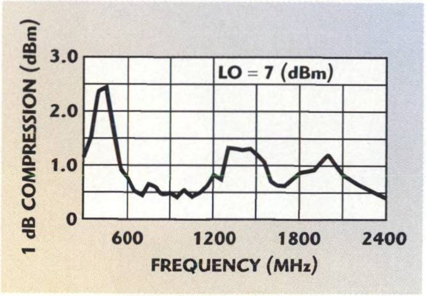


Figure 5 shows LO-to-RF (L-R) isolation vs. frequency and temperature. Note that the variation with temperature is negligible. Variation of isolation with LO power is typically less than ±3 dB. L-R isolation is typically in excess of 40 dB to 1.5 GHz and in excess of 30 dB over the rest of the range. This characteristic is very useful when these mixers are used in image reject, single-sideband and I/Q mixers. ***Figure 6*** shows the LO-to-IF (L-I) isolation of the same mixers with temperature. Note the L-I isolation is greater than 20 dB over most of the range and temperature variation is negligible. ***Figure 7*** shows the IP3 of the mixer. This mixer has approximately 15 dBm or higher IP3 at 1 GHz. ***Figure 8*** shows the mixer's IF response and ***Figure 9*** demonstrates the 1 dB compression performance. Note the input power required for 1 dB compression is typically around 1 dBm.

A series of mixers were developed to cover the 300 to 6000 MHz frequency range. For example, model MCA1-24 covers the frequency range 300 to 2400 MHz and operates with 7 dBm of LO power. Models MCA1-24LH and MCA1-24MH cover the same frequency band, except they operate with 10 and 13 dBm LO power. Higher LO power generally results in higher 1 dB compression and IP3. ***Table 1*** summarizes the performance of these and other mixers developed using LTCC.

CONCLUSION

A series of double-balanced mixers has been developed to cover the 300 to 6000 MHz frequency range. These mixers have a low height profile of 0.065", a small 0.25" × 0.30" size and are temperature insensitive.

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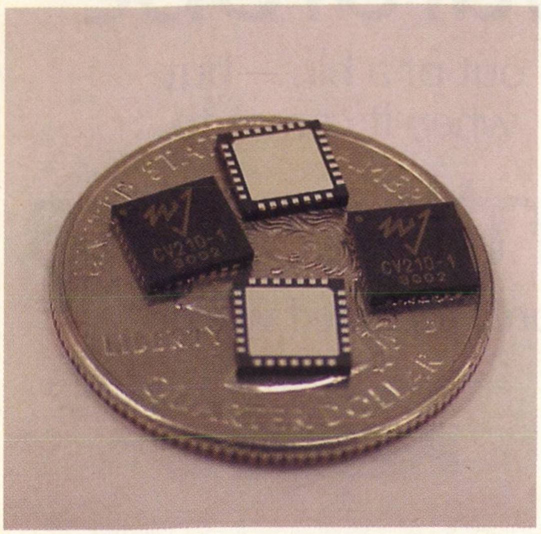
Circle No. 302

TABLE I
ELECTRICAL SPECIFICATIONS

Model No.	Frequency (MHz)		Conversion Loss (dB)		LO-RF Isolation (dB)		LO-IF Isolation (dB)		IP3@ Center Band Typ (dBm)
	LO/RF	IF	AVG	MAX	TYP	MIN	TYP	MIN	
MCA1-24	300–2400	DC-700	6.1	8.9	40	25	25	15	10
MCA1-24LH	300–2400	DC-700	6.5	8.9	40	25	22	12	13
MCA1-24MH	300–2400	DC-700	6.1	8.9	40	20	25	14	13
MCA1-42	1000–4200	DC-1500	6.1	8.9	35	23	20	12	10
MCA1-42LH	1000–4200	DC-1500	6.0	8.9	38	23	20	11	12
MCA1-42MH	1000–4200	DC-1500	6.2	8.9	35	20	20	10	16
MCA1-60	1600–4400	DC-2000	6.3	8.3	32	20	17	—	9
	4400–6000	DC-2000	6.2	8.5	23	18	18	—	8
MCA1-60LH	1700–4400	DC-2000	6.6	7.9	35	23	17	—	13
	4400–6000	DC-2000	6.0	8.3	27	20	21	—	11
MCA1-60MH	1600–4400	DC-2000	6.9	8.5	32	25	17	—	15
	4400–6000	DC-2000	6.0	8.5	22	18	15	—	15

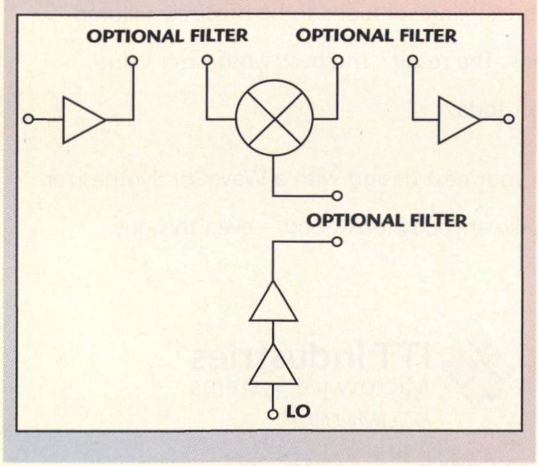


SINGLE- AND DUAL-BRANCH DOWNCONVERTER ICs FOR WIRELESS BASE STATION APPLICATIONS

A new family of single- and dual-branch converter integrated circuits has been introduced for use in mobile infrastructure base stations. The new CV series converters are all priced below $10 in volume and are available in a 6 × 6 mm QFN package, as shown above. Their small size makes them ideal for base station upgrades required to expand capacity. In addition, the performance of these converters is well suited for the newer 2.5/3 G protocols.

The functionality of these converters includes high linearity RF amplification, frequency conversion, IF amplification and LO driver amplification. Functional block diagrams for the single- and dual-branch converters are shown in ***Figures 1*** and ***2***, respectively. The dual-branch converters are ideal for base station transceivers requiring both primary and diversity channels with a common local oscillator. The single-

Fig. 1 Single-branch converter block diagram.



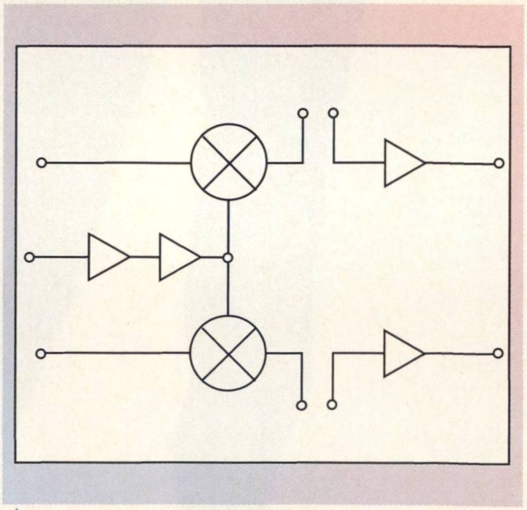


Fig. 2 Dual-branch converter block diagram.

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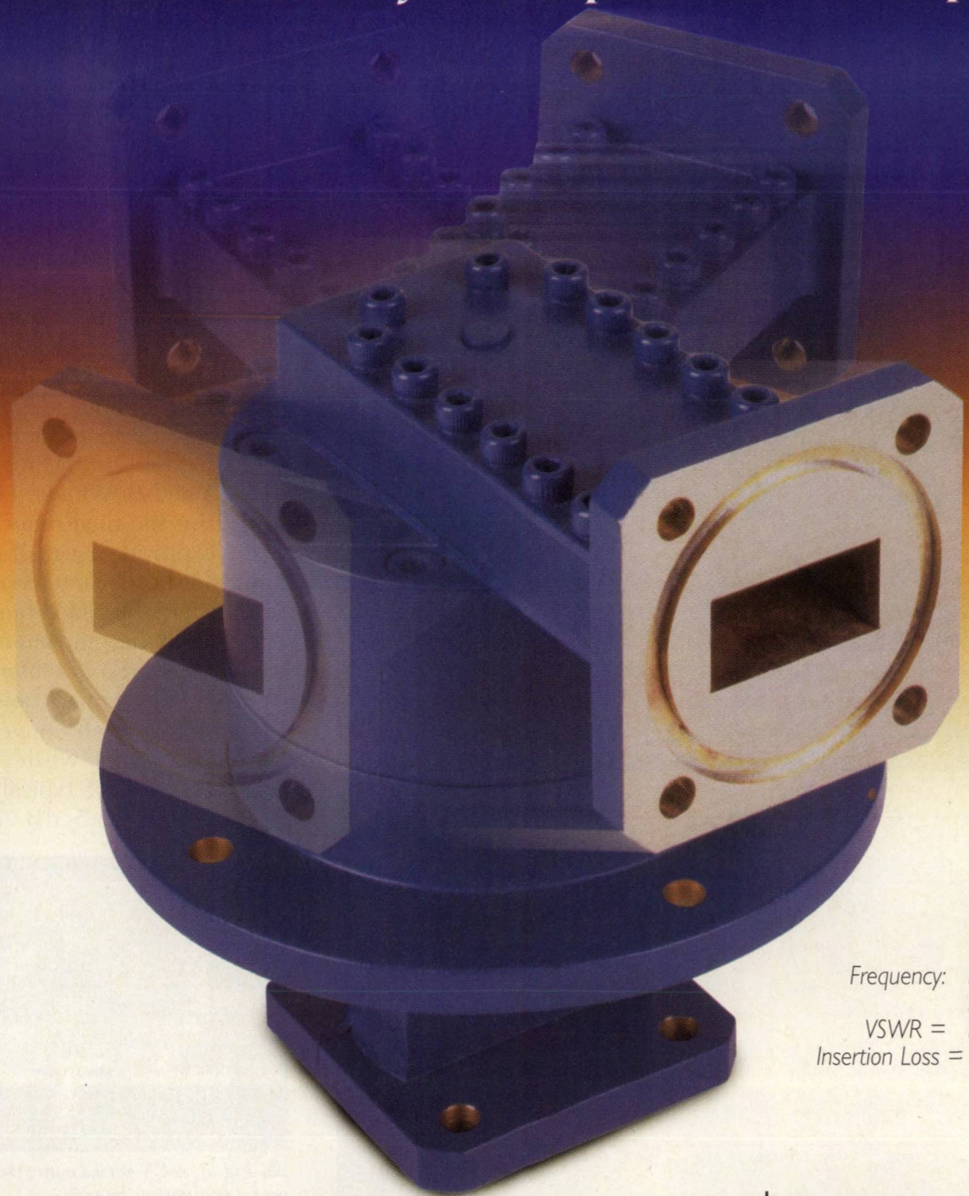

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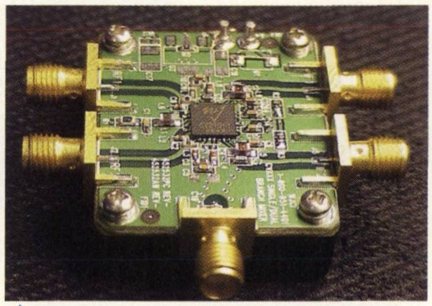
branch converters find application in power amplifier error correction circuits as well as for microcells and repeaters that only require a single converter.

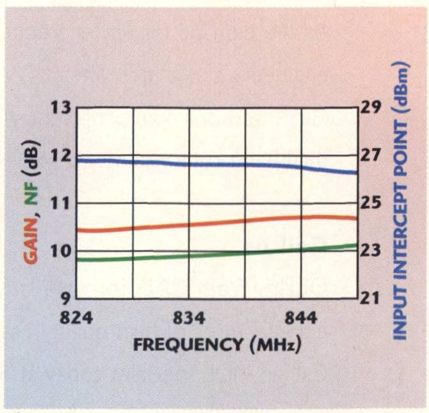
The small size of these converters significantly reduces the size of the circuit board required for this function. A discrete implementation of the functionality in one of the single-branch converters would typically require four square inches of circuit board space, while only one square inch is required with a CV series converter integrated circuit, as shown in ***Figure 3***. The CV series also provides a significant cost advantage compared to discrete implementations. The cost of the equivalent discrete parts found in one of the dual-branch converters, for example, is approximately $20, while the cost of the CV integrated circuit is less than $10 in volume.

The CV product family incorporates reliable GaAs MESFET and InGaP HBT semiconductor technologies. The frequency conversion function is passive which realizes a low noise characteristic.

Nine different CV models are being offered, including four single-branch and five dual-branch versions. Models for both the single- and dual-branch converters are available to cover the cellular, Personal Communications Service (PCS) and Universal Mobile Telecommunications System (UMTS) frequency ranges. In addition, performance has been optimized for low or high IF frequencies. Typical performance specifications for the various CV series models are included in ***Appendices A*** and ***B***. With an LO input level of 0 dBm the dual-branch converters typically provide a gain of 10 dB and an input third-order intercept point of 27 dBm, while the single-branch converters typically have a gain of 22 dB and an output third-order intercept point of 35 dBm. The typical noise figure for the single-branch converters is less than 5.5 dB, while the dual-branch converter's typical noise figure is less than 12.5 dB. ***Figures 4***,



▲ *Fig. 3 A CV series converter IC mounted on an evaluation board.*



▲ *Fig. 4 CV210-1 dual-branch converter (IF = 70 MHz) performance.*

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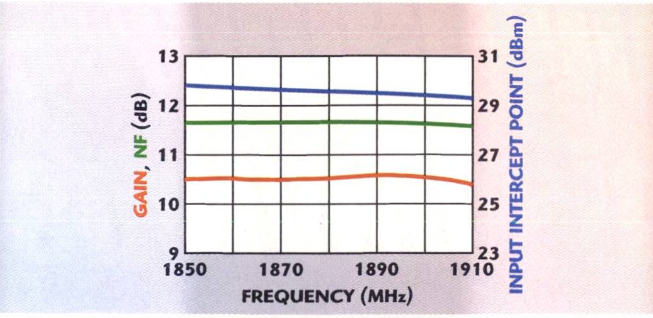
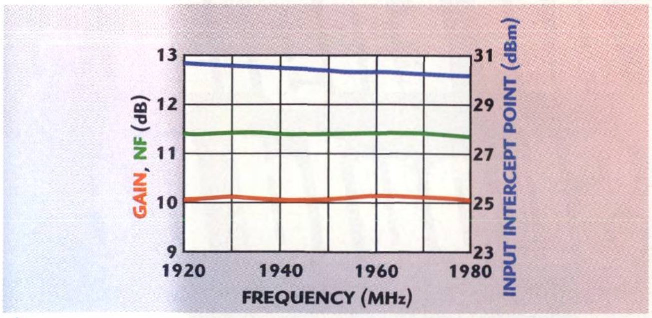


▲ *Fig. 5 CV211-1 PCS dual-branch converter (IF = 250 MHz) performance.*



▲ *Fig. 6 CV211-2 UMTS dual-branch converter (IF = 250 MHz) performance.*

5 and **6** show typical performance data for three of the dual-branch converters, one for each of the cellular, PCS and UMTS bands, respectively.

The CV series is available in a 28-pin, 6 × 6 mm QFN package and provides ports to add external filters to optimize performance in particular bands. Operating at 5 V these multichip modules require less than 2.5 W input power and are rated to operate over the full –40° to +85°C temperature range. Fully assembled evaluation boards and loose samples are available upon request.

WJ Communications Inc.,
San Jose, CA
(800) 951-4401, www.wj.com.

Circle No. 300

[Continued on page 112]

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VECTOR MODULATOR w/Typical Attenuation up to 25 dB					
2100-2200 MHz	MV212A-70TK	3.0	390°	+42/+40	$15.01
2100-2200 MHz	MV212A-35TB	2.5	200°	+42/+40	$9.91
1930-1990 MHz	MV192A-70TK	3.0	390°	+42/+40	$14.78
1930-1990 MHz	MV192A-35TK	2.5	200°	+42/+40	$9.91
SURFACE MOUNT VOLTAGE VARIABLE PHASE SHIFTER w/Solder Reflow to 240° C					
2100-2200 MHz	VP212A-35NJ	2.5	360°		$10.30
2100-2200 MHz	VP212A-60BK	1.7	190°		$5.32
2100-2200 MHz	VP212A-60CN	1.0	100°		$5.03
1930-1990 MHz	VP192A-35NJ	2.5	360°		$10.60
1930-1990 MHz	VP192A-60BK	1.7	190°		$5.32
1930-1990 MHz	VP192B-60CN	1.0	100°		$5.26
SURFACE MOUNT VOLTAGE VARIABLE ATTENUATOR w/Attenuation 20 dB & Solder Reflow to 240° C					
2100-2200 MHz	VA212B-60TK	0.6		+45	$4.25
1930-1990 MHz	VA192B-60TK	0.6		+45	$4.25

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APPENDIX A

SINGLE-BRANCH CONVERTERS

Model No.	Frequency Range (MHz) RF	IF	LO Power (dBm)	Conversion Gain (dB)	Output IP3 (dBm)	Input P1dB (dBm)	NF (dB)	Current (mA)	Bias (V)
CV110-1	806–915	70–120	0	22	35	18	5.5	430	5
CV111-1	1710–1910	70–250	0	22	35	18	5.5	430	5
CV111-2	1900–2200	150–300	0	22	35	18	5.5	430	5
CV111-3	1900–2200	65–200	0	22	35	18	5.5	430	5

APPENDIX B

DUAL-BRANCH CONVERTERS

Model No.	Frequency Range (MHz) RF	IF	LO Power (dBm)	Conversion (dB)	Input IP3 (dBm)	Input P1dB (dBm)	NF (dB)	Current (mA)	Bias (V)
CV210-1	806–915	70–120	0	10	26	11	11.5	430	5
CV210-3	800–925	200–350	0	10	27	11	11.5	430	5
CV211-1	1710–1910	70–250	0	10	27	11	11.5	430	5
CV211-2	1900–2200	150–300	0	10	27	11	11.5	430	5
CV211-3	1900–2200	65–200	0	10	27	11	11.5	430	5

An RF Signal Generator Offering Full Digital, Vector and Analog Modulation

The humble signal generator has come out of its modest, functional shell and taken on a streamlined, compact, state-of-the-art persona with the development of the 3410 series. This family of digital RF signal generators has evolved in response to the worldwide growth of second- and third-generation wireless communications systems and the prevailing demand for products with digital modulation capabilities. The call is for RF signal generators that deliver wider baseband modulation bandwidth and improved dynamic range, provide more arbitrary waveform generator memory and run at greater speeds. Also, with many wireless formats having their own special characteristics, additional functionality is made available to the user.

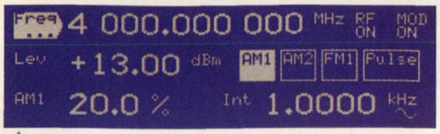
To meet these needs there are currently three models in the series addressing the frequency ranges 250 kHz to 2 GHz (model 3412), 250 kHz to 3 GHz (model 3413) and 250 kHz to 4 GHz (model 3414). All three use the same housing.

Developed for testing and emulation of 2G, 3G and the emerging 4G systems, digital Private Mobile Radio (PMR), Wireless Local Area Networks (WLAN) and Bluetooth systems, this high performance digital RF signal generator family combines full digital, vector and analog modulation in a 2U rack size.

Both analog (FM, AM, phase and pulse modulation) and broadband vector modulation are standard, with a digital dual-channel arbitrary waveform generator (ARB) available as an option. Fitted internally and providing good modulation accuracy and linearity, the ARB is capable of generating 2G, 2.5G, 3G and PMR digital radio signals.

[Continued on page 118]

IFR Systems Inc.
Wichita, KS



▲ *Fig. 1 Main screen operation.*

▲ *Fig. 2 ARB file catalog.*

▲ *Fig. 3 The 3410 series uses globally recognized icons.*

The added functionality and sophistication of the 3410 series is a serious development and is allied to simple operation and suitability for its intended users. To satisfy both seasoned RF engineers and new graduates from the PC generation, the design makes use of emerging technologies while retaining the traditional look and feel of a signal generator. It offers familiarity together with widely used international icons and symbols.

KEEPING IN TOUCH

Based on a compact touch-panel display system, with a keyboard control alternative that can be used simultaneously, the series provides an interface that is simple to use yet capable of controlling all the advanced features required for digital and vector modulation. The simplicity is epitomized by the fact that by using the touch-screen to combine the selection and indication process there is no need for dedicated function keys. As is consistent with those found so often in everyday life, the touch-screen adopts an action-on-release operation. As for the hard-key alternative, this facility enables the signal generator to be used in harsh working environments where gloved operation is required.

Explaining the basic operation is simple. First, the main screen operation parameter is selected and made the current function by pressing the appropriate function label (for example, Freq, Lev, AM1, IQ, W'form) on the touch-screen and the selected parameter is highlighted, as shown in ***Figure 1***. Once a parameter has been selected, its value can be changed in a conventional manner using the numeric keypad, increment/decrement keys or rotary control.

The 3410 series offers more than 30 different modulation combinations. Selection and control of any summarized modulation is made using the touch-screen. Pressing the required modulation summary box causes the display area to be reconfigured and the selected modulation settings displayed. The modulation parameters can then be adjusted by touching the appropriate function label.

Function sub-menus contain advanced features and additional controls for the main signal generator screen parameter selected. The available sub-menus are indicated at the bottom of the display as a series of touch "tabs" and can be selected in turn by pressing the touch-screen. The use of "tabs" creates a two-tier, flat menu structure, which means the operator can quickly switch from one to the other without having to scroll down and back up again. Therefore, the user is only one key press away from the main signal generator screen, where what is visible on the screen is what is being generated.

THE ARB FEATURE

As mentioned earlier, the 3410 series includes an optional dual-channel arbitrary waveform generator, incorporating an interpolation filter design that reduces the ARB configuration process to a simple file selection operation. The interpolation rate of the filter is automatically set in such a way that aliasing products of the wanted signal are shifted into the stop band range of the anti-aliasing (reconstruction) filter. As a result, incorrect instrument configuration is avoided and correct file generation is guaranteed. Software control means that the user does not have to bother with setting it up as this is done by the software and hardware.

Files loaded into the ARB can have sample rates ranging from 17 kHz to 66 MHz. In addition, the interpolation hardware takes care of the (sin x)/x distortion that is a direct consequence of the sampling process and allows files to be created that have low nominal sample rates, resulting in smaller file sizes.

The ARB can store a maximum of 22.5 M samples in its non-volatile flash memory. This is partitioned into 60 sectors, each of which can be further divided into three sub-sectors, providing 180 sectors of file storage at any given time. Also, sectors and sub-sectors can be merged together to form larger files. The user can inspect the files stored in the ARB, as shown in ***Figure 2***. The list can be scrolled up and down and the required file selected.

SWEEP OPERATION

A standard feature of signal generators is the provision of an automated method of changing parameters such as carrier frequency and RF. The 3410 series provides a simple method to provide this sweep configuration by using a novel method of user interface control. Sweep operation is set up and controlled by pressing a dedicated key, whereby globally recognized icons (see ***Figure 3***) are displayed that mimic the controls seen on compact disk players and videocassette recorders. Pressing the appropriate touch-target allows the sweep to be started, paused and reset. When paused, additional controls are displayed that allow the sweep to be manually stepped backward and forward.

Parameter settings are accessed via the "Params" tab. From here start, stop, step size and step time may be entered. Likewise, configuration settings are available from the "Control" tab. The parameter to be swept can be defined (for example, carrier frequency) and the trigger operation (single shot/continuous) specified.

CONCLUSION

The 3410 series is a family of modular and upgradeable RF signal generators that is compact and portable and combines full digital, vector and analog modulation in one streamlined unit. Designed for R&D and manufacturing test applications it incorporates an entirely new interface that makes complex test scenarios easy to configure. In operation it exhibits the benefits that would be afforded by soft keys and a large screen but through the combination of a touch panel display and a keyboard alternative.

IFR Systems Inc.,
Wichita, KS (316) 522-4981
or (800) 835-2352.

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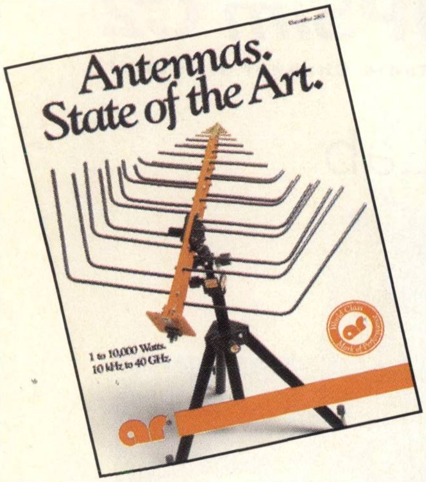
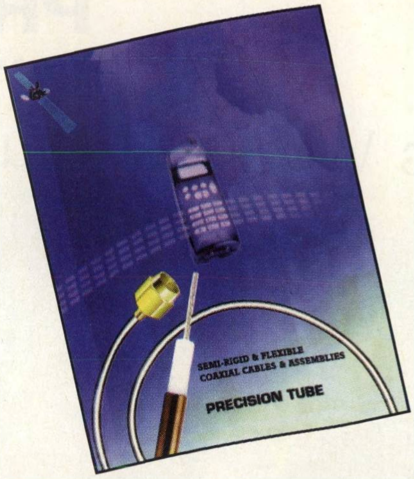


▲ High Power Antennas

This 24-page catalog features the company's wide range of rugged, high power antennas and accessories. Product photographs, descriptions, performance graphs and specifications are included. A glossary of terms and an information request card are also provided.
Amplifier Research,
Souderton, PA (215) 723-8181.

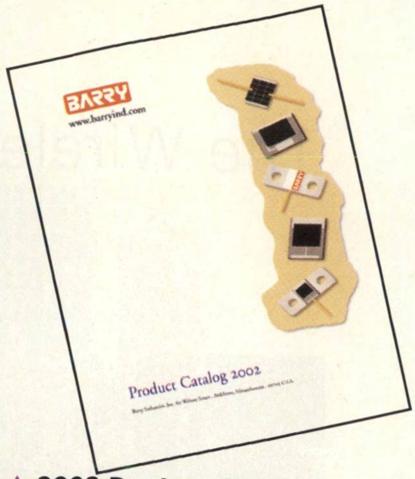
Circle No. 310



▲ Product Catalog

This catalog describes the company's broad line of semi-rigid cables, delay lines and flexible cables. Semi-rigid cables are produced with outer jacket materials of aluminum, copper or stainless steel. Cables sizes range from 0.020" to 0.500" with impedances from 10 to 100 Ω.
Precision Tube,
Salisbury, MD (410) 546-3911.

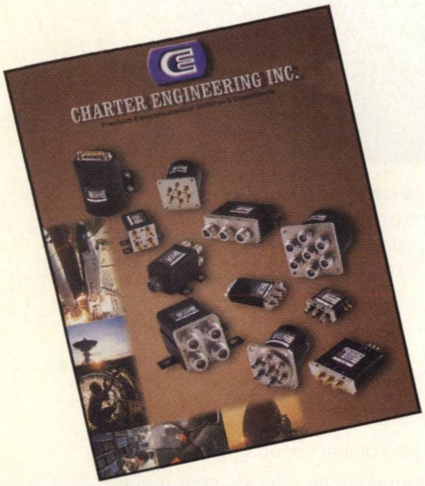
Circle No. 311



▲ 2002 Product Catalog

This catalog includes high power passive resistive components featuring terminations, resistors and attenuators in various configurations. Packages are available in chip form, chips with leads and flanged devices. Also featured are standard precision chip packages, thick film circuit capabilities, cable load and power sensors. Packages are available in a variety of material offerings including alumina, BeO, BeO free and aluminum nitride substrates.
Barry Industries Inc.,
Attleboro, MA (508) 226-3350.

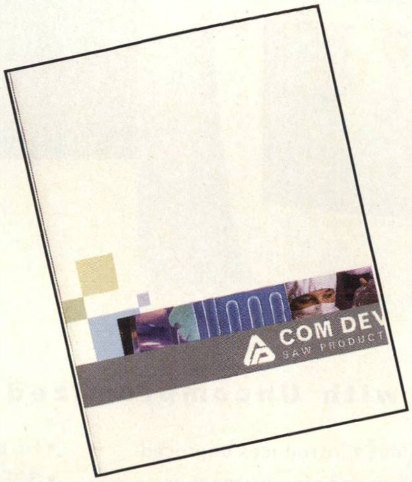
Circle No. 312



▲ Precision Electromechanical Switches and Components

This 52-page catalog features the company's state-of-the-art coaxial RF switches, fixed attenuators, terminations, isolators/circulators and other RF and microwave components. The table of contents lists 26 different product groups, each providing product photographs, outline drawings, specifications, applications, available options and ordering information.
Charter Engineering Inc.,
Largo, FL (727) 549-8999.

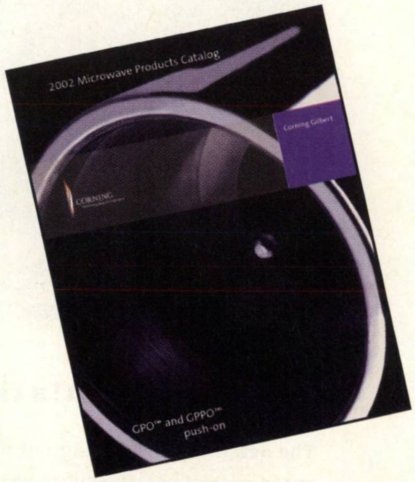
Circle No. 313



▲ SAW Products

This folder provides a variety of brochures and application notes detailing the company's SAW foundry services, SAW filters and "How to Specify a Custom SAW Filter." Photographs, detailed product descriptions, specifications, performance graphs and ordering information are provided.
COM DEV SAW Products,
Cambridge, Ontario, Canada
(647) 887-7297.

Circle No. 314

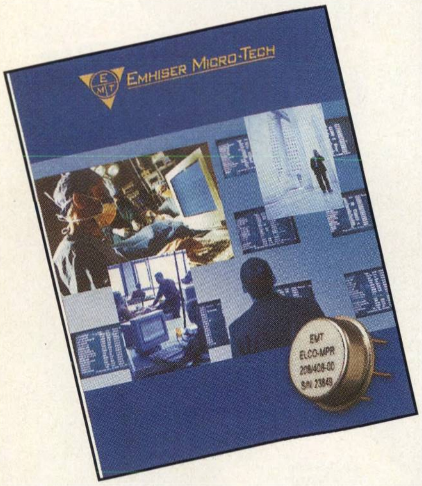


▲ Microwave Products Catalog

This 52-page microwave products catalog includes a vast array of products featuring the company's GPO and GPPO interconnects. Products are profiled in a concise, easy-to-read format that includes photos, line drawings and tool information.
Corning Gilbert Inc.,
Glendale, AZ (800) 651-8869.

Circle No. 315

CATALOG UPDATE

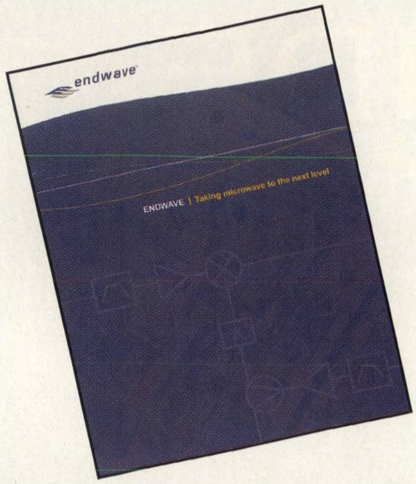


▲ Product Brochure

This brochure features the company's model ELCO-MPR-208/408-00 wideband VCO. The VCO tunes a 2000 to 4000 MHz octave from 0 to 24 V. Product information including common instrumentation/telecommunications specifications, packaging information and performance characteristics are included in the brochure.

Emhiser Micro-Tech,
Reno, NV (775) 345-0461.

Circle No. 316

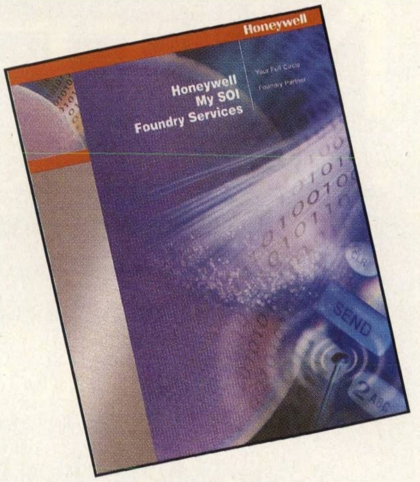


▲ Microwave Technology Catalog

This 13-page catalog overviews the company and its capabilities. Information on its custom RF engineering and design, product solutions, integrated circuit technologies, manufacturing, quality and partnership is provided. A brief company profile as well as a variety of product photographs is also included.

Endwave, Sunnyvale, CA (408) 522-3100.

Circle No. 317



▲ Foundry Services Brochure

This six-page brochure details the company's range of foundry services. The company's My SOI Foundry is a complete foundry solution for all RFIC manufacturing needs. The company is equipped to develop customer's state-of-the-art ICs using proven SOI technology, service and expertise.

Honeywell, Solid State Electronic Center,
Plymouth, MN (800) 323-8295.

Circle No. 318

▲ Catalog and Interactive CD-ROM Update

This new product catalog and interactive CD-ROM showcases custom products with actual test data as well as product software downloads. Product descriptions, performance graphs, specifications, outline drawings, applications and ordering information is all provided.

K & L Microwave Inc.,
Salisbury, MD (410) 749-2424.

Circle No. 319

▲ Company Brochure

This five-page brochure details the company's PCB procurement capabilities, including an overview of its design engineering resources, real manufacturing, virtual manufacturing and supply chain management. A folder in the back of the brochure also provides various news clippings on the company and a sampling of its newest press releases.

M-Wave, Bensenville, IL (630) 860-3560.

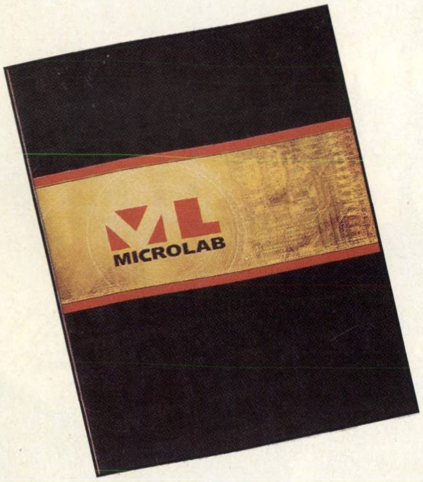
Circle No. 320

▲ Short Form Catalog

This short form catalog provides a complete listing and descriptions of the company's microwave and wireless components. Products include attenuators, terminations, adapters, DC blocks, bias tees, equalizers and other items. Products operate in the DC to 50 GHz frequency range, with power handling of 1 to 300 W. Broadband DC blocks and broadband bias tees are also included.

MCE/Inmet Corp.,
Ann Arbor, MI (734) 426-5553.

Circle No. 321



▲ Product Folder

This folder provides information on the company's MagLatch™ RF MEMS switch. The switches are micro magnetic latching switches designed for switching RF signals from DC to tens of GHz in 50 Ω. The device fabrication is based on a surface micromachining approach and is thus a high volume, low cost production method. A product description, technology overview, engineering evaluation, data sheet, and corporate overview are provided.

Microlab, Chandler, AZ (480) 926-9500.

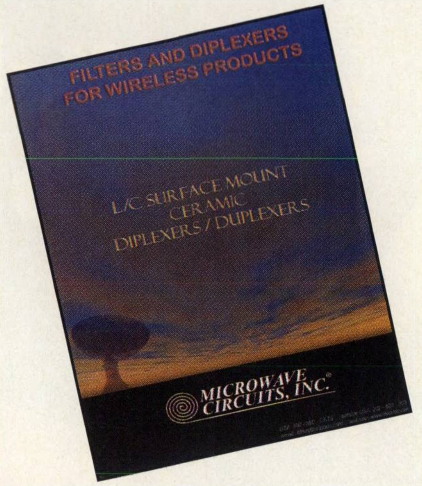
Circle No. 322

▲ Data Sheet

This data sheet details the company's model MSSS-6110 female blindmate interconnect. Product photographs, a performance graph, electrical and mechanical specifications and available materials and finishes are all included.

Micro-Mode Products Inc., El Cajon, CA (619) 449-3844.

Circle No. 323

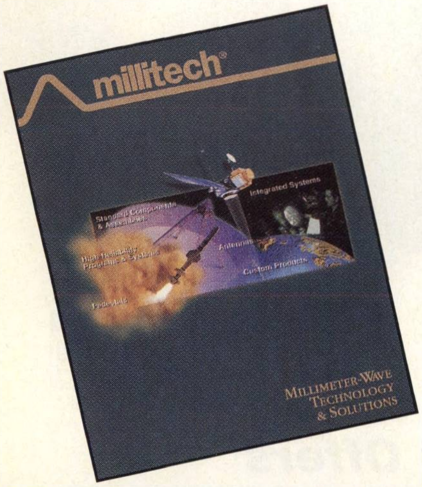


▲ Filters and Diplexers Catalog

This 44-page catalog features the company's line of filters and diplexers for wireless products, including L/C surface-mount filters, ceramic bandpass filters, diplexers, and cavity filters and duplexers. Product photographs, descriptions, specifications and typical performance graphs are included. A folder inside the front cover provides recent press releases and a company overview.

Microwave Circuits Inc., Washington, DC (800) 642-2587.

Circle No. 324



▲ Millimeter-wave Technology and Solutions

This 41-page catalog features the company's millimeter-wave products and services, such as: antennas and quasioptical products, mixers and detectors, oscillator and amplifier products, multiplier products, control components, filters and ferrite products, passive waveguide products, and test and measurement products. A brief company overview and a product reference guide is also included.

Millitech LLC, Northampton, MA (800) 664-5548.

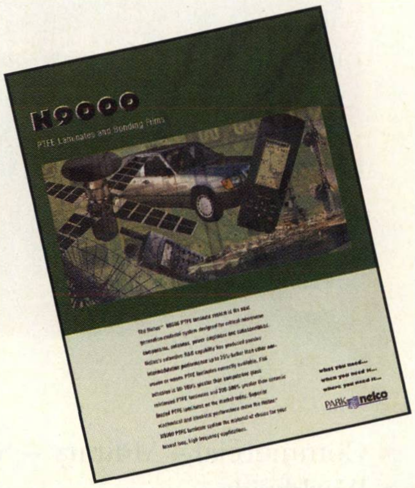
Circle No. 325

▲ CD-ROM Catalog

This CD-ROM catalog includes new products, updated datasheets with more comprehensive information and measurement curves, application notes, and a complete listing of the company's international sales representative network. The CD-ROM is also hyperlinked to the company Web site to facilitate the collection of additional information.

Mimix Broadband Inc., Webster, TX (281) 526-0536.

Circle No. 326



▲ Product Brochure

This four-page brochure details the company's N9000 PTFE laminates and bonding films. This next generation materials system is designed for critical microwave components, antennas, power amplifiers and subassemblies. Typical engineering values, standard available laminate thicknesses, constructions, cladding information, a product description, key engineering values and ordering information are all provided.

Neltec, Tempe, AZ (480) 967-5600.

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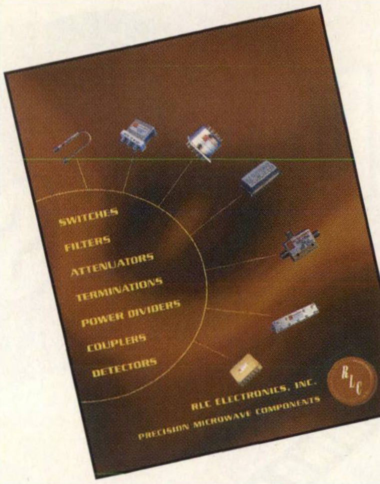
CATALOG UPDATE

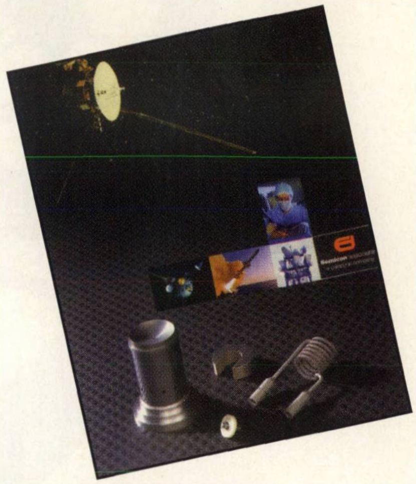
▲ CD Catalog

The company's complete line of quartz components is available free on CD-ROM. The CD features SMD TCXOs and VCTCXOs, thru-hole TCXOs and VCTCXOs, clock oscillators and crystals, GPS chipset crystals and TCXOs, custom oscillators and miniature oscillators. Technical tutorial help, technical definitions and a product selection guide is also included.
Rakon Ltd.,
Auckland, New Zealand +64 9 573 5554.
Circle No. 328



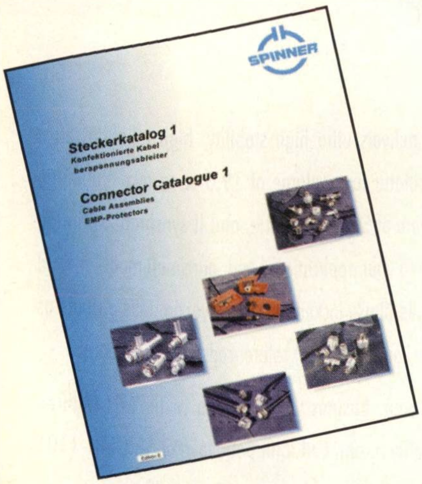
▲ Full-line Catalog

This 91-page catalog includes a number of new products, including both PIN diode and waveguide switches, as well as coaxial switches up to 65 GHz. The filter section now includes a range of Bessel filters, both absorptive and reflective, as well as cable filters. Other products include programmable attenuators, high power couplers, 40 GHz power dividers, detectors and 40 GHz bias tees.
RLC Electronics Inc.,
Mt. Kisco, NY (914) 241-1334.
Circle No. 329



▲ Dispenser Cathode and Samarium Cobalt Magnet Brochure

This 12-page brochure features technical capabilities and product offerings. Information on tungsten dispenser cathodes and samarium cobalt (rare-earth) magnets for the microwave tube industry and other industries is provided.
SEMICON Associates,
Lexington, KY (859) 255-3664.
Circle No. 330

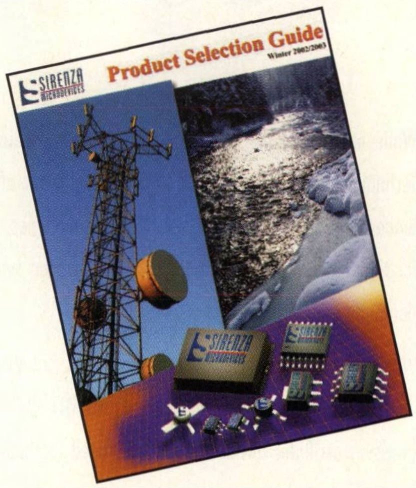


▲ Connectors Catalog

The connectors featured in this catalog offer a high contact reliability due to their design and the selection of materials as well as their surface treatment, providing excellent corrosion resistance. For all connectors sizes listed the company supplies measuring equipment, including directional couplers, terminations, attenuators, high power loads as well as switches.
Spinner GmbH,
Munich, Germany +49 89 136 01 257.
Circle No. 331

▲ Passive Components Catalog

This 54-page catalog covers the company's range of passive component products offered to the North American market. The catalog's table of contents lists 19 product sections, including capacitors, inductors, ferrite beads, thermistors, choke coils and EMI suppression filters. Each section provides designers with valuable information on a product group's features, applications and operating temperature ranges.
Taiyo Yuden Co. Ltd.,
Schaumburg, IL (847) 925-0888.
Circle No. 332



▲ Product Selection Guide

This eight-page Winter 2002/2003 product guide presents key performance characteristics of the company's low noise amplifiers, power amplifiers, IF amplifiers, fiber-optic transimpedance amplifiers, high power and high linearity discrete components, gain blocks, multi-component modules and CATV amplifiers. A reference guide to the company's application notes is also included.
Sirenza Microdevices Inc.,
Sunnyvale, CA (408) 616-5400.
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Introducing

Wideband VCOs for a wireless world.

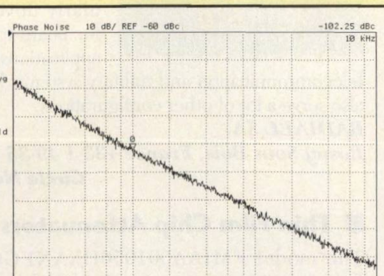
A broadband world requires broadband signal sources that offer low noise, linear tuning and load-insensitive performance. At Vari-L, we apply the same precision engineering and manufacturing to our Wideband VCOs as you have come to experience in our Narrow band VCOs. Excellent phase noise performance and tuning linearity enable consistent PLL loop bandwidths, settling time and low integrated noise. And, our wideband VCOs low frequency pulling will minimize your system phase error.

To find out how Vari-L's Wideband VCOs can be "a part in your future," please visit our website at www.vari-l.com, or send an email to sales@vari-l.com.

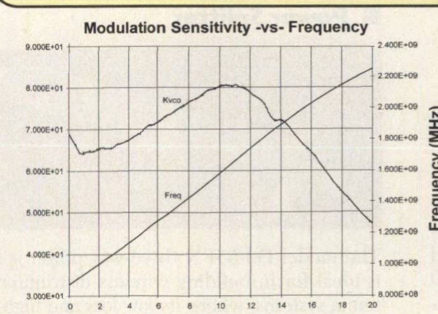
Part Number	Frequency Range(MHz)	Tuning Voltage	Typical 10 kHz Phase Noise	Supply Voltage	Output Power	Package Size
VCO790-600T	400-800	0.0 - 20.0	-102 dBc/Hz	+5 V	+3 dBm	0.5 x 0.5 x 0.18 in.
VCO790-1500T	1000-2000	0.0 - 20.0	-98 dBc/Hz	+5 V	+2 dBm	0.5 x 0.5 x 0.18 in.
VCO790-2300T	2100-2500	1.0 - 4.0	-89 dBc/Hz	+5 V	+3 dBm	0.5 x 0.5 x 0.18 in.
VCO793-600T	400-800	0.0 - 20.0	-104 dBc/Hz	+12 V	+7 dBm	0.5 x 0.5 x 0.18 in.
VCO793-1500T	**1000-2000**	**0.0 - 20.0**	**-99 dBc/Hz**	**+12 V**	**+7 dBm**	**0.5 x 0.5 x 0.18 in.**

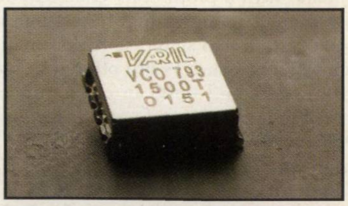
Actual data for VCO793-1500T

Phase noise from HP3852 for 1000-2000 MHz VCO



Tuning Sensitivity from HP3852 for 1000-2000 MHz VCO





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OUR PRODUCTS INCLUDE:

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COMPONENTS

■ SP6T RF Switch

The model H6N-742109 SP6T latching switch features indicator circuitry and operates from DC to 26.5 GHz. The low IM switch features a –130 dBc (min) third-order IM and –160 dBc (min) fifth-order IM. This model is offered with various actuator and mounting options. Special materials allow for superior RF performance and outstanding switching characteristics across the band. Delivery: stock to two weeks.

Charter Engineering Inc.,
Largo, FL (727) 549-8999.

Circle No. 216

■ MEMS Switch Family

This MEMS switch technology enables design engineers to create new wireless products featuring low insertion loss and high isolation capabilities in a smaller package. The MEMS technology platforms will enable the fast design and prototyping capabilities necessary to bring handset and microwave communications systems to market quickly. The MEMS switches can be customized and integrated with passive and active components on ICs for RF mixed-signal functions. The family is designed to operate from DC to 40 GHz with a low insertion loss of < 0.2 dB for die and < 0.4 dB for packaged devices. The switches provide high isolation of > 25 dB at 40 GHz and > 40 dB at 2 GHz.

Coventor Inc., Cary, NC (919) 854-7500.

Circle No. 217

■ RF Chip Capacitors

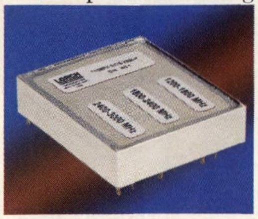
The S-series line of low ESR, high Q, high frequency multi-layer ceramic capacitors is designed for high volume wireless products such as RF modules, cellular amplifiers, WLAN, cable components and RF matching. The series is made with a proprietary combination of low loss dielectric and a highly conductive electrode system that significantly lowers the resistance. The capacitors are offered in size 0201, 0402, 0603 and 0805 in capacitance values from 0.2 to 220.0 picofarads. Price: 4¢ (1000). Delivery: stock to six weeks (ARO).

Johanson Technology Inc.,
Camarillo, CA (805) 389-1166.

Circle No. 218

■ 3-channel Bandpass Filter

The model T10BPX-2175/X550-P three-channel bandpass filter is designed for military applications and covers the 1200 to 3000 MHz frequency range in (3) 600 MHz bands. Passband SWR and insertion loss are 1.5 and 2.0 dB (max), respectively. Stopband rejection is 60 dB (min) at center frequency 900 MHz. Size: 1.54" × 1.30" × 0.37". Delivery: four weeks (ARO).

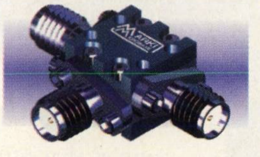


Lorch Microwave,
Salisbury, MD (410) 860-5100.

Circle No. 219

■ Mixer

The M9-0444 mixer covers 4 to 44 GHz with a DC to 3 GHz IF. Designed for wideband applications requiring a relatively high IF, the mixer is a unique double-balanced mixer design, available in a 2.92 mm connectorized outline. Local oscillator drive levels are +9 to +13, or +13 to +17 dBm. Typical conversion loss is 7 dB.

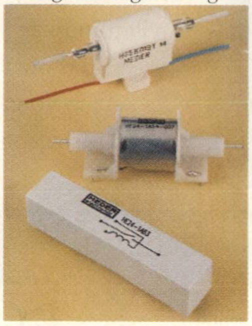


Marki Microwave Inc.,
Morgan Hill, CA (408) 778-4200.

Circle No. 220

■ High Voltage Reed Relays

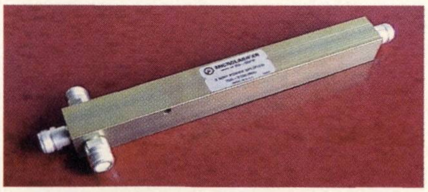
The HF series of line of reed relays is offered in high voltage or high frequency and high power configurations for PCB mount or free-standing applications. The relays are designed to switch high voltages and feature switching voltages up to 10,000 V DC and breakdown voltages to 15,000 V DC, with 1000 gigaΩ between coil and contact, and carry current up to 5 A. They come in PCB mount or axial-leaded versions, and are available with 1 to 2 Form-A, 1 Form-B or 1 Form-C contacts. They also can include a wide range of options such as power switching up to 100 W, special pin-outs and case sizes. Applications range from high voltage test sets to medical equipment.



MEDER Electronic Inc.,
Mashpee, MA (508) 539-0002.

Circle No. 221

■ Power Splitter



The model D3-55FN three-way power splitter is ideal for in-building wireless distributed antenna systems, where its low loss and high reliability are important. It has exceptional bandwidth covering 700 to 2700 MHz, which includes existing cellular bands, the new 700 MHz band, the W-LAN frequencies at 2400 MHz and the projected UMTS band that runs up to 2690 MHz. All joints are moisture sealed to meet the IP65 rating and the mechanical shape allows simple attachment to pole or wall using the bracket provided.

Microlab/FXR,
Livingston, NJ (973) 992-7700.

Circle No. 222

■ High Q Resonator

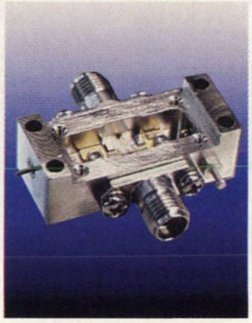
These 20 and 40 GHz DRO based filters (resonators) have Q of 12000 and conversion losses of 3 to 5 dB. To meet the demand and mission-critical system requirements, the package can be customized to various customer application needs and the resonators are available in surface-mount, drop-in, hybrid module and other types. This product can be used in various microwave and instrumentation applications.

Milli Optics Inc.,
Portland, OR (503) 629-0680
or (732) 940-9304.

Circle No. 223

■ Connector

The model NB00378 miniature size K connector features robust characteristics provided by a thin film hybrid MIC process ensures an operating temperature range of –30° to +70°C. The amplifier incorporates internally protected voltage regulators and can be biased in a wide range of DC voltage. High gain of 21 dB and P-1 dB of 19 dB make the amplifier ideal for any general-purpose application.

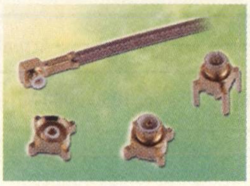


Nextec Microwave & RF Inc.,
Santa Clara, CA (408) 727-1189.

Circle No. 224

■ Microminiature Coaxial Connectors

The MMBX series features a minimum board-to-board distance of 7 mm, an axial misalignment of 0.6 mm and a radial misalignment of 0.4 mm. These connectors are particularly developed for board-to-board applications in civil telecommunication and military systems, but will also serve a lot of other configurations.



RADIALL SA,
Rosny Sous Bois, France +33 1 49 35 35 35.

Circle No. 225

■ Thin Film Chip Attenuators

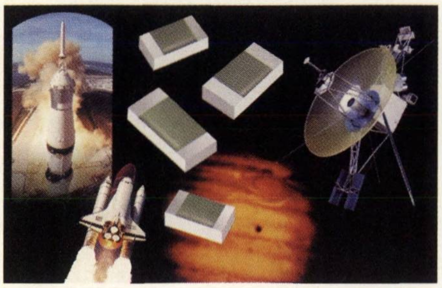
The model FMIAA001050DXANFGO surface-mount chip attenuator is ideal for applications requiring precision attenuation in a small form factor. Single component reduces circuit area and board space while replacing discrete components and improving performance. The thin film technology also insures a stable attenuation over time and temperature. Wire bondable pads are on the top surface and ground wrap eliminates the need for wire for shunt element. The attenuator operates over the DC to 22 GHz frequency range with 50 Ω of impedance and a power rating of 250 mW. The mod-

[Continued on page 130]

NEW PRODUCTS

el features an attenuation range of –1 dB through –20 dB in 1 dB steps.
SatCon Electronics,
Marlborough, MA (508) 485-6350.
Circle No. 226

Chip Resistors



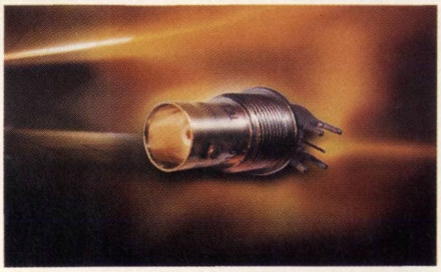
This expanded line of established high reliability chip resistors qualified to MIL-PRF 55342. The new QPL sizes are as follows: RM0502 is a 0.050" × 0.020" with power ratings of 10 mW characteristics E, H and 20 mW characteristics K, M. Maximum voltage rating for the RM0502 is 40 V. RM0402 is a 0.040" × 0.020" with power ratings of 40 mW characteristics E, H, K and M. Maximum voltage rating is 25 V. M0603 is a 0.060" × 0.030" with power ratings of 70 mW characteristics E, H and M. Maximum voltage rating is 50 V. Available termination styles are solderable nickel barrier, epoxy bondable and gold wire bondable.
State of the Art Inc.,
State College, PA (800) 458-3401.
Circle No. 227

Connector

This 1.85 mm connector was developed to go beyond the 2.4 mm connector's maximum performance. The connector is threaded with performance to 60 GHz, utilizing an air interface. It operates from DC to 60 GHz, with a 1.25 (max) SWR, 0.30 dB insertion loss and 19 dB (max) return loss. The connector operates over a temperature range of –55° to +165°C.

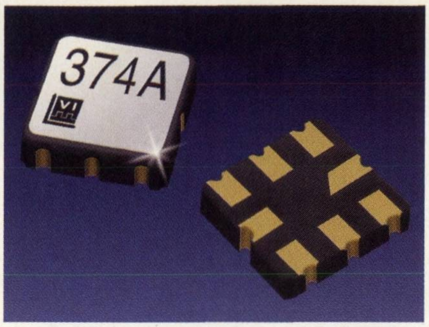
Tensolite,
St. Augustine, FL (877) 890-7483.
Circle No. 228

Bulkhead BNC Jack



The model UCBBJR29 pcb-mounted right angle bulkhead BNC jack is designed for true 75 Ω performance and carrier class applications. It is an ideal solution for OEM equipment applications that involve high data rates, high bandwidths and/or high frequencies with low return loss. A unique bulkhead feature allows torque of the BNC coupling mechanism to be transferred to a panel front in lieu of the board, ensuring the integrity of the board to connection junction. Price: $11.25 (5000).
Trompeter Electronics,
Westlake Village, CA (800) 982-2629.
Circle No. 229

WLAN IF SAW Filters



The model TFS374A and TFS374B low loss, low profile surface-mount IF SAW filters are designed for wireless local area networks (WLAN). The 17 MHz wide filters provide low insertion loss, a small group delay ripple and a high stop band attenuation. The filters have a center frequency of 374 MHz and can be driven balanced or unbalanced. Size: 3.8 × 3.8 mm or 5.0 × 5.0 mm.
Vectron International,
Hudson, NH (888) 328-7661.
Circle No. 230

AMPLIFIERS

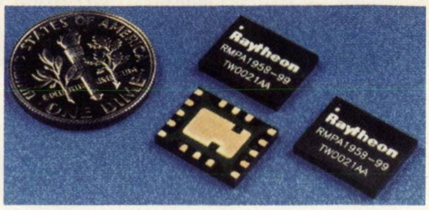
GaAs MMIC Power Amplifier

The model AM13515030WM-KM is a part of the company's new series of GaAs PHEMT power amplifiers. The unit has been designed to operate over the 13.0 to 16.5 GHz frequency band and is available in a SMT ceramic package with both RF and DC leads at the sides of the package to facilitate low cost assembly to the PC board. Typical performance at 13.5 to 15.0 GHz is a gain of 30 dB, input return loss of 5 dB^3, output return loss of 12 dB and efficiency of 20 percent. The amplifier is well suited for VSAT and military applications.
Amcom Communications,
Clarksburg, MD (301) 353-8400.
Circle No. 231

Low Noise, Wideband Amplifier

The model AML018P2001 low noise, wideband amplifier operates in the 0.1 to 8.0 GHz frequency range and provides 20 dB gain (min) and +20 dBm output power at 1 dB gain compression. Noise figure is 4 dB (max) and gain flatness is ±1.0 dB (max). Input and output SWR is 2.0 (typ). The amplifier operates with a voltage of +15 V DC and draws a nominal 340 mA. Internal DC regulator, reverse voltage protection and field removable SMA (f) connector shells are standard. Size: 1.25" × 0.75".
AML Communications Inc.,
Camarillo, CA (805) 388-1345.
Circle No. 232

Quad-band Power Amplifier

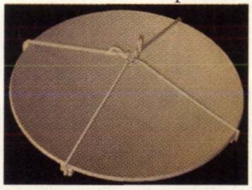


The model RMPA1958-99 high efficiency power amplifier module is designed for GSM/GPRS quad-band applications. The module, which has an overall frequency range of 824 to 1910 MHz, uses the company's proprietary InGaP MMIC technology together with a CMOS control circuit in an integrated design, affording greater flexibility and user convenience. Features include internal 50 Ω input and output matching with internal DC blocking and a leadless chip-carrier module with on-board band select and output power control, reducing handset design complexity and minimizing loss. The amplifier is designed to operate at a supply voltage of 3.5 V DC and delivers an output power of 35 dBm for GSM applications, and 32.5 and 31.5 dBm, respectively, for DCS and PCS.
Raytheon RF Components Division,
Andover, MA (978) 684-8900.
Circle No. 233

ANTENNA

Doppler Radar Antenna

The model 0143-800 35 GHz Doppler radar antenna offers superior sidelobe and cross-polarization performance. It consists of a 28" solid parabolic reflector with a 9" focal length, four support struts, two WR-28 waveguides to run to the edge of the reflector and one dual polarized feed assembly.



Seavey Engineering Associates Inc.,
Pembroke, MA (781) 829-4740.
Circle No. 234

INTEGRATED CIRCUITS

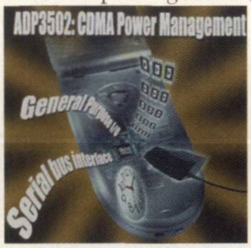
RF ASIC

The ASTRIC (application specific transmit and receive IC) mixed signal RF ASIC technology platform delivers system-on-chip solutions that significantly reduce the system cost, power consumption, form factor and time-to-market of short range, low data rate, wireless applications. It provides a scalable path for integrating board-level and modular transmitter, receiver and transceiver applications into true SoC implementations. ASTRIC solutions are ideally suited to license-free, one-way and two-way wireless designs that require data rates up to 1 Mbps for short range applications. As a result, target data applications include telemetry, security systems, medical monitoring, interactive toys, intelligent agriculture and remote vehicular products.
AMI Semiconductor (AMIS),
Pocatello, ID (208) 233-4690.
Circle No. 235

[Continued on page 135]

NEW PRODUCTS

■ Multi-function Chip



The model ADP3502 CDMA power management system that includes 11 low dropout regulators (LDOs), each optimized for one CDMA sub system, and four backup LDOs for standby mode operation. This is a multi-function chip optimized for CDMA-1x cell phone power management in the handset baseband and RF sections. Integrated features include a real time clock for the system, serial bus interface and charging control for Li-Ion/Li-Polymer batteries. Sophisticated controls are available for power-up during battery charging, keypad interface and include a general-purpose input/output function. The ADP3502 has a high level of integration, which significantly reduces the design effort, number of discrete components and solution size/cost. The main-sub LDO structure reduces the standby current consumption and as a result, greatly extends the standby time of the phone. Price: $5.37 (1000).
Analog Devices, Wilmington, MA (800) 262-5643.

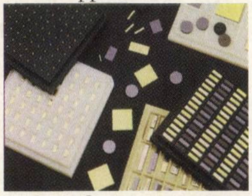
Circle No. 236

■ TETRA Band Receive Filter Assembly

The model WSFA-00020 TETRA band receive filter assembly features an integral low noise amplifier with high and low level multicoupled outputs, internal DC power regulator and visual plus electric LNA fault detection. The receive center frequency (Fo) is designed to be factory tuned between 380 and 430 MHz, and is configured for 5 MHz passband, with 10 MHz separation between receive Fo and transmit Fo. In the receive path, the WSDA-00020 offers a low noise figure of 2.8 dB (max) for the high gain output and 3.4 dB (max) for the low gain outputs. The receive path is designed to be tuned on the low side of the transmit passband, and offers –60 dBc (min) rejection from DC to Fo-12.5 MHz, –80 dBc rejection from Fo +7.5 MHz to 1000 MHz and –60 dBc (min) from 1000 to 4000 MHz. Passband return loss is specified at 15 dB (min) at all ports. Operating temperature is –30° to +50°C. Delivery: 8 to 10 weeks.
K&L Microwave Inc., Salisbury, MD (410) 749-2424.

Circle No. 237

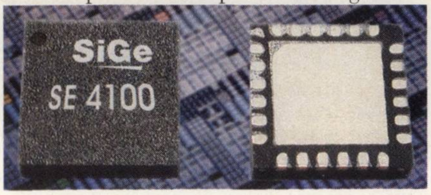
■ Heat Spreaders



The Diamonex® CVD diamond heat spreaders are ideal for high power device applications such as laser diodes, microwave FETs and MMICs and advanced multi-chip modules. Due to diamond's extremely high thermal conductivity, these heat spreaders improve performance by reducing junction temperatures, allowing for increased power output, speed and reliability. In addition, Diamonex CVD materials have a high electrical resistivity, which allows top-to-bottom isolation in the package design.
Morgan Advanced Ceramics, Allentown, PA, sales@diamonex.com.

Circle No. 238

■ Integrated Receiver IC



The PointCharger™ SE4100 integrated receiver IC delivers benchmark levels of power consumption and integration to enable smaller, less expensive and longer battery powered operation of peripheral devices used for automotive vehicle location, covert tracking, security, cellular, PDA and personal navigation systems. This IC integrates the IF filter, VCO, tank circuitry and LNA into a package with a typical draw of 10 mA from a 2.7 V supply. Integrating the complete receiver chain onto a single device lowers the bill of materials compared to most commercially available radios, thereby reducing cost and form factor while easing assembly, manufacture and test.
SiGe Semiconductor, Ottawa, Ontario, Canada (613) 820-9244.

Circle No. 239

[Continued on page 136]

MATERIAL

Thermal Interface Material

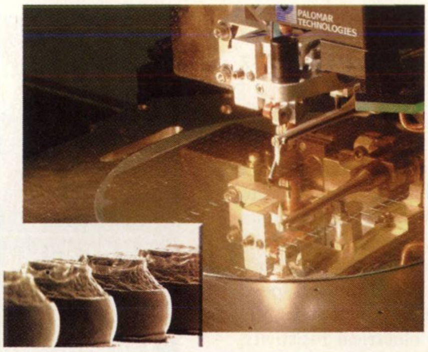
POLARCHIP™ CP7500 thermal interface material is a highly compressible, thermally conductive material ideally suited for filling air gaps between heat generating devices and heat sinks, heat spreaders and metal chassis. At 0.010" thick, this material provides excellent thermal performance in applications such as optical modules. It is especially effective in applications where there are surface irregularities and where low stress on components is required. In addition, the material passes Bellcore Silicone specifications. The material can be supplied in sheet form or in precision die-cuts that are suitable for high volume automated assembly systems. Price: 10¢ per square inch in high volumes.

W.L. Gore & Associates Inc.,
Elkton, MD
(800) 445-4673.

Circle No. 240

PROCESSING EQUIPMENT

High Precision Assembly System



The Gold Connection consists of the company's new Gold Bumper™ and Flip Chip TCB™. The Gold Connection is an integrated solution that addresses the need for smaller package density, increased reliability and increased signal performance, while providing a clean, environmentally safe alternative to lead-based processes. The Gold Bumper produces gold wire ball bumps for flip chip applications. Using standard 1 mil gold wire in a process similar to wire bonding, the Gold Bumper creates planarized, tailless bumps in a consistent, repeatable, single-step process with up to 5 micron placement accuracy. Planarity and a consistent top surface area on each bump provide ideal connectivity and attachment for flip chip applications. It provides the flexibility to quickly and easily change the ball array, position and bump shape to match the desired attach process.

Palomar Technologies Inc.,
Vista, CA
(760) 931-3600.

Circle No. 241

SOFTWARE

Circuit Simulation Software

Version 6.0 of LINMIC+/N microwave and RF IC design suite is a physics-based suite of integrated tools for the efficient EM-based design and layouting of passive and active, linear and nonlinear microwave circuits. A completely redesigned 2.5D PEEC simulation engine for multiplayer components with extended layout library from basic elements up to complete baluns and transformers with orders magnitude speed advantage compared to 3D planar tools. An extended harmonic balance algorithm for nonlinear circuits with digitally modulated excitation signals is also included. New nonlinear MESFET/HEMT/MOSFET models for harmonic balance simulation, including mode parameter extraction from measured data, are provided. Additionally, the functions and look and feel of the GUI have been further improved.

AC Microwave GmbH,
Aachen, Germany +49 241 8793022.

Circle No. 242

Filter Test Automation Program

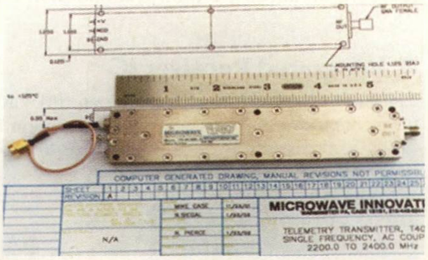
The FTAP™ filter test automation program is designed to be an "off the shelf" program to automate users' filter test needs, while reducing the cost and increasing the accuracy of making filter measurements. FTAP is intended to increase accuracy and throughput, while reducing repetitive procedures. It offers a clean easy to navigate interface, utilizing the familiar look and feel of the Windows™ interface. The program supports two modes of operation, engineering and production. In engineering mode all functionality of the program is brought forward to the main screen, allowing for complete control of the grogram. In production mode, FTAP falls back into the traditional "serial" mode of operation, prompting the operator through every step of the measurement.

CorNic Technologies,
Ellicott City, MD (410) 627-0795.

Circle No. 243

SOURCES

Video and Telemetry Transmitter



The T400 series of transmitters offers improved efficiency and features ultra-high shock survival capabilities while operating on reduced voltages in a small form factor package. These characteristics make the transmitter conducive to modern telemetry as well as remote video applications. Typical current consumption of less than 800 mA at 8 V DC ap-

[Continued on page 138]

plied voltage allows users to resize battery requirements possibly freeing up on board space for other electronics and sensor functions. This series is also capable of supporting high data rates as a result of the circuitry design with the resultant being able to support the most modern PCM telemetry systems with greater than 15 Mbps throughput. The transmitter operates over the 2200 to 2400 MHz frequency range with up to 2 W power output from –40° to +85°C.

Microwave Innovations,
Warminster, PA (215) 443-5244.

Circle No. 245

Ultra Low Noise VCO

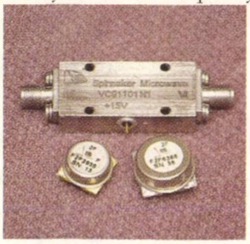
The model MW500-1241 voltage controlled oscillator (VCO) is designed for CATV and other wireless applications. It has a very low phase noise level of –112 dBc/Hz at 10 kHz offset, –132 dBc/Hz at 100 kHz. This VCO is also very clean and stable and harmonics are below –27 dBc, pushing is 0.17 MHz/v, pulling 0.9 MHz peak-to-peak and temperature drift is –0.05 MHz/°C from –40° to +80°C. Supply voltage is +5 V at 22 mA, power output is +4 dBm ±0.3 dB with tuning voltage range of 0 to 10 V. This VCO does not use a coaxial resonator. Size: 0.50" × 0.50" × 0.15".

Micronetics VCO Products Division,
Hudson, NH (603) 579-0900.

Circle No. 244

Low Noise VCO

The F2F series of low noise VCOs covers 2 to 20 GHz (in bands) and is ideally suited for frequency synthesizer applications. The fundamental output has a minimum of 20 dB isolation to the oscillator and is normally used to drive a phase locked system. The second output is achieved by using active doubling or filtering circuitry directly coupled to the oscillator and then connected to a buffer amplifier. This method of harmonic generation will reduce the noise figure to a minimum when the unit is used as a local oscillator. For synthesizer applications, the overall prescalar value can be reduced, improving noise floor performance. The series is packaged in hermetically sealed TO-8, TO-8B or SMA module packages and is guaranteed to meet specifications over a temperature range of –20° to +75°C.



Spinnaker Microwave Inc.,
Santa Clara, CA (408) 732-9828.

Circle No. 247

High Performance VCO

The model V495ME01 VCO is designed for the Mobitex radio market. It uses innovative design techniques to deliver unparalleled SSB phase noise while drawing little current. The VCO covers the 485-505 MHz frequency range within 0.5 to 4.5 V DC tuning range making it ideal for quick integration into PLLs where the error voltage can be taken directly from the ICs charge pump circuitry. It exhibits a spectral purity of –115 dBc/Hz (typ) at 10 kHz from the carrier while preserving battery life. The V495ME01 consumes only 10 mA (typ), while operating from a 5 V DC supply. The VCO will further enhance the performance of any Mobitex radio PLL due to its 1.1:1 linearity over frequency and temperature. The oscillator typically suppresses harmonic levels to better than –7 dBc and with an average tuning gain of only 10 MHz/V across the frequency band. This VCO is designed for the harshest outdoor environment as it is specified to operate over the extended commercial temperature range of –40° to +85°C. Size: 0.50" × 0.50" × 0.16". Price: $15.95 each.

Z-Communications Inc.,
San Diego, CA (858) 621-2700.

Circle No. 248

[Continued on page 140]

NEW PRODUCTS

■ VCXO/TCXO

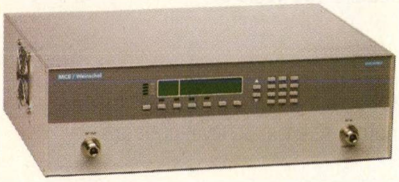
These popular TCXO (XO3080/XO3082) and VCXO (XO7080/XO7082) oscillator families have been extended to incorporate frequencies in the range of 10 to 20 MHz. These common family platforms had previously addressed frequency references from > 20 MHz through 125 MHz. The extension of the family to cover these frequencies was achieved through the incorporation of a special AT-cut crystal resonator process. The net result of this is an improvement in close in phase noise performance (–90 dBc/Hz at 10 Hz and –125 dBc/Hz at 100 Hz offsets), as well as the enabling of tighter frequency/temperature performance across all family members over extended operating temperature ranges. The extension to these families is targeted at applications where guaranteed superior stability over extended periods of time (10 to 20 years) and/or over extended operating temperature ranges are absolute application requirements.

Piezo Technology Inc. (PTI),
Orlando, FL (407) 298-2000.

Circle No. 246

SUBSYSTEM

■ Programmable Attenuator Unit



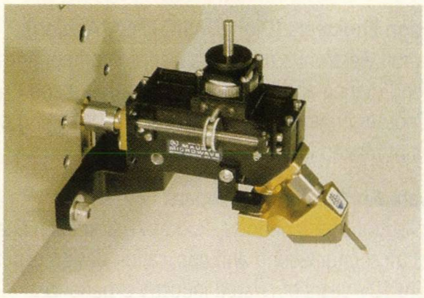
The 100 W hot switching SmartStep™ programmable attenuator is designed using a highly adaptable platform that allows configuration of the step attenuator to the customer's requirements using either a remote control or through front panel control. These units provide a flexible, easy to program, low cost solution for bench test/calibration setups and subsystem applications.

MCE/Weinschel,
Frederick, MD (800) 638-2048
or (301) 846-9222.

Circle No. 249

SYSTEM

■ Wafer Probe Mount and Pre-match Tuners



The model MT902 precision 2.4 mm wafer probe mount and pre-match tuners operate from 8 to 50 GHz. There are three configurations: a high frequency 21.5 to 50.0 GHz pre-match tuner; a low frequency 8.0 to 21.5 GHz pre-match tuner; and an 8 to 50 GHz wafer probe mount. The series of pre-matching tuners are highly stable, low loss wafer probe mounts used in on-wafer device characterization applications. The pre-matching tuners are used to extend the matching range of the company's automated tuners for performing device characterization measurements on devices that have low impedance.

Maury Microwave,
Ontario, CA (909) 987-4715.

Circle No. 250

TEST EQUIPMENT

■ AutoCal® Modules

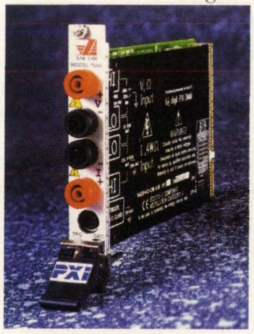
The 36584 series AutoCal® modules provide fast, repeatable and high quality coaxial calibrations for 2-, 3- and 4-port S-parameter requirements. The precisely characterized AutoCal modules decrease downtime in the manufacturing line by requiring only a single connection instead of the separate short, open, load thru (SOLT) connections of a manual calibration. AutoCal modules are alternatives to SOLT calibrations because they deliver more repeatable calibrations, which translates into increased throughput, lower manufacturing costs and improved yield by avoiding mistakes caused by improper manual calibration procedures. The series covers the 10 MHz to 9 GHz frequency range. Price: $7900. Delivery: eight weeks.

Anritsu Corp.,
Morgan Hill, CA
(800) 267-4878.

Circle No. 251

■ Digital Multimeters

These two compact PCI/PXI digital multimeters (DMMs) are designed for automated production testing,



laboratory automation, portable/field testing, disk drive testing and resistor network testing applications. The model 7040 DMM has 6-3/4 digit performance with 0.006 percent basic DVC accuracy, and can be used as a general purpose DMM, providing resolution, accuracy, functionality and speed. The model 7044 digit LCR sourcing digital multimeter provides additional measurement functions, including inductance, capacitance and resistance measurement and sourcing capabilities. It was designed for applications demanding precision sources with simultaneous measurements, such as parametric testing. Self-calibrating and able to provide up to 1000 readings per second, both models provide flexible, full-featured auto-ranging and sourcing.

ASCOR Inc.,
Fremont, CA (510) 490-2300.

Circle No. 252

NEW LITERATURE

"Myths" Brochures

This range of brochures is based on "Wireless Myths" and is aimed at those involved with the selection, purchase or design of wireless systems for use in a wide range of OEM applications. The four literature pieces include valuable advice concerning equipment selection, standards, interoperability and approvals.

AeroComm Inc., Lenexa, KS (800) 492-2320.

Circle No. 200

General Purpose Test Instruments Catalog

This 65-page catalog features the company's general purpose test instruments such as RF and microwave instruments, digital design and debug tools, basic instruments, test software and connectivity products, and accessories.

Agilent Technologies, Englewood, CO (800) 452-4844.

Circle No. 201

RF/Microwave CW Generators Brochure

This 15-page brochure features the company's MG3690A family of CW generators. Product photographs, descriptions, performance graphs, specifications, spectral purity, RF output, inputs and outputs, and ordering information are provided.

Anritsu Microwave Measurements Division, Morgan Hill, CA (800) 267-4878.

Circle No. 202

Short Form Catalog

This seventh edition of the company's short form catalog covers a broad range of interconnection and packaging products. The 12-page catalog includes the Correct-A-Chip™ technology and products, which enable designers to convert virtually any package type or footprint to any other.

Aries Electronics Inc., Frenchtown, NJ (908) 996-6841.

Circle No. 203

Crystal Oscillators and Quartz Crystals Catalog

This 52-page catalog features the company's clock oscillators, VCXO oscillators, TCXO oscillators, TCVCXO oscillators, OCXO oscillators, OCVCXO oscillators, automated test systems and crystals. Product outline drawings, descriptions, information, features, specifications and applications are provided.

Bliley, Erie, PA (814) 838-3571.

Circle No. 204

Ferrite Catalog

This catalog features a range of ferrite transformers, an essential component of broadband technology, along with a variety of other products such as capacitors, varistors, chokes and surge arresters. Ferrite transformers are used in a variety of functions in broadband technology, such as high pass and low pass filters, impedance matching and insulation transformers.

EPCOS UK Ltd., London, UK 08705 550 5000.

Circle No. 205

Integrated Microwave Assembly Brochure

This eight-page integrated microwave assembly brochure features full color photographs, block diagrams and salient performance characteristics of complex modules including synthesized up and down converters, phase and amplitude control for simulator systems, solid-state receiver protectors, wide band switch matrices and transceivers.

Herley Industries, Farmingdale, NY (631) 630-2000.

Circle No. 206

Components Catalog

This 192-page components catalog, deemed Catalog 223, features more than 390 new products including power components, test equipment, network accessories, passive components, design accessories and computer products. The company has expanded its brand name products while acquiring new lines of power supplies and converters.

Jameco Electronics, Belmont, CA (650) 592-8097.

Circle No. 207

Materials Catalog

This catalog features the company's newest addition to its Meldin® family of high temperature polyimides, the Meldin 7000 series. Operational temperatures are +600°F for continuous operation, and +900°F for intermittent exposure. Whereas the Meldin 2000 series has been handling these high temperatures for over 20 years, the Meldin 7000 series polyimides are unique because they can be processed by direct forming.

Saint-Gobain Performance Plastics, Bristol, RI (401) 253-2000.

Circle No. 208

Antenna Element Solutions Brochure

This six-page brochure provides information on the company's antenna solutions development, including consulting, range testing, modeling and design, prototyping, testing, manufacturing, and logistics. Product photographs, applications, features and benefits, and performance characteristics are also included.

Spectrum Control Inc., Fairview, PA (814) 835-1650.

Circle No. 209

CD-ROM Catalog

This CD-ROM catalog features a full line of microwave connectors, including hard-to-find parts ranging from UG styles to 40 GHz custom types. It features connectors ranging in size from MMCX to 7-16 and covers virtually all microwave connector applications.

TRU Corp., Peabody, MA (800) 262-9878.

Circle No. 210

Interconnection Solutions Catalog

This catalog offers important reference material for electronic designers and lists the company's complete line of connectors for surface-mount and through hole applications, as well as its high performance assembly equipment.

Zierick Manufacturing Corp., Mt. Kisco, NY (800) 882-8020.

Circle No. 211

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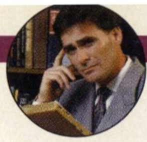

THE BOOK END

■ *Theory and Design of Microwave Filters*

Ian C. Hunter

The Institution of Electrical Engineers
353 pages; $89
ISBN: 0-85296-777-2

Microwave filters are important components used in many RF and microwave systems, such as cellular radios, satellite communications and radar. The classic treatise on microwave filters and couplers by Matthaei, Young and Jones, published 36 years ago, is still widely used but has never been revised. This book includes other filter types and design theories which did not exist then.

The purpose of this book is to provide a single source for filter design, which includes basic circuit theory, network synthesis, and the design of a variety of microwave filter structures. The philosophy throughout the book is to present design theories, followed by specific examples with numerical simulations of the designs. Where possible, examples of real devices have been used to illustrate the theory. The book is aimed at final year undergraduates, and MSc and PhD students. It should also form a useful reference for research workers and engineers who are designing and/or specifying filters for commercial systems. The author makes extensive use of mathematics throughout the book.

"The purpose of this book is to provide a single source for filter design..."

After an introduction showing applications and realizations of RF and microwave filters, Chapter 2 is devoted to basic network theory, covering linear passive time-invariant networks, loss less networks, ladder networks, synthesis and analysis of two-port networks, and other types of analysis. Chapter 3 is dedicated to the designs of lumped low pass prototype networks. Chapter 4 covers circuit transformations of lumped prototype networks, including impedance transformations and practical procedures for measurements of the different couplings and Q-factors of the resonators. TEM transmission line filters are the subjects of Chapter 5. Broadband TEM filters with generalized Chebyshev characteristics, parallel-coupled transmission lines, interdigital filters, combine filters and narrow band coaxial resonator filters are described. Chapter 6 is dedicated to waveguide filters and Chapter 7 to dielectric resonator filters. Chapter 8 describes miniaturization techniques for microwave filters, including super conducting filters, surface acoustic wave filters and active microwave filters.

To order this book, contact: The Institution of Electrical Engineers, c/o Whitehurst & Clark, 100 Newfield Ave., Edison, NJ 08837 (888) 438-2517; or PO Box 96, Stevenage, Herts SG1 2SD, UK +44 1438 313311.

■ *RF Measurements of Die and Packages*

Scott A. Wartenberg

Artech House Inc.
224 pages; $89, £62
ISBN: 1-58053-273-x

Accurate RF measurements are an important phase in the design and development of RFIC and MMIC circuits. The goal of this book is to provide the reader with methods and procedures to perform better RF measurements. It is based principally on the use of vector network analyzers (VNA) and explains how to use coplanar probes and test fixtures to characterize the circuits.

Chapter 1 introduces the topics covered subsequently and details the essential elements in an RF test system: the interface between the system and device under test (DUT), VNA and connecting cables. Chapter 2 explains the errors found in an RF test system and how they can be mathematically removed by applying error models. Chapter 3 discusses the construction and RF characteristics of coplanar probes. Chapter 4 describes a typical high volume test setup, focusing on the membrane probe. Typically, the final product is not a bare die but one that has been wire-bonded and packaged. Chapter 5 covers how to design an RF test fixture. In particular, it discusses the parasitic effects of the fixture on the DUT as well as a detailed discussion of how to design RF transitions in the fixture. The often-challenging task of calibrating a test fixture is also included. Chapter 6 explains how to use RF coplanar probes to measure die on the wafer. This chapter centers on how to de-embed the effects of the probe pads and interconnects leading to the DUT. Moving beyond the DUT to coplanar probe interface, Chapter 7 describes the rest of the RF test systems, including a noise measurement system, a high power RF test system and a thermal (hot and cold) measurement system. Chapter 8 explores package-testing, breaking the test fixture down section-by-section and explaining the RF aspects of its design. It also covers techniques on how to characterize packages, both empty and with the die mounted inside. Finally, Chapter 9 looks at future trends in the characterization of RF and microwave circuits.

"The goal of this book is to provide the reader with methods and procedures to perform better RF measurements."

To order this book, contact: Artech House Inc., 685 Canton St., Norwood, MA 02062 (781) 769-9750 ext. 4002; or 46 Gillingham St., London SW1V 1HH, UK +44 (0) 207 596-8750.

Dan Massé

Dan Massé is a member of the Microwave Journal *staff.*

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