A PENTON PUBLICATION MARCH 2001

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FOR DESIGNERS AT HIGHER FREQUENCIES

Microwaves & RF

Wireless Technology/ Show Wrapup Issue

NEWS
Wireless Symposium signals changes to come

DESIGN FEATURE
Analyzing mm-wave vector-analyzer calibrations

PRODUCT TECHNOLOGY
YIG-based synthesizers silence phase noise

Amplifier IC powers 2.4-GHz WLAN applications

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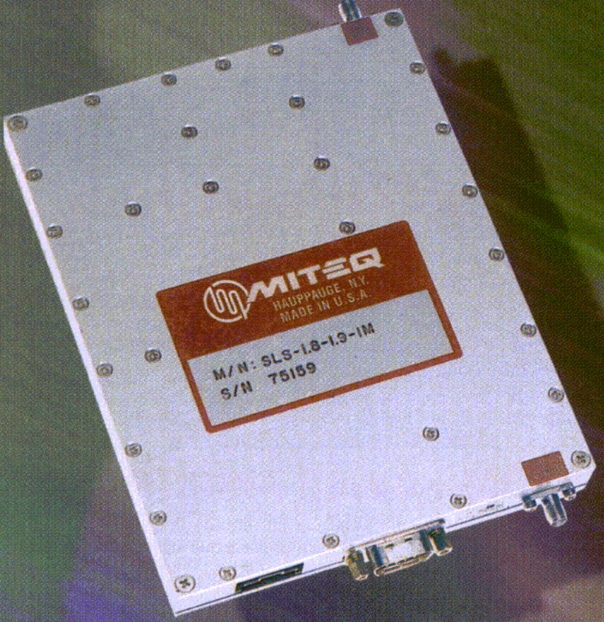
LOW COST FAST SWITCHING SYNTHESIZERS

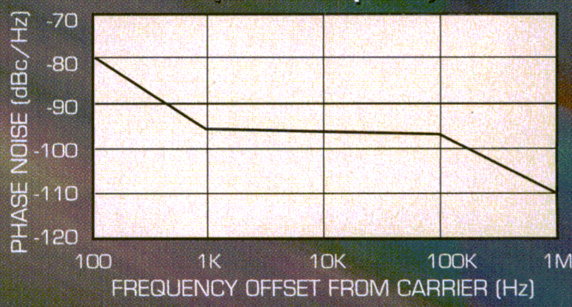


- **Operating Bands From 1 – 15 GHz**
- **Ideal for Wireless Applications**

OPTIONS

- **12 Volt Operation**
- **Optimized Bandwidth/Tuning Speed Combination**

TYPICAL PHASE NOISE AT 2 GHz (2 MHz Step Size)



SPECIFICATIONS

MODEL	SLS SERIES
Frequency	1–15 GHz
Frequency step size	200 kHz to 10 MHz
Tuning range	Up to half octave
Switching speed	500 μs*
Output power	10 dBm min.
Output power variation	±2 dB min.
In band spurs	70 dBc min.
Harmonics	20 dBc
Phase noise	See graph
Reference	Internal or external
External reference Frequency Input power	 5/10 MHz 3 dBm ±3 dB
Frequency control	BCD or binary
DC power requirement	+15 or +12 volts, 200 mA 5.2 volts, 500 mA
Operating temperature	-10 to +60°C
Size	5" x 6.5" x 0.6"

* Acquire time depends on step size (low as 25 μs).

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3 YEAR WARRANTY

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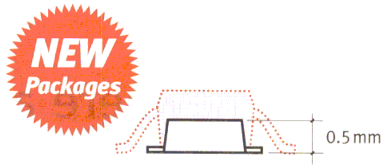
New, Smaller Packages



- **Flat Lead** design reduces parasitics and improves electrical performance
- **Low Profile** is ideal for VCO modules and other space-constrained designs

Oscillators & Buffer Amps

With the best *1/f* performance available, these devices help you achieve the phase noise your design demands. They're also available in Twin Transistors.

Part Number	Corner Freq*	V_{CE}	I_C	Package
NE856M13	3 KHz	3 V	30 mA	M13
NE685M13	5 KHz	3 V	5 mA	M13

Review Application Note AN1026 on our website for more information on 1/f noise characteristics and corner frequency calculation.

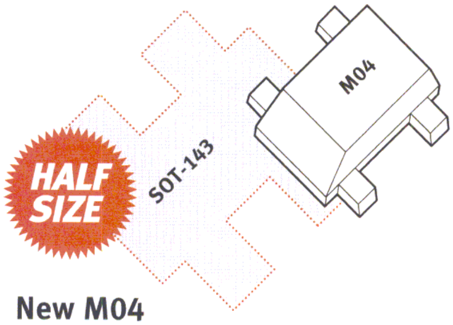
New M13

One sixth the footprint area of a SOT-323

LNAs

Need low noise and high gain in an ultraminiature package for your hand-held wireless products? These new high frequency NPN transistors deliver!

Part Number	Description	NF	Gain	Freq	Package
NE687M13	11 GHz f_T LNA	1.2 dB	13 dB	1 GHz	M13
NE661M04	25 GHz f_T LNA	1.2 dB	22 dB	2 GHz	M04
NE662M04	23 GHz f_T LNA	1.1 dB	20 dB	2 GHz	M04

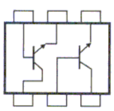


New M04

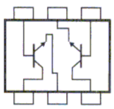
Half the footprint area of a SOT-143

Twin Transistor Devices

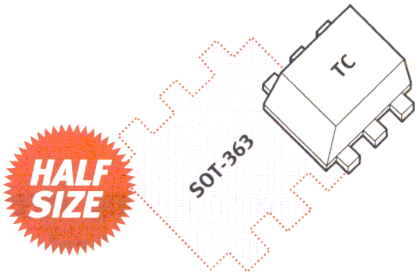
Cascode LNAs, cascade LNAs and oscillator/buffer combinations are just three possible uses of these versatile devices. *Matched Die* versions pair two adjacent die from the wafer to help simplify your design, while *Mixed Die* versions — an NEC exclusive — let you optimize oscillator performance while achieving the buffer amp output power you need. 40 different combinations available.



Part Number	Description	Q1 Spec	Q2 Spec
UPA810TC	Matched Die/Cascade LNA	NE856	NE856
UPA814TC	Matched Die/Cascade LNA	NE688	NE688



Part Number	Description	Q1 Spec	Q2 Spec
UPA826TC	Matched Die/Osc-Buffer Amp	NE685	NE685
UPA840TC	Mixed Die/Osc-Buffer Amp	NE685	NE681



New TC Twin Transistors

Half the footprint area of a SOT-363

Data Sheets and Application Notes are available at **www.cel.com**

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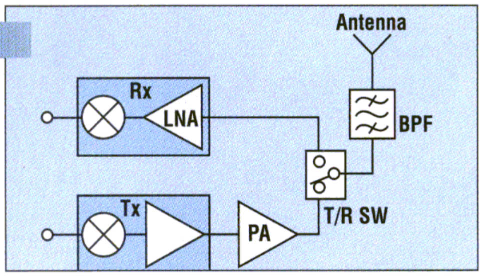

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WEBWATCH

DESIGN FEATURES

PRODUCT TECHNOLOGY

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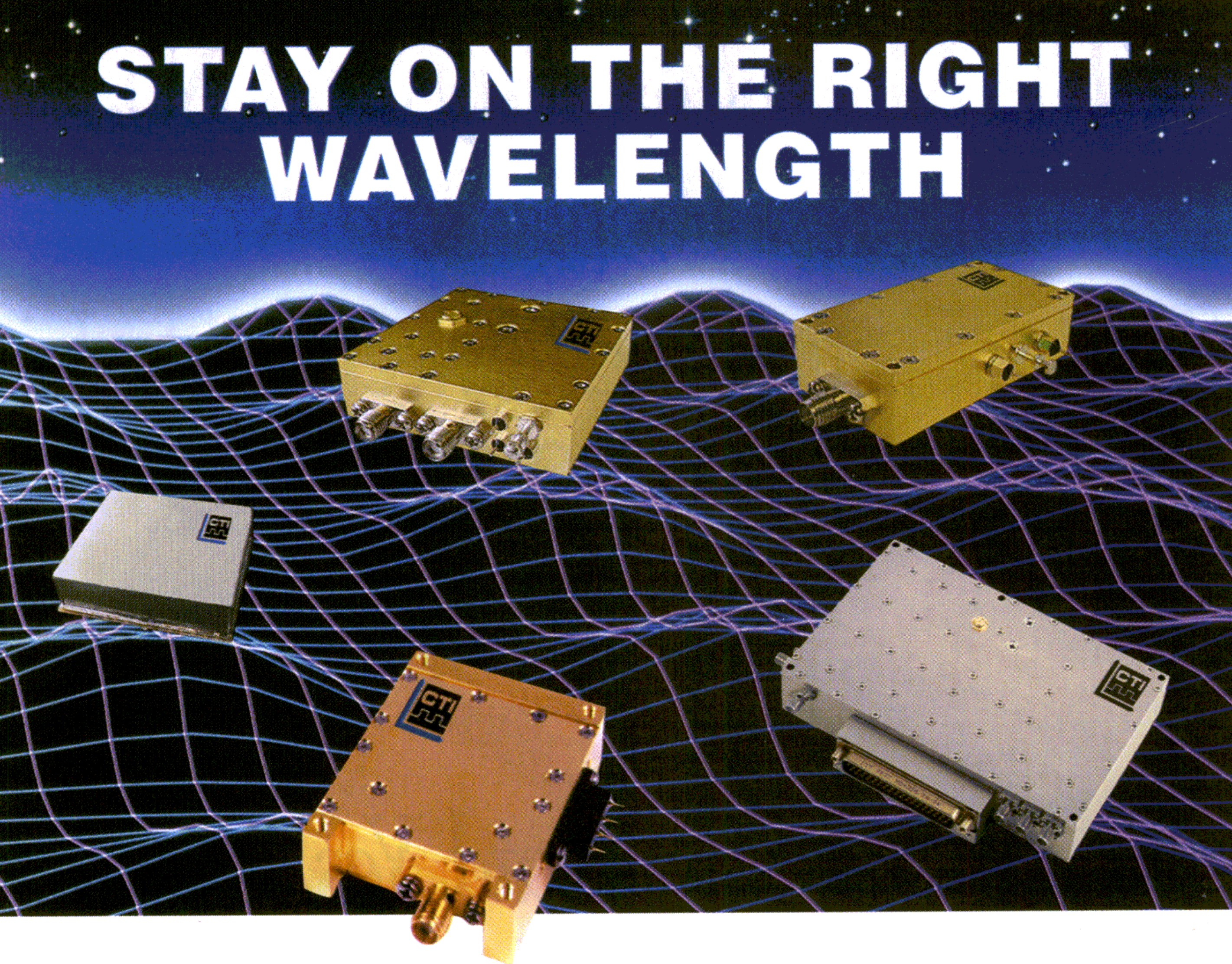
ME7840A Power Amplifier Test System (PATS)



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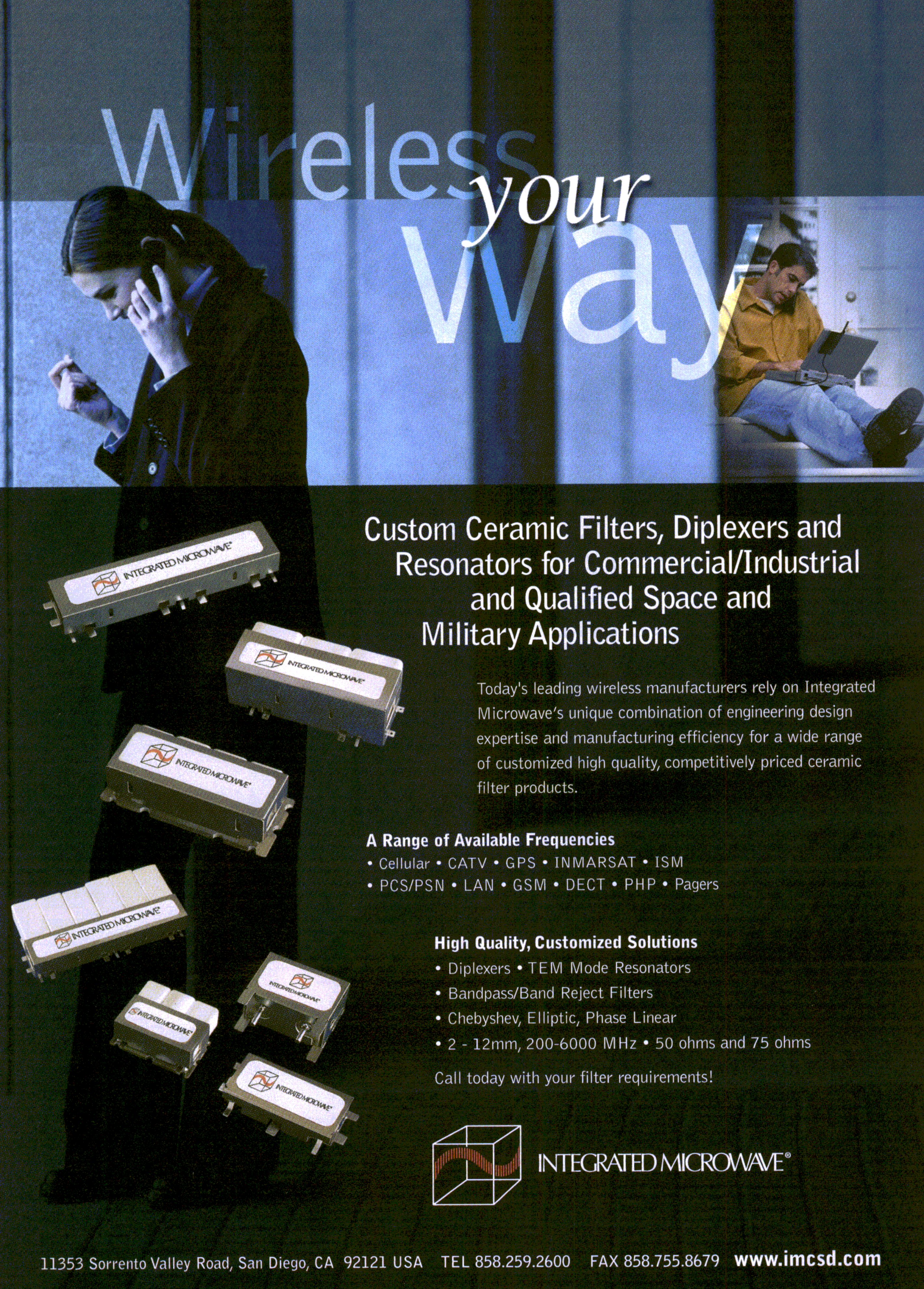
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DEFENSE SPENDING

To the editor:

I read and enjoyed the article "Defense Spending Choices Force A Balancing Act" on defense spending for military electronics (June 2000, p. 29) by Gene Heftman.

You pointed out a key problem faced by military contractors. They want to buy cutting-edge components in low volume at commercial high-volume prices. This is not an easy challenge to meet.

The commercial-off-the-shelf (COTS) program has helped to meet this challenge to some extent, providing contractors with greater flexibility to seek out components for their projects. The other factor, hybridization, has probably helped a great deal too. But I think there is another solution that has been largely ignored. Programmable components could provide the military with the technical edge that they are looking for without imposing serious price penalties.

In the digital world, we are starting to see field-programmable gate arrays (FPGAs) that rival high-performance application-specific integrated circuits (ASICs) in terms of gate count and speed. Increasingly, these components carry many mixed-signal functions. On the analog side, there have been a number of attempts to build sophisticated programmable arrays of analog functions in order to create more configurable designs. However, they have not really caught on, because they cost a bit too much and do not seem to have a market-building application yet. But their potential for high performance and complex functionality will only improve over time. I believe that the US military could benefit by devoting resources to their development as well as the development of FPGAs. I believe this would give defense contractors an edge toward creating high-performance equipment that meets the strictest military-specification standards.

Of course, many believe that the commercial electronics industry can reap the same benefits, but sometimes federally sponsored research and design are needed to lay the groundwork first, due to the economics that are involved.

In any event, keep up the good work.

Stan Schurer

Please comment

Microwaves & RF welcomes mail from its readers. Letters should be typewritten and must include the writer's name and address. The magazine reserves the right to edit letters appearing in "Feedback." Address letters to:

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The future of wireless is here: Bluetooth™* has arrived. And to really exploit those cable-free market opportunities - in phones, home appliances, computers and peripherals - you'll need a semiconductor vendor that delivers quickly. **Philips Semiconductors** is that vendor. Evidence? Already a leader in wireless interconnectivity standards like 802.11 and IEEE 1394, Philips Semiconductors brought the first Bluetooth chipsets to market. And became one of the world's largest producers of Communication ICs. More than just chipsets, we provide optimized solutions involving ICs, software, OEM designs and unrivalled support in all stages of development. So if you have Bluetooth capabilities, we provide embedded cores for


create a cable-free world.
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CHARTING THE COURSE OF WIRELESS MARKETS

Change is coming to the industry, perhaps to all industries. Business has been so good for so long that financial forecasters are loathe to use words like "slump" when referring to a current softening of orders. Certainly, the "R" word (recession) brings even more discomfort to business managers who must now account for lofty projections and sales budgets based on the almost automatic rapid growth of the last several years throughout the electronics industry, and especially in the high-frequency portion of the industry serving wired and wireless communications applications.

But is everything as bad as it seems? The perception of our economic health is certainly not good and, unfortunately, perception is everything in the world of economics. Ironically, many companies are still showing growth in sales for 2001 compared to previous years, just not at the levels they had anticipated. When the average growth per year for a three-year period is in the area of 40 percent, a growth rate of 10 percent will appear almost lackluster (although in hard times, that 10 percent may not look so bad). Based on many recent announcements from large electronic companies, the economic health of the industry is at least questionable. When daily news reports are filled with announcements of layoffs by Lucent Technologies, Motorola, Cisco Systems and, most recently, Intel, it is not surprising to also learn about eroding consumer confidence and a hesitancy on the part of the general public to purchase that next "electronic toy."

After all, although the high-frequency industry is rooted in military and commercial applications, ultimately it is consumer confidence that dictates the direction of many firms' efforts. The recent Wireless/Portable Symposium and Exhibition (San Jose Convention Center, February 12-16, 2000) afforded the opportunity to take a three-day "snapshot" of opinions on the health of the industry and those opinions basically reinforced the idea that the high-frequency industry is extremely resilient—it has already faced the loss of a massive market in military electronics towards the end of the 1980s and survived, helping to fuel the growth of a large wireless industry.

Opinions at the show were varied, but many seemed to agree that "data" was one of the keys to future growth. Many were looking at the potential for markets such as Bluetooth and wireless local-area networks (WLANs). Some were even pinning their hopes on high-speed digital applications. But perhaps the greatest number of engineers and marketing professionals at the show mentioned the fiber-optic market as the place they would go if any part of their wireless business abandoned them. There is strong logic behind this opinion, since the manufacturing processes needed to produce microwave components are very similar to those used for producing fiber-optic components. In any case, the business environment may change, even become shaky, but this industry has shown the fortitude to survive and prosper.

Jack Browne

Publisher/Editor

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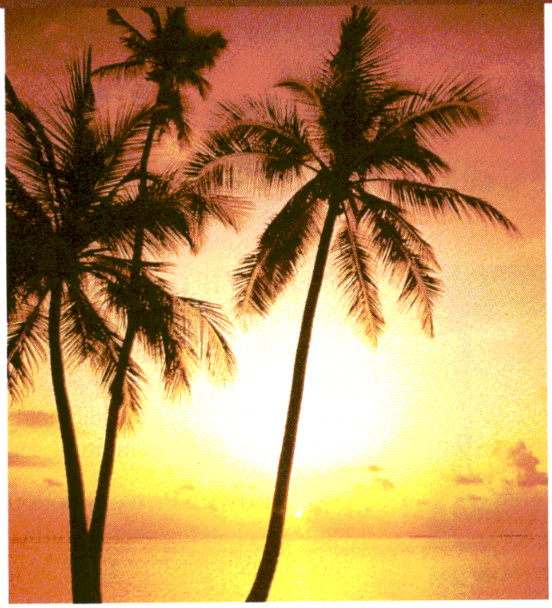

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MSA-2543	4.5	13.8	+13	12
MSA-2643	3.6	15.9	+21.9	27
MSA-2743	4	15.5	+28	50
ATF-54143*	0.55	17.4	+36	60@3V

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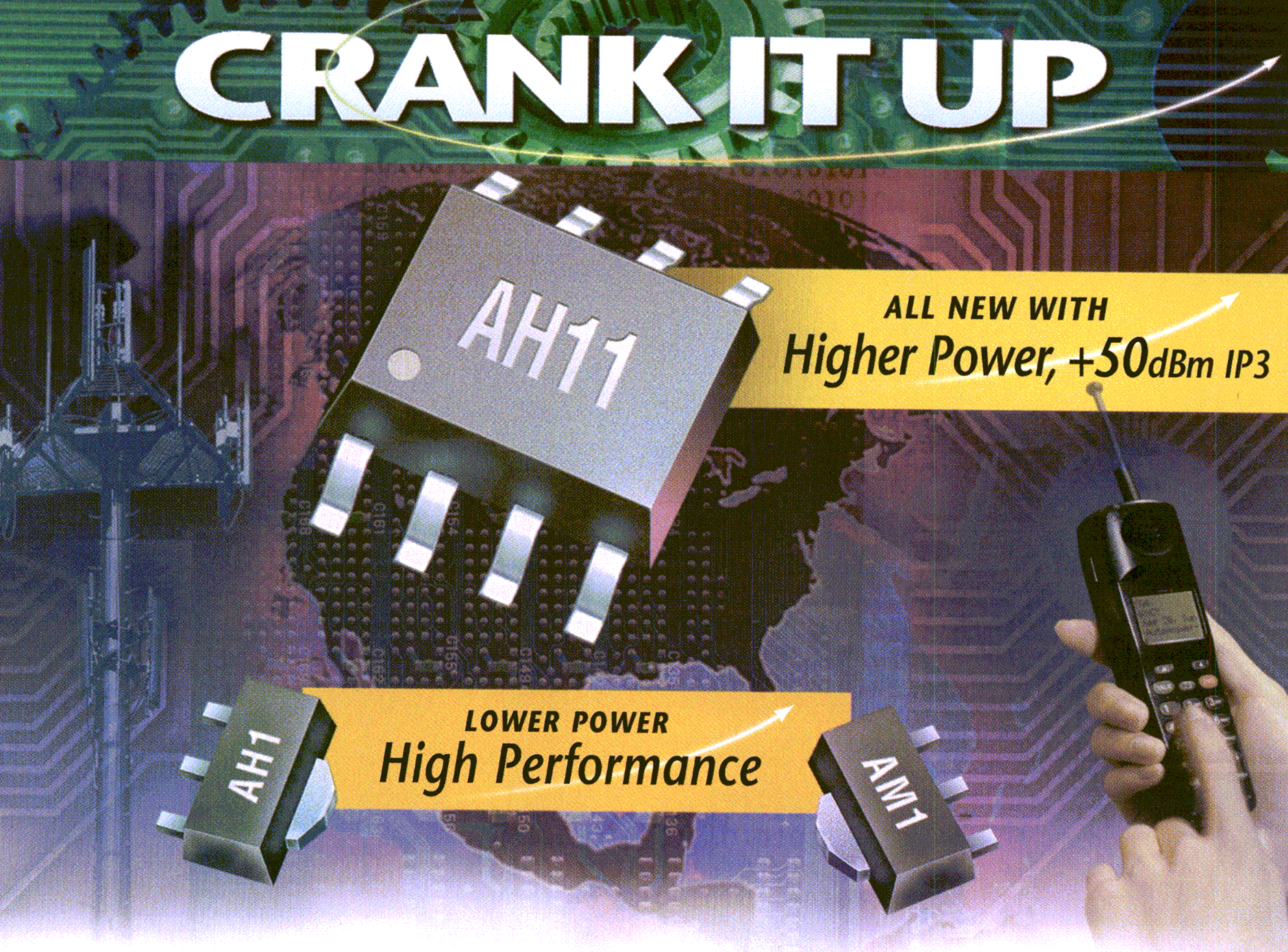

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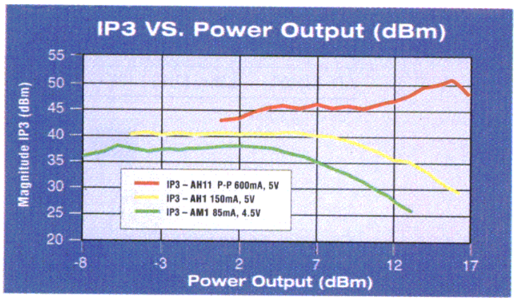

WJ High Dynamic Range Amplifiers

Product	Frequency (MHz)	IP3 (dBm, typ.)	P1dB (dBm, typ.)	NF (dB, typ.)	Bias current (mA, typ.)
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AH1	250-3000	41	21	2.9	150
AM1	250-3000	36	18	2.6	75

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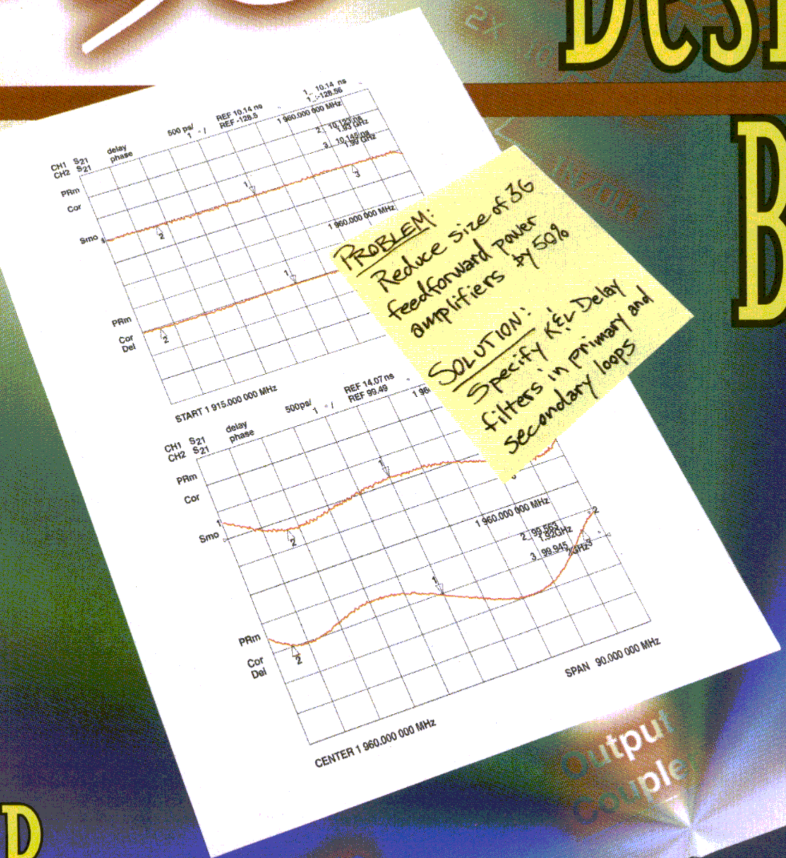
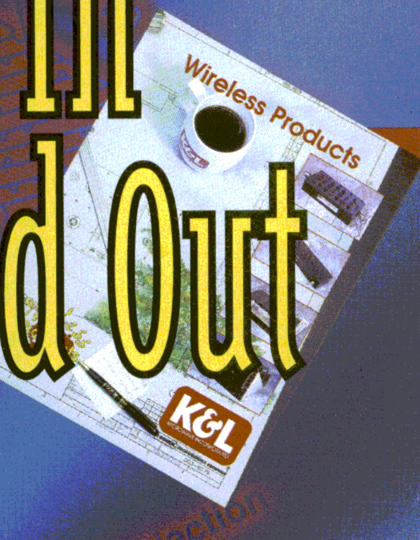
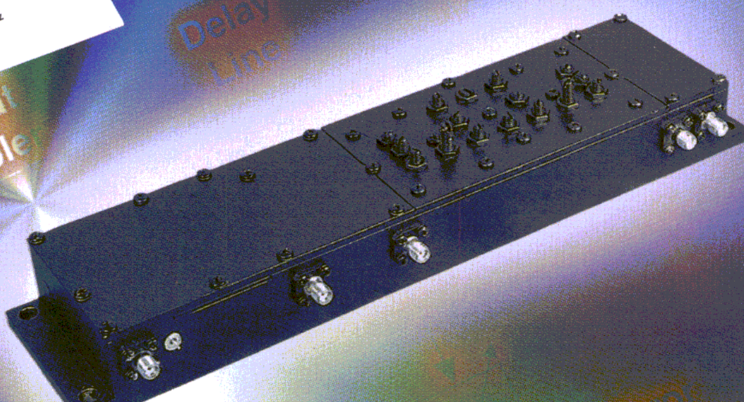
3G

Design In Build Out

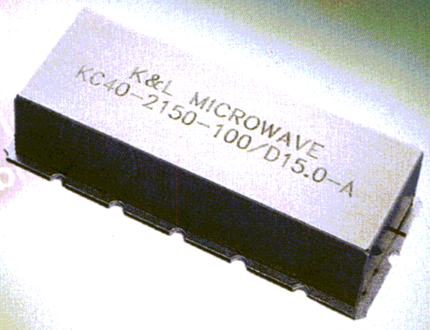






Primary loop delay filter assemblies integrate high power cavity delay filters, couplers and isolators into a single compact module for performance improvement, space savings and cost reduction.

Secondary loop miniature delay filters utilize a Patent Pending topology to provide delay equalization. The filters exhibit excellent delay and phase flatness in a miniature surface mount package. The 3G model measures a mere 1.5"L x 0.60"W x 0.4"H and can be mounted directly onto your PWB with pick and place machinery.



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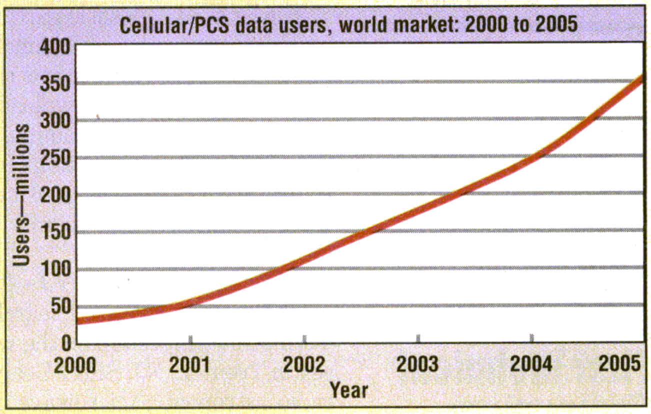
Wireless Is Still Strong Across The Globe

OYSTER BAY, NY—Despite recent reports concerning the slowdown in wireless growth, the reality is that wireless is still expanding at a rapid pace. Subscriber numbers have simply failed to meet the numerous irresponsible, overblown predictions which were made for the wireless market. Overall, wireless subscribers of every type will continue to grow, while the deployment of infrastructure supporting narrowband and broadband wireless applications will also continue to flourish (see figure), according to an Allied Business Intelligence, Inc. (ABI) study entitled "Wireless Data Networking 2000."



Wireless subscribers will continue to climb in every region of the world as more spectrum is made available in dozens of nations, as third-generation (3G) systems are rolled out, and as wireless technologies are continually improved. While there will be approximately 1.3 billion subscribers on second-generation (2G) and 3G systems by 2005, a growing share will be held by the new licensees currently planning the next generation of services. There will be more than 500 million data subscribers using truncated and actual Internet access over 2G and 3G networks as data services become mainstream throughout the world.

To keep up with these new services and systems, handset shipments will continue to rise substantially, supporting a replacement rate of more than 60 percent between 2002 and 2006.

In addition to mobile cellular phones, there will be a large upswing in laptop shipments and use, with over one-third of users with a laptop using true wireless Internet access by 2005. Personal digital assistants (PDAs) will also be used for truncated data services, with approximately three-quarters of all PDAs in use accessing rewritten Internet content by 2005.

"Wireless Data Networking 2000" forecasts the increase in global and US cell sites and the number of average subscribers per cell site.

North American PCB Market Is Experiencing Unprecedented Growth

SAN JOSE, CA—Complex applications, increasingly compact electronic components, the convergence of voice and data communications, and a booming telecommunications industry are pushing growth in the North American printed-circuit-board (PCB) market to unprecedented levels. In particular, the automotive industry and the computer and computer-peripherals industries have allowed producers to continue to hold high sales stakes in the PCB industry. According to new strategic research by Frost & Sullivan, North American Rigid and Flexible Printed Circuit Markets, high profit potential is expected as powerful multilayer boards with high layer counts continue to meet demands for compact and complex applications. While the overall market in 2000 was approximately $10.03 billion in revenues, a Frost & Sullivan industry analyst forecasts the market to reach revenues of approximately $16.66 billion in 2006.

This analysis also finds that while most single- and double-layer rigid PCB production has shifted to the Pacific Rim, North America remains the technological leader in multilayer rigid PCB initiatives. Innovations, such as high-density interconnects, have allowed manufacturers the ability to reduce the size and thickness of boards by condensing their lines and spaces. Consumer electronics are the major revenue source for rigid single-/double-sided circuits. It is the telecommunications market that dominates the flexible single-/double-sided circuit market, driven by cell-phone manufacturers' desires to reduce the size of their products. Moreover, the growth of the electronics-manufacturing-service (EMS) industry has altered the electronics landscape.

"The primary customers for printed circuits are changing," says the analyst. "Since EMS providers have begun to assemble many of the end products in the electronics industry, they have become a large customer segment for all types of printed circuits."

SDR Forum Supports FCC's Proposed Rules For Software-Defined Radio

WASHINGTON, DC—The Software Defined Radio (SDR) Forum announced its support for the Federal Communications Commission's (FCC) decision to propose new rules to speed the adoption of SDR technology. SDR technology will allow wireless phones and other mobile-communications devices to be upgraded and reconfigured by downloading software over the air. The SDR Forum is in favor of the FCC's adoption of proposed rules reflecting a minimal regulatory approach to the certification of software-defined radio transmitters (Txs).

The FCC's proposal is particularly important because it clarifies that SDR is permitted under current rules, and launches a proceeding that is designed to reduce the regulatory burdens of re-certifying and re-labeling. The ability to modify SDR-enabled products in the field by software downloads will allow customers to easily upgrade or alter the capabilities of their mobile communications devices after purchase. It will also make it easier for wireless communications companies to make fuller use of the spectrum by deploying radios that are capable of using different parts of the spectrum depending upon the software downloaded into them.

SETI League Announces Its First Technical Symposium

LITTLE FERRY, NJ—The SETI League, Inc., a not-for-profit organization involved in the privatized search for extraterrestrial intelligence, will be holding its first Technical Symposium on the weekend of April 28 and 29, 2001 at the College of New Jersey in Trenton, NJ. SETI League members from around the world will present papers on radio astronomy, microwave communications, and the hardware, software, and search strategies being used to seek scientific evidence of other intelligent civilizations in the cosmos. A respectable sampling of the SETI League's 1200 members from 60 countries will be in attendance, including many of the more than 100 SETI League members building and operating their own observing stations.

Pre-registration is requested by no later than April 1, 2001. The conference registration fee ($30 US for current SETI League members, and $80 for non-members) includes one copy of the Conference Proceedings, being published as a service to The SETI League by the American Radio Relay League.

SETI scientists seek to determine through microwave and optical measurements whether humankind is alone in the universe. Since Congress terminated NASA's SETI funding in 1993, The SETI League and other scientific groups have been attempting to privatize the research. Experimenters interested in participating in the search for intelligent alien life, or citizens wishing to help support it, can visit The SETI League's website at http://www.setileague.org for more information.

The First East Coast 300-mm Wafer-Chip Plant Is Slated To Open

RICHMOND, VA—Governor Jim Gilmore of Virginia has announced that Infineon Technologies will expand its presence in Henrico County by becoming the first semiconductor plant to commercially produce 300-mm wafers on the East Coast. Infineon Technologies Richmond, formerly known as White Oak Semiconductor, expects to create 1100 new jobs at full build-out as a result of the expansion. Production is due to start in 2002.

"It is gratifying to see that Virgina's pro-business climate has sparked another major semiconductor expansion," says Governor Gilmore. "My administration has positioned Virginia at the forefront of the latest advances in technology. As one of the first companies to produce 300-mm wafers in the US, Infineon Technologies is a perfect match for The Digital Dominion."

"We decided to expand our operations in Virginia because of the ongoing technology- and education-infrastructure assistance from the state and Henrico County," says Henry Becker, president of Infineon Technologies Richmond. "Because of our recent success, we were already in the process of hiring 300 new employees. Our partnership with Governor Gilmore and the Commonwealth of Virginia made the difference in our final decision."

In order to increase production capacity for leading-edge communication integrated circuits (ICs), Infineon Technologies Richmond will equip a new shell building now under construction on its current site. Under the first phase, the company will start to outfit the new module with 300-mm equipment. Leading-edge memory chips, which are currently manufactured on the 200-mm line, will move to the 300-mm line, making existing capacity available for production of communication ICs. Investments for similar facilities throughout the world have ranged from $1 billion to $1.5 billion at full completion.

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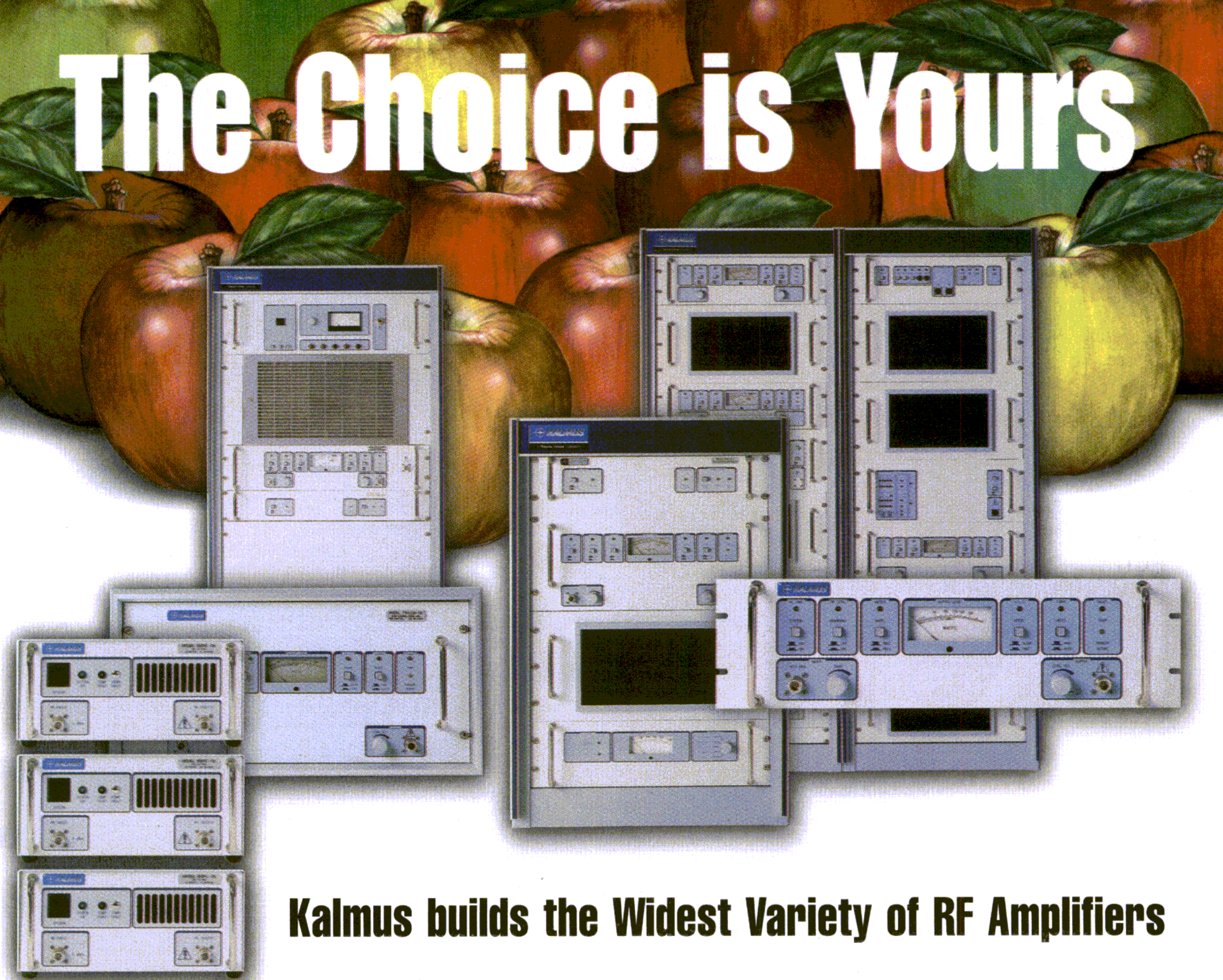

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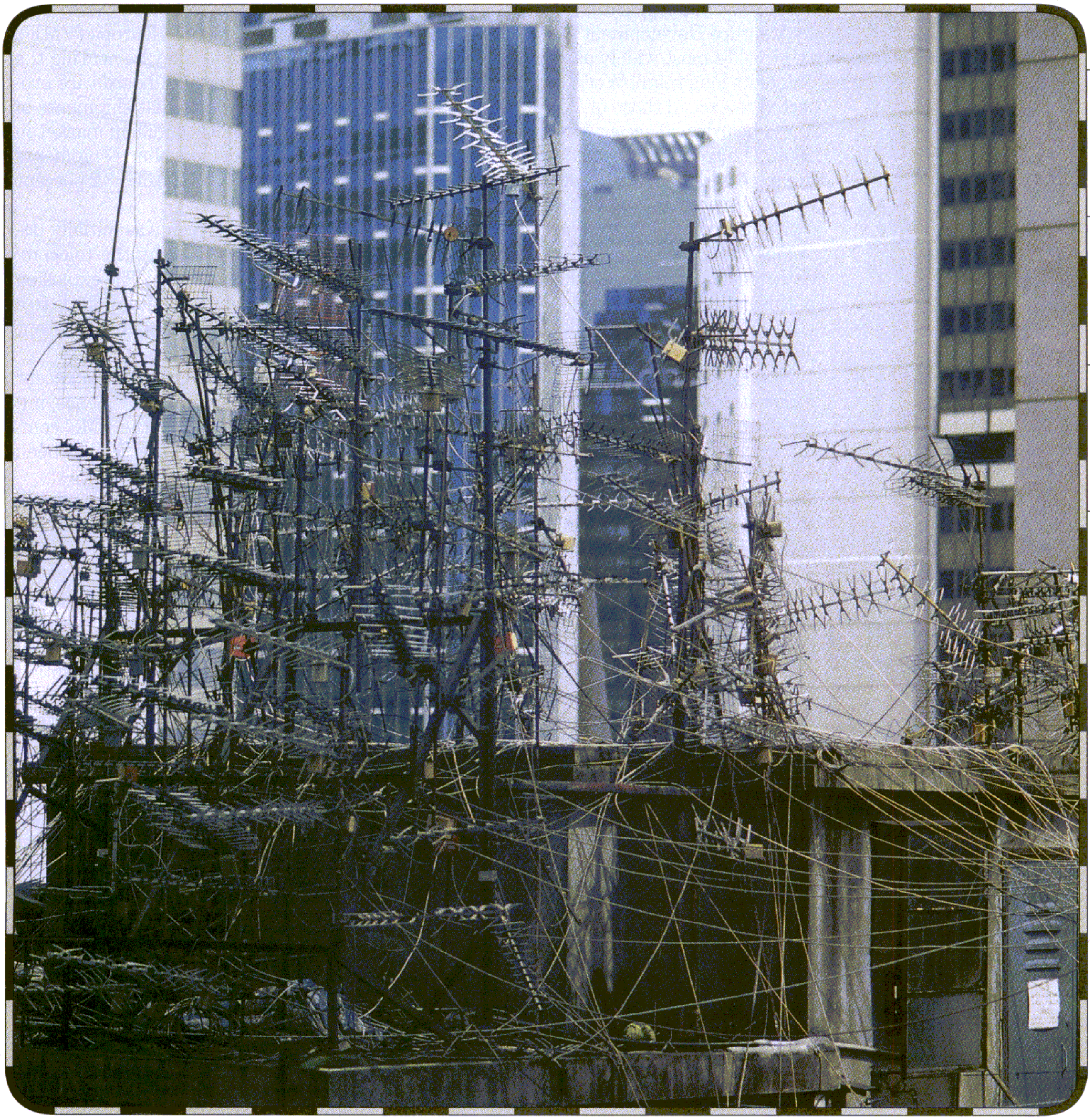

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Is VME Being Phased Out?

NATICK, MA—"Year 2000 Worldwide Market for Computer Boards in Embedded and Real-Time Applications, Volume 1A-Market Analysis Report," a new market study by Venture Development Corp. (VDC), indicates that the versa module Europa (VME), the world's most widely used bus architecture for these applications, may be nearing the end of its long reign. Worldwide sales volumes for PCI and CompactPCI boards are projected to exceed those of VME boards in the year 2002. VDC expects that shipments of VME boards will account for $842.6 million or 28.3 percent of a $2980.6 million market in 2002. The trend is expected to continue; VME merchant-board dollar-volume shipments are expected to exhibit a negative compound annual-growth rate (CAGR) of −8.2 percent over the period from 2000 to 2004.

The primary competing architecture of VME is CompactPCI, which was initially developed for precisely this purpose. Compact PCI has been embraced by the telecom/datacom industry, largely due to its highly publicized "hot swap" capability. The explosion of this industry is expected to drive sales of CompactPCI merchant computer boards to a CAGR of 30 percent through 2004. In the latter year, CompactPCI is likely to represent 40.8 percent of a $3477.1 million market.

However, CompactPCI does not offer significant performance advantages over recent incarnations of VME. VME's supporters have demonstrated considerable resilience, implementing new variations and extensions on a regular basis. In addition, the VME community is championed by a highly proactive industry association (VITA), which has been accredited as an ANSI standards-development organization.

Although technology-wise, VME appears to be very much alive and well, VDC believes that the drive toward smaller size and lower costs will cause an increased platform migration from VME to CompactPCI.

AIA Urges Bush Administration To Take Action On Aerospace Issues

WASHINGTON, DC—The Aerospace Industries Association (AIA) has identified the industry's most pressing issues requiring immediate attention by the Bush administration in the coming months. AIA has prepared a set of 16 white papers on critical aerospace issues for the Bush administration, recommending action that would maintain the health of the US aerospace industry.

AIA has recommended that the Bush administration prepare a budget supplement request to the fiscal year 2001 budget that would increase the Defense Department's aerospace procurement budget by $4 billion. According to AIA president and CEO John W. Douglass, post-Cold War reductions in defense spending have resulted in aging weapons systems with high maintenance costs. "Today's low production rates for major weapon systems are threatening the capability and capacity of the US defense industrial base," he says. "The US must research and produce at a rate sufficient to maintain a healthy and responsive defense industrial base," he adds.

Kudos

RF Micro Devices, Inc., a provider of proprietary RF integrated circuits (RF ICs) for wireless communications applications, announced that it has been added to the Standard & Poor's MidCap 400 Index...Sprint, a global communications company which provides Telecommunications Relay Service (TRS) in 27 states to deaf, hard-of-hearing, deaf-blind, and speech-disabled consumers, as well as to the Federal government, has become a Gold Sponsor for Deaf Way II, which will be held next year at Gallaudet University and in the Washington, DC area on July 8-13, 2002. Sprint made a $150,000 contribution to Deaf Way II...JDS Uniphase Corp. recently announced the dedication of its new facilities in Ewing Township, NJ. JDS Uniphase is one of the fastest-growing high-tech firms in New Jersey, according to the New Jersey State Chamber of Commerce...Decibel Products' Educational Assistance Program encourages company employees to further their knowledge and expertise by reimbursing 100 percent of the cost of attending an approved or accredited public school or college, provided that the employee maintains a "B" or above average...Renaissance Electronics Corp. announced that their multichannel-multipoint-distribution-system (MMDS) Fixed Wireless Transceiver has been named one of the Top 20 products for the year 2000 by *Wireless Design and Development*. Chosen from more than 1550 new products, the MMDS Fixed Wireless Transceiver was selected for being technologically innovative, useful, and unique in design.

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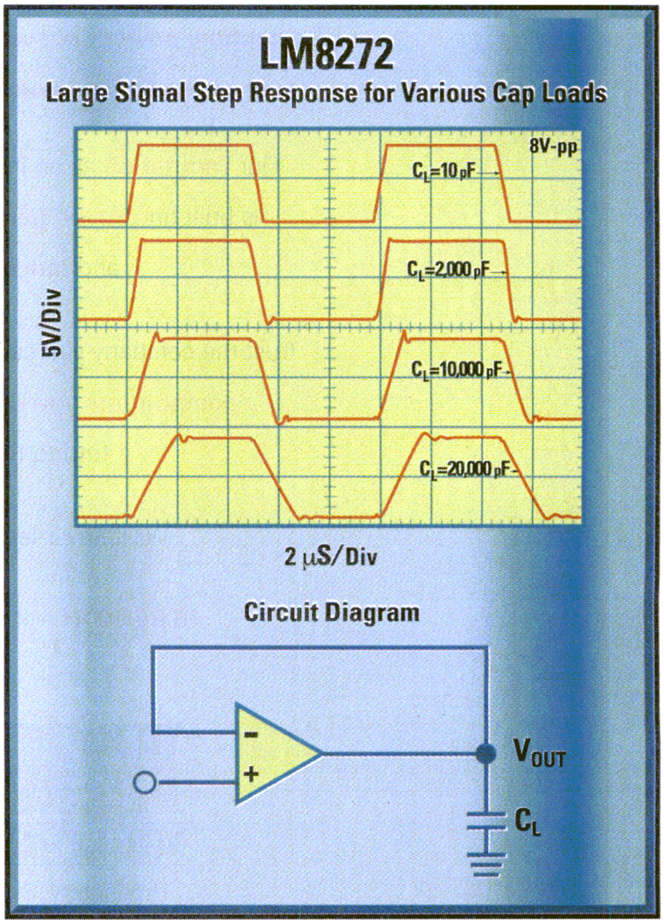


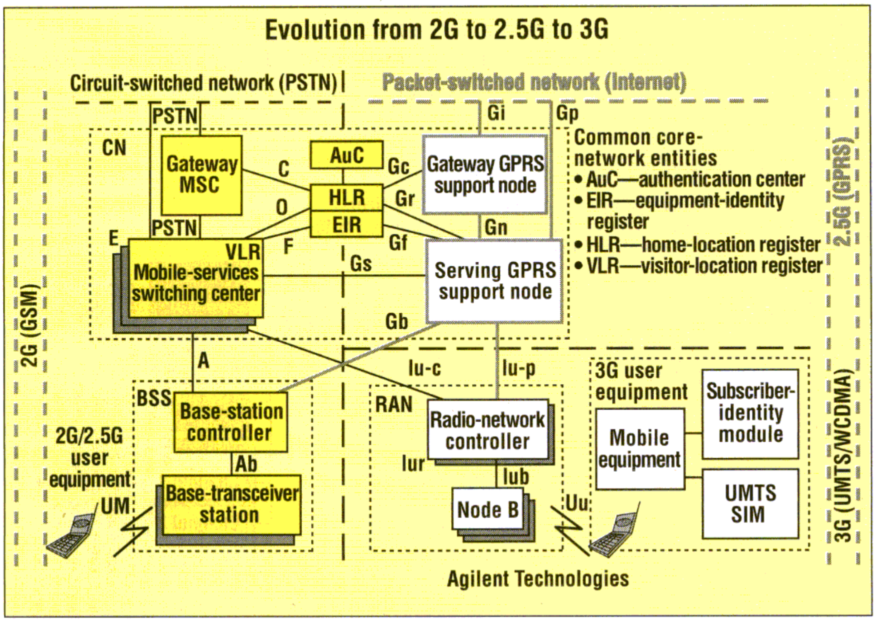
This show's technical sessions covered a multitude of topics and offered a wealth of opportunities for designers to keep up with the latest developments in wireless innovation.

Symposium Conference Sessions Mirror Industry's Expansion

DON KELLER
Senior Editor

LIKE a supernova, the wireless industry is expanding at an explosive rate—dispersing its influence in all directions and spinning off new sub-industries and technologies. These developments are exciting, but, for design engineers, technology marketers, and others involved in the industry, the developments can also be disorienting. To help them understand and navigate these fast-moving developments, the Ninth Annual Wireless Symposium—held at the San Jose McEnery Convention Center (San Jose, CA) from February 12-16, 2001—offered dozens of technical conference sessions covering more than 20 wireless subjects.

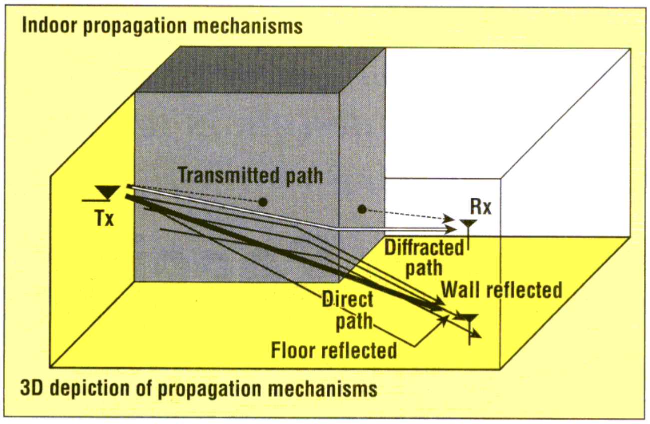
The trend at the Symposium has been to cover more subjects and offer more sessions each year, mirroring the industry's expansion. Last year's show offered 93 technical conference sessions covering 17 subjects. This year, the show offered 123 sessions covering 21 subjects. The Symposium's Conference Advisory Committee discontinued three existing subjects: "High Power Design for Handsets," "Advanced Techniques," and "Systems, Buses, & Architectural Issues," but expanded three other subjects by splitting them and converting them into three pairs of spinoff subjects. On top of that, the Committee added four new subjects to the show's agenda. The result was a net increase of four—a total of 21 subjects—covered at this year's Symposium.



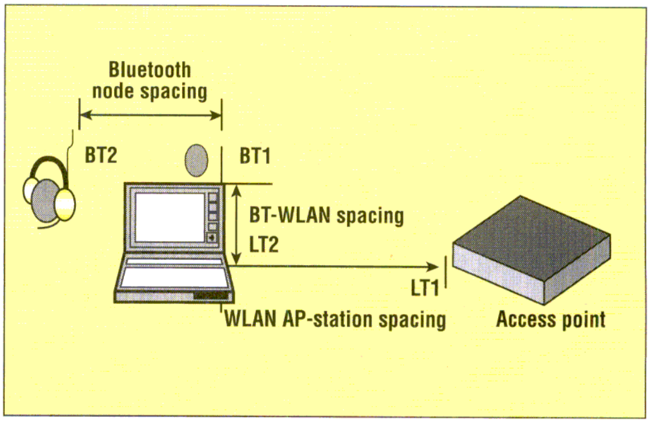
1. The evolution of 3G will require significant changes in base-station architecture.

The three pairs of spinoff subjects came about by expanding on three subjects: "Base Stations;" "Antennas;" and "Wireless LAN, Bluetooth, and Home RF." "Base Stations" was split into "Base-Station Amplifiers" and "Base-Station Architecture." "Antennas" was split into "Antennas" and "Indoor Propagation." And "Wireless LAN, Bluetooth, and Home RF" became "Wireless LAN" and "Bluetooth & Personal-Area Networks." The four entirely new subjects created by the Advisory Committee for this year's show are "Filters," "Software Radio," "Wireless Internet Technology," and "Wireless e-Commerce."

One of the sessions offered under the spinoff subject "Base Station Amplifiers," introduced a new family of low-noise, low-cost, small-signal transistors for base stations. "Low Noise Enhancement Mode PHEMT FETs for Low Cost Commercial Applications," delivered by Julie Kessler, Henrik Morkiner, Al Ward,



2. Indoor propagation of a transmitted signal is typically impeded by reflection, refraction, and absorption.



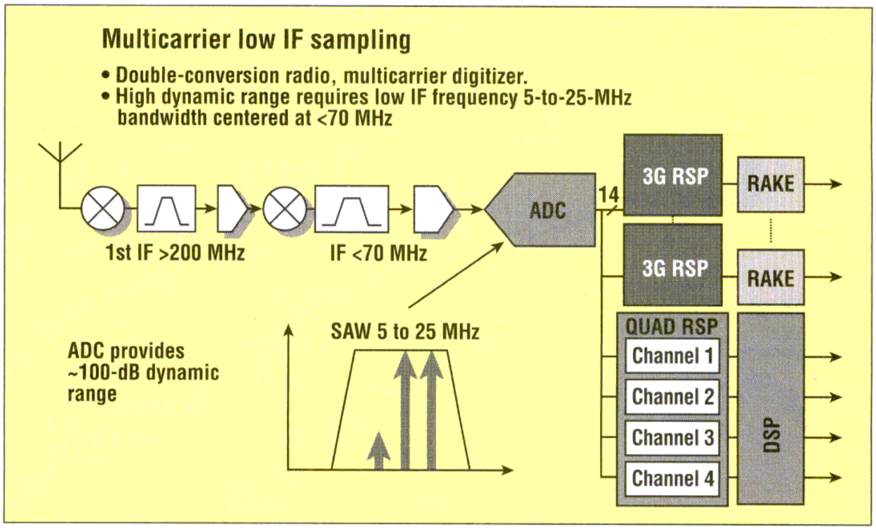
3. This test configuration shows the spacing of Bluetooth and WiFi devices operating simultaneously.

Thong-Lin Tan, and Floyd Oshita of Agilent Technologies, compared different transistor technologies used in base stations. The authors described the dominance of depletion-mode, gallium-arsenide (GaAs) field-effect transistors (FETs) in the microwave and RF industry, and contrasted this with recent advances in enhancement-mode devices. The discussion pointed to four advantages of enhancement-mode devices: they don't require a negative DC supply, they can be biased using simple resistor networks or adaptive biasing, they have superior gain, and they are capable of true power-down using simple logic control. The family of enhancement-mode, pseudomorphic, high-electron-mobility transistors (PHEMTs) introduced in this session operates from 450 MHz to 6 GHz with a gain of 16.5 dB, an OIP3 of +36 dBm, and a noise figure of 0.5 dB.

On the corresponding spinoff subject, "Base Station Architecture," Geoff Nelson, also of Agilent Technologies, delivered a session titled "Challenges in Developing and Deploying 3G Radio Access Networks." In this session, Nelson gave an overview of third-generation (3G) radio-access networks (RANs) (Fig. 1) and discussed ways of developing and testing these networks. Nelson reviewed the role of 3G standards and the Third-Generation Partnership Project (3GPP) in the transition, such as establishing RAN network elements, which include user equipment (cell phones, personal digital assistants, and cellular modems), base-station controllers, the radio-network controller (RNC), and the core-network interface. He also reviewed the 3GPP's role in developing RNC and base-station protocols, test methods, and verification.

The antenna is a key component in any wireless system, and "Antennas" has always been a key subject at the Wireless Symposium. "Development Trends in Antennas for Mobile Phones" was one of several antenna sessions offered at this year's show. In it, Claes Beckman of the KTH Center for Wireless Systems (Stockholm, Sweden) offered an overview of the trends that currently affect the development of antennas for mobile phones, along with a general overview of cellular-communications systems and the evolution of 3G. Beckman discussed the importance of terminal antenna gain, efficiency, and specific absorption rate (SAR), and presented some methods for measuring these characteristics. Issues such as terrain path loss, multipath propagation, and the shadowing effect of the human body on antenna efficiency were discussed. One of Beckman's contentions throughout the discussion was that antenna performance must be tested with methods that more closely approximate "real-life" conditions. He also covered micro electromechanical systems (MEMS) and their implications for future mobile-phone systems.

On the related spinoff subject "Indoor Propagation," Peter S. Rha of San Francisco University (San Francisco, CA) delivered "A Tutorial on Indoor Propagation." In this session, Rha reviewed the basic concepts and physical theory behind electromagnetic (EM) waves, espe-



4. One example of software-radio architecture is multicarrier IF sampling.

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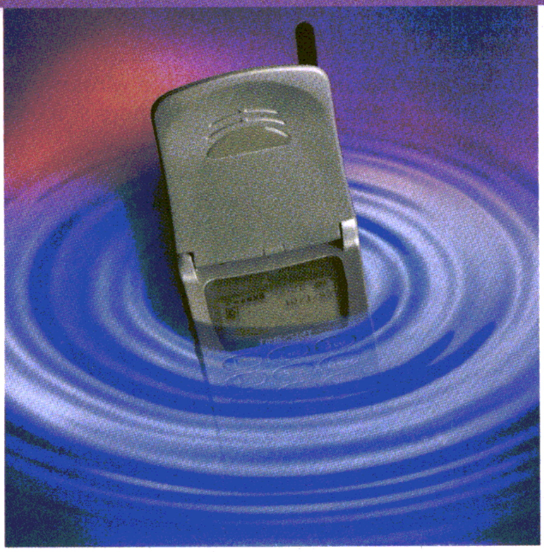

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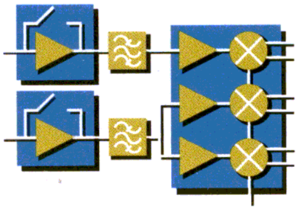
Performance Table

Performance of MGA-72543, MGA-71543 and HPMX-7102 as DBTM receiver chain (assumes 2.5dB of loss in bandpass filter between LNA and mixer).

Part #	Gain (dB)	NF (dB)	IIP3 (dBm)	Average Icc* (mA)
CDMA-1900MHZ	23.5	2.2	-12.6	13
CDMA-800MHZ	28.3	2.1	-10.4	13
AMPS	28.6	2.3	-9.7	13

** Takes into account that the LNAs are only "on" for 30% of the time.*



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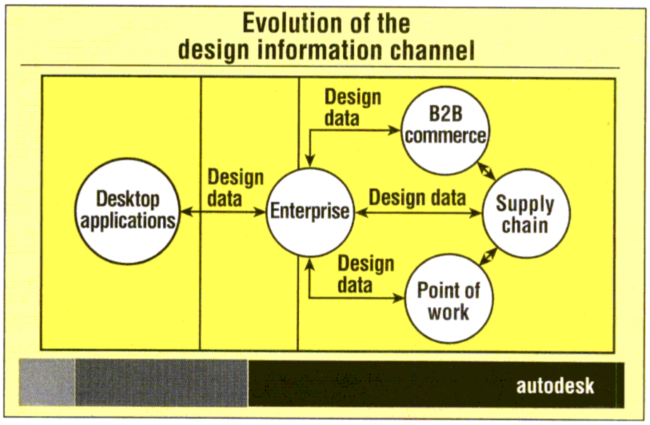
Agilent Technologies, Inc www.agilent.com CDMA2 11/00 cially as they pertain to indoor environments. The session covered topics such as plane-wave propagation, polarization, free-space propagation, power received by an isotropic antenna, outdoor channel characteristics, and indoor propagation mechanisms (Fig. 2).

The IEEE 802.11b specification for wireless local-area networks (WLANs) that operate in the 2.4-GHz industrial-scientific-medical (ISM) band has been very successful, but the push is on to extend data capacity. The current standards support data rates to 11 Mb/s and provide backward compatibility with older 1- and 2-Mb/s standards, but pressure is building to increase data rates to 20 Mb/s and beyond. Carl Andren of Intersil Corp. delivered a session on this subject titled "IEEE 802.11b WLANs: Where Are They Going?" In this session, Andren explored the reasons for the push to higher data rates, the activities and progress of the IEEE task group involved in this push, and the modulation candidates that might be used to achieve higher data rates. Some of the reasons for the push include consumer demand for multimedia in the home, business demand for higher bandwidth, and the superior range and performance/price ratio of 2.4-GHz technology versus 5-GHz technology. The goal of the IEEE high-rate task group, designated IEEE 802.11 HR (g), is to accomplish higher rates without increasing bandwidth. The candidate modulation schemes proposed to achieve this goal, such as codeword modulation, symbol modulation, multicode modulation, low-power quadrature phase-shift keying (QPSK), and their advantages and disadvantages, were also discussed.

But what about Bluetooth? It operates in the same 2.4-GHz band as IEEE 802.11b LANs (also called WiFi). Will they interfere with one another? This potential conflict was addressed by Jim Lansford of Mobilian Corp. in a session titled "WiFi (802.11b) and Bluetooth Simultaneous Operation: Characterizing the Problem." The session introduced the issues of Bluetooth's co-existence with WiFi, focusing on scenarios where the two systems operate simultaneously and in close proximity to each other. To measure the impact that each system can have on the other, the session described a test situation where a laptop was equipped with Bluetooth and WiFi (Fig. 3). The test showed that Bluetooth caused a significant degradation of WiFi throughput, and that WiFi degraded Bluetooth throughput, though to a lesser extent.

One of the four new subjects added to this year's conference agenda focused on filters. And one of the sessions offered on this subject concerned the kind of filter that is found in virtually every handset— the surface-acoustic-wave (SAW) filter. "Progress in SAW Filters for Wireless Applications," delivered by Jidong Dai of RF Monolithics, Inc., reviewed the developments in SAW technologies from an applications point of view. The session identified and discussed three generations of SAW technology: the high-loss, bidirectional SAW filters of the 1960s, the low-loss, unidirectional SAW filter of the 1970s, and the coupled resonator SAW filters of the 1980s. It also discussed new developments that have evolved in SAW technology since the 1990s, including variations of the single-phase, unidirectional transducers (SPUDTs) introduced in the 1970s.

As communications technology continues its rapid transition from analog to digital, more radio-system functions are implemented using software rather than hardware. Thus, "Software Radio" was another new conference subject added to this year's show. In a session titled "Current Issues in Software Radio Design," authors Scott Behrhorst and Brad Brannon of Analog Devices (Greensboro, NC) defined a software radio as one whose channel-modulation waveforms are defined in software. The session explored single-carrier architectures such as traditional baseband using analog- or digital-detection techniques and IF sampling, and multicarrier IF-sampling architectures (Fig. 4). The authors also presented case studies of digital AM/FM radios using software-radio techniques.



5. With the convergence of Internet and wireless technologies, information created by designers will be used to empower a customer's business.

One of the hottest new sub-industries in the wireless arena is Wireless e-Commerce. One of the sessions offered on this subject was "The Web, Wireless, and the New Business World." In this session, author Scott Bordouin of Autodesk presented an overview of the convergence of Internet and wireless technologies and how that convergence affects business. He also investigated the ways that this convergence impacts the marketplace in two major areas—design innovation and design information. The former concerns the ways that technology affects the design process itself. The latter concerns the ways that information created by designers is used to empower a customer's business (Fig. 5).

The fourth new subject added to this year's conference also pertains to the Internet—"Wireless Internet Technology." Several sessions were offered, including "M-Commerce: Reaching the Mobile Customer through the Wireless Internet." In this session, Kayvan Alikhani of MagNetpoint, Inc. (Novato, CA) discussed the challenges of delivering wireless Internet to mobile customers and proposed a new, rules-based message-conversion-and-delivery method that is independent of the user's location or type of device. ••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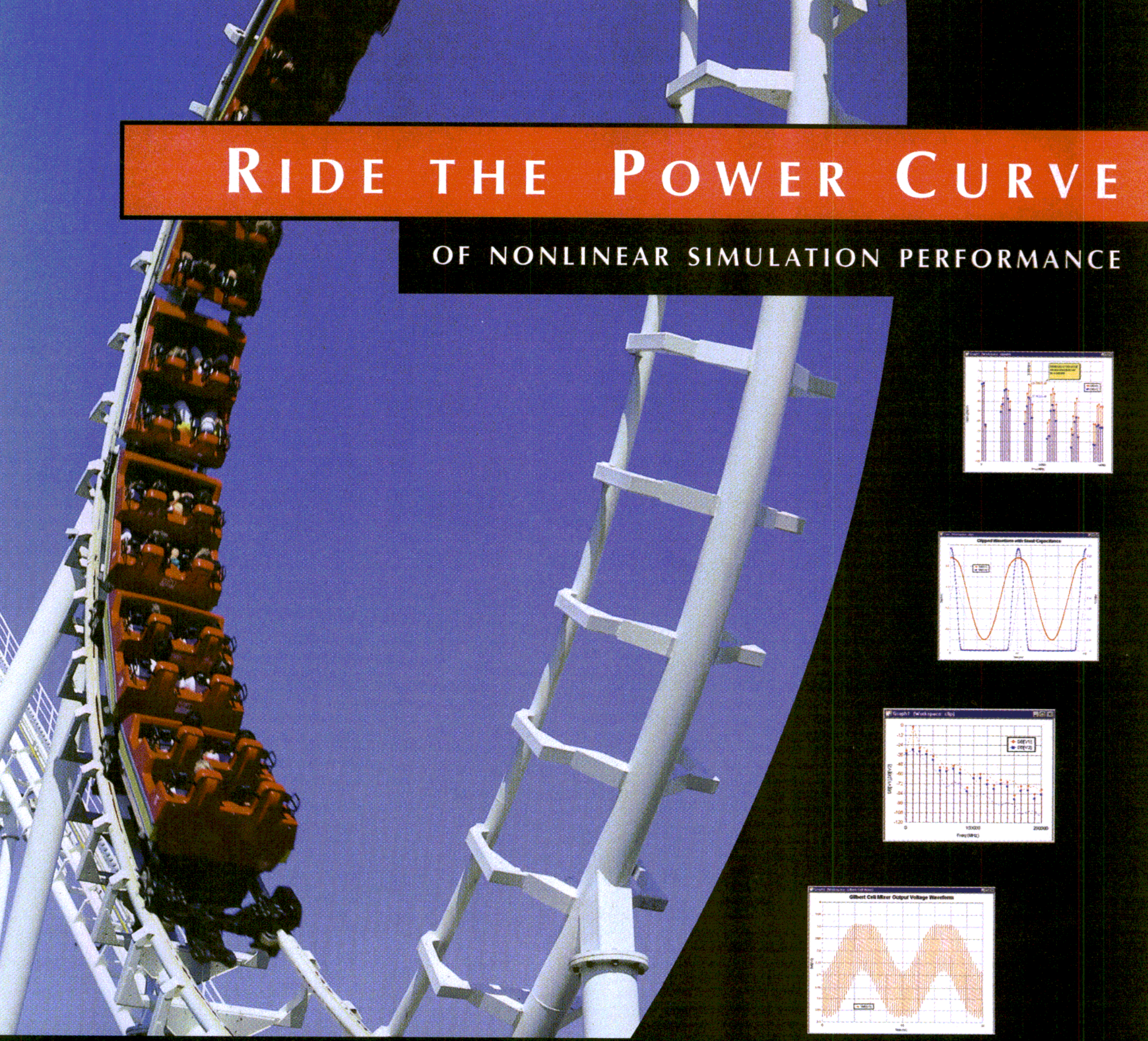
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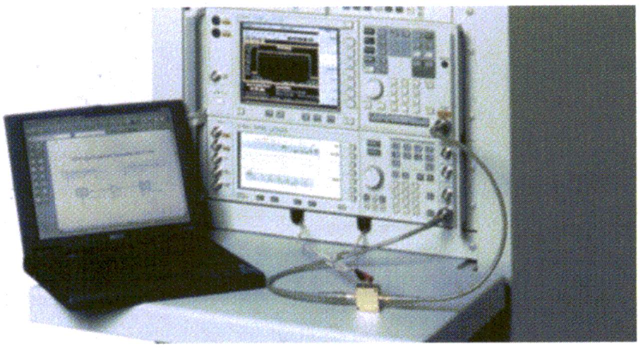
GENE HEFTMAN
Senior Editor

TO hear Michael Karasick, CTO of IBM's Pervasive Computing Division tell it, the joining of the computing and connectivity technologies are being taken for granted, or as the name of his division suggests, pervasive. It is the coming together of wireless communications and information technology (IT) using devices that are simpler and far more portable than the desktop personal computer (PC). And it could lead to an entirely new paradigm in the way people communicate, conduct business, and handle many other aspects of modern life. It could put a face on the hazy wireless term "third generation (3G)" and provide it with the substance needed to make it a reality. Karasick presented his ideas as the keynote speaker at the ninth annual Wireless/Portable Symposium & Exhibition which ran from February 12 to 16, 2001 in San Jose, CA. In addition to thousands of design engineers and engineering managers attending the event, approximately 400 companies demonstrated the hardware, test equipment, and software that will power this revolution in the way the world works. What follows is a sampling of some of the interesting and innovative products on display at the show.

Any technological revolution begins in the minds of people who create the ideas and design its enabling products. Wireless product design is becoming increasingly difficult due to factors such as rapid technological changes, competition that speeds up cycle times, fast transitions from prototypes to volume production, and high expectations for quality and reliability. Particularly troublesome for circuit designers is the problem of determining whether the results of computer simulations match the measurements on an actual prototype chip or design verification. To aid designers, Agilent Technologies (Palo Alto, CA) developed an electronic-design-automation (EDA) tool known as ValiFire for handset power-amplifier (PA) designs. The system incorporates Agilent's established Advanced Design System (ADS) software together with test equipment for making measurements. The instruments are the E4406A vector signal analyzer, E4433B RF signal generator and several 66319B power supplies built into a system rack (Fig. 1). Proprietary software links the EDA tools and test gear together. ValiFire permits the automation of testing by eliminating the need to write test code and assembling the necessary test equipment to make measurements on a device. It can handle the key measurements for next generation advanced wireless standards such as the Third Generation Partnership Project (3GPP) and Enhanced Data Rates for GSM Evolution (EDGE). The system software sequences measurements in the design environment and test equipment and then correlates the results into a single display for ease of comparison between the virtual world of EDA simulation and the real world of a semiconductor device.



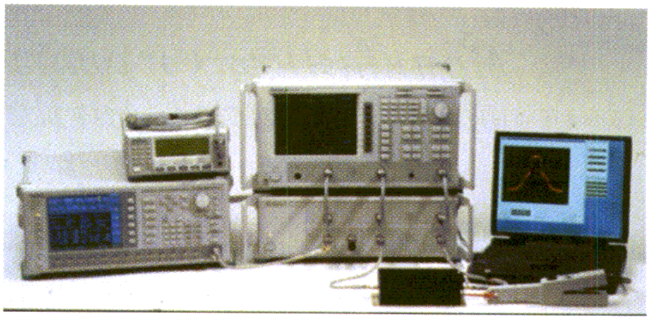
1. Agilent Technologies' ValiFire system integrates software (EDA tools) and hardware (test equipment) to allow RF circuit designers to correlate simulation results with actual measurements.

A different type of EDA tool has been developed by Computer Simulation Technology (CST) of America (Wellesley, MA). Known as the CST Microwave Studio, version 3.0, it is a specialized tool for the solution of three-dimensional (3D) electromagnetic (EM) high-frequency problems. It can simulate high frequency problems on a PC in a Windows environment with applications such as filters, couplers, integrated-circuit (IC) packages, antennas, and connectors. It uses a new perfect-boundary-approximation (PBA) technique for precise geometrical representation together with the finite-integration (FI) numerical method to solve complex problems. An interesting feature is its time-domain solver which supports specific-absorption-rate (SAR) calculations, or the amount of radiation emitted from a wireless phone into human tissue. Health and safety issues associated with phone use have become a major factor in recent months, and the simulation of radiation effects can save considerable time compared to building and testing a prototype. CST Microwave Studio is embedded in a larger design environment produced by the company known as CST Design Studio, which breaks complex systems down into smaller components, each described by an S-matrix. All the matrices are combined and the total system behavior can be calculated in a few seconds.

TEST COMBOS

As more types of communications hardware and standards come to market, testing requirements increase in complexity, number, and speed. To deal with this situation, test-equipment manufacturers must either put together combinations of instruments and software or develop single instruments that can measure a variety of different functions.

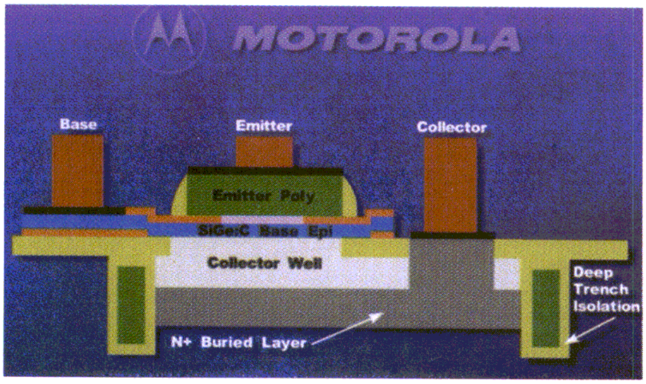
An example of the former is the ME7840A Power Amplifier Test System (PATS) from Anritsu Co. (Richardson, TX). The company has upgraded the system to perform additional measurements, such as adjacent-channel power ratio (ACPR), power-added efficiency (PAE), intermodulation distortion (IMD), compression, harmonics, and S-parameters through only a single connection. PATS combines the Scorpion vector-network measurement system (VNMS), the Scorpion PA navigator interface, and a testset to deliver an integrated test solution for increasing design and production-testing measurement throughput (Fig. 2). The testset enables the software and hardware to work together and supports the connection of external instruments for ACPR measurements. The VNMS is an S-parameter analyzer that can perform harmonic and IMD measurements from 10 MHz to 6 GHz. Pulling these pieces together is the Navigator interface, which is the vehicle for setting up tests, as well as calibrating and analyzing the measurement results. Navigator also enables the integration of an optional power meter, modulation synthesizer, and analyzer into the ME7840A.



2. Software and hardware are combined in Anritsu's ME7840A PATS, which can be used in either production or research and development (R&D) for measuring a broad range of PA parameters.

At the other end of the test spectrum is the NetTek base-station field tool from Tektronix, Inc. (Beaverton, OR). This compact, modular instrument is intended for field installation and maintenance routines and serves the purpose of multiple pieces of test gear. It performs the most common diagnostic tests for onsite base-station transmitter (Tx) verification. Frequency, output power, and modulation quality are included. Options include automated functions to help locate interference sources, such as pager signals and TV, or competing wireless provider signals. Wireless standards that can be measured are the Global System for Mobile Communications (GSM), IS-136 and CDMAOne. The NetTek weighs approximately 5 kg and can run on battery power.

Tektronix also introduced a pair of new spectrum analyzers at the show, the FSU3 and FSU8, which are aimed at two emerging wireless standards, wideband code-division multiple access (WCDMA) and EDGE. Applications run the gamut from amplifiers and filters to mobile sets and base-station modules. The FSU3 covers 20 Hz to 3.6 GHz, and the FSU8 spans 20 Hz to 8 GHz.

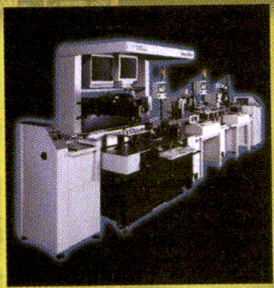


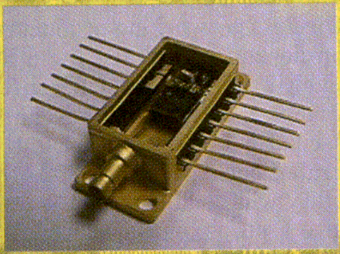
3. Going a step beyond SiGe, Motorola introduces SiGe:C, an RF BiCMOS process that offers high speed, low power consumption, and the ability to integrate a variety of passive components on-chip.

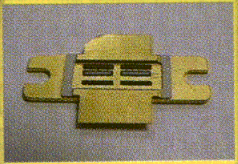
NEW SEMIS

For wireless communications and information technology to deliver the promise of a new paradigm in connectivity, both technologies will depend largely on advances in semiconductors, which are the backbone of all electronics systems. This year's Wireless Symposium introduced some of the devices that will find their way into future systems.

From Motorola's Semiconductor Product Sector (Phoenix, AZ) comes the



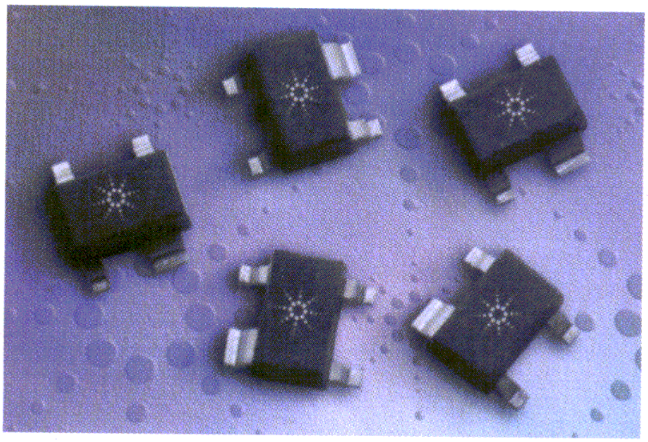




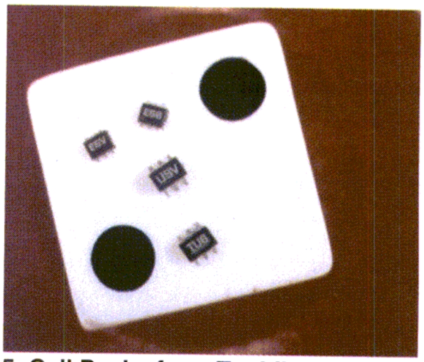
announcement of the successful merging of silicon (Si) and carbon (C) (not carbide) in a new process. It is known as silicon germanium carbon (SiGe:C) and it will be added to the company's 0.35-μ RF bipolar-complementary-metal-oxide-semiconductor (BiCMOS) process family (Fig. 3). The process is said to be able to integrate a variety of high-quality active and passive devices on-chip, including copper (Cu) inductors and transformers. SiGe:C transistors will join heterojunction bipolar transistors (HBTs) fabricated in RF BiCMOS that the company claims has demonstrated 45-GHz and 90-GHz performance for f_t and f_{max}, respectively, at half the current flow of traditional SiGe. With the addition of C to the process, Motorola hopes to be able to integrate sufficient components to offer system-on-a-chip (SOC) devices that will provide additional phone features and longer battery life. The first standard product in SiGe:C, due out in May, will be a low-noise amplifier (LNA) with selectable current settings.

Another new wrinkle in semiconductor technology is an enhancement-mode pseudomorphic high-electron mobility transistor (E-pHEMT)—said to be first of its kind—developed by Agilent Technologies Semiconductor Products Group (Palo Alto, CA). A gallium-arsenide (GaAs) device, the ATF-54143 differs from other GaAs devices that operate from a positive supply voltage but need a negative voltage to switch them on (Fig. 4). Since the E-pHEMT device requires only a single positive supply, circuit designers can conserve valuable board space, while also sparing themselves the additional design effort of a second power supply. It is intended for applications in cellular/personal-communications-services (PCS) base stations, multichannel multipoint distribution systems (MMDS), and other equipment that operates over the range of 450 MHz to 6 GHz. Specifications include a maximum noise figure of 0.9 dB, and an output third-order intercept point (OIP3) of 36.2 dBm at a frequency of 2 GHz.

The past few months have seen a number of direct-conversion radio chip sets come onto the market as chip makers attempt to reduce the component count and cost of wireless handsets and push the technology away from conventional super heterodyne radio. Analog Devices (Norwood, MA), which led the way in this technology a year-and-a-half ago, introduced its second-generation (2G) direct-conversion radio chip set at the Symposium. Known as Othello One—its predecessor was Othello—the company says it retains all of the functionality of the original but offers designers the ability to further reduce the total component count. The figure provided by the company is a 40-percent reduction in total component count and board area compared to the original. Othello One integrates an RF transceiver, multiband fractional-N phase-locked-loop (PLL) synthesizer, LNAs for all three GSM bands, RF power control, and low-dropout (LDO) voltage regulators. A major cost saving of direct-conversion architectures is the elimination of surface-acoustic-wave (SAW) filters, the most expensive components of a super heterodyne radio.



4. A new type of GaAs transistor, the E-pHEMT from Agilent Technologies, offers designers single-supply operation as opposed to the dual supplies needed to run a conventional GaAs FET.

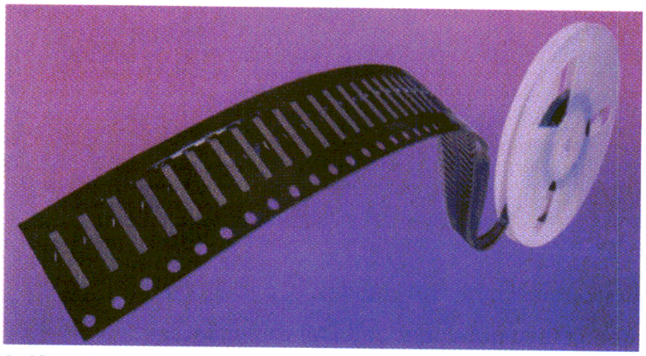


5. Cell Packs from Toshiba are tiny modules that provide complete functions, such as amplifiers or oscillators, to simplify the design and reduce the size of handheld wireless products.

A leader in the field of wireless local-area-network (WLAN) chip sets, Intersil Corp. (Palm Bay, FL) introduced a new version of its PRISM chip set known as PRISM 2.5. The enhanced set features the first single-chip baseband processor (BBP) and media-access controller (MAC) that integrates the functions previously done by two ICs. Personal Computer Memory Card International Association (PCMCIA) and Universal Serial Bus (USB) interfaces that will allow equipment manufacturers to add a USB interface into next generation IEEE 802.11b wireless networking products for the home and office are included. By packing all the ICs, software, firmware, and voltage-controlled oscillator (VCO) into a tightly integrated package, IEEE 802.11b capability will be able to be incorporated into laptops, personal digital assistants (PDAs), and so-called Web-Pad Internet appliances that could help further the concept of pervasive computing mentioned in the keynote address at the Symposium.

As WLAN systems continue to fill up the 2.5 GHz band, manufacturers of these systems are moving to more spacious territory in the 5-GHz Unlicensed National Information Infrastructure (UNII)z Unlicensed National band. Raytheon Company's Commercial Electronics division (Marlborough, MA) is getting aboard the UNII bandwagon with a radio chip set designed for IEEE 802.11a,

operating at a data rate of 54 Mb/s. Known as Tondelayo, the four-chip set encompasses a PA/switch module and RF, intermediate-interference (IF), and baseband components. It uses a type of orthogonal frequency-division multiplexing (OFDM) known as C-OFDM as the modulation method. An interesting aspect of the set is that it employs multiple semiconductor technologies: GaAs for the RTPA-5250 PA/switch, SiGe for the RTCV-5500 LNA up/down-converter and RTIF-5500 IF converter, and 0.18μ for the RTRB5500 baseband IC. CardBus and peripheral-component-interface (PCI) reference designs will be available when the set goes into volume production later this year.

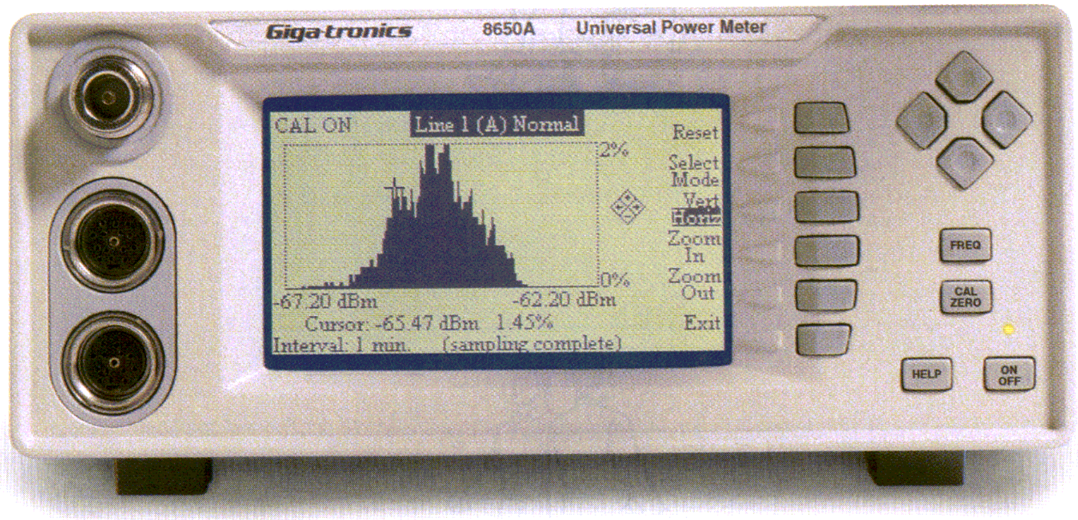


6. Keeping radiation from affecting the operation of wireless communications devices is accomplished with these small EMI gaskets from W.L. Gore. They attach to circuit boards with standard SMT.

Packing more functionality into less real estate is a critical goal in ICs because light, handheld appliances will be a key enabler of the convergence of computers and wireless technology. To aid product designers in this effort, Toshiba America Electronic Components, Inc. (Irvine, CA) has designed multifunction RF ICs known as Cell Packs (Fig. 5). The purpose of the Cell Pack concept is to eliminate the need for multiple discrete devices to perform functions such as wideband amplifier, mixer, switch, etc. A complete function (i.e., wideband amplifier, switch) is housed in an ultra compact surface-mount package—as small as 1.6 × 2.0 × 0.55 mm—that can fit in a wireless phone, personal digital assistants (PDA), and other handheld devices. In addition to the wideband amplifier Cell Pack, a crystal oscillator and an SPDT switch are available.

With GSM making a concerted effort to gain share in the US market, more time-division-multiple-access (TDMA)/GSM ICs are becoming available to support its handset market. An example from the show is the RF2492 dualband LNA/mixer from RF Micro Devices, Inc. (Greensboro, NC). The company claims that it is one of the first ICs to comply with the GSM/ANSI-136 Interoperability Team (GAIT) speci-

Proven.



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fications which supports TDMA and GSM/General Packet Radio Service (GPRS) air-interface standards to a single device. The RF2492 is a complete receiver (Rx) front end and has dual IF outputs to interface with two independent IF SAW filters.

GLUE PARTS

While ICs play the glamour role in handsets, PDAs, Web appliances, etc., these products could not be realized without the supporting cast of passive components, shielding materials, gaskets, plastics, and numerous other components.

They may be tiny, but the Gore-Shield surface-mount-technology (SMT) electromagnetic-interference (EMI) gaskets from W.L. Gore & Associates, Inc. (Newark, DE) are critical to the EMI performance of all wireless products based on radio Rxs (Fig. 6). The pads can be placed along the ground trace on a printed-circuit board (PCB) using standard SMT pick-and-place equipment. The pads form a gasket and act as a conformable, conductive interface between two parts of an EMI enclosure—the ground plane of the PCB and the metal or metallized plastic cover of the enclosure. The purpose is to keep radiating fields from leaving or entering the enclosure. As an RF grounding pad or interconnect, Gore-Shield gaskets conduct current of a primary RF signal in much the same way as a connector conducts RF currents from a PCB to a coaxial cable. A sample application is when an RF signal is sent from one board to another and the two are sandwiched together. This occurs frequently where wireless devices connect to multiple boards or to connect a patch antenna of a wireless phone or device to a PCB.

A high-loss Si rubber sheet absorber is produced by Cuming Microwave Corp. (Avon, MA) as a suppressor of surface waves at microwave frequencies. Applications for C-RAM GDSS include modification of antenna patterns, lowering the quality factor (Q) of a cavity and acting as a transmission-line attenuator. Since the material is thin and elastomeric, it conforms to the curvature of the surface it is applied to. It does not conduct electricity, can withstand a wide temperature range (–65 to 400°F) and survive outdoor exposure.

In anticipation of rapid growth in areas such as Bluetooth, HomeRF, IEEE 802.11b, and 2.4-GHz WLANs, Murata Electronics of North America, Inc. (Smyrna, GA) is preparing to offer a wide range of passive components to manufacturers who desire to do some one-stop shopping. Included on the company's menu are capacitors, EMI filters, chip inductors, resistors, piezoelectric products such as ceramic filters, resonators, SAW filters, and others. The company will also enter into the active-device area with units such as PLL modules, VCOs, and GaAs field-effect transistors (FETs). ••

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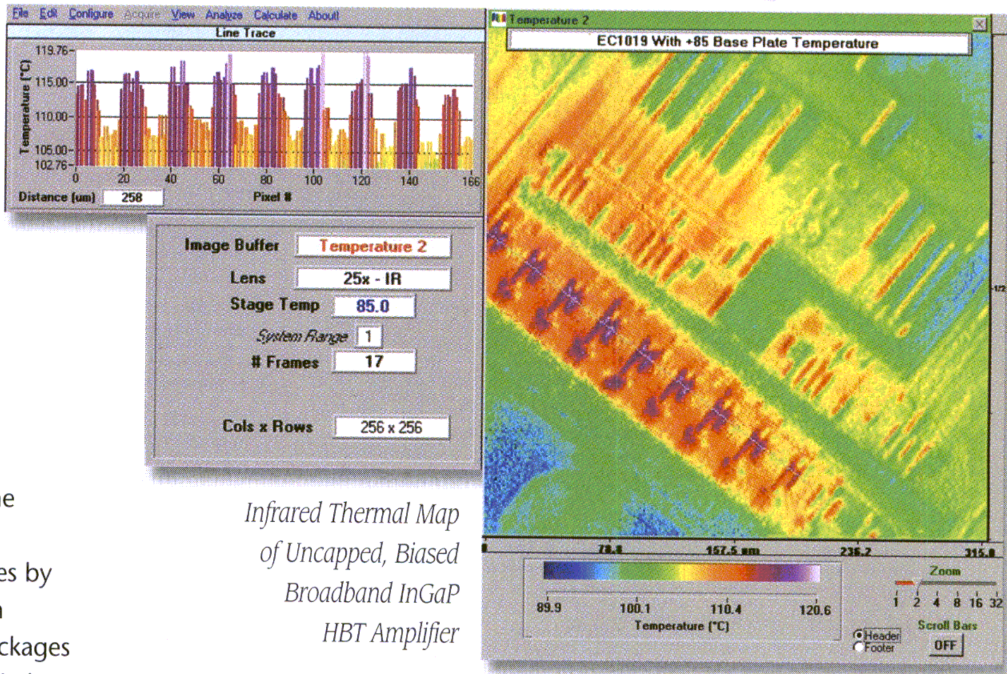

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P/N	Gain	Output P1dB	Output IP3	Øj	ΔTj	BW
ECG001	20dB	12dBm	26dBm	270° C/W	30°C	DC-6 GHz
ECG004	15dB	12dBm	26dBm	280° C/W	35°C	DC-6 GHz
ECG002	20dB	15dBm	29dBm	233° C/W	40°C	DC-6 GHz
ECG006	15dB	15dBm	30dBm	278° C/W	50°C	DC-6 GHz
ECG003	20dB	23dBm	39dBm	50° C/W	45°C	DC-3 GHz
ECG008	15dB	23dBm	40dBm	55° C/W	55°C	DC-3 GHz
ECG009	19dB	24dBm	41dBm	85° C/W	65°C	DC-2 GHz
ECG011	20dB	8dBm	20dBm	355° C/W	47°C	DC-6 GHz
ECG012	14dB	20dBm	36dBm	120° C/W	45°C	DC-2.5 GHz
EC-1089	15dB	23.5dBm	>42dBm	~85°C/W	~65°C	DC-2.5 GHz
EC-1019	18.5dB	19dBm	34dBm	120°C/W	40°C	DC - 3 GHz
EC-1078	19.5dB	21dBm	37dBm	120°C/W	60°C	DC - 3 GHz
EC-1119	14.8dB	18.6dBm	36dBm	150°C/W	60°C	DC - 3 GHz

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NEWS

ARFTG Update

The 56th meeting of ARFTG brought together measurement experts on frequency- and time-domain issues, all interested in improving the accuracy of their methods.

Measurement Group Tackles Telecom Testing Accuracy

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JACK BROWNE

Publisher/Editor

METROLOGY is an often unappreciated but vital science in support of other engineering advancements. For microwave engineers, the Automatic RF Techniques Group (ARFTG) has long been instrumental in setting high standards for RF techniques, including metrology, computer-aided design (CAD), and modeling. Recently, the group held its 56th biannual meeting, focusing on the importance of metrology for telecommunications.

The 56th ARFTG Conference and Short Course, co-sponsored by the IEEE Microwave Theory and Techniques Society (MTT-S) and the National Institute of Standards & Technology (NIST, Boulder, CO), took place during two days last fall (November 30-December 1, 2000). With a theme of "Metrology and Test for RF Telecommunications," the meeting was held at the Omni Hotel near Boulder, CO and featured 24 technical presentations covering all aspects of microwave metrology. The general conference chairperson was Dylan Williams of NIST's RF Technology Division, and technical program chairs were Dr. Michael Steer from North Carolina State University and Dr. Kate Remley also from NIST's RF Technology Division.

A presentation by Hyunchul Ku and associates from the Georgia Institute of Technology (Atlanta, GA), "Carrier-to-Interference Ratio Estimation of Arbitrary Signals Distorted by Nonlinear Devices," offered a new method of carrier-to-interference (C/I) estimation for nonlinear devices. Using the technique, the C/I ratio versus input power for any nonlinear device can be determined for any arbitrary input signal, provided that the input-signal peak-to-average power ratio is known.

Measurements involving large modulated signals were also the concern of Jan Verspecht and co-workers from Agilent Technologies (Brussels, Belgium). Their presentation, "Network Analysis Beyond S-parameters: Characterizing and Modeling Component Behavior Under Modulated Large-Signal Operating Conditions," describes a large-signal network analysis technique that can be used for measurements involving higher-power modulated signals. Measurements were performed on a prototype nonlinear network-measurement system with a range of 600 MHz to 20 GHz. The system includes four directional couplers to detect and measure all relevant IM tones of the fundamental test signal and its harmonics. Harmonic sampling is used to downconvert the test signals to a 4-MHz-wide intermediate-frequency (IF) bandwidth where they are then digitized through four precision analog-to-digital converters (ADCs). A sophisticated calibration technique is used to correct absolute amplitude errors and to account for the phase errors of the harmonic signals relative to the fundamental test signals.

A 1.9-GHz amplifier was evaluated to demonstrate the system. A signal comprised of 29 tones with 50-kHz symmetrical spacing around a 1.9-GHz center frequency was used to emulate a CDMA test signal with a total bandwidth of 1.4 MHz. Measurement results included dynamic harmonic distortion and spectral regrowth through the amplifier.

The second day of the "Metrology and Test for RF Telecommunications" session included work from Olav Andersen and associates from Ericsson (Gavle, Sweden) and the University of Gavle (Gavle, Sweden). They examined the nonlinear behavior of high-frequency components based on different input signals, and demonstrated that amplifier AM/AM and AM/PM distortion changes depending upon the choice of input signal. The presentation, "Nonlinear Characterization of Multiple-Carrier Power Amplifiers," considers Class AB laterally-diffused-metal-oxide-semiconductor (LDMOS) and Class A GaAs FET amplifiers for the 2-GHz band.

Also in that session, Lowell Hoover and Alexander MacMullen of the Technology Service Corp. (Bloomington, MN and Los Angeles, CA, respectively) debuted the microwave-component analyzer (MCA), a novel instrument for making automated signal-to-noise-ratio (SNR) measurements in continuous-wave (CW) and pulsed modes. The analyzer consists of a vector demodulator that converts microwave signals into in-phase (I) and quadrature (Q) signal components, which are then digitized. A rotating phase-reference technique is used to correct vector demodulator linear distortions, followed by high-speed digital signal processing (DSP), supporting real-time measurements of SNR.

The 56th ARFTG meeting included special sessions on "Temporal Measurements for Microwave Systems" as well as "Accuracy in Microwave RF Measurements." Jim Andrews of Picosecond Pulse Laboratories (Boulder, CO) and Paul Hale of NIST's Optoelectronics Division 815 chaired the temporal measurements session; Raian Kaiser of NIST's Radio Frequency Technology Division 813 chaired the session on measurement accuracy.

In the temporal measurements session, Michael Nelson of Tektronix (Beaverton, OR), in his presentation, "A New Technique for Low-Jitter Measurements Using Equivalent-Time Sampling Oscilloscopes," presented a new timebase technology for equivalent-time sampling oscilloscopes. The technology allows low-jitter measurements to be made hundreds of microseconds from the trigger position, compared to earlier techniques that required the measurements to be close in time to the trigger. Since the new technology provides high accuracy even with long offsets, it can be effectively used to observe a complete Synchronous Optical Network (SONET) frame without horizontal axis degradation.

Nick Paulter and Don Larson of NIST (Gaithersburg, MD), in their presentation, "Improving the Uncertainty Analysis of NIST's Pulse Parameter Measurement Service," reported on steps being taken to improve the organization's measurements of high-speed samplers and oscilloscopes. The service is based on the use of commercial 20- and 50-GHz samplers and 20-GHz pulse generators. Analysis included measurements of pulse amplitude, transition duration, overshoot and undershoot, and the effects of temperature on measurement accuracy. The results of the work include a set of equations that describe the fundamental dependence of the pulse parameters on measurement variables, which will be used with additional measurements to develop a calibration procedure for pulsed measurements.

Sampling techniques were also the basis for a presentation made by Kensuke Kobayashi and co-workers from Teratec Corp. (Tokyo, Japan), "A Quasi-Coherent Sampling Method for Wideband Data Acquisition." The quasi-coherent sampling method, when combined with a new sampling system with pretrigger capability and reduced jitter, can dramatically improve the throughput of wideband data acquisition (DAQ).

The presentation voted Best Paper of the conference was given in the Accuracy in Microwave RF Measurements Session. Nick Ridler and Martin Salter of the National Physics Laboratory (Middlesex, England) described preferred techniques for analyzing measurement data in "Evaluating and Expressing Uncertainty in Complex S-Parameter Measurements." Their recommendations are described in easily accessible terminology and are based on internationally recognized guidelines. They describe the difficulties in attempting to apply statistical analysis to data represented in terms of magnitude and phase. They recommend performing all statistical analysis in terms of real and imaginary components, and reporting final results in terms of magnitude and phase.

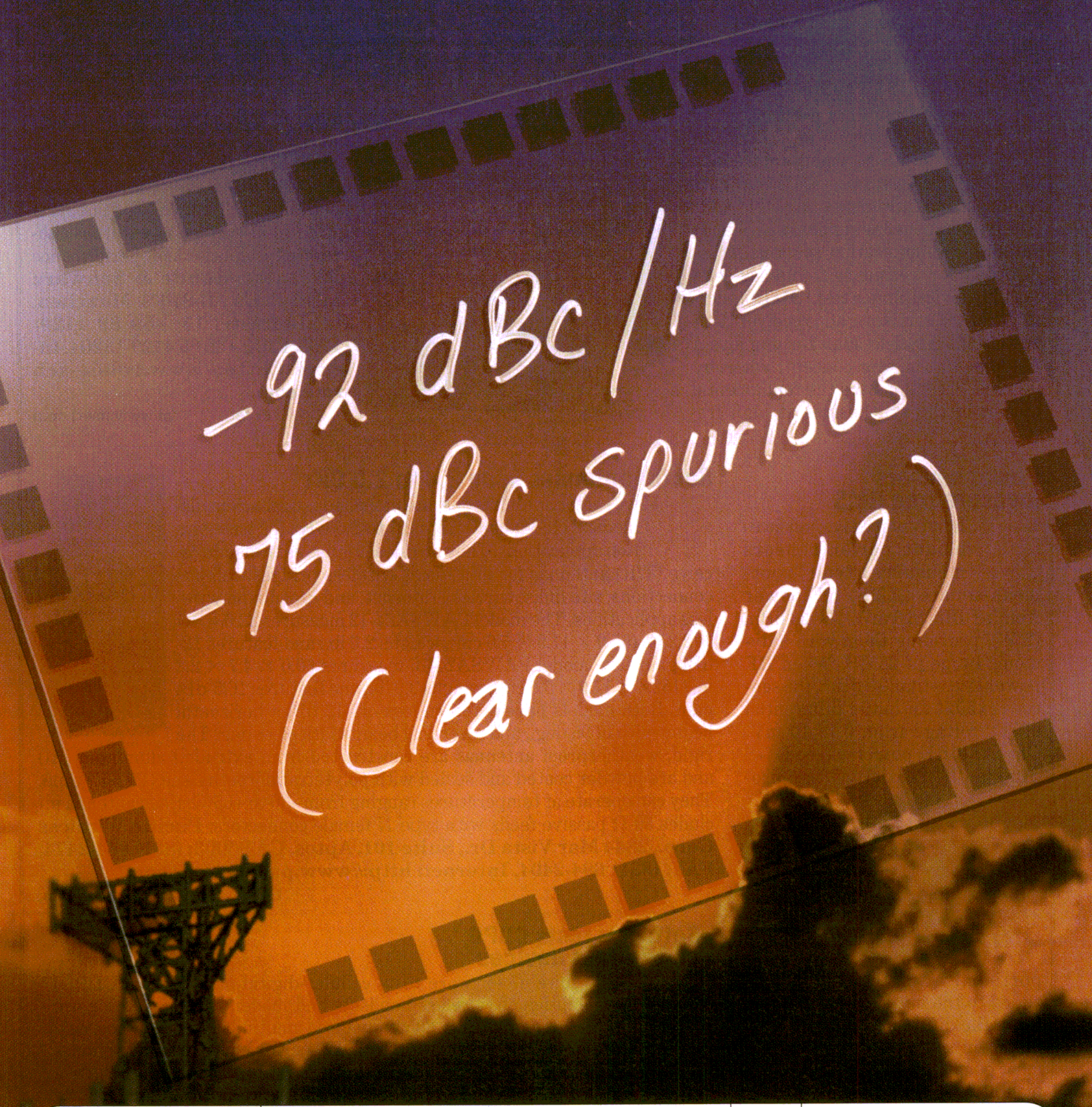
In the general ARFTG session, Balaji Lakshminaraganan and Tom Weller from the University of South Florida (Tampa, FL), in their presentation "Experimental Results for Parasitic Coupling and Attenuation of Coplanar Waveguides on High Resistivity Silicon," unveiled a measurement-based estimate for minimum spacing between coplanar-waveguide (CPW) lines on silicon.

Also in the general ARFTG session, Krishna Naishadham of Philips Broadband Networks (Manlius, NY) offered a calibration technique to compensate for the pin- and edge-connector mismatches from vertically-mounted printed-circuit boards (PCBs). In his presentation, "Accurate Probing of RF Amplifiers Using Vertical Interconnect Boards," he notes the increasing use of RF amplifiers mounted on vertical PCBs for high-speed telecommunications systems and cable-television (CATV) systems. While these plug-in circuit boards can save real estate on a motherboard, they also introduce parasitic elements and impedance mismatches due to the plug-in pins and edge connectors. The calibration technique helps to correct for these parasitic elements and mismatches, as shown in the evaluation of a high-gain 1-GHz amplifier.

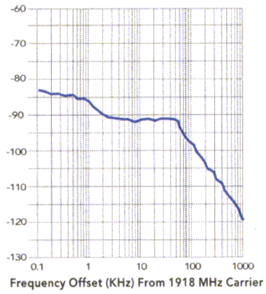
The ARFTG conference included a special exhibit celebrating NIST's 100th anniversary as a federal agency. The exhibit contained artifacts, photographs, seminal publications, and descriptions of important NIST contributions to RF metrology. Keynote talks celebrating NIST's centennial featured Bob Kamper, former director of the NIST Boulder Laboratories, and Dennis Friday, chief of the NIST Radio Frequency Technology Division 813. The exhibition will be repeated at the upcoming Microwave Theory & Techniques Symposium (MTT-S) in Phoenix, AZ.

The next (57th) meeting of ARFTG, with a theme of "Best Practices and Strategies for RF Test," is scheduled for May 25, 2001 in conjunction with the MTT-S in Phoenix, AZ. Conference technical program chairs are John Barr of Agilent Technologies (Santa Rosa, CA) and David Walker of NIST. For more information on this conference and on ARFTG in general, visit the group's website at www.arftg.org.

[clear communications ICs]



Typical PE3236 Phase Noise



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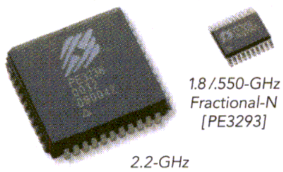
PLLs



2.2-GHz Integer-N [PE3236]

1.8/.550-GHz Fractional-N [PE3293]

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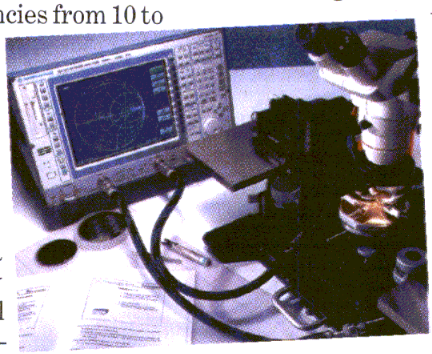
VNA performs measurements to 40 GHz

The ZVK vector network analyzer (VNA) performs S-parameter, intermodulation (IM), and mixer measurements at frequencies from 10 to 40 GHz. It performs precise linear and nonlinear measurements on active and passive components in microwave- and satellite-communication systems. It is also ideal for measuring frequency-converting devices under test (DUTs), such as generators, mixers, and receiver (Rx) subassemblies. The analyzer employs a fundamental mixing concept, whereby its receive section uses the fundamental output of the synthesizer at high frequencies. Through this method, the analyzer achieves a dynamic range better than 110 dB. At a measurement bandwidth of 10 Hz, the sensitivity ranges to below –110 dBm. Direct access to the generator and all four test Rxs supports flexible configuration of external bidirectional testsets for high-performance applications. **Rohde & Schwarz GmBH & Co., D-81671 Munchen, Muhldorfstr. 15; +49 89 4129-11765, FAX: +49 89 4129-13204, Internet: http://www.rohde-schwarz.com.**



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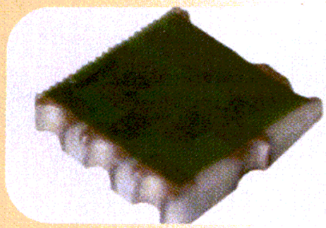
Power sensors measure true RMS

A family of passive, surface-mount power sensors measures true root-mean-square (RMS) RF power from +8 dBm (6.3 mW) to +33 dBm (2 W), providing them with a dynamic range of 25 dB. When RF power is less than +8 dBm, the sensors exhibit an initial differential offset voltage from 0 to 10 mV. Once the RF power exceeds +8 dBm, a differential voltage proportional to the power level is added to the initial offset voltage. Since the differential voltage output from the sensors is small, it must be passed through an instrumentation-grade optical amplifier for useful power measurement. The sensors are housed in 0.15^2-in. (3.81^2-mm) packages that are pin-compatible with existing power sensors. They draw 2 to 8 mA from a +5-VDC source. **Barry Industries, Inc., 60 Walton St., Attleboro, MA 02703; (508) 226-3350, FAX: (508) 226-3317, Internet: http://www.barryind.com.**



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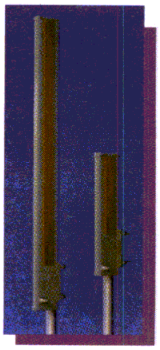
Sector antennas span 2.4 to 2.5 GHz

Two sector antennas operate in the industrial-scientific-medical (ISM) band from 2.4 to 2.5 GHz for base-station applications. They are ideal for use as transmit/receive (T/R) antennas for multipoint wireless bridges, campus connections, site links, wireless Internet, and broadband wireless applications. The model PAWSA24-12 measures 22.0 × 4.7 × 2.2 in. (55.9 × 11.9 × 5.6 cm), weighs 2.6 lb., and features 12-dBi gain. The model PAWSA24-16 measures 60.0 × 4.7 × 2.2 in. (152.4 × 11.9 × 5.6 cm), weighs 3.9 lb., and features 16.5-dBi gain. Both models have a return loss of –12 dB, a horizontal beamwidth of 95 deg., and a vertical beamwidth of 18 deg. The rigid, weatherproof antennas are constructed from extruded aluminum (Al) and are powder coated and sealed with polytetrafluoroethylene (PTFE) tape. They can operate at temperatures ranging from –30 to +65°C. Each antenna includes 50-Ω passive feeds with type-N female connectors. **Pacific Wireless Corp., 2844 Mar Vista Dr., Suite 101, Aptos, CA 95003; (831) 684-2474, FAX: (831) 684-2494, Internet: http://www.pacwireless.com.**



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Software tests CDPD on wireless devices

A new suite of software tests cellular-digital-packet-data (CDPD) capabilities on wireless handsets and modems. Designed for use with the model IFR 2959 advanced multimode testset, the new software suite allows users to test the CDPD performance of mobile phones and mobile modems operating at 19.2 kb/s. Users can test various parameters of their devices, including power levels and blocking rates, as well as the protocol performance of their systems. The software augments the 2959 testset, which itself contains a full set of troubleshooting features for Advanced Mobile Phone Service (AMPS) and time-division-multiple-access (TDMA) cellular-handset and wireless-modem testing. Its CDPD cellular modem tests include Gaussian minimum-shift-keying (GMSK) modulation and burst power measurements. **IFR, Inc., 10200 West York St., Wichita, KS 67215-8999; (316) 522-4981, Internet: http://www.ifrsys.com.**

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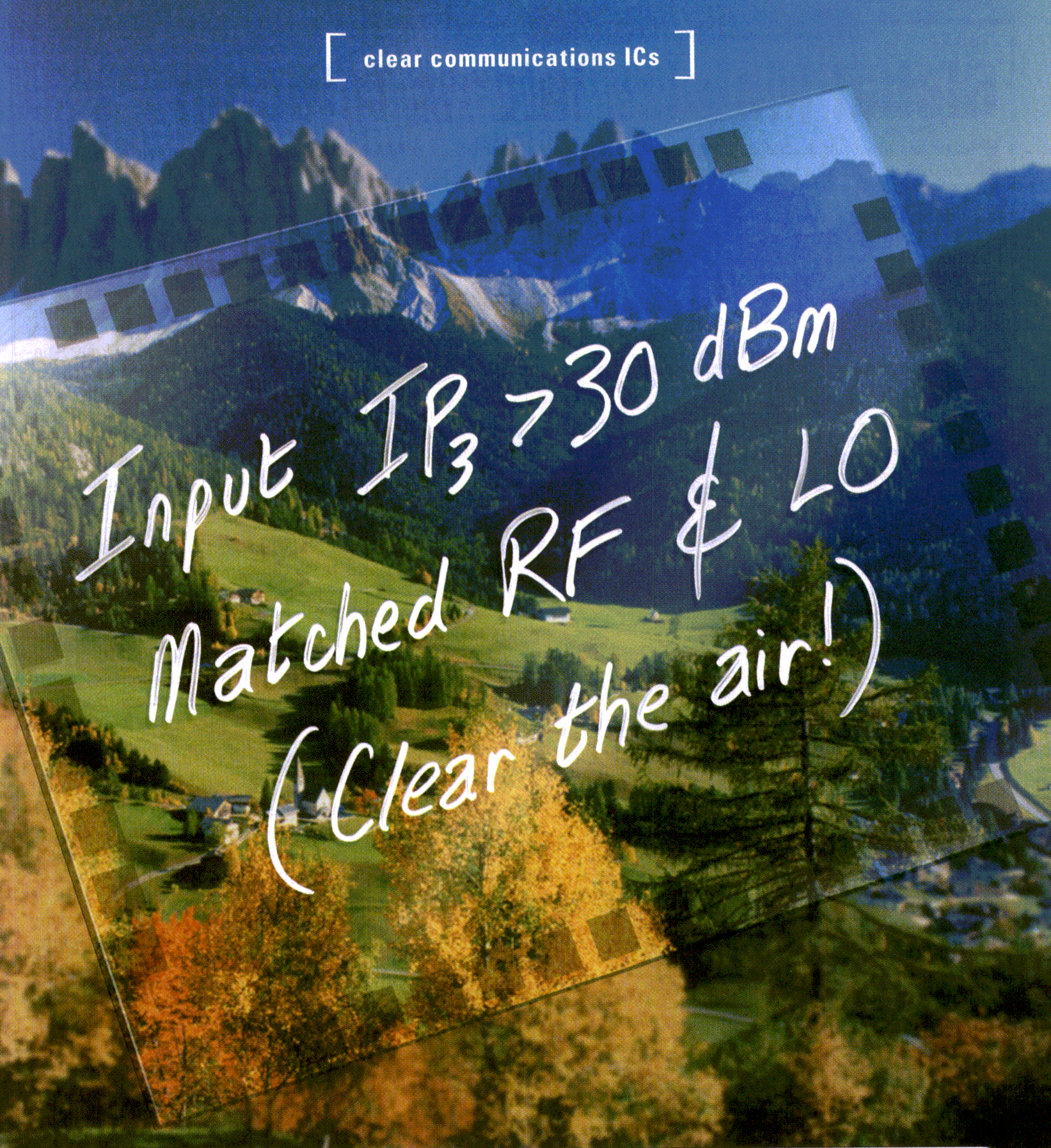
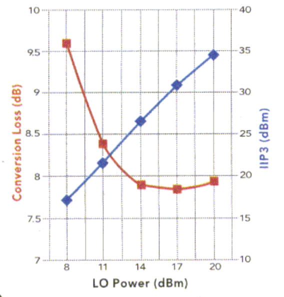


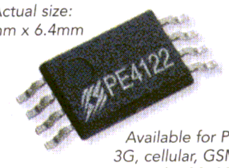
PE4122 PCS/3G
Receive Mixer



Extend the reach of your base stations with our high linearity integrated receive mixers. Their remarkable input IP_3 performance of >30 dBm will pick distant signals out of the haze. Their integrated matching RF and LO networks eliminate the need for bulky mixer modules or external RF baluns. The tiny TSSOP package is a real space saver, too. It's all made possible by our Sapphire CMOS technology. For details, visit our web site or call 858-455-0660.

Mixer

Actual size: 3mm x 6.4mm



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Global Malaise Infects Telecom

Fears of an economic recession in the US are rippling around the globe as the already-stressed communications industry continues to feel the ill effects of last year's slowdown (see "Turbulence Muddies The Telecom Waters," *Microwaves & RF*, December 2000, p. 29). On the same day, early last month, when networking-equipment leader Cisco Systems reported disappointing earnings, France Telecom had to scale back the offering price of shares in its Orange wireless business and Matsushita Communication Industrial Co. Ltd.—Japan's largest cell-phone manufacturer—projected poor earnings for the year ahead.

Cisco's well-documented problems of 2000 stemmed from large cutbacks in capital spending by big telecommunications players, such as AT&T, WorldCom, BellSouth, and others. In February's earnings announcement, Cisco also forecast slower information-technology (IT) sales to its enterprise customers in manufacturing aside from telecommunications. Analysts believe that this weakness, showing up early in the year, could last well into the second quarter and beyond, assuming that the US does not go into a recession. As occurred earlier with the telecommunications cutbacks, Cisco's woes spread to its semiconductor suppliers such as PMC-Sierra, which saw its share price tumble from a high of $96 a few weeks ago to below $64. Cisco itself closed at just over $31, a 19-percent drop this year and approximately two-thirds less than its 52-week high.

The huge debt problems of European telecommunications manufacturers are another sore point in the telecommunications business, which are now creating negative investor sentiment. France Telecom bought the Orange wireless unit less than a year ago from Vodafone and hoped to sell shares in it to the public for approximately 14 billion euros ($13.02 billion) to finance the deal. But the public is not biting and the company had to slash the pending offering price to approximately half (6.5 billion euros, $6.04 billion) to attract investors. And it is not a sure thing that investors will buy at this lower price. A concern circulating in Europe about wireless is that it is experiencing a general slowdown in new customers, and that new mobile services for generating fresh revenue, such as Internet connections, could be delayed.

High-technology and telecommunications worries linked to the slowing US economy are making Japanese investors skittish. Matsushita's poor earnings forecast is causing many investors to reduce their exposure to the telecommunications sector. The slump in high-technology shares has spread to the broader market with the Nikkei stock index falling to a 28 month low in early February. ••

Contracts

EMCORE Corp.—Announced the receipt of an additional $12 million order from Space Systems/Loral (SS/L), based in Palo Alto, CA, for high-efficiency, triple-junction solar cells. The solar cells will be used by SS/L to provide power in space for advanced communications satellites.

Andrew Corp.—Will supply WildBlue Communications, Inc. with turnkey services for twelve Ka-band gateway systems to be deployed in WildBlue's broadband service network across the US. The value of the contract with WildBlue is more than $20 million. The first six WildBlue gateways are scheduled for completion by the end of 2001.

ITT Industries, Avionics Division—Has been awarded a $20.7 million low-rate-initial-production (LRIP) contract for the CV-22 survivability suite by Bell-Boeing.

Endwave Corp.—Has signed a three-year, multimillion-dollar agreement with Allgon Microwave, a business area of Allgon AB and a manufacturer of wireless products for telephony and data communications. Under the terms of the agreement, Endwave will supply Allgon Microwave with RF transceivers for deployment in second- and third-generation (2G and 3G) cellular networks throughout Europe, North America, Latin America, Asia, and Australia.

Surrey Satellite Technology Ltd. (SSTL)—Has been awarded a further $120,000 by NASA to contribute to SSTL's Magnetospheric Multiscale (MMS) mission study—a constellation of small spacecraft to investigate the Earth's magnetosphere. SSTL's latest contract from NASA follows on from the earlier Phase A study, successfully completed by SSTL for NASA in September 2000, which investigated the range of suitable concepts for an initial five-spacecraft mission. The new study awarded to SSTL is to conduct an in-depth concept investigation of four MMS spacecraft flying in a tetrahedral configuration to study the Earth's magnetosphere and interaction with solar radiation.

Fresh Starts

Libertel-Vodafone—Has chosen Data Distilleries' Analytical CRM software to better manage customer relations. Data Distilleries software will constitute an integral part of Libertel-Vodafone's CRM infrastructure.

Renaissance Electronics Corp.—Announced the signing of a manufacturer's representative agreement with Axel Representations Ltd. of Athens, Greece. Under the terms of the agreement, Axel will market Renaissance's products in Greece.

matthews/mark—Was named agency of record by JABRA Corp., a provider of hands-free communication products in the mobile consumer market. The agency was hired to develop a national branding program that includes advertising, public relations, trade-show promotions, and media-planning services.

Waterloo Maple, Inc. (WMI) and ENGINEERING.com, Inc.—Have jointly announced the availability of Maple-enabled solutions on ENGINEERING.com. These solutions allow engineers, as well as students, architects, robotics designers, and other non-engineers, to perform complex calculations interactively using only a browser. No additional software or plug-ins are needed to get at the results.

Monitor Products Co., Inc.—Has signed a letter of intent to acquire the operations of Quartztek, Inc. of Phoenix, AZ. Terms of the transaction are not being disclosed.

RF Micro Devices, Inc.—Announced that it intends to develop and manufacture integrated circuits (ICs) using indium phosphide (InP), a next-generation semiconductor-process technology. InP is widely viewed by industry experts as having performance characteristics that are superior to those of existing process technologies.

Xpedion Design Systems, Inc.—Has established a worldwide network for sales and support of its GoldenGate family of RF simulation and modeling tools. The Xpedion sales and support network consists of 11 direct and distributor representatives in North America, Europe, Japan, Taiwan, Korea, Singapore, and India.

Symmetricom—Announced that it is providing Telephone Electronic Corp. (TEC) with synchronization for Voice over ATM (VoATM) services. TEC offers local and long-distance services and is the nation's largest privately held telecom company.

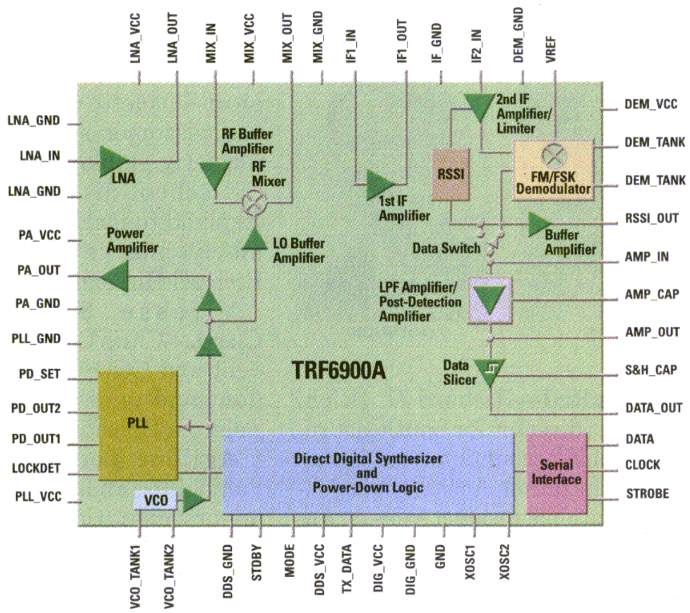
Accelerated Technology, Inc. (ATI)—Announced that its Nucleus PLUS real-time kernel has been chosen by Honeywell for the Enhanced Ground Proximity Warning System (EGPWS)—a new system that alerts pilots of dangerous terrain. The EGPWS compares the airplane's location to an internal data base of the world's terrain and provides a display of nearby terrain features.

Merrimac Industries, Inc.—Announced the formation of a business-to-business (B2B) initiative that will allow all of the company's domestic and international facilities to be networked with each other and its customers and suppliers worldwide. The initiative enables design engineers to share data, designs, simulated performance, design data bases, and product outlines securely with customers through the Internet.

Avnet Asia—Launched its new Asia Regional Programming Center in Singapore—the company's first center of this kind in Asia. The Avnet Regional Programming Center will provide chip and component-programming services to major original equipment manufacturers (OEMs) in Singapore and the region, where memory devices for products such as cellular phones, computers, and palmtops can be programmed.

Mimix Broadband—Has acquired Tadiran Microwave Network's Australian Design subsidiary at an undisclosed amount. This acquisition significantly expands Mimix Broadband's capabilities to design and develop gallium-arsenide (GaAs) monolithic microwave integrated circuits (MMICs) and modules for broadband-wireless-access applications that meet customer requirements.

Industry's most integrated RF transceiver/transmitter ICs.



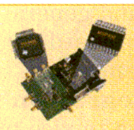
- *Single-chip solution with direct digital synthesizer supports wide-band applications with fixed or frequency hopping spread spectrum*
- *Integrated voltage controlled oscillator, phase-locked loop and adjustable power amplifier decreases board space*
- *TRF6900 contains integrated mixer, demodulator, data slicer and Received-Signal-Strength Indicator for interface with a microcontroller or DSP*
- *Operates in Europe/U.S. ISM-band at 850 MHz to 950 MHz*
- *30-µs frequency hops*
- *SW programmable frequency settings*
- *2.2-V to 3.6-V operation ensures low power consumption*
- *No external adjustments required*

Part Number	Function	Current Consumption		Output Power	Transmit	DDS Lock Time		Package	Price[†]
		Standby	Active*			Standby To rec	Standby To xmit		
TRF4900	Transmitter	0.5 µA	22 mA	7 dBm	FM/FSK	N/A	500 µs	24-pin TSSOP	$1.92
TRF6900A	Transceiver	0.5 µA	21 mA	4.5 dBm	FM/FSK	600 µs	500 µs	48-pin PQFP	$4.55

[†]Price is per device in quantities of 1,000.

The ISM-band TRF6900 transceiver and the TRF4900 transmitter from Texas Instruments utilize cutting-edge technology to bring you the integration and low-power operation that your RF designs require. The TRF6900 and the TRF4900 include a fully programmable direct digital synthesizer (DDS) for fast, accurate frequency hopping. The small size, low power consumption and fast standby to transmit operation (500 µs) make these RF components ideal for battery-powered applications. From security systems and toys to utility metering devices and home automation, TI's integrated RF transceiver and RF transmitter ICs are the perfect fit.

48-pin PQFP shown actual size



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* Power amplifier at 20 dB attenuation. The red/black banner is a trademark of Texas Instruments. 1621-11P MSDS10584E

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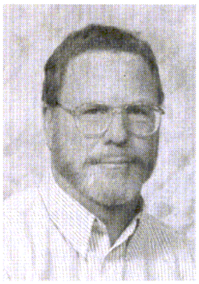
TEXAS INSTRUMENTS

Barry Industries, Inc.—Ronald H. Schmidt to vice president of engineering and technology; formerly principal engineer at M/A-COM.

American Microsystems, Inc. (AMI)—Steve Hayes as director of Eastern area sales, located in Andover, MA; formerly a partner and president of I Squared, Inc.



HAYES

GOMRICK

VertexRSI—Richard D. (Rich) Gomrick to director for Southeast region national accounts for the Group Sales organization; formerly responsible for national product sales at Andrew Corp.

SaRonix—Pat Lawlor to CFO; formerly senior financial manager at Aerojet Fine Chemicals.

Telelogic AB—Cris Kobryn to chief technologist for its Product Development Division; formerly chief technologist for EDS's E.solutions.

Motorola, Inc. and Cisco Systems, Inc.—Yuval Bloch of Motorola to president and general manager of Invisix™, a joint venture between Motorola and Cisco; formerly president and general manager for the Telecom Carrier Solutions Group in Israel.

Schema Ltd.—Shai Farkash to vice president of research and development (R&D); formerly director of product development for TTI-Telecom.

EMS Technologies—Alfred G. Hansen to CEO; formerly president and COO. Also, Jay R. Grove to vice president and general manager for EMS Space & Technology Group—Atlanta; formerly director of Mobile SATCOM Systems for ViaSat, Inc.

Falarion Technologies—Dr. Andrew (Andy) Viterbi to the board of directors; formerly vice chairman of Qualcomm, Inc.

w-Technologies—Frank Zammataro to chief marketing officer; formerly first vice president of e-Investments and e-Alliances in Merrill Lynch's Private Client Group.

CMC Wireless—Gabriel Carrasco to vice president of operations; formerly manufacturing manager for the aluminum-nitride (AlN) product line.

Kathrein, Inc., Scala Division—Danette (Daniela) Hovland to the customer service department; formerly employed in the Ashland, OR school district. Also, Harry Ekelund to marketing manager; formerly marketing manager at Richard Hirschmann of America.

Vitesse Semiconductor Corp.—Chris Gardner to vice president and COO; formerly vice president and general manager of the Telecom Division.

Agilent Technologies—Peter Sahjani to product manager of gallium-arsenide (GaAs) products in the RF Business Unit, Wireless Semiconductor Division; formerly director of internal sales and marketing for the Filtronic Solid State Group.

SAHJANI

GAFFNEY

ITT Industries, Avionics Division—Steven F. Gaffney to president and general manager; formerly vice president and director of programs.

Integration Associates—Jan Nilsson to vice president of marketing; formerly director of marketing for Vishay Intertechnology, Inc.'s Siliconix power integrated-circuit (IC) and Telefunken infrared (IR) data-communications business units.

RF Monolithics, Inc.—Jon S. Prokop to vice president of manufacturing; formerly director of manufacturing engineering.

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Reston, VA 20190-5630
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IP Over Wireless Broadband
April 4-6 (Boston, MA)
Global Knowledge
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Cary, NC 27511
(800) Courses, FAX: (919) 461-8646
Internet: http://am.globalknowledge.com

Phase-Locked Loop (PLL) Systems
April 5-7 (San Francisco Airport, San Francisco, CA)
University of California-Berkeley
Continuing Education in Engineering
Berkeley, CA 94720
(510)642-4111, FAX: (510) 642-0374
Internet: http://www.unex.berkeley.edu/enroll.

Planning and Implementing Point-to-Point Microwave Radio Systems
April 9-11 (Orlando, FL)
Dept. of Engineering Professional Development
University of Wisconsin-Madison
Madison, WI 53706
(800) 462-0876, FAX: (608) 263-3160
e-mail: custserv@epd.engr.wisc.edu
Internet: http://epd.engr.wisc.edu

Understanding Wireless Technologies for Non-Engineers
April 10-11 (McLean, VA)
TeleStrategies, Inc.
P.O. Box 4109
McLean, VA 22103
(703) 734-2600, FAX: (703) 556-3959

Introductory RF and Microwaves RF Power Amplifiers, Classes A through S
April 19-20 (Baltimore, MD)
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Utica, NY 13501
(315) 735-4328, FAX: (315) 735-4217
e-mail: RAWood@rawood.com
Internet: http://www.rawood.com.

Meetings

Embedded Systems Conference—San Francisco
April 9-13 (Moscone Center, San Francisco, CA)
CMP Media, Inc.
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e-mail: esc@cmp.com

IMAPS Advanced Technology Workshop on Thermal Management for High-Performance Computing and Wireless Applications
April 20-21 (Sheraton Palo Alto Hotel, Palo Alto, CA)
International Microelectronics and Packaging Society (IMAPS)
General Chair: Dave Saums
Power Devices, Inc.
Newburyport, MA
(978) 499-4990
e-mail: dsaums@msn.com

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Internet: http://www.ifp.com.lb

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Hasbrouck Heights, NJ 07604
(888) 947-3734, FAX: (201) 393-6297
e-mail: lwilczynski@penton.com
Internet: http://militaryelectronicsshow.com

2001 International Reliability Physics Symposium
April 30-May 3 (Wyndham Palace Resort at Disneyworld, Orlando, FL)
Institute of Electrical and Electronics Engineers (IEEE)
Anthony S. Oates, General Chair
Lucent Technologies
Orlando, FL 32819
(407) 371-7536, FAX: (407) 371-7639
e-mail: AOATES@Lucent.com

2001 IEEE Radar Conference
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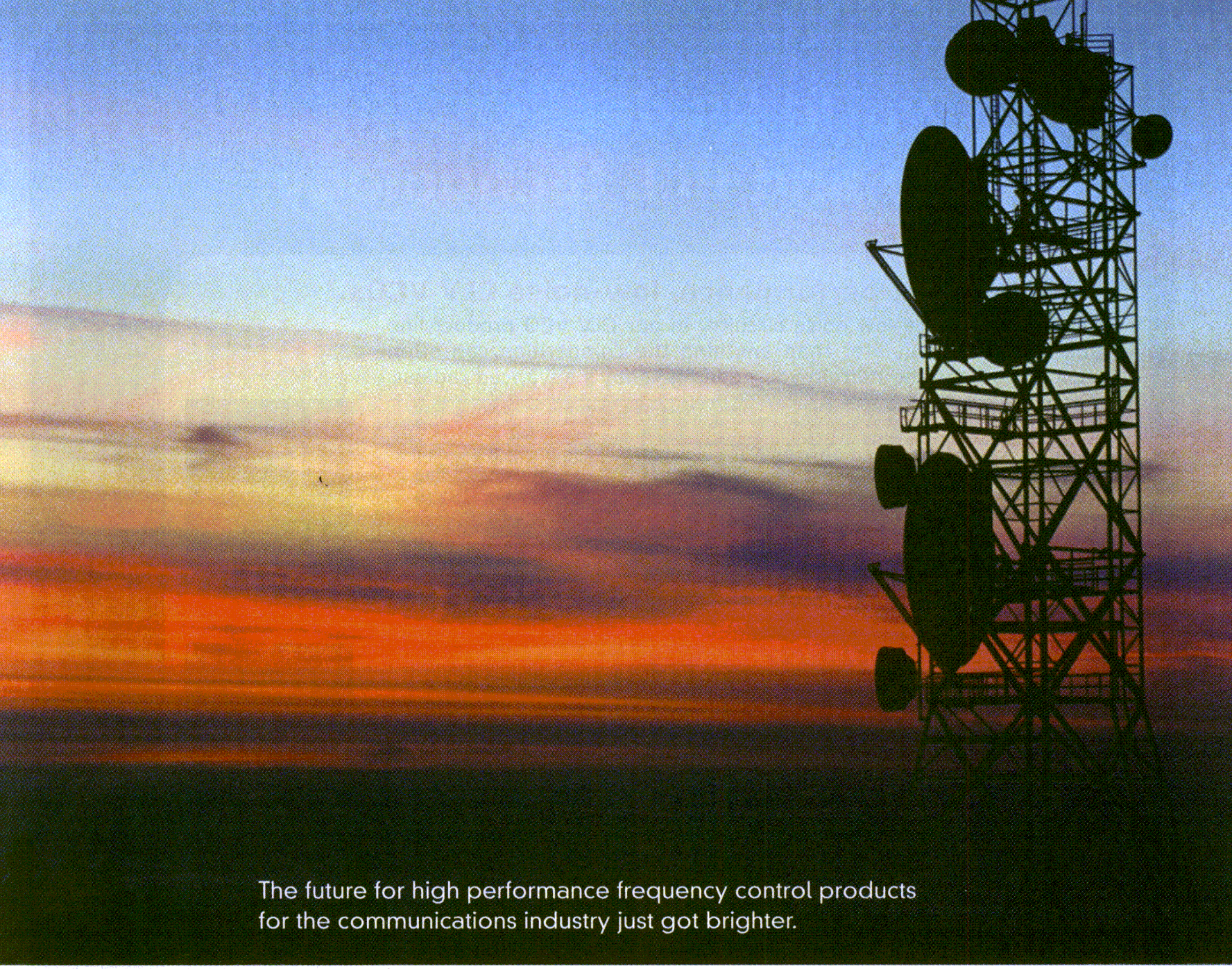
Deadline for abstracts: May 1



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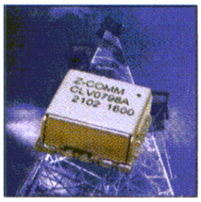
CLV0815E	806	824	0.5-4.5	11	-113	-35	5.0	11
CLV0950E	865	1035	1-10	27	-114	-11	5.0	24
CLV0915A	902	928	0-4	17	-108	-30	3.0	10
CLV1085E	1050	1086	0.5-4.5	21	-112	-20	5.0	20
CLV1385E	1370	1400	0.5-4.5	18	-110	-20	5.0	20
CLV1550E	1500	1600	0.5-5.0	44	-106	-35	5.0	22
CLV2465E	2436	2496	1-4	26	-107	-20	5.0	25



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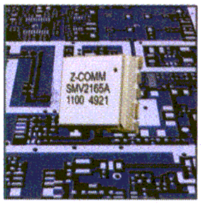
Part Number	Maximum Start Freq. (MHz)	Minimum Stop Freq. (MHz)	Tuning Voltage (Vdc)	Tuning Sensitivity (MHz/V)	Phase Noise @10 kHz (dBc/Hz)	Harmonic Suppression (dBc)	Supply Voltage (Vdc, nom.)	Supply Current (mA, typ.)
SMV0162A	125	200	0.7-8.3	12	-100	-6	5.0	36
SMV1570L	1540	1600	0.5-2.5	128	-90	-15	2.7	9
SMV2165A	2118	2218	0-3	148	-91	-10	3.3	16
SMV2390L	2290	2485	0-4	116	-90	-11	5.0	16
SMV2660L	2620	2700	0.5-4.5	90	-91	-17	5.0	21



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Part Number	Maximum Start Freq. (MHz)	Minimum Stop Freq. (MHz)	Tuning Voltage (Vdc)	Power Output (dBm)	Phase Noise @10 kHz (dBc/Hz)	Harmonic Suppression (dBc)	Supply Voltage (Vdc, nom.)	Supply Current (mA, typ.)
USSP2330	2300	2360	0.5-2.5	0±3	-83	-15	2.7	8

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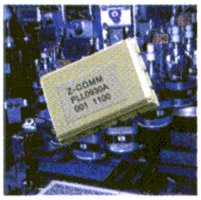
Part Number	Start Freq. (MHz)	Stop Freq. (MHz)	Step Size (kHz)	Int. Phase Noise (°RMS)	Phase Noise at 10kHz (dBc/Hz)	Output Power (dBm)	Supply Voltage (Vdc)	Supply Current (mA)
PLL0210A	200	230	100	0.50	-105	3.5±2.5	+5	25
PLL0930A	900	960	100	0.75	-101	3±2	+5	40
PLL1260A	1230	1290	1000	0.75	-102	1±2	+5	40
PLL1456A	1420	1490	1000	0.75	-103	1±2	+5	40
PLL2710A	2670	2740	1000	1.25	-98	1±4	+5	30



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Boosting bandwidth and gain of gyro-TWTs

Gyro-traveling-wave tubes (gyro-TWTs) are vacuum-electronic devices capable of high output-power levels at millimeter-wave frequencies. Work performed by Mukul Agrawal, G. Singh, P.K. Jain, and B N. Basu at the Centre of Research in Microwave Tubes, Dept. of Electronics Engineering, Institute of Technology, Banaras Hindu University (Varanasi, India) has focused on optimizing the beam and background magnetic-field parameters of these devices through vane loading. The researchers considered two schemes for two-section vane loading of a gyro-TWT, using two identical vane depths at different vane angles, as well as using different vane depths. For the approach with different lengths, one of the vane sections is slightly "detuned" from synchronism so that the beam-mode dispersion line intersects the waveguide-mode dispersion curve at two different points. This results in a gain-frequency response for the vane section with two peaks corresponding to the two intersecting points. By similarly tuning the second section and controlling the lengths of the sections, the gains of the individual sections can be controlled. The gains of the individual sections are added to create a wideband device with high gain, compared to a single-stage device. See "Two-Stage Vane Loading of Gyro-TWTs for High Gains and Bandwidths," *Microwave and Optical Technology Letters*, November 5, 2000, Vol. 27, No. 3, p. 210.

Creating an accurate picture of near-field radiation patterns

Mathematical representations are commonly used to analyze and predict antenna near-field radiation patterns. But attempts to visualize the physical radiation patterns and energy flow around an antenna often fall short due to the difficulty of associating physical phenomena with mathematical formulas. However, work performed by E.K. Miller and F.J. Deadrick of Santa Fe, NM attempts to clarify the physical picture of radiation around a dipole and to provide a more interpretable perspective of the radiation process. Their work involves the use of computer graphics to display the dipole field quantities in enough detail that an observer can relate a mathematical description of the phenomena to physical behavior. The researchers present near-field plots of Poynting's vector and electric- and magnetic-field intensities, all computed for a half-wavelength thin wire which is excited as a radiator or scatterer. The field distributions were computed from a method-of-moments (MoM) solution for time-harmonic excitations, and are displayed as a function of time to show the ebb and flow of the fields near the wire. Within their article, the presenters (who can be reached by e-mail at emiller@ieee.org or fdeadrick@home.com) offer a Macintosh computer disc of programs that display various field solutions. See "Visualizing Near-Field Energy Flow and Radiation," *IEEE Antennas and Propagation Magazine*, December 2000, Vol. 42, No. 6, p. 46.

Analyze a compact patch antenna with C-shaped slot

Microstrip patch antennas are attractive due to their good performance, small size, and light weight. They can be made to conform to a variety of shapes, and are well-suited for personal-communications-services (PCS) handsets. Jun-Hai Cui, Shun-Shi Zhong, and Chun Yu from the Dept. of Communications Engineering of Shanghai University (Changhai, China) recently reported on their analysis of a microstrip patch antenna with a C-shaped slot using the finite-difference-time-domain (FDTD) method. The antenna studied was etched on a substrate with a relative dielectric constant of 2.2 and thickness of 1.575 mm. The patch antenna had length of 22 mm and width of 1.5 mm, fed by a coaxial probe with a radius of 0.5 mm. The rectangular-mesh and the conformal FDTD methods were used to study the characteristic impedance of the coaxial transmission-line probe used with the antenna, and the rectangular-mesh approach was used for the study of the antenna. The analysis of the antenna, based on a study of return loss, showed a resonant frequency of approximately 1.48 GHz, with a bandwidth of 2.2 percent based on an analysis of the 10-dB return loss. A similar-sized antenna without the C-shaped slot yielded a resonant frequency that was considerably higher, at approximately 4.3 GHz. The length of a conventional microstrip antenna operating at 1.48 GHz would be approximately 66.8 mm, with a bandwidth of approximately 1.4 percent based on its 10-dB return loss. These studies show that the patch antenna with a C-shaped slot is approximately 67 percent smaller than a conventional microstrip antenna at the same frequency. See "FDTD Analysis of a Compact Microstrip Antenna with a C-Shaped Slot," *Microwave and Optical Technology Letters*, November 5, 2000, Vol. 27, No. 3, p. 210.

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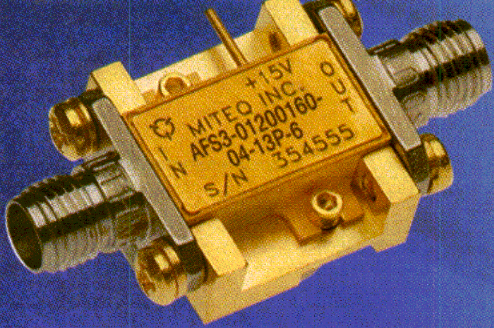

AMPLIFIERS

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
TEMPERATURE COMPENSATED AMPLIFIERS								
AFS3-01000200-15-TC-6	1–2	36-40	1.00	1.5	2.0:1	2.0:1	+5	125
AFS2-02000400-15-TC-6	2–4	22-26	1.00	1.5	2.0:1	2.0:1	+5	125
AFS3-02000400-15-TC-6	2–4	22-26	1.00	1.5	2.0:1	2.0:1	+5	125
AFS2-04000800-20-TC-2	4–8	18-22	1.00	2.0	2.0:1	2.0:1	+5	100
AFS3-04000800-18-TC-4	4–8	26-30	1.00	1.8	2.0:1	2.0:1	+8	150
AFS2-02000800-40-TC-2	2–8	14-19	1.50	4.0	2.0:1	2.0:1	+5	100
AFS3-02000800-30-TC-4	2–8	22-27	1.50	3.0	2.0:1	2.2:1	+8	150
AFS2-08001200-30-TC-2	8–12	12-16	1.00	3.0	2.0:1	2.0:1	+5	100
AFS3-08001200-22-TC-4	8–12	24-28	1.00	2.2	2.0:1	2.0:1	+8	150
AFS4-12001800-30-TC-8	12–18	22-26	1.00	3.0	2.0:1	2.0:1	+8	250
AFS4-06001800-35-TC-6	6–18	22-26	1.00	3.5	2.0:1	2.0:1	+8	250
AFS6-06001800-35-TC-8	6–18	30-34	1.00	3.5	2.0:1	2.0:1	+8	400
AFS4-02001800-45-TC-5	2–18	18-24	1.50	4.5	2.2:1	2.2:1	+8	175

Note: All specifications guaranteed -54 to +85°C.
Many other frequencies, noise figures and gain windows are available.

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
HIGHER POWER AMPLIFIERS								
AFS4-00050100-25-25P-6	0.5–2	36	1.50	2.5*	2.0:1	2.5:1	+25	325
AFS3-00100100-23-25P-6	.1–1	38	2.00	2.3	2.5:1	2.5:1	+25	280
AFS3-00100200-25-27P-6	.1–2	33	1.50	2.5	2.0:1	2.5:1	+27	300
AFS3-00100300-25-23P-6	.1–3	25	1.50	2.5	2.0:1	2.5:1	+23	300
AFS3-00100400-26-20P-4	.1–4	26	1.50	2.6	2.0:1	2.0:1	+20	250
AFS4-00100600-25-20P-4	.1–6	32	1.50	2.5	2.0:1	2.0:1	+20	300
AFS4-00100800-28-20P-4	.1–8	30	1.50	2.8	2.0:1	2.0:1	+20	300
AFS4-00101200-40-20P-4	.1–12	20	1.50	4.0	2.0:1	2.0:1	+20	300
AFS4-00501800-60-20P-6	.5–18	25	2.75	6.0	2.5:1	2.5:1	+20	350
AFS5-00102000-60-18P-6	.1–20	25	3.00	6.0	2.5:1	2.5:1	+18	360
AFS3-01000200-20-27P-6	1–2	33	1.50	2.0	2.0:1	2.0:1	+27	350
AFS3-02000400-30-25P-6	2–4	28	1.50	3.0	2.0:1	2.0:1	+25	250
AFS3-04000800-40-20P-4	4–8	20	1.00	4.0	2.0:1	2.0:1	+20	200
AFS4-08001200-50-20P-4	8–12	22	1.25	5.0	2.0:1	2.0:1	+20	200
AFS6-12001800-40-20P-6	12–18	28	2.00	4.0	2.0:1	2.0:1	+20	375
AFS6-06001800-50-20P-6	6–18	23	2.00	5.0	2.0:1	2.0:1	+20	365
AFS4-02001800-60-20P-6	2–18	23	2.50	6.0	2.5:1	2.0:1	+20	350

*Noise figure degrades below 100 MHz. Please consult factory for details.
Note: Noise figures increase below 500 MHz in bands wider than .1-10 GHz.

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Model Number	Frequency Range (GHz)	Gain (Min.) (dB)	Gain Flatness (±dB)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
MODERATE BAND AMPLIFIERS								
AFS2-00700080-05-10P-4	.7–.8	30	0.50	0.45	1.5:1	1.5:1	+10	90
AFS2-00800100-05-10P-4	.8–1	30	0.50	0.45	1.5:1	1.5:1	+10	90
AFS3-01200160-05-13P-6	1.2–1.6	40	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-01400170-05-13P-6	1.4–1.7	40	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-01500180-04-13P-6	1.5–1.8	40	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-01500250-06-13P-6	1.5–2.5	36	0.50	0.60	2.0:1	2.0:1	+13	150
AFS3-01700190-04-13P-6	1.7–1.9	36	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-01800220-05-13P-6	1.8–2.2	36	0.50	0.50	1.5:1	1.5:1	+13	150
AFS3-02200230-04-13P-6	2.2–2.3	36	0.50	0.40	1.5:1	1.5:1	+13	150
AFS3-02300270-05-13P-6	2.3–2.7	34	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-02700290-05-13P-6	2.7–2.9	32	0.50	0.50	1.5:1	1.5:1	+13	150
AFS3-02900310-05-13P-6	2.9–3.1	32	0.50	0.45	1.5:1	1.5:1	+13	150
AFS3-03100350-06-10P-4	3.1–3.5	29	0.50	0.6	1.5:1	1.5:1	+10	150
AFS4-03400420-06-13P-6	3.4–4.2	40	0.50	0.60	1.5:1	1.5:1	+13	225
AFS3-04400510-07-5P-4	4.4–5.1	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-04500480-07-5P-4	4.5–4.8	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05200600-07-5P-4	5.2–6	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05400590-07-5P-4	5.4–5.9	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-05800670-07-5P-4	5.8–6.7	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS3-07250775-06-5P-4	7.25–7.75	30	0.50	0.60	1.5:1	1.5:1	+5	100
AFS3-07900840-07-5P-4	7.9–8.4	30	0.50	0.70	1.5:1	1.5:1	+5	100
AFS4-08500960-08-5P-4	8.5–9.6	32	0.75	0.80	1.5:1	1.5:1	+5	125
AFS3-09001100-09-5P-4	9–11	26	0.50	0.90	1.5:1	1.5:1	+5	100
AFS4-09001100-09-5P-4	9–11	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS4-10951175-09-5P-4	10.95–11.75	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS4-11701220-09-5P-4	11.7–12.2	32	0.75	0.90	1.5:1	1.5:1	+5	125
AFS2-12201280-10-8P-4	12.2–12.8	14	0.75	1.00	1.5:1	1.5:1	+8	80
AFS4-12201280-10-12P-4	12.2–12.8	27	0.75	1.00	1.5:1	1.5:1	+12	200
AFS4-12701330-13-10P-4	12.7–13.3	27	0.75	1.30	1.5:1	1.5:1	+10	175
AFS4-13201400-14-10P-4	13.2–14	24	0.75	1.40	1.5:1	1.5:1	+10	175
AFS4-14001450-14-10P-4	14–14.5	24	0.75	1.40	1.5:1	1.5:1	+10	175
AFS4-20202120-20-8P-4	20.2–21.2	20	1.00	2.00	1.5:1	1.5:1	+8	175
AFS4-21202400-22-10P-4	21.2–24	18	1.00	2.2	2.0:1	2.0:1	+10	100
OCTAVE BAND AMPLIFIERS								
AFS3-00120025-09-10P-4	.12–.25	38	0.50	0.9	2.0:1	2.0:1	+10	175
AFS3-00250050-08-10P-4	.25–.5	38	0.50	0.8	2.0:1	2.0:1	+10	125
AFS3-00500100-05-10P-6	.5–1	38	0.75	0.5	2.0:1	2.0:1	+10	150
AFS3-01000200-05-10P-6	1–2	38	1.00	0.5	2.0:1	2.0:1	+10	150
AFS3-01200240-05-10P-6	1.2–2.4	34	1.00	0.5	2.0:1	2.0:1	+10	175
AFS3-02000400-06-10P-4	2–4	30	1.00	0.6	2.0:1	2.0:1	+10	125
AFS3-02600520-10-10P-4	2.6–5.2	28	1.00	1.0	2.0:1	2.0:1	+10	150
AFS3-04000800-07-10P-4	4–8	30	1.00	0.7	2.0:1	2.0:1	+10	125
AFS3-08001200-09-10P-4	8–12	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS3-08001600-15-8P-4	8–16	26	1.00	1.5	2.0:1	2.0:1	+8	80
AFS4-12002400-25-10P-4	12–24	20	2.00	2.5	2.0:1	2.0:1	+10	85
AFS4-12001800-18-10P-4	12–18	26	1.00	1.8	2.0:1	2.0:1	+10	125
AFS4-18002650-28-8P-4	18–26.5	18	1.75	2.8	2.5:1	2.2:1	+8	150
MULTIOCTAVE BAND AMPLIFIERS								
AFS1-00040200-12-10P-4	.04–2	15	1.50	1.2	2.5:1	2.0:1	+10	75
AFS3-00300140-08-10P-4	.3–1.4	33	1.00	0.8	2.0:1	2.0:1	+10	150
AFS2-00400350-12-10P-4	.4–3.5	22	1.50	1.2	2.0:1	2.0:1	+10	80
AFS3-00500200-08-15P-4	.5–2	38	1.00	0.8	2.0:1	2.0:1	+15	125
AFS3-01000400-09-10P-4	1–4	30	1.50	0.9	2.0:1	2.0:1	+10	125
AFS3-02000800-09-10P-4	2–8	26	1.00	0.9	2.0:1	2.0:1	+10	125
AFS4-02001800-23-10P-4	2–18	25	2.00	2.3	2.0:1	2.0:1	+10	175
AFS4-06001800-22-10P-4	6–18	24	2.00	2.2	2.0:1	2.0:1	+10	150
AFS4-08001800-22-10P-4	8–18	26	2.00	2.2	2.0:1	2.0:1	+10	150
ULTRA WIDEBAND AMPLIFIERS								
AFS3-00100100-09-10P-4	.1–1	38	1.00	0.9	2.0:1	2.0:1	+10	150
AFS3-00100200-10-15P-4	.1–2	38	1.00	1.0	2.0:1	2.0:1	+15	150
AFS3-00100300-11-10P-4	.1–3	32	1.00	1.1	2.0:1	2.0:1	+10	150
AFS3-00100400-13-10P-4	.1–4	28	1.00	1.3	2.0:1	2.0:1	+10	150
AFS3-00100600-13-10P-4	.1–6	28	1.25	1.3	2.0:1	2.0:1	+10	125
AFS3-00100800-14-10P-4	.1–8	25	1.50	1.4	2.0:1	2.0:1	+10	125
AFS4-00101200-22-10P-4	.1–12	28	1.50	2.2	2.0:1	2.0:1	+10	175
AFS4-00101400-23-10P-4	.1–14	24	2.00	2.3	2.5:1	2.5:1	+10	200
AFS4-00101800-25-10P-4	.1–18	25	2.00	2.5	2.5:1	2.5:1	+10	175
AFS4-00102000-30-10P-4	.1–20	20	2.50	3.0	2.5:1	2.5:1	+10	175
AFS4-00102650-40-8P-4	.1–26.5	18	2.50	4.0	2.5:1	2.5:1	+8	175

Note: Noise figure increases below 500 MHz in bands greater than 0.1-10 GHz.

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WIRELESS telephones provide a convenient and reliable method of communication. But they can also provide a lifeline during times of emergency. A mobile telephone, when equipped with Global-Positioning-System (GPS) capability, can serve as an invaluable tool as part of the enhanced-911 (E-911) emergency service in the US. Adapting existing code-division-multiple-access (CDMA) handset architectures to also provide GPS is a matter of intelligent design and applying available advances in filter technology.

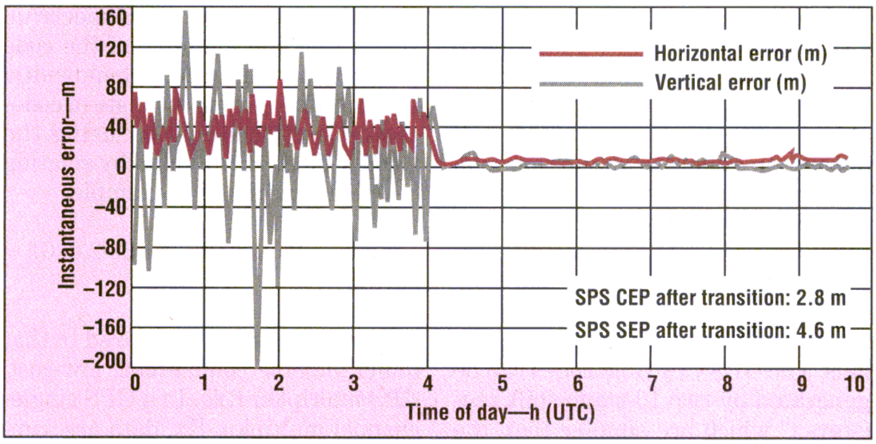
In 1999, the number of 911 emergency calls placed from mobile telephones in the US numbered 118,627 a day.[1] All 911 emergency calls are routed to a public-safety answering point (PSAP), where the operator dispatches the appropriate service amongst those closest to the incident. For wire-line calls, Federal Communications Commission (FCC) rules have been widely implemented and, as a result, PSAP operators immediately know the location of a private wire-line call.

However, PSAPs can only determine the most general location of a wireless caller—such as the cell site or cell-sector area. Thus, PSAP dispatchers need to question all wireless callers to determine their exact location before any help can be sent.

Approximately 60 to 70 percent of all fatal car crashes occur in rural areas which take emergency services longer to reach.[2] In a comment to the FCC, it was stated that, "It is estimated that 25 percent of wireless 911 callers are unsure of where they are."[3] Such problems are greatly compounded when a county's 911 system can include 18 PSAPs, 42 fire districts, and 27 police departments.[3]

In order to address these public-safety location issues, the FCC released a new revision of the rules covering E-911 services on October 6, 1999.[4] Within the rules document, the use of GPS technologies is specifically mentioned.

Recent developments in GPS service have made the use of GPS more attractive for incorporation into future mobile handsets. The most significant improvement was the switching off of selective availability (SA) in May 2000.[5] SA was controlled



1. By switching off the SA feature in GPS, a high level of accuracy is now available to civilian users.

by varying the navigation-message orbit-data parameter (epsilon) and/or dithering the satellite clock frequency. By switching off SA, civilian users have access to greater accuracy.

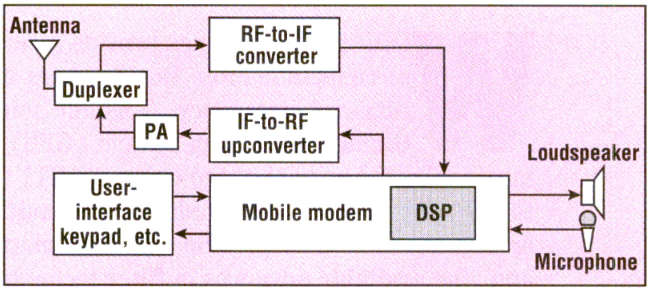
Another GPS improvement, announced by former Vice President Al Gore,[6] was the future addition of a second coarse/acquisition (C/A) code signal at 1227.60 MHz for civilian users. The second C/A code signal provides greater flexibility for mobile-telephone designers to implement GPS circuits over a wider range of user frequencies. While the FCC rules support "handset" or "network" location technologies, this article mainly considers handsets, and primarily those employing CDMA technology—the most rapidly growing air interface.

CDMA networks employ dynamic transmitter (Tx) power control, which reduces a mobile unit's transmitted power when close to a base station. This can reduce a mobile unit's transmitted power to the point where it can only be received by the closest base station. Many network-based location systems use triangulation methods, and must receive the mobile unit's signal at more than one station. For this reason, CDMA position location has been considered challenging. But due to improvements in GPS positioning accuracy, and because GPS is also a CDMA system, the inclusion of GPS as an alternative location system in CDMA handsets is gaining support.

For handset-based technologies (e.g., GPS in a CDMA telephone) to meet the location accuracy requirements of the FCC rules, it is necessary to locate 67 percent of mobile 911 calls to within a radius of 50 m (164 ft.) and 95 percent of 911 calls to within 150 m (492 ft.). For the remaining 5 percent, a location estimate must be provided to the PSAP.[4]

Prior to May 2, 2000, GPS (with SA "on") would provide precision of at least 156 m in three dimensions 95 percent of the time.[6] With selective availability turned off, single-channel C/A code ionospheric delay effects will dominate Rx errors. Ionospheric errors contribute between 9.8 and 19.6 m[7] user-equivalent range error (UERE). If measurements are made using dual-frequency L1/L2 Rxs, the ionospheric-error contribution can be reduced to approximately 4.5 m.[8] Typical L1 C/A code Rxs will now provide two-dimensional (2D) position solutions of approximately 10 m 95 percent of the time.

Figure 1 shows the accuracy improvement for a civil standard-positioning-service (SPS) Rx as time transitioned through the SA switch off.[9] [Note that CEP refers to circular error probable, since a circle's radius contains 50 percent of the points in a horizontal scatter plot. The term SEP refers to spherical error probable, due to a sphere's radius containing 50 percent of the points in a three-dimensional (3D) scatter plot.]



2. This block diagram shows a typical CDMA mobile-telephone architecture.

CDMA MOBILE UNITS

Figure 2 shows a typical block diagram of a CDMA mobile unit. The mobile unit's modem contains a digital-signal-processing (DSP) section that decodes the CDMA signals. In a CDMA telephone, which conforms to published Telecommunications Industry Association (TIA) CDMA standards, the DSP section will decode or generate the orthogonal Walsh codes used in the system spread-spectrum signaling. Walsh codes are used in the telecommunications system, while orthogonal Gold codes are used by GPS satellites to create the GPS spread-spectrum signals. The GPS C/A Gold codes can be generated by two 10-stage shift registers,[10] which are simpler than the Walsh 42-b long codes required by the CDMA telecommunication system. Since both systems operate in the CDMA mode (all GPS satellites transmit on the same frequency but with a different Gold code assigned to each satellite), it is clear that no completely new engineering concepts need to be added to the mobile modem DSP in order to decode GPS spread-spectrum signals. Manufacturers of the modem/DSP chips have indicated that future chips will support GPS.

Figure 3 shows the first stages of the RF-to-intermediate-frequency (IF) downconverter. One of the most expensive parts is the surface-acoustic-wave (SAW) IF filter. For GPS, the C/A code RF signal is spread over a 2.046-MHz bandwidth null-to-null.[7] GPS Rxs typically use a 2-MHz IF filter to preserve the downconverted code bandwidth. To add an additional 2-MHz-wide IF filter and a switch (if using the existing downconverter) means adding several extra parts, all of which consume valuable printed-circuit-board (PCB) space. PCB space will be at a premium in future mobile telephones, especially as the telephone manufacturers would like to incorporate many other features, such as Internet browsing, Bluetooth communications, and stereo MPEG audio-playback capability.

Working on the principle of using as many of the existing CDMA resources as possible leads to the question of whether the existing CDMA IF filter can be used for GPS. Examination of the GPS spectrum shows that the majority of the code power is within a 1-MHz bandwidth. A simple first-order estimate of code-power loss, incurred by using the CDMA filter, is provided by relating both bandwidths. For example,

$$\text{Loss (dB)} = |(10\log(1.23/2.046)| = 2.2 \text{ dB}$$

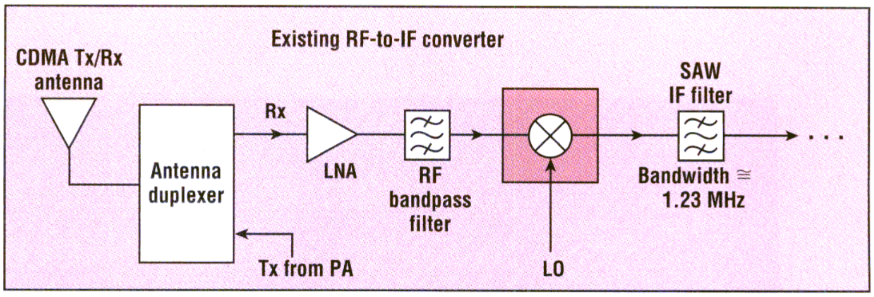
This loss is small compared to that found in some commercial, low-cost, GPS multiplex Rxs. In a GPS single-channel multiplex Rx, data are sampled by switching between the satel-

lites being tracked, typically at a 50-Hz rate. This architecture leads to a loss of recovered carrier-to-noise ratio (CNR), for any satellite being tracked, of 10log(n), where n = the number of satellites being tracked. Since four satellites must be tracked for a 3D solution and user-clock corrections, this Rx has a built-in carrier-to-noise degradation of 6 dB.[8] However, many of these early types of GPS Rxs performed well in the field. Modern CDMA telephones use multiple correlator systems referred to as "rake Rxs." GPS support can be expected to use "n" digital correlators rather than the lossy multiplex system described before.

Furthermore, GPS Block 1 satellites were designed in the 1970s, and the corresponding Rx front-end noise figures at 1.575 GHz were much higher compared to what is possible with modern gallium-arsenide (GaAs) active devices. The significant improvement in achievable front-end noise figure acts to minimize the impact of the 2.2-dB bandwidth losses, with respect to the noise figures expected by the GPS system designers. For example, pseudomorphic-high-electron-mobility-transistor (PHEMT) devices (such as models ATF-37143 and ATF-38143) from Agilent Technologies (San Jose, CA) are low-cost plastic-packaged GaAs components that provide noise figures of less than 1 dB at 1.575 GHz. For other discrete components suitable for GPS, see ref. 17.

While reducing the GPS bandwidth to 1.23 MHz has a small negative effect on the received code power, there is a positive side. Despite being a spread-spectrum system, GPS can be vulnerable to interference. Several instances of interference have been documented.[11] If one considers continuous-wave (CW) interference then, by using the existing 1.23-MHz bandwidth CDMA IF filter, the bandwidth is reduced to 60 percent of 2.046 MHz. With this bandwidth reduction, there is a lesser probability of E-911 services being jammed.

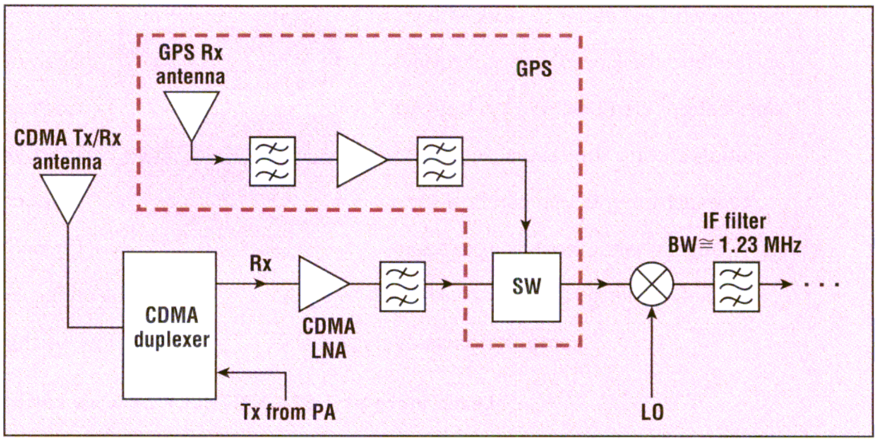
Given that it is possible to use the existing telecommunications 1.23-MHz channel-select SAW IF filter for GPS, and that the digital DSP section of a CDMA telephone will support the decoding of GPS signals, it is possible to consider a minimum of additional parts that must be added to support GPS operation. By using the existing CDMA downconversion mixer (Fig. 3) and setting the GPS gain stage so that it provides comparable levels to the mixer as the present CDMA front-end lineup, it is possible to create a GPS signal path from the antenna to DSP. The minimum blocks required to do this are shown (with a dashed outline) in Fig. 4. Gain variations and signal-level calibration at the analog-to-digital converters (ADCs), are accommodated by the existing IF automatic-gain-control (AGC) mechanism that is used for CDMA operation (not shown in Figs. 3 or 4).



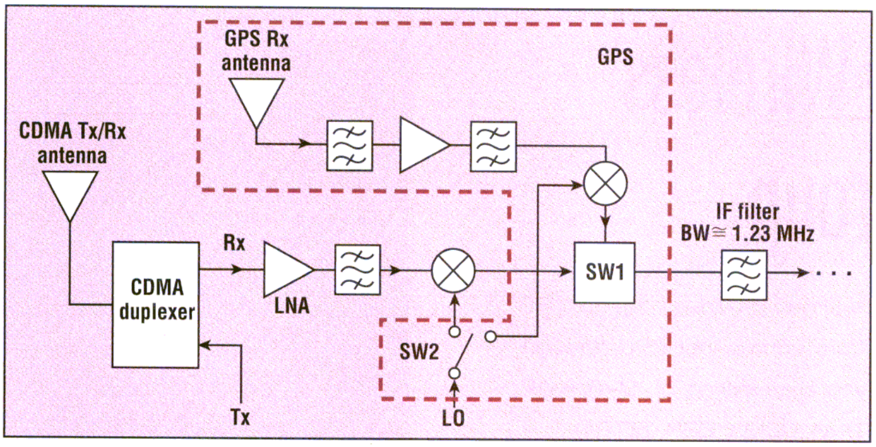
3. The first stages of the RF-to-IF downconverter in a CDMA mobile unit include the expensive SAW filter.

One disadvantage of the scheme shown in Fig. 4 is that the switch inevitably has losses in the CDMA RF band. These losses will add directly to the mixer noise figure and reduce the Rx sensitivity. While the sensitivity problem of these losses can be overcome by increasing the CDMA low-noise-amplifier (LNA) gain, any gain increase results in a reduction of the input third-order intercept point (IIP3) for the CDMA section. The balance between optimizing sensitivity and IIP3 is critical in the telecommunications CDMA system due to large (in-band RF) signals that occur in normal operation. Additionally, intermodulation (IM) problems are further complicated by the cross-modulation caused by transmit-power leakage through the duplexer.

An alternative to the scheme shown in Fig. 4 is to carry out CDMA/GPS selection on the IF side of the first mixer (Fig. 5). This still uses the existing CDMA IF filter. Again, the additional GPS-related components are shown enclosed by a dashed line. In this arrangement, the switch losses are reduced because the switch now operates at approximately 210 MHz rather than 1.9 GHz, or 85 MHz instead of 890 MHz,



4. This CDMA/GPS plan makes use of the existing CDMA downconversion mixer, setting the GPS gain stage so that CDMA and GPS levels to the front-end mixer are comparable.



5. In this CDMA/GPS scheme, the CDMA section mixer and LNA are switched into standby mode while the lower current GPS mixer and LNA are activated.

depending on which of the two current CDMA systems is incorporating GPS. It might appear that adding two blocks is a high price to pay for simply lowering the GPS/CDMA RF path-selector-switch operating frequency. Strict management of battery loading in receive functions (a telephone spends more time listening than transmitting) might lead to a preference for the scheme of Fig. 5. A reason for this is that CDMA mixers and LNAs use high currents to meet the necessary high-linearity requirements. With GPS, the linearity requirement is not as high, particularly if good RF filtering is implemented—there is not a mass of other licensed Txs in the same band. For GPS operation, the CDMA section mixer and LNA can now be switched into standby mode while the lower-current GPS mixer and LNA are activated.

As systems add more user functions, component space becomes critical if one is to maintain small-form factors. Advances in filter technology, such as the semiconductor thin-film bulk acoustic resonator (FBAR) from Agilent Technologies, however, will aid designers to incorporate RF functions such as GPS without the penalty of greatly increasing size. These devices have already been used to manufacture the smallest personal-communications-services (PCS) 1900-MHz duplexer available.[12] The same device technology can be used to manufacture the GPS RF filters shown in Figs. 4 and 5. Since an FBAR duplexer will handle more than 2.5 W, using these devices in a receive-only application will not only offer small size but high reliability.

A particular problem with GPS front-end design is rejecting transmissions from mobile satellite systems (MSS) which operate on frequencies adjacent to those for GPS. The MSS frequencies are designated for specific use by the International Telecommunications Union (ITU) and the FCC. The L1 frequency (1575.42 MHz) used by GPS is within an allocated frequency band of 1559 to 1610 MHz, while MSS is assigned the frequency bands on both sides of this allocation—1525 to 1559 MHz and 1610 to 1660.5 MHz. Difficulties can also be experienced with the Inmarsat satellite communications services, which transmit in the 1626.5-to-1660.5-MHz band. For GPS L1 frequencies, the worst-case frequency separation is only 51 MHz, or 3.2 percent of the GPS filter center frequency.

At a 5-deg. elevation angle, the received right-hand-circularly-polarized (RHCP) GPS signal is –160 dBW with a receive-antenna (linear-polarized dipole) gain of 2.15 dB.[10] Inmarsat standard "C" terminals, used on Marine vessels, radiate +14-dBW RHCP at 5-deg. elevation angles from an omnidirectional antenna. This type of antenna-radiation pattern is used to prevent loss of communications under pitch and roll conditions.[16] For co-located antennas this represents a level difference of 174 dB. A similar problem occurs if a personal-communications-services (PCS) CDMA telephone is required to transmit while receiving GPS. In this case, the frequency separation is approximately 276 MHz and the level difference [PCS (Class III) to GPS] is 160 dB. Even if the PCS transmit is "off," the filtering needs to protect GPS operations from any other nearby PCS users. Many E-911 calls are likely to be made from ports or marinas where Inmarsat terminals could also be operating. Other frequency allocations in different regions are also potential interference sources [e.g., the personal-digital-communications (PDC) transmit band of 1501 to 1513 MHz in Japan].

Filters using FBAR technology can be constructed with additional "placed" poles of attenuation. A GPS FBAR filter with two additional attenuation poles will occupy less than 0.5 × 0.5 mm, including all input/output (I/O) pads. Existing FBAR products use a package with a 1.5-mm height profile. FBAR technology enables the integrated module shown in Fig. 5.

Since FBAR is a semiconductor process, it is expected that price trends will follow a similar downward slope with high-volume production, as seen in other semiconductor devices. This cost reduction will be important to service providers, who supply mobile-telephone handsets to the end user, since a large part of the costs for adding GPS is the recurring cost of GPS parts in the mobile, due to the sheer number of units involved.

Figure 6 shows a frequency plan based on a readily available CDMA SAW IF filter (210.38 MHz) for the PCS 1900-MHz system. By using a local oscillator (LO) set to "high" for GPS when operating with the PCS system, the additional LO frequency range required is trivial, less than 7.5 MHz. Switches SW1 and SW2 are shown in the "GPS" operating position and both switches change over for PCS operation.

For future systems, where the C/A code is available on the GPS L2 channel, one can expect that similar minimum voltage-controlled-oscillator (VCO) range frequency plans will be developed—all aimed at minimizing

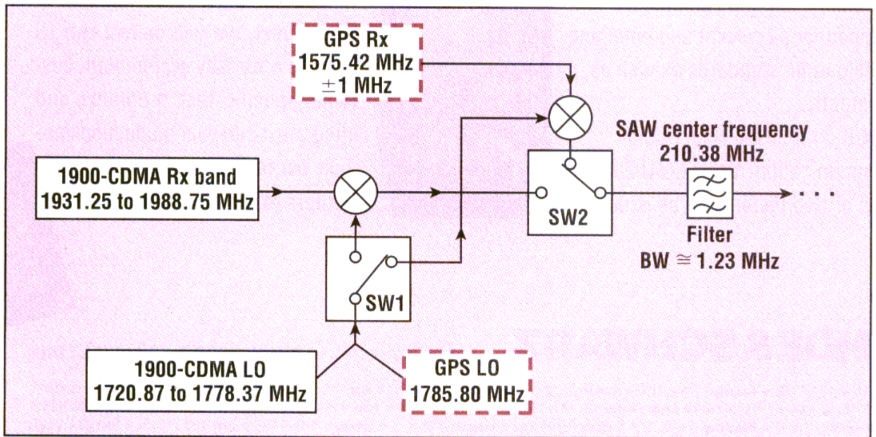
components and cost. Using the CDMA SAW IF filter for GPS operations can provide an additional 40-to-45-dB rejection of Inmarsat signals after the first downconversion.

Providing GPS support and the lowest handset cost means that the service providers must add facilities at the network end. Before SA was turned off, wireless carriers would have been forced to apply differential GPS (DGPS) corrections to guarantee meeting the accuracy demanded by FCC regulations. (See ref. 8 for DGPS concepts and implementation methods.) With SA disabled, the infrastructure and network overhead is no longer required to meet the FCC accuracy requirements. Only those service providers offering the best-accuracy location services will need to implement DGPS differential corrections.

However, due to the large number of base stations involved, GPS E-911 support still represents a huge amount of work and investment for the network operators. To reduce the processing and memory requirements in the handset, there are two well-known methods that have been investigated under US military-funded programs in the early 1980s. One method is to decode the GPS signals and derive pseudo-range and pseudo-delta-range data for the number of satellites required. These data are then transmitted over the air to a central processor where the position and velocity calculations are performed.[13] In this case, the GPS section of the mobile station acts as a pseudorange sensor. This saves a significant amount of random-access memory (RAM) and read-only memory (ROM), and reduces the amount of mobile processing time required. An alternative method is for the mobile unit to receive the GPS signals (all on the same frequency and in the same bandwidth), translate them to the base-station frequency, and retransmit these signals. At the base station, a special GPS Rx tracks all the satellites contained in the translated signal, processes all GPS data, and calculates the mobile unit's position. This type of system has been tested using L1 C/A code for real-time missile tracking.[14]

The translated GPS system is a minimum component solution for the mobile unit, no GPS baseband-processing support is required. However, it does add complexity and, hence, additional costs at the base station.

There is additional overhead that a network base station must absorb. In the case of a "roaming subscriber" (e.g., one who flies into a city and activates the mobile telephone at a location that might be hundreds of miles from the last point used), the Rx memory will contain valid GPS data (satellite-orbit information) for the last-used location but not the current location. In this situation, the GPS Rx will not be able to produce position data rapidly, because it will be searching for satellites visible at the last location rather than those available at the new location. To overcome this problem, new GPS satellite data, for satellites visible from the new cell site, must be downloaded to the Rx memory. This will then greatly improve the time taken to track the necessary satellites. In the case where the tracking sequence is primarily determined in the mobile unit, it would only be necessary to provide a set of satellite numbers for the constellation now in view.



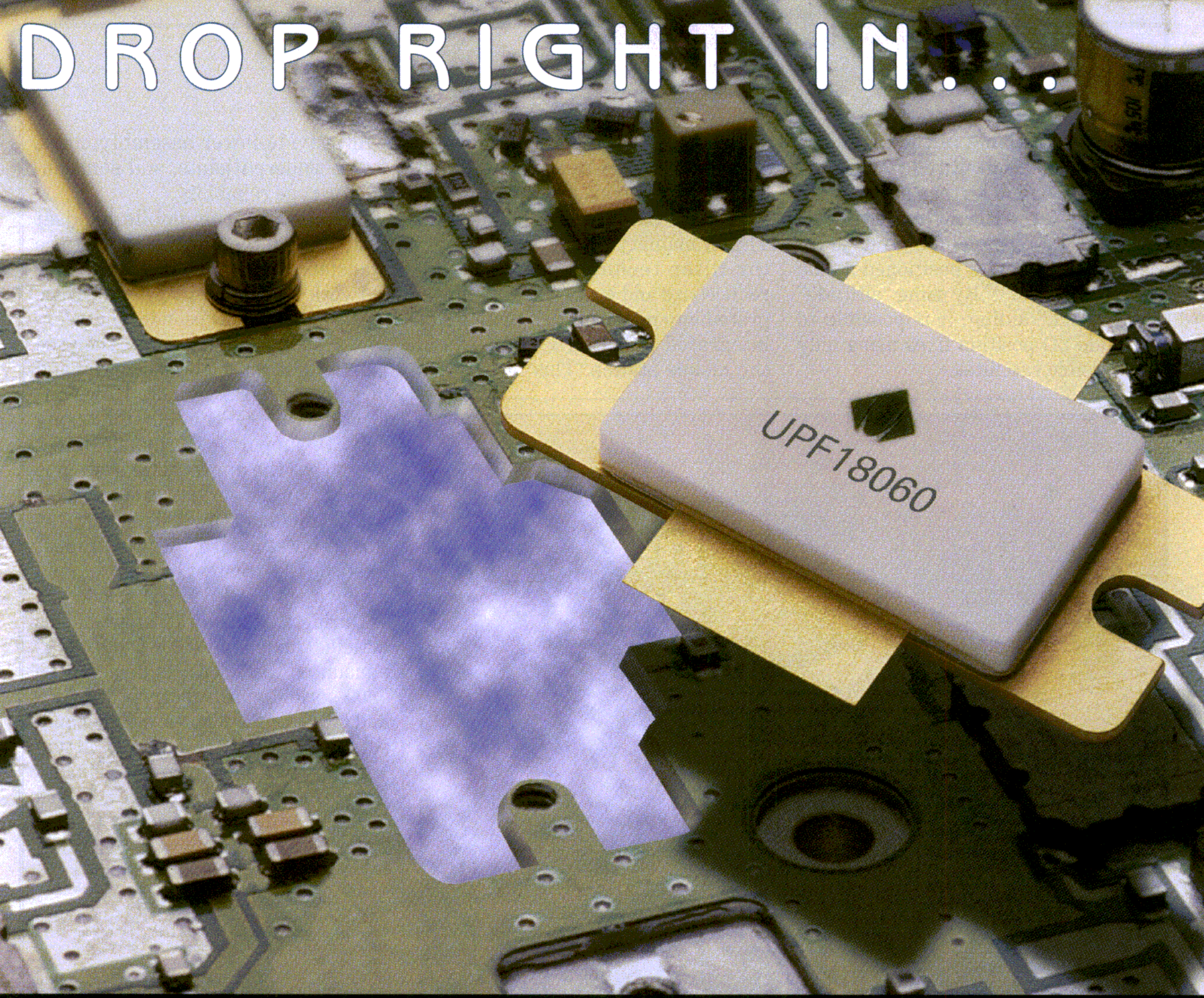
6. A frequency plan based on a readily available CDMA SAW IF filter (210.38 MHz) for the PCS 1900-MHz system is shown here.

The telecommunication CDMA system uses GPS time to synchronize stations, by the use of a GPS Rx at the base station. Dual-channel derivations of ionospheric corrections may also be forwarded to the mobile Rx to further improve accuracy, since ionospheric errors are the largest error source with SA disabled. Where DGPS has been implemented, as part of the network facilities, it will provide local-area corrections for ionospheric and troposphere delays, along with ephemeris (orbit) errors and satellite-clock errors.

Additional forms of aid include clock aiding and two-satellite-aided fixes. A stand-alone GPS Rx needs to track four satellites to produce a 3D position fix and clock correction. This "clock correction" compensates for any offset between the precise GPS atomic clocks and the Rx's low-cost crystal clock. CDMA base stations and mobile units are synchronized by data sent from the base station, which is used to control the CDMA mobile system oscillator, a voltage-controlled crystal oscillator (VCXO). Thus, the system can assume that the Rx clock is "precise" (since it is synchronized to a GPS reference clock) and compute a 3D fix from only three satellites. If this method is used, then the accuracy of position derived from the range measurements will be related to any errors in the clock-aided time.[8]

Under normal usage there will be instances where the GPS antenna does not have a clear field of view (e.g., when obscured by skyscrapers in cities) [often referred to as the "urban canyon"]. In these instances, the tracking of even three satellites may not be possible.

GPS operates with a defined Earth Centered Earth Fixed (ECEF) coordinate system—the World Geodetic Survey of 1984 (WGS-84).[7] If altitude



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data are available in the form of a downloaded mean altitude for the cell sector for example, then altitude can be added to the Earth's radius to provide a range measurement to an imaginary satellite positioned at the earth's center.[8,15] By using "altitude" and "clock" aiding, it is possible to provide 2D position fixes using only two visible satellites.

Adding GPS to a CDMA mobile unit may not necessarily involve high additional component costs or greatly increase the size of the mobile unit. The availability of new semiconductor filter technology will act to reduce size and costs when it is integrated into miniature RF modules or integrated circuits (ICs) for use in the mobile station. This integration will provide lower assembly costs, fewer soldered joints, and semiconductor-type reliability.

To minimize the mobile handset cost, much of the "load" is likely to be transferred to the service-provider network and the networks interface to the PSAPs. If a "pseudorange-sensor" system is implemented, then the mobile unit must support baseband decoding of GPS signals. However, location with GPS is possible using only RF support in the mobile unit—given that the appropriate system is adopted by the service-provider network. Implementing this infrastructure, in a standard form, will most likely be the greatest barrier to rapid deployment of GPS E-911 services.

During the final draft stage of this article, Qualcomm (San Diego, CA) announced the release of devices (the 3300 series) which incorporate GPS and CDMA functions for mobile handsets. Details can be found at http://www.qualcomm.com/cdmate chnologies/. The FCC produced a Forth Memorandum Opinion and Order, FCC 00-326 concerning E-911 rules, released on September 8, 2000. ••

Acknowledgments

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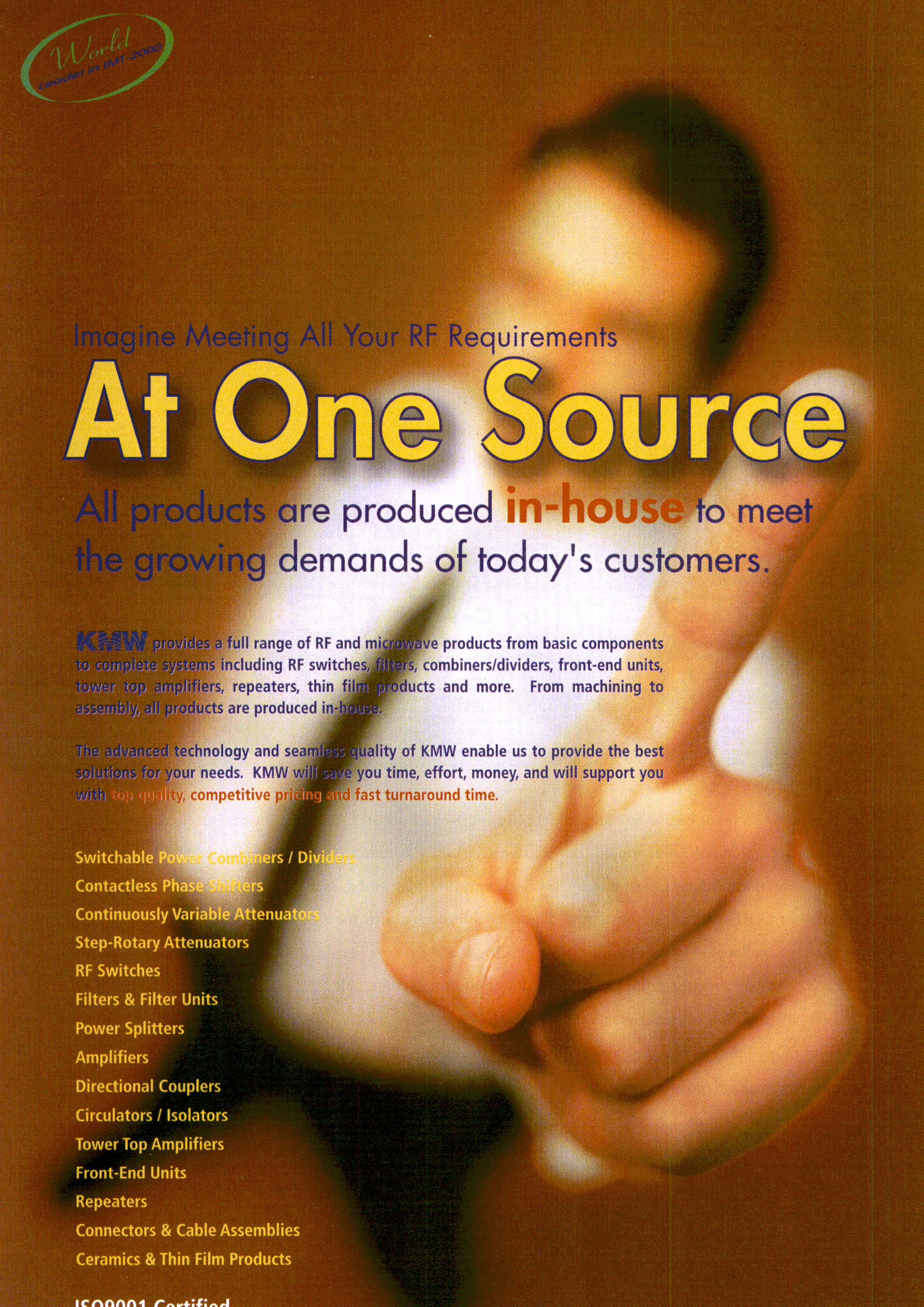
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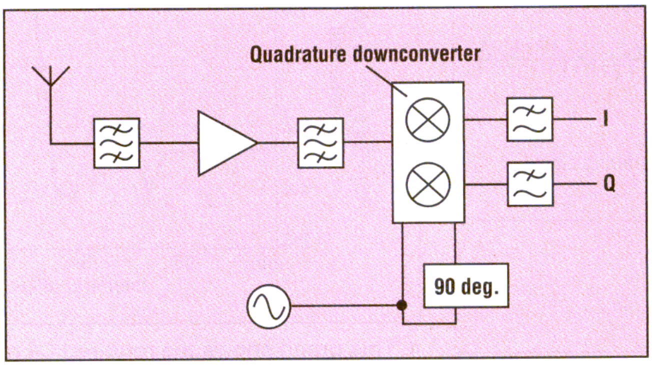
DIRECT-CONVERSION receivers (Rxs) are highly integrated and capable of multiband and multistandard operation. They also have the potential for low power consumption. So it is not surprising that the introduction of direct-conversion Rx chip sets for the Global System for Mobile Communications (GSM) market[1] has sparked an immense interest in the GSM industry. But suppressing the spurious detection of interfering amplitude-modulated (AM) signals is a major problem in direct-conversion Rx design.

In this article, the GSM Rx's air-interface requirements for AM suppression are translated into a second-order intercept point (IIP_2) requirement. The IIP_2 is directly usable for RF design and can be measured with familiar two-tone tests.

Figure 1 shows a simplified block diagram of a single-band, direct-conversion Rx. In this Rx, the incoming signal is downconverted directly from RF to baseband without any intermediate-frequency (IF) stages. But the level of the baseband signal at the output of the quadrature (Q) downconverter is low. To maintain an acceptable carrier-to-interference ratio (C/I), all spurious baseband signals generated in the Q downconverter must also be small.



1. This is a simplified block diagram of a single-band direct-conversion Rx.

Spurious baseband signals originate mainly from second-order distortion. Consider a general modulated signal described by its time-varying envelope $a(t)$ and its instantaneous phase $\Theta(t)$:

$$x(t) = a(t)\cos[2\pi f_c t + \theta(t)] \quad (1)$$

This signal is input to a system with second-order distortion. This system has:

$$y(t) = x^2(t) \quad (2)$$

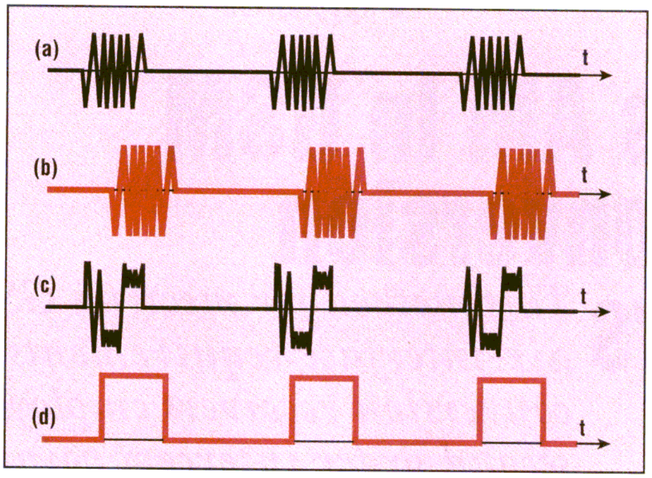
The output signals are:

$$y(t) = x^2(t) = \frac{1}{2}a^2(t) + \frac{1}{2}a^2(t)\cos[4\pi f_c t + 2\theta(t)] \quad (3)$$

The output of this system is the sum of a high-frequency component, which is removed by filtering, and a baseband signal, which is the square of the signal envelope. Due to the similarity of this process to AM detection, this spurious baseband signal is here referred to as the AM-detected signal.

The GSM standard[2] incorporates two tests that challenge the second-order distortion rejection of the Rx. The first test is the blocking test, whose main parameters are listed in Table 1.

In the blocking test, a strong continuous-wave (CW) signal is applied to the Rx. Since this signal has a constant envelope, the AM detector converts it to DC. This DC is cancelled by the DC-offset-removal circuitry, which is present in all direct-conversion Rxs. Even if the signal's amplitude is high, it is cancelled and does not degrade the Rx's bit-error rate (BER).



2. This time-domain plot of signals in the GSM AM suppression test shows: (a) the desired signal, (b) the interferer, (c) the downconverted in-phase signal, and (d) the AM-detected signal that is caused by second-order distortion.

The AM-suppression test is the more difficult test to pass. Table 2 lists the main parameters of this test.

In the AM-suppression test, a strong modulated interferer together with a small desired signal is presented to the Rx. The interferer is active in the same time slot as the desired signal, but delayed by approximately half a burst period. Since the Gaussian minimum-shift-keying (GMSK) modulation used in GSM has a constant envelope, the AM-detected signal alternates between two states. It is zero when the interferer is off and it rises to some other value when the interferer is on. Figure 2 shows the time-domain waveforms for this test. The AM-detected signal appears as a square wave.

In the AM-suppression test, the desired signal is 3 dB higher than the reference sensitivity level. Thus, the Rx is able to withstand some amount of AM detection before the BER requirements are compromised. In the following discussion, the ratio of the power of the desired baseband signal to the power of the undesired interfering baseband signal is denoted C/I. The required value of C/I, $(C/I)_{req}$, is the minimum value of C/I required to ensure an acceptable BER and frame erasure rate (FER). This number must be known before the IIP_2 requirements can be calculated.

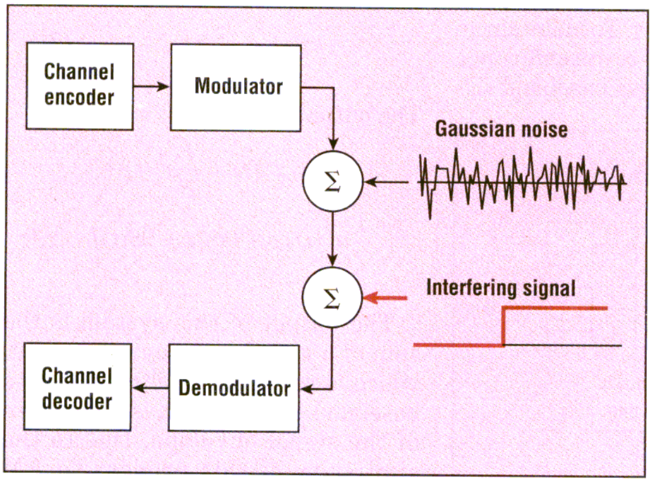
LINK SIMULATOR

The required $(C/I)_{req}$ is most accurately extracted from link simulations. This can be performed quite conveniently, since the complex baseband representation of the interfering signal is only a step signal delayed with respect to the start of the desired burst.

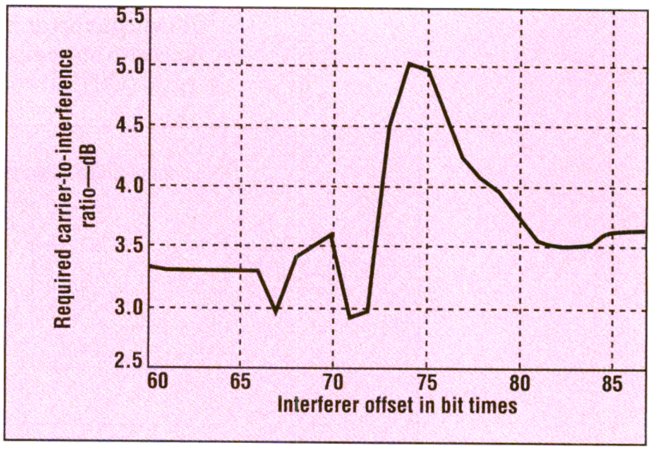
In this discussion, a proprietary C-coded GSM link simulator is used to perform the link simulations (Fig. 3). Some assumptions have been made. The Rx's noise figure is assumed to be 10 dB, which is rather high for today's equipment. Implementing a better Rx noise figure would improve the production margin. The channel-filter bandwidth is 200 kHz. The AM-detected signal is distributed equally between the in-phase (I) and Q-phase branches, but this does not seem to matter much. The calculation of $(C/I)_{req}$ demands a BER that is lower than 2.0 percent and an FER of lower than 0.1 percent. This is for a near-optimum Viterbi data demodulator. A total of three million bursts were processed to yield an accurate FER.

Figure 4 shows the results of the simulations. At a time offset of 74 bit times, there is a peak for which $(C/I)_{req}$ is 5 dB. At this time offset, the interferer starts in the middle of the midamble of the desired burst.

Simple graphical analysis yields the following expression for the required Rx IIP_2:



3. This is a block diagram of the simulator.



4. This graph shows the required C/I ratio, $(C/I)_{req}$, versus time offset in bit times.

$$IIP_2 = (C/I)_{req} - (P_{desired}) + 2 \times (P_{interferer}) = 5\ dBm + (-99) dBm + 2 \times (-29\ dBm) = 46\ dBm \quad (4)$$

There are two principal sources of second-order distortion:

- Device nonlinearity.
- RF-to-local-oscillator (LO) leakage in the downconverters.

An example of device nonlinearity is the quadratic response of a field-effect transistor (FET). Device nonlinearity is most effectively mitigated through careful balancing of the circuit. Chip-set designers must pay close attention to device matching[3] and maintain high levels of common-mode rejection.[4]

RF-to-LO leakage in the downconverters refers to the fact that if a signal leaks from the RF to the LO port of the downconverters, it multiplies with itself inside the downconverters. This creates some second-order distortion that cannot be separated from the distortion caused by device nonlinearity.

An approximate relationship among RF-to-LO isolation, LO power, and IIP_2 is:

$$IIP_2 = Isolation + P_{LO} \quad (5)$$

This equation shows that the RF circuit-board designer must pay careful attention to the RF-to-LO isolation of the board. Also, the LO power should be reasonably high. This is also important for another reason: hard switching of the mixer core helps prevent second-order distortion generated in the mixer input stage from reaching the output.

Recent research[5] indicates that the RF-to-LO isolation of the Rx chip itself can be very high. The obtainable isolation is probably limited by the packaging technology.

Table 1: Blocking test

Desired signal power	–99 dBm
Interfering signal power	–23 dBm
Interferer frequency offset	3 MHz
Interferer modulation	CW

Table 2: AM suppression test

Desired signal power	–99 dBm
Interfering signal power	–29 dBm
Interferer frequency offset	6 MHz
Interferer modulation	GMSK
Interferer time offset	6- to 86-b periods

BASEBAND SOLUTIONS

All direct-conversion chip sets must be able to cope with large DC offsets, since a large gain is obtained at baseband. Therefore, they invariably incorporate some sort of dynamic DC-offset compensation. The details can vary, but the effect of dynamic DC-offset compensation is highpass filtering of the received data. A fast offset compensation implies a high cut-off frequency of the highpass filter. This may compromise performance due to phase and amplitude distortion of the desired signal.

In general, DC-offset compensation is most effective against the AM detection of interferers that have a constant envelope during the duration of the burst. Its protection against non-constant-envelope interference is more limited, and it is possible to imagine scenarios where the DC-offset compensation scheme does more harm than good. DC-offset compensation is really not a substitute for a good IIP_2.

A direct-conversion Rx for GSM must comply with the AM suppression test. The best way to do this is to ensure that the Rx has an IIP_2 of at least +46 dBm. ••

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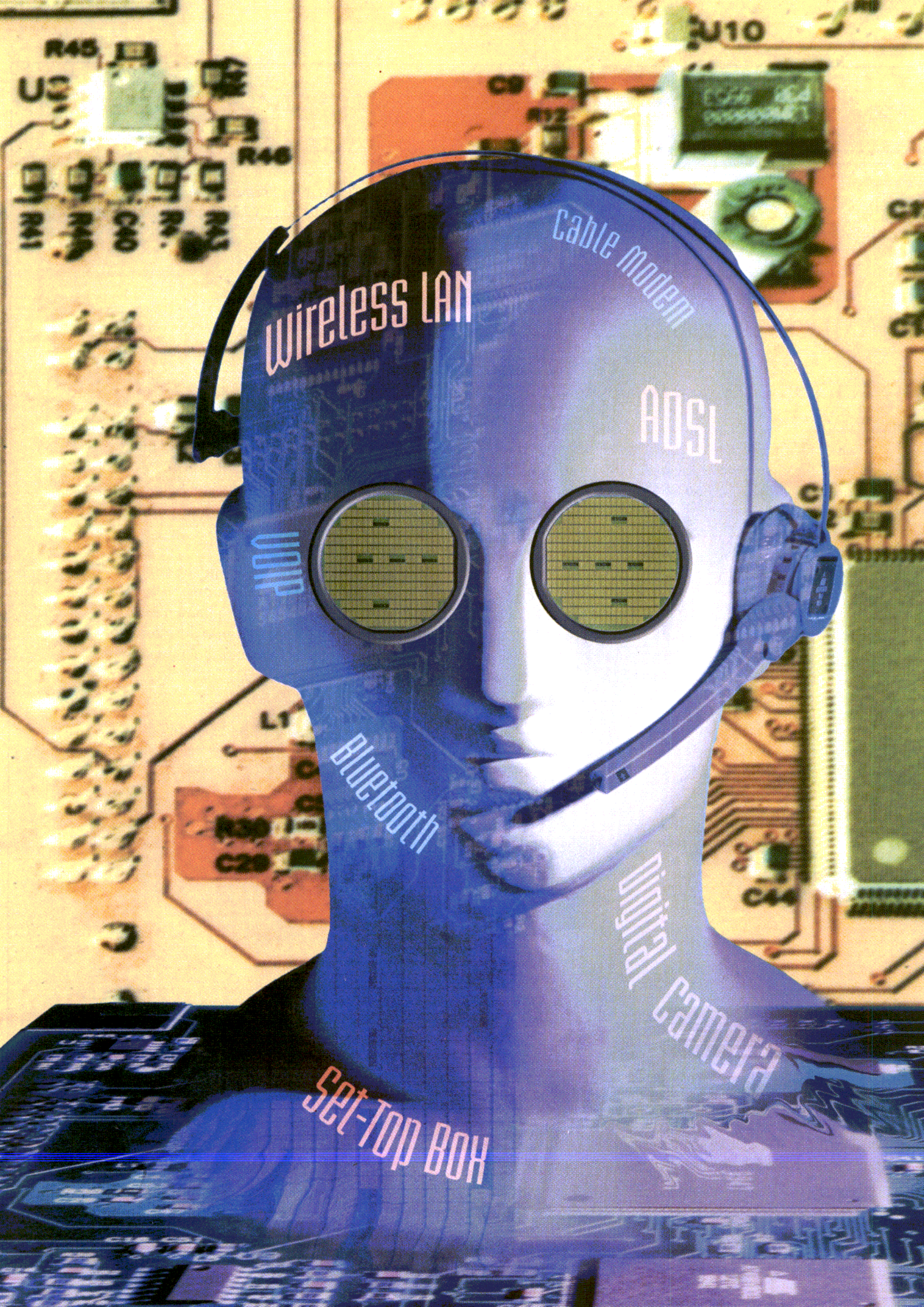
4. Soren Laursen, "Second Order Distortion in CMOS Direct Conversion Receivers for GSM," *Proceedings of the 25th European Solid-State Circuits Conference*, 1999, pp. 342-345.
5. Soren Laursen, "Analysis of Mixer Port Crosstalk Using Microwave Matching Measurements," *Proceedings of the 18th NORCHIP Conference*, Turku, Finland, November 2000, pp. 268-273.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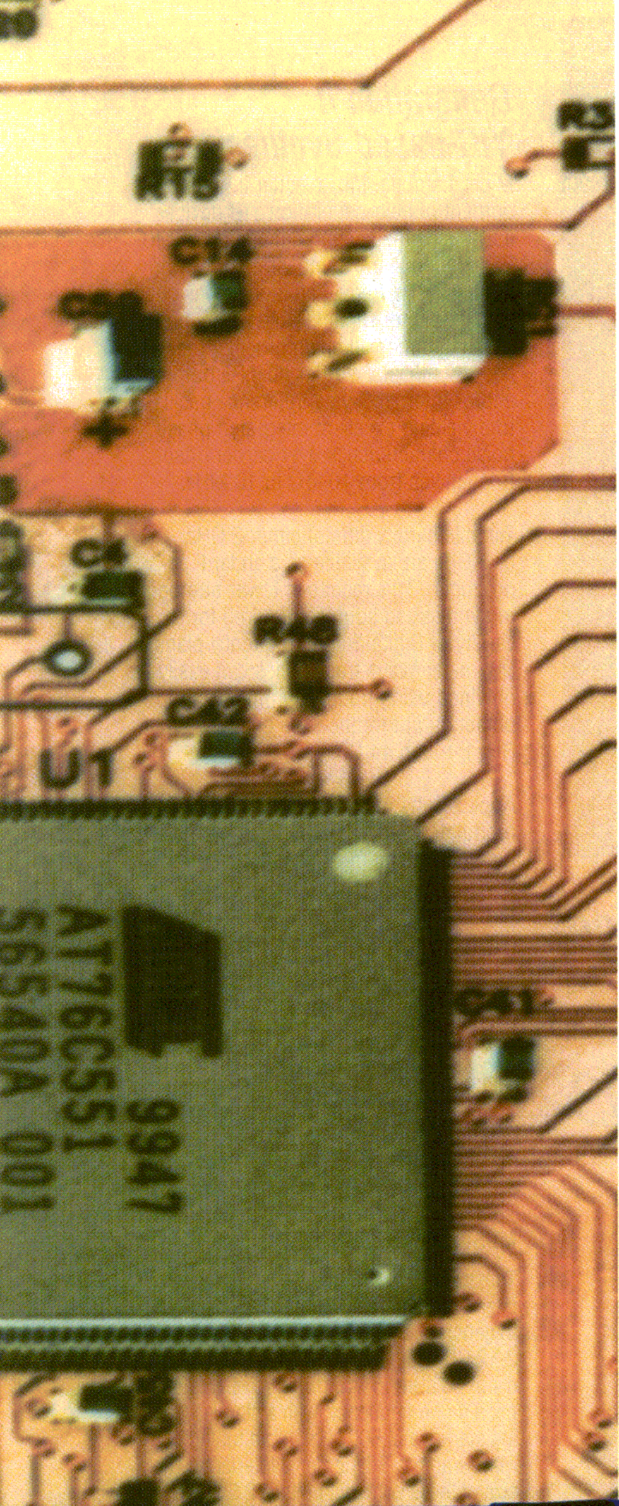

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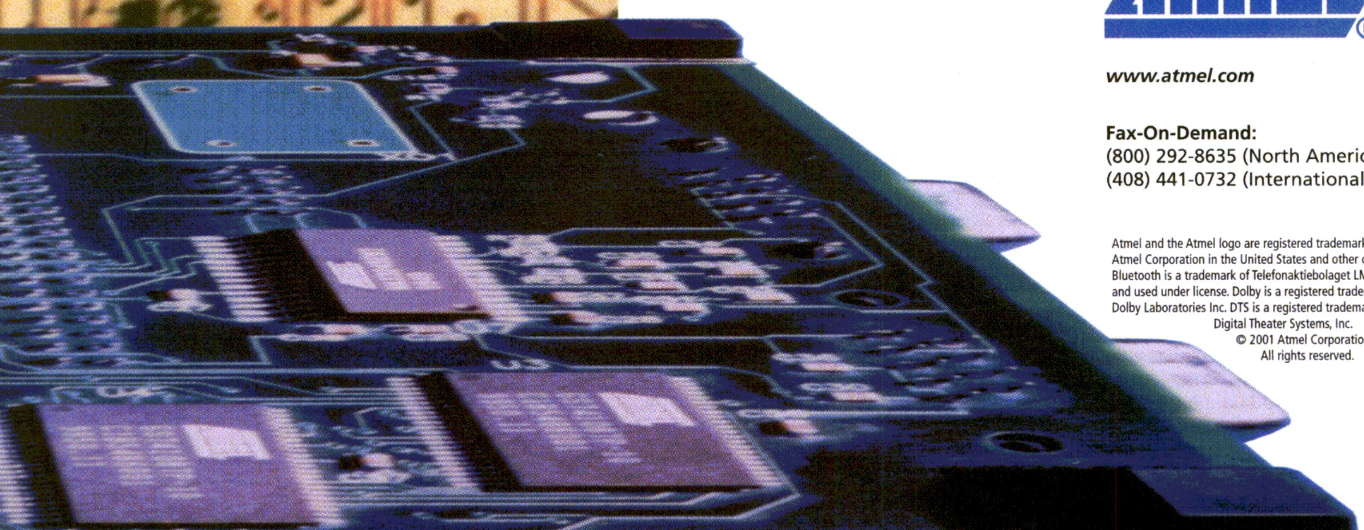

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Probe On-Wafer Diodes

This novel approach uses horizontal coplanar-waveguide probes to minimize parasitics and maintain accurate RF measurements.

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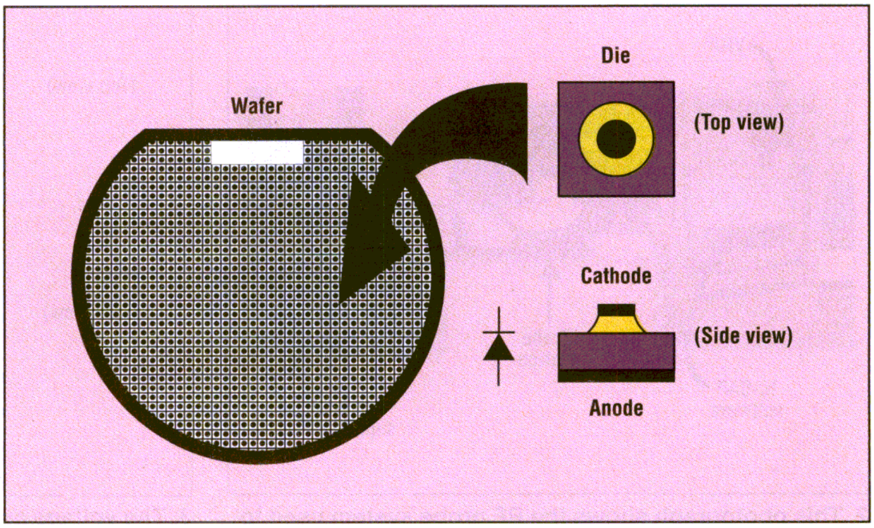
IC processing of nonplanar discrete diodes, such as Schottky and PIN diodes, places the cathode on the top and the anode on the bottom of the wafer (Fig. 1). But in traditional on-wafer RF probing, the probes contact either the top or the bottom surface—not both. This poses a physical problem for performing RF measurements on these devices. A common solution to this problem is mounting a single die to a connectorized test fixture. But test fixtures are more susceptible to parasitics than on-wafer test methods, and these parasitics can cloud the test results.

This article describes a technique for measuring the RF characteristics of nonplanar diodes using horizontal coplanar-waveguide (CPW) RF probes. This method retains all of the advantages of conventional RF on-wafer characterization while providing faster design-turnaround time and better model accuracy than the test-fixture approach. The success of the method described here depends on three important techniques: ground isolation, calibration, and de-embedding.

SYSTEM DESCRIPTION

The new test system centers on an Electroglas probe station, shown in Fig. 2. Figure 3 shows the CPW probe making contact with two diode dice. These diodes are side by side on the wafer surface, aligning with the probe pitch. The ground probe contacts one diode and the signal probe



1. This figure shows a typical diode wafer and the vertical nature of the die.

contacts the diode under test. The signal and ground probes are DC-isolated from lab ground. The RF path contains two connectorized DC-blocking capacitors. One blocks DC from the vector-network-analyzer (VNA) signal path and the other blocks DC from the VNA ground path. This arrangement permits independent biasing of the signal and ground probes.

The voltage on the signal probe is designated as V_s, and the voltage on the ground probe is designated V_g (Fig. 3). Both power supplies connect to a bias tee mounted inline between the blocking capacitors and the diode under test. A third bias, V_{ch}, is supplied to the chuck. Applying a chuck potential keeps leakage current from flowing to the wafer's backside. The chuck itself is DC- and AC-isolated from the lab ground. Force and sense lines run to opposite sides of the chuck. HP 4142B programmable power supplies provide the three biases. Plugging equipment into isolation transformers rather than the wall outlet further isolates them from all grounds. The general-purpose interface bus (GPIB) connects to each instrument through opto-isolators. (Without the opto-isolators, ground sneaks in through the GPIB.) The net result of these connections is full DC ground isolation to the diode under test. The AC ground arrives to the diode under test through a single path: the RF cable shield.

Calibration de-embeds the blocking capacitors, the bias tee, and other system effects. An alumina substrate contains precision impedance standards for on-wafer calibration. Schottky diodes require low-capacitance testing, but parasitic capacitance that is associated with the gold (Au) contact pads can swamp the diode's junction capacitance. To quantify the parasitic capacitance, one can fabricate a dummy wafer with the same pitch and pads as the diode-under-test wafer. This dummy wafer contains contact pads and no active devices underneath. Measuring it reveals the pad capacitance and any residual chuck capacitance. Isolating ground from the system lowers the parasitic capacitance of the system.

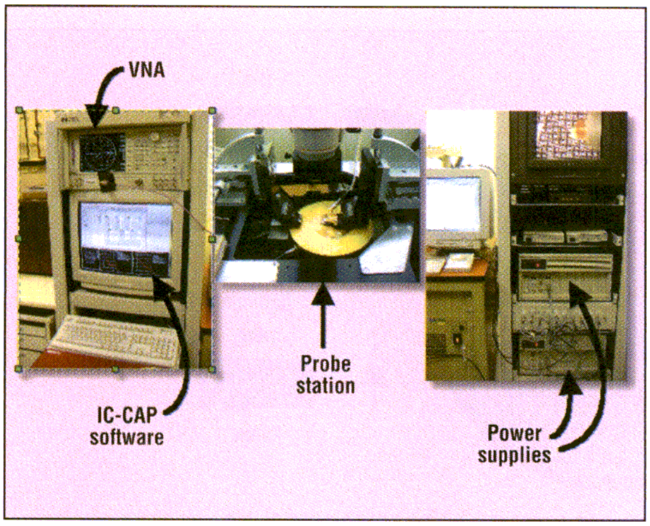
A TECHNIQUE FOR MEASURING THE RF CHARACTERISTICS OF NONPLANAR DIODES USING HORIZONTAL COPLANAR-WAVEGUIDE (CPW) RF PROBES IS DESCRIBED. THE SUCCESS OF THE METHOD DEPENDS ON GROUND ISOLATION, CALIBRATION, AND DE-EMBEDDING.

De-embedding the ground diode from the measurement should yield the diode under test. One can assume that adjacent diodes are similar. Biasing them identically should yield two diodes with nearly the same characteristics. Another way to de-embed the ground diode is to fully forward-bias it. This creates a small resistance from the ground probe to the backside of the wafer. De-embedding the S-parameters shifts the reference plane from the ground probe to the back of the wafer. Since the two diodes are biased independently, locating a problem with either diode becomes simpler. A virtual ground to the wafer backside, along with ground isolation, enables RF probing of nonplanar devices.

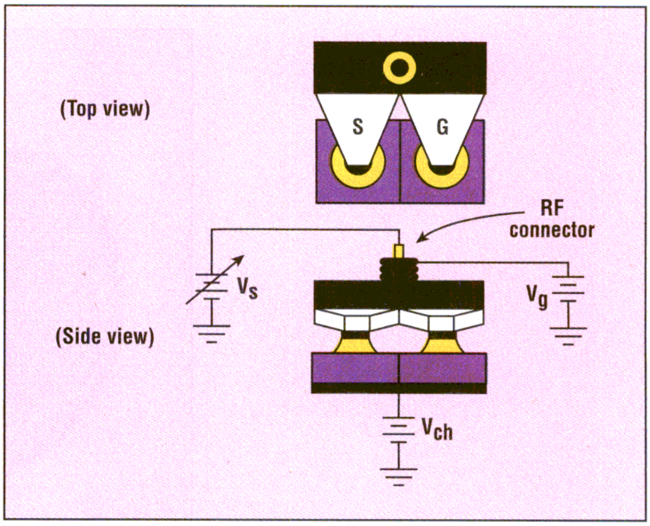
MEASURED RESULTS

Two diode figures of merit are carrier lifetime τ and series resistance R_s. High-volume production requires these characteristics to be automatically tested on each wafer. Assembling an RF on-wafer test system to the specifications mentioned met this need. Use Caverly's method[1,2] to calculate τ and R_s with S-parameters. A software routine written in IC-CAP, Agilent's device-characterization program, enables quick calculation of τ and R_s.

Calibrating the DC path is



2. This photograph shows the RF probe system used to test PIN and Schottky diodes on-wafer.



3. The voltage assignments for biasing through the coplanar probes are shown above.

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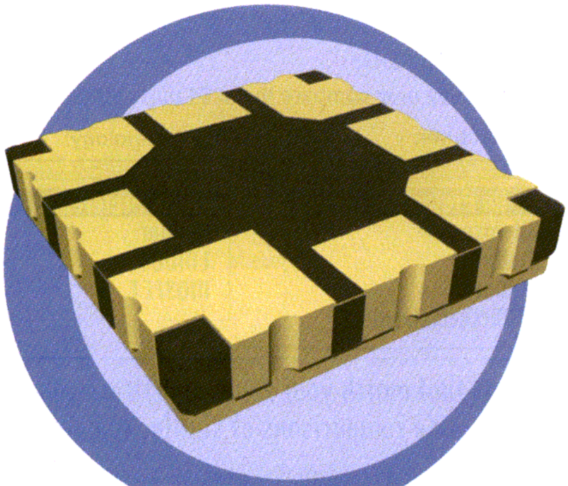

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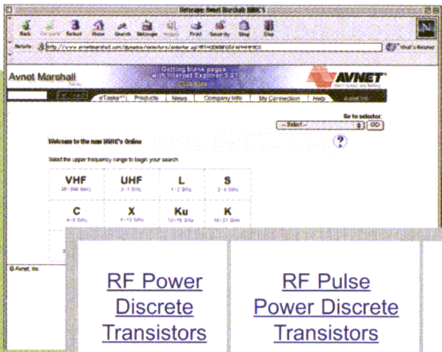

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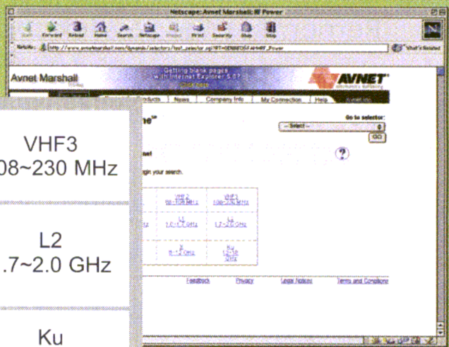

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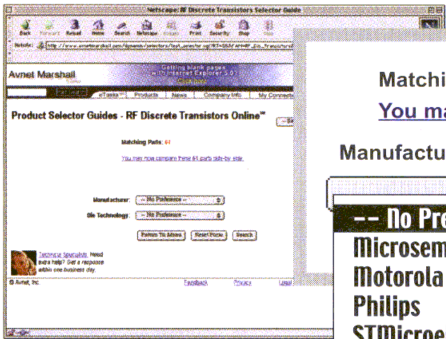

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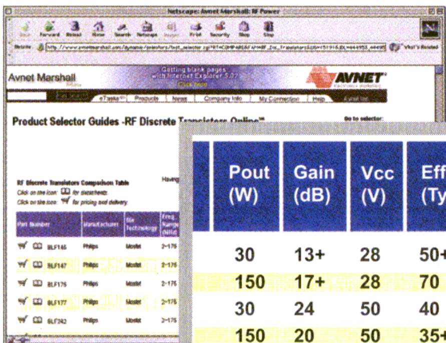

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150	17+	28	70	0.8	28/108	-	AB/B	Comm Source	SOT121	SSB/FM
30	24	50	40	2.6	28/108	-	A/AB/B	Comm Source	SOT123	SSB/FM
150	20	50	35+	0.8	28/108	-	AB/B	Comm Source	SOT121	SSB/FM
5	16	28	60	11	175	-	A/B	Comm Source	SOT123	FM Broadcast

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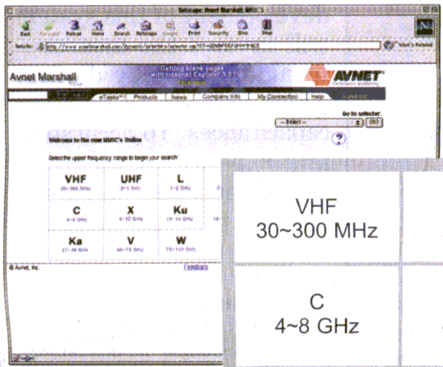

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C 4~8 GHz	X 8~12 GHz	Ku 12~18 GHz	K 18~27 GHz
Ka 27~40 GHz	V 40~75 GHz	W 75~110 GHz	

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Matching Parts: 6

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- 9.1~17.9

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- 70milstrip
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- 85milstrip
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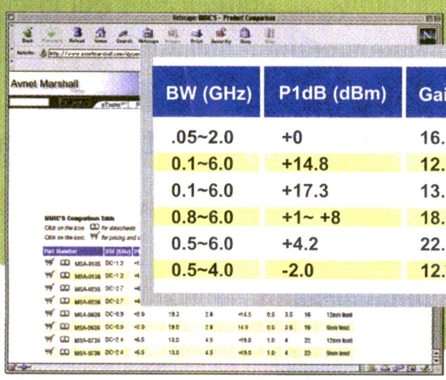
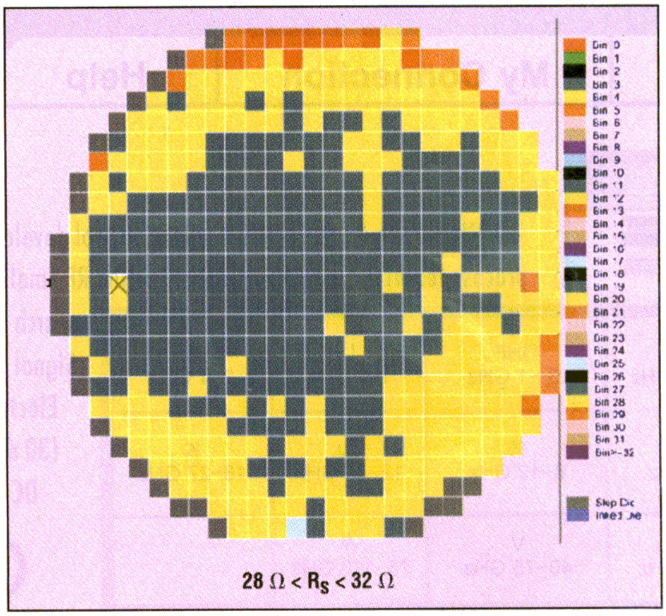


BW (GHz)	P1dB (dBm)	Gain (dB)typ	NF (dB)typ	IP3 (dBm)	@ GH	Vd (V)	Id (mA)	Comments
.05~2.0	+0	16.0	2.0	+15.0	0.9	3	1~10	Var Gain
0.1~6.0	+14.8	12.3	2.7	+27.0	2.0	3	42	-
0.1~6.0	+17.3	13.5	2.2	+31.0	2.0	3	84	-
0.8~6.0	+1~ +8	18.5	1.9	+12~ +17	2.0	3	15~50	Var Gain
0.5~6.0	+4.2	22.5	1.6	+15.0	2.4	5	14	-
0.5~4.0	-2.0	12.5	1.6	+8.0	2.4	3	4.5	-

Additionally, the tool also provides access to formal datasheets, online technical support as well as pricing and availability information from Avnet straightforward. Measuring a precision resistor with the CPW probes determines the cable voltage drop. Precision resistors and other standards are found on Cascade Microtech's impedance-standard substrate (ISS). It can also be used to calibrate the RF path. This sets the reference plane at the coplanar probes. The next step is to move the ground-reference plane to the back of the wafer. Fully biasing both diodes results in a small resistance and reactance between the signal and ground probes. Model the diode under test as two identical diodes connected anode to anode. Half the behavior approximately equals one diode. De-embedding half from the total measurement provides the diode under test. With the ground diode at a fixed bias point, the diode under test can be characterized at any bias. Figure 4 shows high-frequency wafer maps of R_s. These values fell to within 15 percent of those measured using conventional time-domain techniques.[3]



4. This is a map of the wafer containing the PIN diodes.

The next phase in the development of this system will involve the measurement of Schottky diodes, which have small junction capacitances. To accurately and repeatably measure them, one must de-embed the system capacitance down to the fempto-Farad level. ••

Acknowledgements

The authors thank Domingo Figueredo, Steve Randle, Alan Rixon, and Ray Waugh of Agilent Technologies' Wireless Semiconductor Division, Newark, CA for their unwavering support.

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Waveguide Irregularities Impair VNA Millimeter-Wave Measurements

Mechanical imperfections of millimeter-wave waveguides prevent reliable vector-network-analyzer calibration and measurement above 90 GHz.

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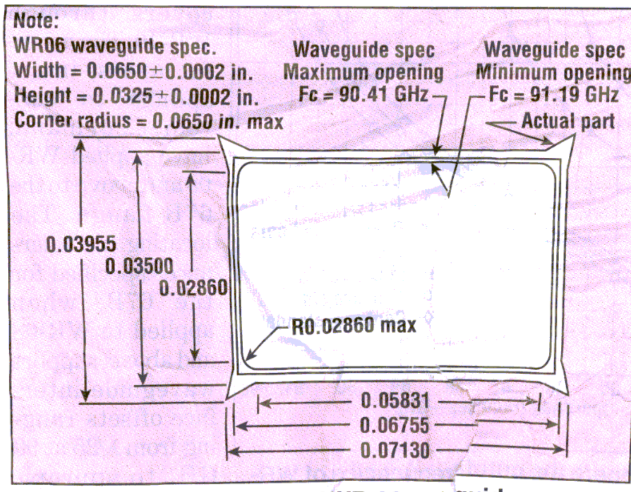
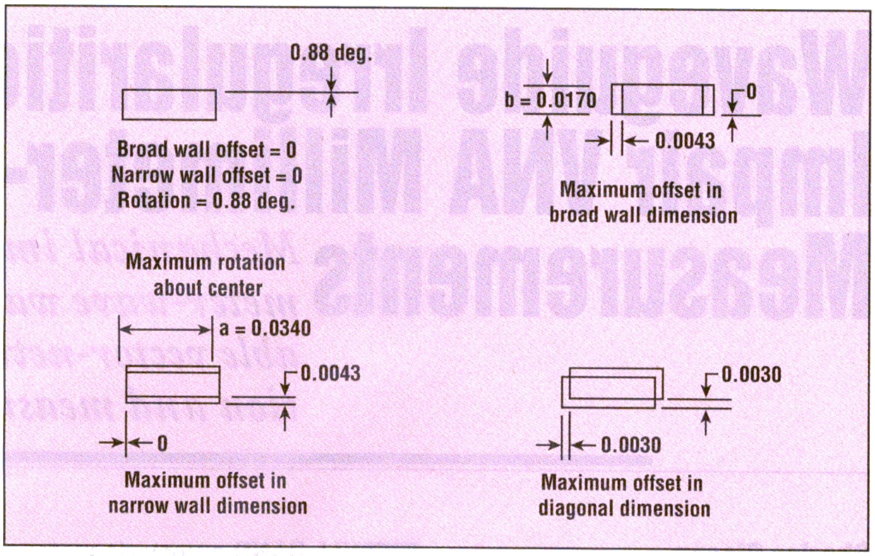
FULL-BAND automatic vector network analysis is currently available up to 220 GHz and will, in the near future, go up to 325 GHz. To perform these high-frequency measurements however, special VNA calibration kits for the waveguide bands WR-08 through WR-03 (90 to 325 GHz) are required. Waveguide and waveguide-flange performance is very important because the tendency of waveguide at these frequencies is to be oversize, causing the incorrect entry of the waveguide's cutoff frequency during VNA calibration.

A lack of repeatability—or instability—of VNA calibrations above 90 GHz led to the investigation of not only calibration kits, but military specifications that define the size, flange alignment, tolerances, forward reflection, and other characteristics of these waveguides (MIL-F-3922/67B-xxx and MIL-W-85/3-xxx). In addition to oversize waveguides, significant waveguide misalignment is possible under current military-specification tolerances, and there is no widely accepted technique for precise alignment. Moreover, common waveguide irregularities occur due to inadequately developed manufacturing and assembly processes, and these are so small that they can be detected only with microscopic examination.

The state of the art in waveguide manufacturing is limited by the tolerances attainable during the process of drawing waveguide and cost-effective geometric techniques for identifying the "true center" of the waveguide to locate the flange-hole pattern and associated locator pins. Much work remains in advanced manufacturing methods for waveguide and flanged components.



1. A dimensional drawing of WR-06 wavguide illustrates the manufacturing defect caled "dog ears" at each corner of the guide.

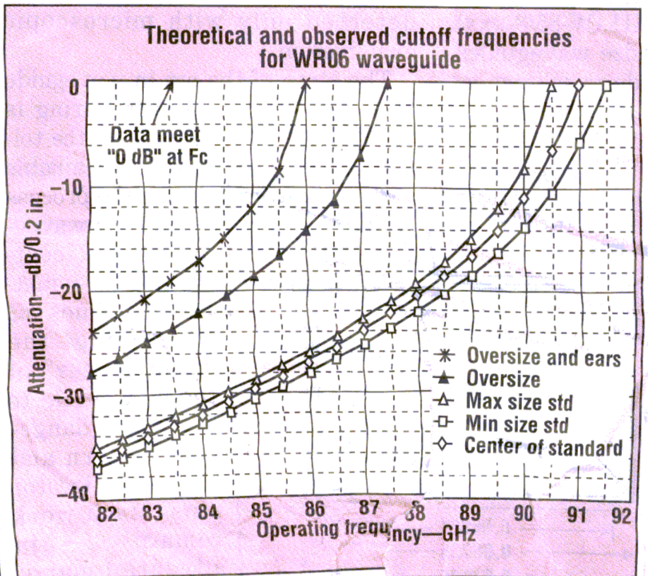


3. The maximum offset from true alignment for a WR-03 standard waveguide flange is shown here for different misalignments: broad wall, narrow wall, diagonal, and rotated.

Today's problem is that practitioners of high millimeter-wave technology have significant inventories of WR-08 and higher-frequency waveguide components that do not meet any reliable specification. Much of the 90-GHz and above waveguide currently in laboratories is left over from previous programs. It is likely that these components have not been mechanically or electrically characterized. New waveguide is similarly suspect. The published specifications for WR-08 and above under MIL-W-85/3-xxx are not being adhered to. For WR-06 and above raw waveguide, only one vendor exists and that company does not guarantee that its product will meet the military specification. In general, there are two manufacturing problems. First, waveguide in the aforementioned bands is usually oversize, more significantly as the frequency increases. Second, a deviation from the specification known as "dog ears" in the waveguide corners violates the corner-radius specification. This article will show the impact of the latter through analysis and test data.

THE FLANGE PROBLEM

The waveguide flange presents a distinct set of problems. The only agency specification covering waveguide flanges for WR-08 and above is MIL-F-3922/74-00x (74), commonly known as the "mini-flange." The 74 flange is reasonably accurate for use in WR-08 and WR-06, but lacks accuracy when applied to WR-05 and above. Many manufacturers sell a commonly available MIL-L-3922-67B-(67B) flange that is adapted to WR-08 and above, but there are no "agency" specifications covering such an adaptation of this flange. The 67B specification only covers through WR-10. The manufacturers, in response to customer demand, have applied WR-08 and above to the 67B flange. The locating pin tolerances specified for the 67B, when applied to WR-08 and above, support waveguide-interface offsets ranging from λ/25 at 90 GHz to approximately λ/8 at 325 GHz. This problem is not generally understood and waveguide vendors indicate that the 67B flange has outsold the 74 flange by up to 10:1 over the last five years.



2. These curves compare the cutoff frequencies of WR-06 under various mechanical conditions such as oversize, oversize with dog ears, and a guide that is within specification.

One reason for the popularity of the 67B flange is that it is much easier to accomplish an interface for it in a "block"-type component (i.e., mixers, multipliers, phase shifters, etc.). Four manufacturers of waveguide VNA calibration kits have addressed the 67B-flange locator pin-tolerance issue by tightening up the locator pin tolerances and adding two additional alignment pins that have even tighter tolerances. The use of these additional alignment pins is optional, allowing these "precision" 67B flanges to interface with standard 67B flanges.

The "finish" of the waveguide flange is also a potential problem. The flange face is normally "lapped" to achieve flatness and finish quality. Cases were observed where the leading edges of the waveguide aperture in the flange face have become eroded. This is caused by the lapping media welling up into the waveguide opening as the flange is lapped. The action of this excess media is to wear down the leading edges, causing them to be round. This rounding of the waveguide aperture leading edge appears to have little impact on waveguide interfaces at WR-10 and below. The impact

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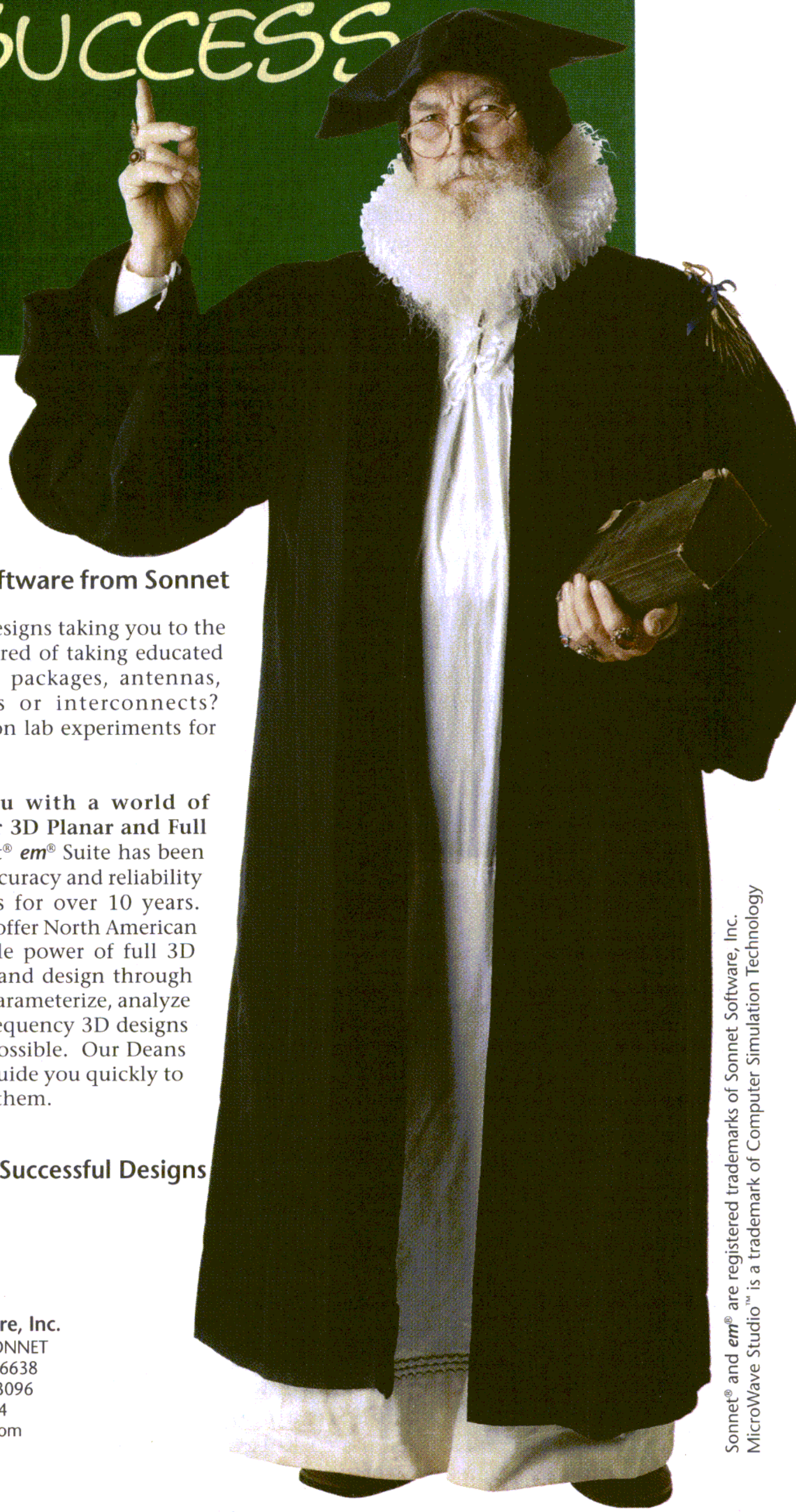

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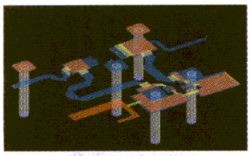

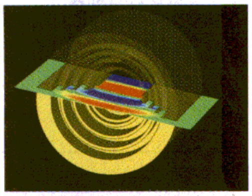

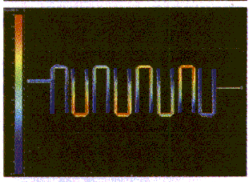

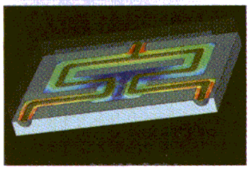

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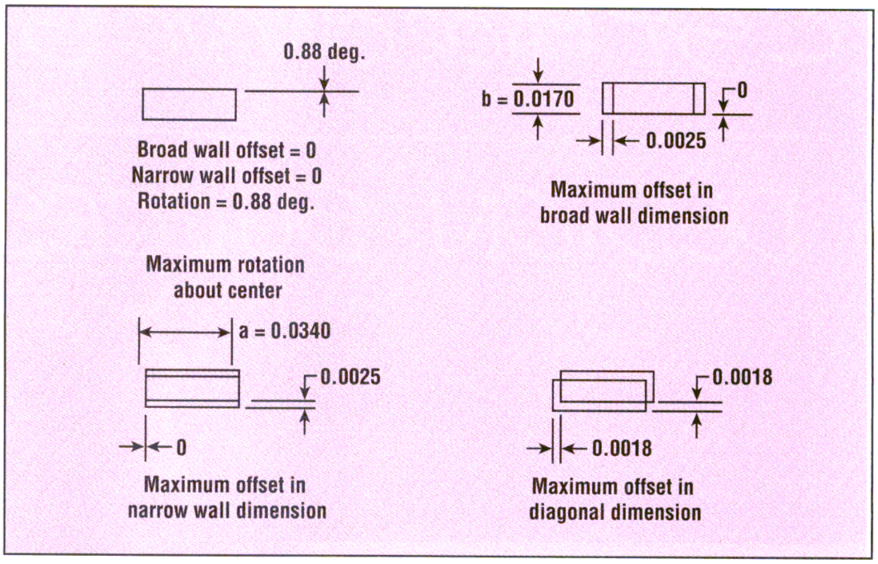
of these rounded edges on waveguide interfaces WR-08 and above was analyzed and tested.

"DOG EARS"

During the development of waveguide calibration kits for WR-08 and above, the impact of the waveguide's dimensional accuracy versus its cutoff frequency was encountered. More than 50 samples of waveguide covering WR-08 through WR-03 were examined using a toolmaker's microscope with an accuracy of 0.0001 in. (0.000254 cm) and a VNA system with WR-15, WR-10, WR-08, and WR-05 capabilities. A definite pattern of waveguide being increasingly oversize as frequency increased was discovered. To help define the source of this pattern, the potential differences that are possible in the waveguide cutoff frequency as permitted by the MIL-W-85/3 waveguide specifications were calculated.

Waveguide for these frequencies is manufactured by drawing round tube into shape around a rectangular mandrel. Removal of the mandrel from the waveguide is difficult due to the small components involved. Some additional clearance is allowed by the manufacturer to expedite this removal process. Additionally, the thin wall of the waveguide can easily overreact to the formulation. The placement of the drawing rollers allows "ears" to be formed that project outward from the corners of the waveguide. These are commonly referred to as "dog ears." The work tolerances applied to, and elasticity of the waveguide material, yield the oversize dimension and deformation observed (Fig. 1). This illustrates the dimensional property observed in a randomly selected sample of new WR-06.

Figure 1 shows the maximum and minimum dimensions specified for WR-06 waveguide. The measured oversize dimensions and "dog ears" are illustrated. The performance of this section of waveguide was simulated using the Ansoft High Frequency Structure Simulator (HFSS) software and plotted versus the performance of a waveguide in "specification" and one which was oversize without the "dog ears" (Fig. 2).



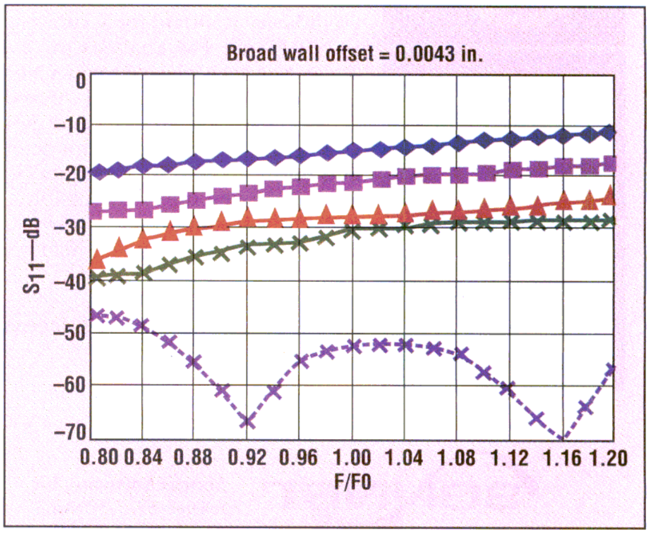
4. The maximum offsets shown here are for the same misalignments in Fig. 3, but the WR-03 flange is a precision rather than standard part.

The calculations presented are based on a theoretical lossless waveguide that is 0.20 in. (0.51 cm) long. The military-specified tolerances support a difference of ±0.5 GHz in cutoff frequency. The oversize characteristic resulted in a calculated 3.5-GHz lower cutoff frequency. When adding the effects of the "dog ears" to the oversize waveguide, the simulation shows a 5-GHz lower cutoff-frequency characteristic.

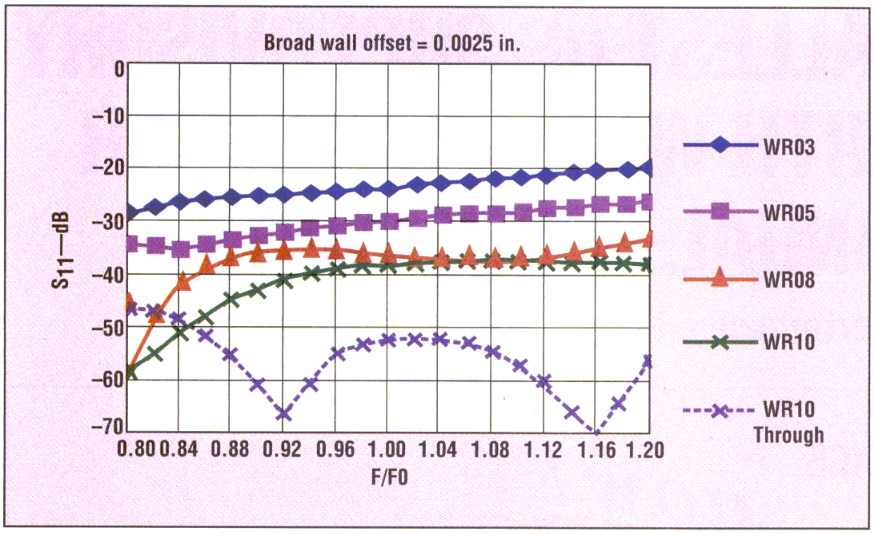
Machining of waveguide, using split-block techniques, and the electroforming of waveguide are inherently more accurate in all dimensional parameters for the bands above 90 GHz. Waveguide components manufactured with these two processes are the basis of all of the "precision" calibration kits available in the marketplace. The three major disadvantages affecting components manufactured with these processes are cost, inability to easily support convoluted shapes, and the limited length that can be achieved for longer section of waveguide—6 to 8 in. (15.24 to 20.32 cm) maximum for split-block machining and 1 to 2 in. (2.54 to 5.08 cm.) for electroforming.

PIN TOLERANCES

The alignment of waveguide sections depends on the proper positioning of the flange-alignment pins,



5. Design-automation software was used to simulate the S_{11} performance of various types of waveguide flanges under different types of misalignment. These curves represent the response of standard 67B flange under broad-wall misalignment.



6. These curves show the same plots and parameters as those of Fig. 5, but with a precision 67B flange in place of a standard flange.

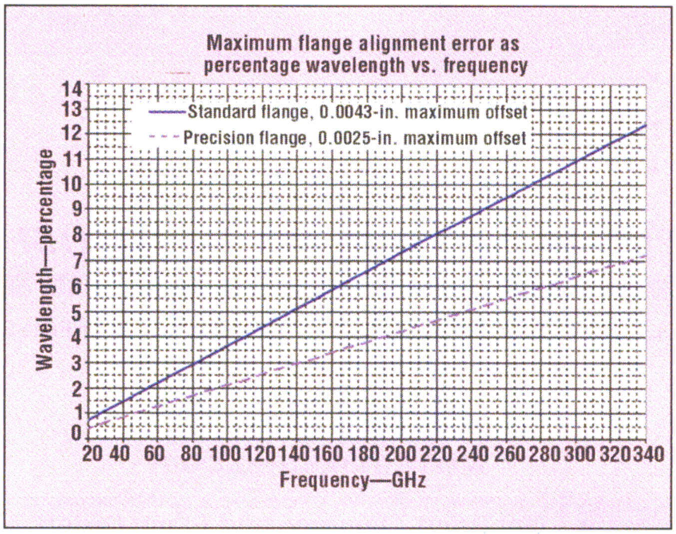
based on the true center of the waveguide aperture within the flange. In the 67B specification, the position of the alignment pins and holes have specified tolerances. Proper placement of these pins depends on how accurately the true center of the waveguide aperture can be determined and the translation of that point to the setup of the computer-controlled machine used for drilling the holes. Touch-off edge finding has been found to be barely possible for WR-08 and not practical for WR-06 and above. Most waveguide manufacturers use precision drill jigs or precision centering with a center-finding microscope mounted in their drilling machining or a combination of both. After numerous discussions with waveguide manufacturers, it was decided that the center-finding process and its possible errors would not be addressed in this investigation; only the errors permitted by the 67B tolerances are examined.

The deviations from true alignment were calculated for four misaligned positions—horizontal, vertical, diagonal, and rotated. These four positions represent the major axial deviations which could be readily modeled. The absolute magnitude of misalignments (offsets) is the same for all waveguide bands, WR08 through WR-03, based on the 67B-flange specification. The magnitude shown in each case is the algebraic worst-case sum of each of the tolerances (i.e., the tolerance of the placement of the hole circle for the alignment pins and holes around the true center of the waveguide aperture, the tolerance-allowed error in rotational position for the alignment pins and alignment holes, and the permitted tolerance on the diameter of the alignment pins and alignment holes). The offset from true alignment for the 67B flange used for WR-03 is illustrated in Fig 3. The offset from true alignment for the "precision" 67B flange used for WR-03 is illustrated in Fig. 4. The true alignment is improved by more than 50 percent through the use of the precision flange.

HFSS simulations of S_{11} were run on all four of the aforementioned misalignment positions. However, only curves for the broad-wall (horizontal) offset are provided in this article (Figs. 5 and 6). For reference, a simulation of a "perfect" WR-10 waveguide section is shown in each figure. These figures illustrate the S_{11} degradation from perfect alignment for the broad-wall offset of the standard 67B flange [0.0043-in. (0.0109-cm) offset] and the precision 67B flange [0.0025-in. (0.0064-cm) offset] for various waveguide bands.

Unfortunately, there are no reliable methods for achieving any of the offsets on a repeatable basis. To understand the potential effect of offsets, the effect of the horizontal offset is plotted in percent of wavelength versus frequency for the standard and precision 67B flanges (Fig. 7).

An extensive search was conducted for specifications for the finish quality of the 67B and 74 flanges. No military specification could be identified. References were found in National Bureau of Standards (NBS) [now known as the National Institute for Standards and Technology] studies of the performance of various waveguide finishes in WR-15, which apparently did not result in specifications. Massachusetts Institute of Technology (MIT) Lincoln Labs did publish specifications for the finish of the waveguide flange face for their projects. While the MIT specifications have not been adopted into any military specification, the flange-face finish of 16 μin.



7. A comparison of a standard 67B flange and a precision flange illustrates the maximum alignment error as a percentage of wavelength versus frequency. These plots are for the broad-wall misalignment cases of Figs. 5 and 6.

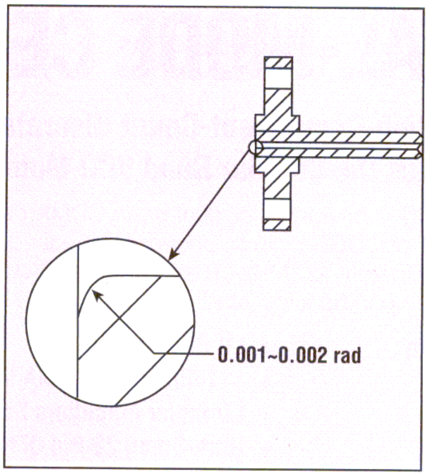
has been used by many commercial waveguide component vendors. Following through the application of this specification, it can be assumed that a perfectly sharp leading edge on the waveguide aperture of the flange face is inherent. What is the definition of a perfectly sharp corner?

A problem in one of the company's first WR-05 VNA calibration kits that led to this effort was rounded leading edges in the 67B flange-face waveguide aperture of a 1/4λ waveguide calibration shim. A reliable calibration could not be achieved. Upon inspection, it was discovered that significant rounding of the waveguide leading edge had occurred. The component was re-made and the problem was solved. Figure 8 is an illustration of the rounding which was found on all four edges. The author's experiments and consultations with several waveguide component vendors led to the conclusion that this rounding resulted from erosion of the edge material caused by excess lapping media welling up into the waveguide aperture.

The degree of rounding encountered should not have caused the degree of calibration problem that was observed. It is probable that the rounded leading edge exacerbated the effects of one of the flange-misalignment possibilities to a degree that was destructive to the calibration process. The simulation plots of the rounded edge are illustrated in Fig. 9.

MEASUREMENTS

S_{11} measurements were accomplished using a one-path reflection calibration with a current-model automated VNA and frequency extensions for WR-10, WR-08, and WR-05. The waveguide cutoff frequency was made using S_{21} measurements with the same equipment, but using a one path, two-port 8-term calibration. The techniques employed included: full waveguide-band frequency response, time (distance)-domain response of the waveguide component string, time domain with gating around the discontinuity of interest, and frequency domain with gating based on the previous time



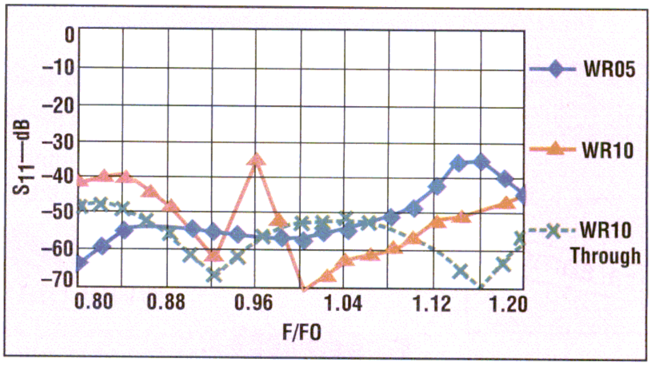
8. Manufacturing imperfections result in the condition called leading-edge rounding as shown here. This rounding of a 67B flange can lead to misalignment and an improperly calibrated VNA calibration kit.

domain.

The definition of cutoff frequency is that frequency (λ_c) for a desired mode, below which the wave is incapable of being propagated in the waveguide. Due to the limited dynamic range of the measurement system, the frequency at which absolute attenuation of the wave occurred could not be measured. For purposes of this effort, cutoff frequency is being defined as the frequency at which the wave is attenuated 40 dB in a 2-in. waveguide section. This level was chosen because it was above the noise floor and thus was very repeatable and easily identified. The measurements were then conservative in that the cutoff was even lower in frequency than the model selected. Dozens of waveguide sections in various bands were measured. WR-03 was chosen for illustration as being the most problematical. In Fig. 10, Marker 1 is placed at the theoretical cutoff frequency for WR-03 waveguide—173.28 GHz. The 40-dB cutoff frequency displayed at Marker 2 is at 163.1 GHz. A VNA calibration made using this waveguide as the calibration port and the theoretical frequency entered as the calibration cutoff frequency constant would have a significant error in its calibration matrix. More than 12 sections of new WR-03 waveguide showed this same oversize induced error. Marker 3 shows the S_{21} dynamic range achieved after the one-path, two-port eight-term calibration was completed.

To measure potential misalignment errors that can be suffered when 67B specifications are applied to WR-08 waveguide and above, an assembly of three new, 2-in. (5.08-cm) long, standard 67B WR-05 waveguide sections was created. As a comparison, a similar assembly of two new, 1.00-in. (2.54-cm) long, precision 67B WR-05 waveguide sections were likewise created. A time-domain analysis of the three standard 67B section assembly is shown in Fig. 11. The markers identify the following:

- The interface of the test-set output flange (the point of calibration) and the first 2-in. (5.08-cm) 67B waveguide section.
- The interface of the first and second 67B waveguide section.
- The interface of the second and third 67B waveguide section.
- The interface of the third 67B waveguide section and the precision load.
- The reflection of the load element within the precision load.



9. A simulation of S_{11} in a leading-edge rounded flange for WR-05 and WR-10 waveguide is illustrated. The bottom curves illustrates a "perfect" W-10 waveguide for comparison purposes.

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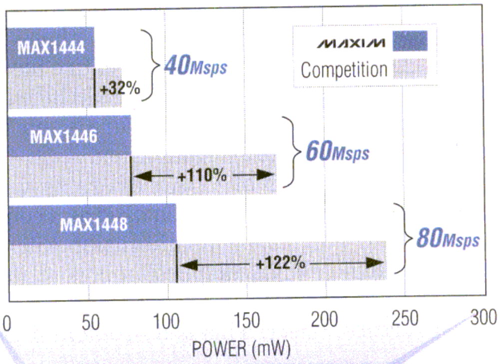

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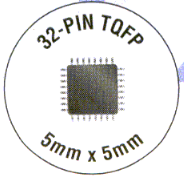

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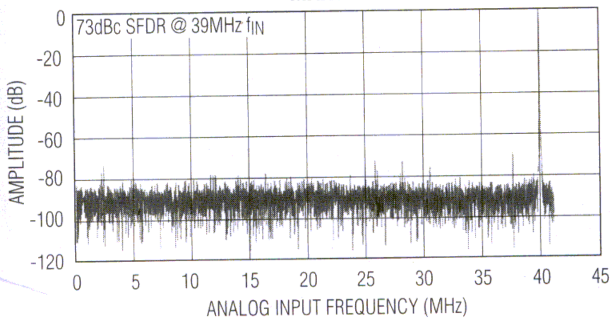

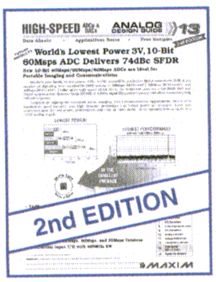

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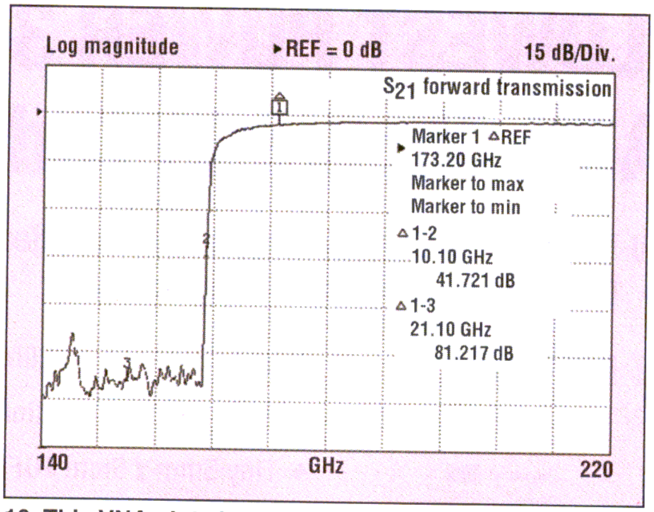
Note that at Markers 2 and 3 there are double traces. These were intentionally created by recording the first result and then randomly loosening, moving, and re-tightening the waveguide interface for the most significant displacement of the measurement. Approximately 10 dB of degradation was achieved. At Marker 3, the interface was taken apart, rotated 180 deg., and reassembled. This resulted in an approximate improvement of 4 dB.



10. This VNA plot shows the S_{21} response of an oversize WR-03 waveguide to determine its cutoff frequency. Marker 1 shows the theoretical cutoff frequency, while Marker 2 is the 40-dB cutoff point or the practical limit of operation for a 2-in. (5.08-cm) section of waveguide.

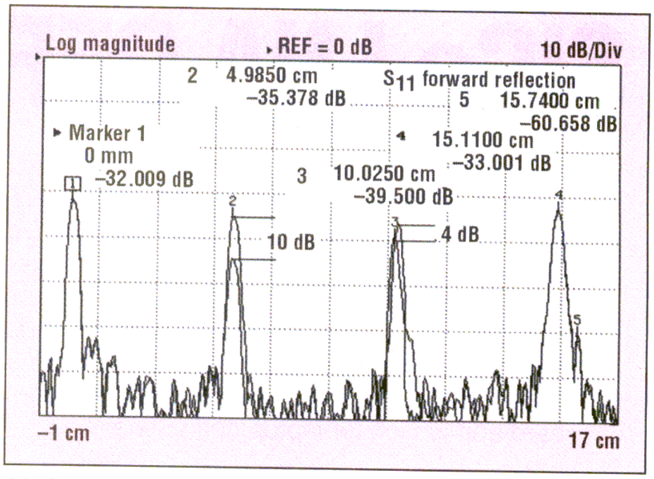
OVERSIZE PROBLEMS

The impacts of various types of waveguide irregularities depend on the type of device being tuned or analyzed. The position the irregular waveguide occupies in the test setup will also have specific effects. If the irregular waveguide forms a component or all of the components in a calibration standards kit, one set of errors will be introduced. But if the irregular section is used as the "test-port adapter," and is left in place as the test port after calibration with a precision set of components, a different set of effects will occur. There are even impacts using an irregular waveguide section as a convenient interconnection to, or as part of the device under test (DUT). Due to the magnitude of errors that can be introduced into the VNA calibration by these irregularities, the entire measurement setup should be well thought out before even beginning calibration.

An oversize waveguide, when used as a component of a calibration kit, will cause VNA dispersion correction and the waveguide-loss model to be incorrect. This is a problem if the waveg-

uide theoretical cutoff frequency (rather than its actual cutoff frequency) is entered during calibration data entry. It will cause the test data to have phase and magnitude errors, as well as time-domain errors.

The use of an oversize waveguide section as a test-port adapter attached to the VNA RF-head test port will create errors that are similar to trying to calibrate a SMA coaxial system with a 3.5-mm calibration kit. These same types of SMA versus 3.5-mm problems will be encountered in system measurements where waveguides of different internal dimensions are intermixed (i.e., precision and standard, etc.).



11. A time-domain analysis of a five-section assembly of standard WR-05 is used to determine misalignment error when the 67B specifications are applied. The five markers on the VNA screen represent measurement taken at various interfaces between the sections.

An offset, such as those that are supported by 67B-specification tolerances between waveguide interfaces during calibration, will introduce an unexpected ripple component in the test data that will impact the quality of measurements, particularly in the high return-loss measurements made in metrology. A standard flange section of waveguide could induce destructive ripple when looking across return losses of 30 dB or more. The lack of repeatability supported by the 67B tolerances can be very disruptive to an orderly calibration organization.

The presence of a rounded leading edge in the waveguide flange can affect the precision and standard 67B flanges—WR-08 and smaller. The effects would most likely exacerbate the degradation that is caused by any offset in the flange interfaces. The ability to predict the relative offset of the two flanges in a 67B interface, coupled with the possibility of leading-edge rounding, has potential impact for any meaningful VNA measurements that are above 90 GHz, with the possible exception of low return-loss characterization such as wafer probing.

Before use in any rigorous testing program, all of the waveguide should be fully characterized for its electrical properties and mechanical compatibility. It is recommended that as many waveguide-flange interfaces as possible be eliminated. The use of a specifically designed single-piece waveguide run that includes all of the necessary twists, bends,and other convolutions is highly recommended.

VNA measurements have shown that the anomalies of the waveguide itself, which can be handled in the process of calibration data entry, are less destructive than the imperfections inherent in the alignment uncertainty of the flange interface.

The use of dedicated waveguide test setups, which are not tampered with once they are assembled, should be considered mandatory. It is even more important for prudent technicians to fully understand and qualify their test sets when they work at these frequencies. ••

Acknowledgement

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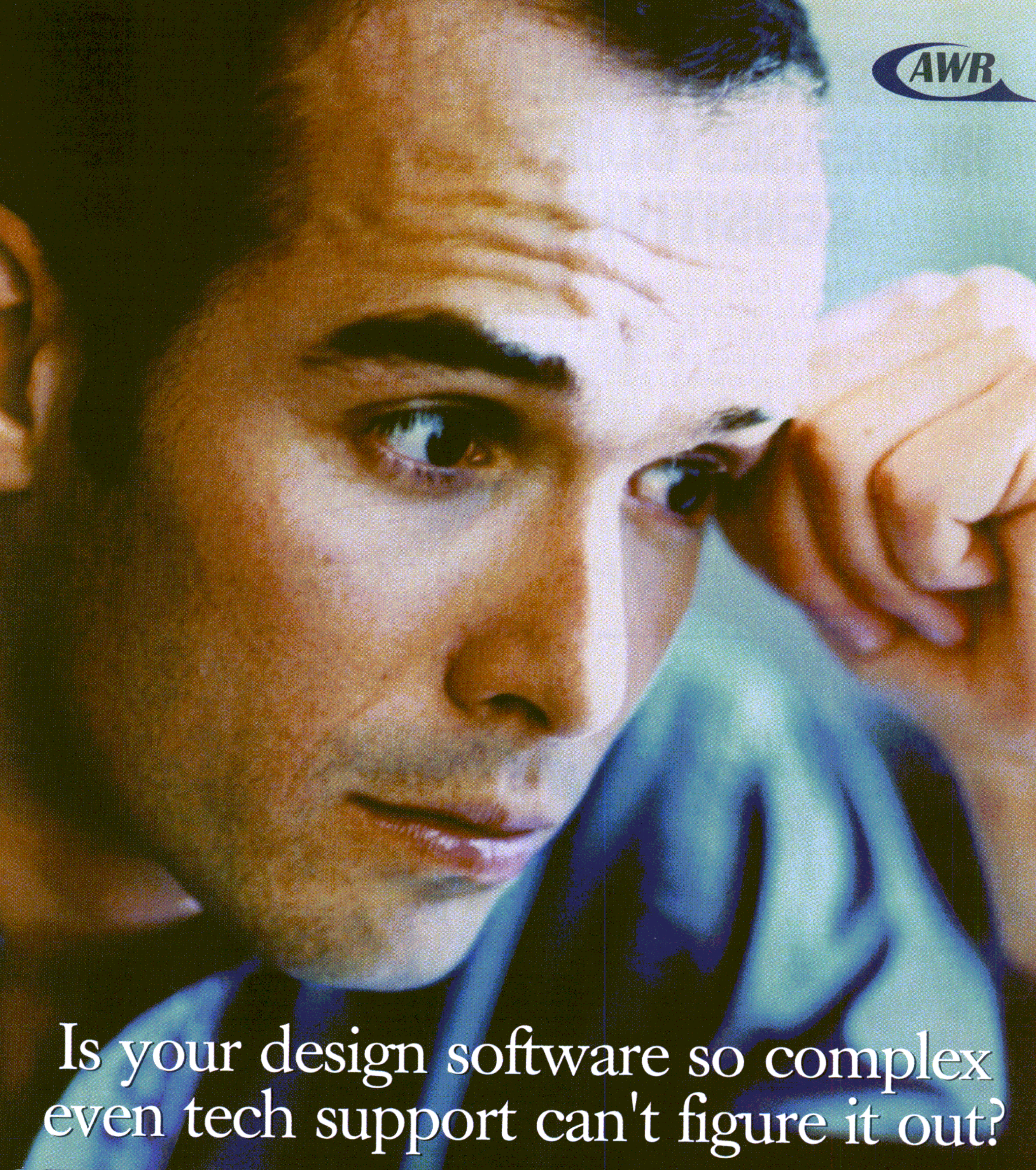

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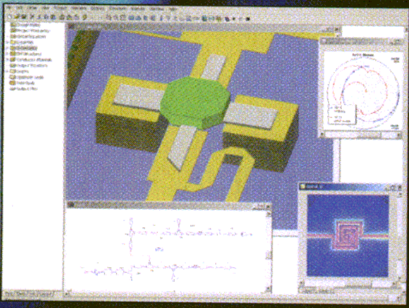

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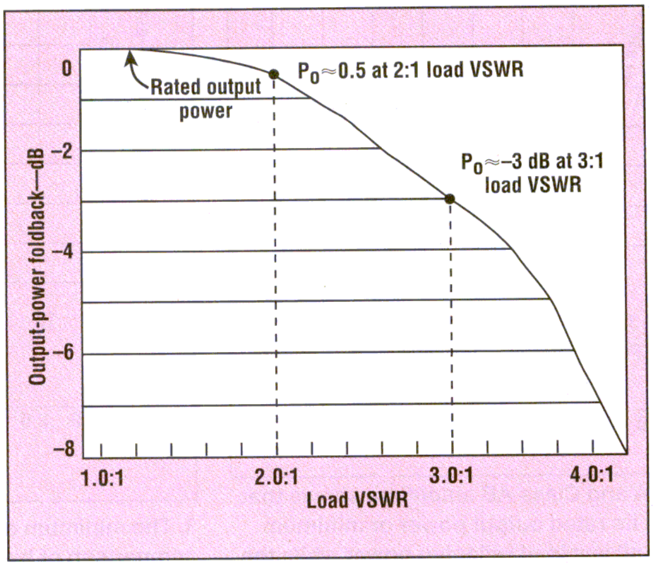
POWER AMPLIFIERS (PAs) are characterized by a set of well-known and generally accepted specifications. The list includes gain, frequency response, and output power. But some less-understood specifications, including noise figure, gain stability, and distortion, must also be considered when comparing the performance of PAs. Of these "secondary" performance specifications, load tolerance may be one of the most overlooked parameters. Depending upon the application, the ability to provide power to loads that vary from an ideal 50 Ω can be crucial. These variations in load impedance are commonplace, especially in electromagnetic (EM) immunity and susceptibility testing applications. In applications of this nature, the load tolerance ultimately determines the effectiveness of the PA.

This article addresses the use of RF PAs in applications characterized by mismatched loads. VSWR variations encountered in immunity testing are discussed in relation to amplifier design. The concept of minimum available power (MAP) is introduced as a quantitative measure of an amplifier's capability to supply power into load with poor VSWR.

Real-life applications rarely involve driving an ideal 50-Ω load. More likely, the load varies with frequency over a wide range of impedances. A case in point is EM immunity testing. This application is plagued by widely varying load impedances due to variations in antenna characteristics, room reflections and resonances, imperfect cables and connectors, and reflections from the device under test (DUT). Specifically, start-



1. In a typical Class AB PA, the output power decreases or "folds back" as the VSWR of the load increases.

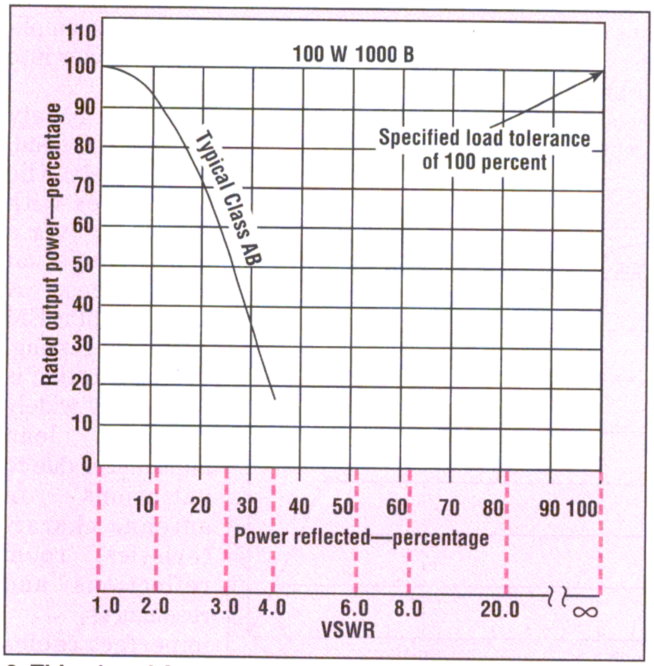
ing with a typical antenna VSWR of 2.50:1 and factoring in room and signal-path effects, it is not uncommon to experience a VSWR in excess of 5.0:1. The problem simply stated is that most RF PAs are not capable of providing full rated power to loads that vary considerably from an ideal 50-Ωimpedance. Engineers working in the area of electromagnetic-compatibility (EMC) testing have had to deal with the problem of delivering power into significant mismatches on a regular basis and, as a result, a line of amplifiers has been developed at Amplifier Research (Souderton, PA) with characteristics that particularly lend themselves to this difficult application.

There are two major types of RF PAs used for susceptibility testing—Class A and Class AB amplifiers. Class A amplifiers exhibit characteristics that are well-suited to applications requiring good load tolerance. By specializing in Class A linear amplifiers especially designed to be load tolerant, Amplifier Research has developed a line of products capable of handling applications involving varying load impedances. While Class A amplifiers are generally larger and more expensive than Class AB amplifiers, the electrical performance advantages of Class A amplifiers outweigh all other considerations. To understand why Class A amplifiers are superior to Class AB amplifiers for EM immunity and susceptibility testing, it is necessary to consider the inherent differences, which lead to their respective strengths and weaknesses.

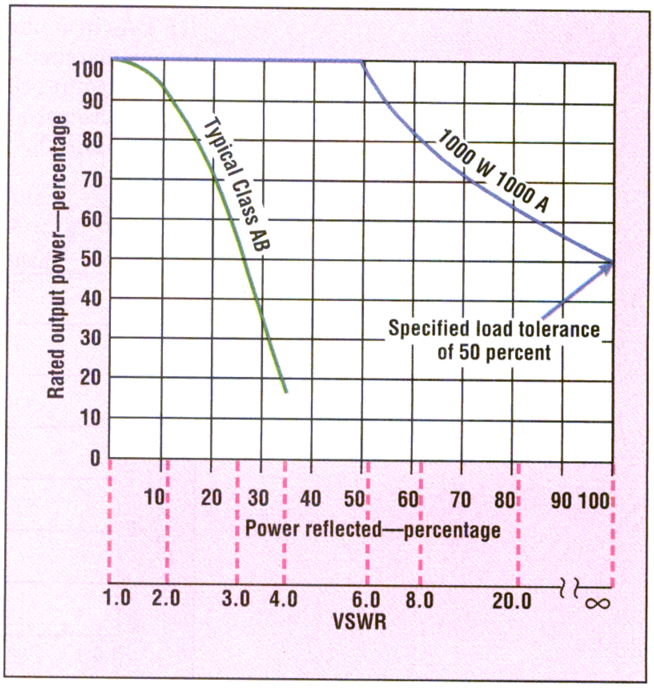
In Class A operation, the active devices are biased to ensure that collector or plate current flows for 360 electrical deg. of the input waveform. When operating below the 1-dB compression point, the RF input and output waveforms will vary uniformly about the DC quiescent point, and lie within the linear region of the characteristic curves for the active device. As a result, a Class A biasing scheme provides excellent linearity and low distortion.

IN A CLASS A AMPLIFIER, ADDITIONAL ATTENTION MUST BE PAID TO HEAT SINKS, COOLING CONSIDERATIONS, AND SELECTION OF RUGGED COMPONENTS THAT CAN ENDURE A REALTIVELY HOSTILE THERMAL ENVIRONMENT.

A properly designed Class A amplifier dissipates maximum power in its quiescent state. Thus, it must be designed for high-power dissipation. In contrast to a Class AB amplifier, a Class A amplifier of necessity requires larger active devices and often a larger number of active devices in to share total heat dissipation. In a Class A amplifier, additional attention must be paid to heat sinks, cooling considerations, and selection of rugged components that can endure a relatively hostile thermal environment. Once an input signal is applied to a Class A amplifier and RF power is dissipated into a load, the RF devices actually run cooler than in the quiescent state. Since these devices are running below their normal operating temperature, power reflections resulting from into high levels of VSWR are not a problem. While its design is inherently superior to a Class AB



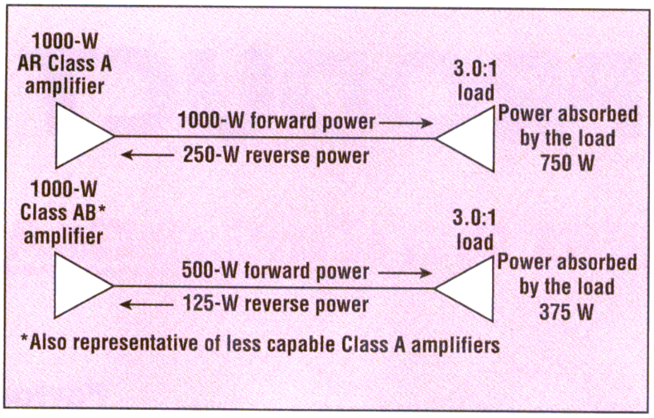
2. This plot of Class A and Class AB amplifiers shows that the former maintains its rated output power or minimum available power with all levels of reflected power while the latter fails to deliver rated output levels except with ideal 50-Ω loads.



3. The minimum available power concept supports the comparison of two 100-W amplifiers, with the Class AB unit maintaining rated levels even for loads as severe as a 6.0:1 VSWR.

amplifier in regards to its ability to dissipate power, a Class A amplifier will undoubtedly be larger, heavier, cost more, and be less efficient with respect to its use of primary power.

The active devices in a Class AB amplifier are biased to produce output current for somewhere less than 360 deg. and more than 180 deg. of the input signal. A Class AB design consumes less power in its quiescent state than when an input signal is applied. Since it consumes less power and is thus more efficient than a Class A amplifier (efficiency is equal to the RF output power divided by the primary input power), fewer transistors are required for a particular output-power level and the amount of power/heat that must be dissipated is less in a Class AB design than in a Class A design, supporting the use of smaller-area silicon (Si) devices. Less heat sinking is required in a Class AB amplifier compared to a Class A design, and the cooling schemes for a Class AB design tend to be less elaborate than those used in Class A amplifiers. Accordingly, the ability of a Class AB broadband amplifier to absorb reflected power is severely compromised when compared to the capability of a Class A amplifier.



4. In a comparison of Class A and Class AB 1-kW amplifiers, the Class A amplifier will dissipate more power in the load while maintaining its rated output level. The Class AB amplifier employs foldback protection to limit its output with a less-than-ideal load.

An example may be useful in demonstrating a comparison of the two amplifier types when handling reflected power. As an example, consider a Class A amplifier that requires 1000 W of primary power to achieve a rated output-power level of 100 W. With no signal input, this amplifier must be capable of dissipating 1000 W. When a signal is applied, the amplifier dissipates 900 W while delivering 100 W to the load.

In contrast, a typical broadband Class AB 100-W amplifier dissipates considerably less than 100 W with no input signal applied. When an input signal is applied, the internal dissipation may rise in excess of 500 W.

This example assumes a perfect 50-Ω load in both cases. How well do these amplifiers fare with real-life loads encountered in typical susceptibility testing situations or applications where impedances may vary widely? As the load varies from an ideal impedance of 50 Ω, output power is reflected back into the output stage. Since the Class A amplifier is designed to dissipate at least 1000 W, power reflected back into the output stage of the amplifier does not present a reliability or performance problem (Fig. 2). Even if the output port were shorted or operated in an open condition, the resulting total reflection of 100 W would not adversely affect the amplifier. Since the additional 100 W of reflected power does not increase the device dissipation above design value, the amplifier would continue to supply forward power of 100 W without overheating, regardless of the load.

In contrast, the Class AB amplifier will have serious problems dealing with load variations, since it is designed for use with nearly ideal loads and the slightest amount of reflected power could cause severe damage to its output stages. Accordingly, Class AB amplifiers employ a protection scheme to limit the amount of reflected power. Figure 1 shows a typical curve of Class AB output power versus output VSWR. The curve shows an alarming inability of the RF devices to sink even a minimal amount of reflected power.

IN CONTRAST, THE CLASS AB AMPLIFIER WILL HAVE SERIOUS PROBLEMS DEALING WITH LOAD VARIATIONS, SINCE IT IS DESIGNED FOR USE WITH NEARLY IDEAL LOADS.

The amplifier must implement "foldback" of the available RF output power in an effort to protect its output stages. Specifically, the curve clearly shows that a 100-W amplifier can not sustain 100 W into a load with VSWR of 2.0:1 (a typical antenna VSWR), but folds back to 89 W. With as little as 11 percent of the output power reflected, the forward power drops to 89 W.

When the load VSWR increases only modestly to a value of 3.0:1, with only 25 percent of the output power reflected back, the forward power of the Class AB amplifier is cut back to 50 W. This lack of power can adversely affect the performance of an EM susceptibility test system that must maintain prescribed electric- and magnetic-field levels despite VSWR variations.

Since PAs are specified according to required power levels delivered to a load, what is needed in comparing PAs for susceptibility testing is a convenient and reliable method of determining the load tolerance and, thus, its suitability when working with a particular type of load. A parameter known as minimum available power (MAP) can be quite useful in comparing the expected output power of different amplifiers under a particular set of load conditions. The typical curve of Class AB output power in Fig. 1 is vague due to the plots of two nonlinear quantities. A much clearer picture of actual amplifier performance can be obtained by plotting the percentage of output power (forward power) versus the percentage of reflected power. The resulting graph presents a clear and unambiguous prediction of an amplifier's MAP.

By using the

MAP parameter, the performance of the model 100W1000B PA from Amplifier Research (Souderton, PA) can be readily compared to the typically Class AB amplifier performance from Fig. 1. The curves show that the Class A model 100W1000B provides 100 percent of its rated power regardless of the load VSWR (Fig. 2). These characteristics, in fact, apply to all of the company's "W" series amplifiers rated for less than 500-W output power. Higher-power "W" series amplifiers (to 3 kW) exhibit the MAP performance shown in Fig. 3. This MAP is characteristic of an amplifier with a load tolerance equal to 50 percent of rated output power at infinite VSWR. The Class AB MAP curve generally applies to all amplifiers of a particular classification regardless of output power and can be determined from the simple relationship:

Load tolerance (percent) = [(Forward power at 100-percent reflection)/(Rated power of amplifier)] × 100 percent

In conclusion, the MAP concept can be applied to a wide range of PAs when comparing different architectures, such as Class A and Class AB units. When an application involves time-varying loads, such as those typically encountered in susceptibility testing, load tolerance is of paramount importance. Selection of load-tolerance amplifiers can avoid the disappointment of an underpowered application, especially when amplifiers are specified with load tolerance expressed in percentage of rated power (Fig. 4). It should be noted that the concept of MAP refers to the maximum available forward power and not the power dissipated in the load. For example, in the extreme case of infinite VSWR (a short or open), no power is dissipated in the load. The MAP concept makes it easier to visualize the effects of load VSWR on output power. Other amplifier characteristics such as low power-line voltage, temperature, input/output VSWR, etc., may affect available output power. ••

THE MAP CONCEPT CAN BE APPLIED TO A WIDE RANGE OF PAs WHEN COMPARING DIFFERENT ARCHITECTURES, SUCH AS CLASS A AND CLASS AB UNITS, ESPECIALLY WHEN AN APPLICATION INVOLVES TIME-VARYING LOADS.

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Range-Doppler Radar Imaging and Motion Compensation

Jae Sok Son, Gabriel Thomas, and Benjamin C. Flores

Radar systems rely on RF energy for illuminating a target, but there is much more signal processing involved in these systems once radar returns have been captured. *Range-Doppler Radar Imaging and Motion Compensation* is a reference guide featuring the latest processing techniques for focusing radar images. It introduces engineers to some of the advanced methods used to analyze and synthesize the echo-transfer functions of inverse-synthetic-aperture-radar (ISAR) targets.

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The opening chapter provides a brief background on ISAR systems and introduces the concept of rotational-motion compensation. Chapter 2 describes basic concepts of ISAR. Chapter 3 formalizes the burst derivative concept, a motion-compensation technique that is not computationally demanding. Chapter 4 introduces the phase-difference method for estimating the translational motion parameters of a target, while Chapter 5 covers least-squares motion-parameter estimation.

Chapter 6 details complex analysis of ISAR signatures, while Chapter 7 highlights Cramer-Reo bounds for motion estimates. Chapter 8 describes weighted least-squares motion-parameter estimation, and Chapter 9 covers signal analysis and synthesis using short-time Fourier transforms, a 2D linear transformation that conveys information in time and frequency through a sliding analysis window. Chapter 10 reviews a selective motion-compensation methods, and Chapter 11 explains imaging-enhancement techniques.

Chapter 12 offers an introduction to rotational motion compensation, while Chapter 13 reviews interpolation methods for rotational-motion compensation. Finally, Chapter 14 details image-enhancement techniques using sidelobe apodization.

Range-Doppler Radar Imaging and Motion Compensation is shipped with a 3.5-in. (8.89-cm) floppy disk containing MATLAB-based software. The software allows the user to simulate the different techniques that are presented in the book. (2000, 238 pp., hardcover, ISBN: 1-58053-102-4, $93.00.) **Artech House, Inc., 685 Canton St., Norwood, MA 02062; (781) 769-9750, FAX: (781) 769-6334, Internet: http: //www. artech-house.com.**

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Understanding Single-Ended And Mixed-Mode S-Parameters

S-Parameters, Part 1

The growing use of differential circuitry in high-speed analog and digital circuitry requires a new look at traditional S-parameters.

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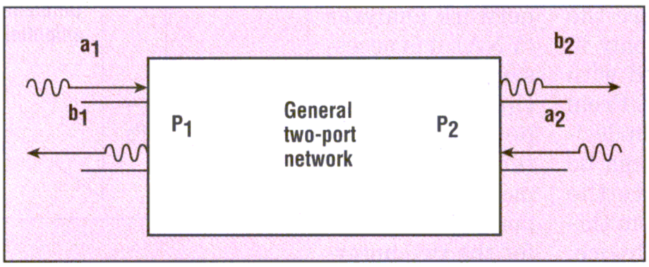
DIFFERENTIAL circuits provide noise-free signal transmission in communications. In the past, these circuits have been associated with low-frequency systems. At relatively low frequencies, these circuits can be designed and analyzed using lumped-element models and techniques. But when differential circuits are applied to systems operating beyond 1 GHz (and equivalently 1 Gb/s in digital communications systems), this lumped-element approach is no longer valid.

To deal with the inability to use lumped-element techniques, distributed models and analysis techniques are used. Scattering parameters (S-parameters) have been developed for this.[1] These S-parameters are defined for single-ended networks. S-parameters can be used to describe differential networks, but a strict definition was not developed until Bockelman *et al.* addressed the issue.[2] Bockelman's work also included a study on how to adapt single-ended S-parameters for use with differential circuits.[2] This adaptation (known as mixed-mode S-parameters) reports on differential and common-mode operation, as well as conversion between the two modes of operation. This opening installment of a four-part article series will examine the use of single-ended S-parameters, mixed-mode S-parameters, and the importance of a proper calibration when making network-analyzer measurements.

The term "S-parameters" refers to how the parameters represent a scattering, or separation, of a signal by a device under test (DUT). These scattered signals are the reflected and transmitted waves that are produced when a device is struck with an incident wave. S-parameters become important when the operating frequencies are high enough so that circuit elements become a significant fraction of a wavelength (approximately one-tenth of a wavelength) and a lumped-element approach must be discarded in favor of a distributed model.

Also, at microwave frequencies, it is difficult to measure voltages and currents (as required for impedance measurements). To overcome this problem, a ratio of the incident and outgoing wave is used (see Fig. 1 and Eq. 1):



1. A typical two-port network exhibits forward and reverse transmitted and reflected waves.

$$S_{ij} = (b_i / a_j) /_{a_k = 0 \text{ for } k \neq j} \quad (1)$$

In matrix form, Eq. 1 becomes:

$$[b] = [S][a] \quad (2)$$

Equation 1 states that to measure S_{ij}, it is necessary to energize port j and measure the response on port i. It is important to note that all ports, except the stimulus port, must be terminated with that port's characteristic impedance. For example, to calculate parameter S_{21} for the network in Fig. 1, it is necessary to energize port 1, take the power out of port 2 and divide it by the power incident on port 1 when there are no incident voltages on port 2. To accomplish this, it is necessary to terminate port 2 with its characteristic impedance [typically 50 Ω in high-frequency, high-speed systems and 75 Ω} in cable-television (CATV) systems].

In eq. 2 [b] is an n × 1 column matrix, [a] is an n × 1 column matrix and [S] is an n × n matrix where:

n = the number of ports in the network (i.e., n = 2 in.) [Fig. 1].

The power waves are related to the voltages and currents by the following equations:

$$a_n = \frac{v_n + i_n Z_n}{2\sqrt{Re(Z_n)}} \quad (3)$$

$$b_n = \frac{v_n - i_n Z_n^*}{2\sqrt{Re(Z_n)}} \quad (4)$$

In Eqs. 3 and 4:

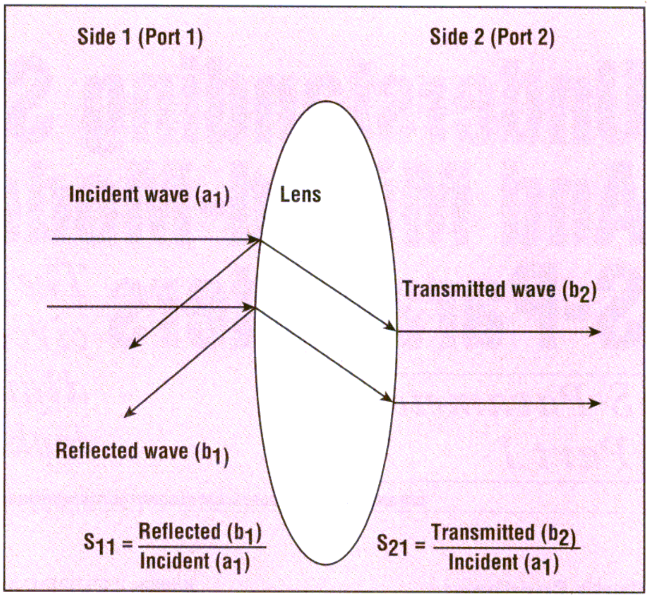
v_n = the total voltage at port n,

i_n = the total current at port n, and

Z_n = the characteristic impedance at port n.

S-parameters are used in many ways to characterize a device or transmission line. In the (S) matrix, the diagonal elements (S_{ii}) are the reflection coefficients if, and only if, all other ports are terminated with their characteristic impedance. From this, the VSWR, return loss (in decibels), and other parameters can be calculated. The S_{ij} terms are the transmission coefficients. From this quantity, gain of an active device, loss in a passive device, insertion loss, group delay, and other related parameters can be found.

An analogy to optics and reflected light is helpful in explaining the concept of S-parameters. For example, a ray-of-light incident on a piece of clear glass (Fig. 2) can be thought of as the equivalent of a_1 of Fig. 1. The reflected wave would be the equivalent of b_1, the transmitted wave would be b_2, and the characteristic impedance would be that of free space (approximately 377 Ω). As a result, the transmitted wave can be thought of as S_{21} and the reflected wave can be thought of as S_{11}.

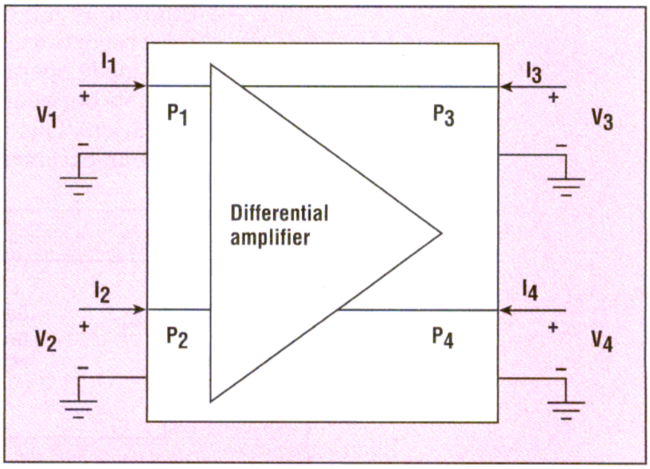


2. It is possible to visualize S-parameters through light incident on a lens.

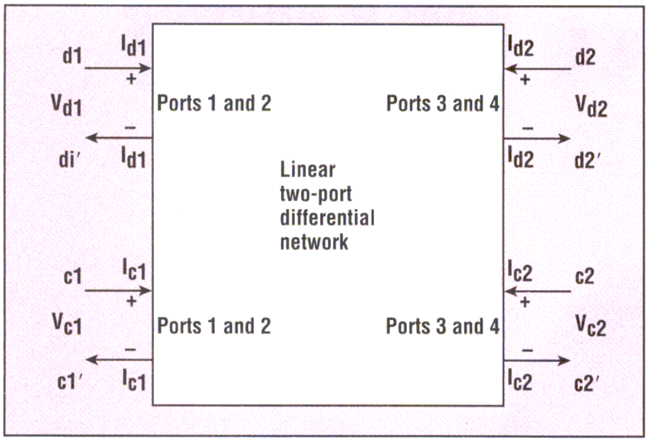
Once S-parameters for single-ended networks are fully understood, it is possible to extend the concept to characterize differential circuits. To begin the understanding of differential S-parameters, a differential amplifier will be studied. An example of a differential amplifier is provided in Fig. 3.

To characterize the differential amplifier of Fig. 3, each lead can be identified as a port and the differential circuit can be labeled as a four-port network. This approach treats the amplifier as a single-ended device. To measure the S-parameters for this single-ended approach using a two-port vector network analyzer (VNA), it is necessary to terminate the two unused ports with 50-Ω terminations and measure the two-port S-parameters for the two unterminated ports. The termination/measurement process continues in this fashion until enough information is gathered to construct the 4 × 4 S-parameter matrix. With the four-port S-parameters measured, the DUT is accurately characterized (assuming there is a good calibration) for single-ended performance. Since the sample amplifier is designed for differential operation, these S-parameters do not provide much insight to the amplifier's differential (or common-mode) operation since each port contains the differential and common-mode responses.

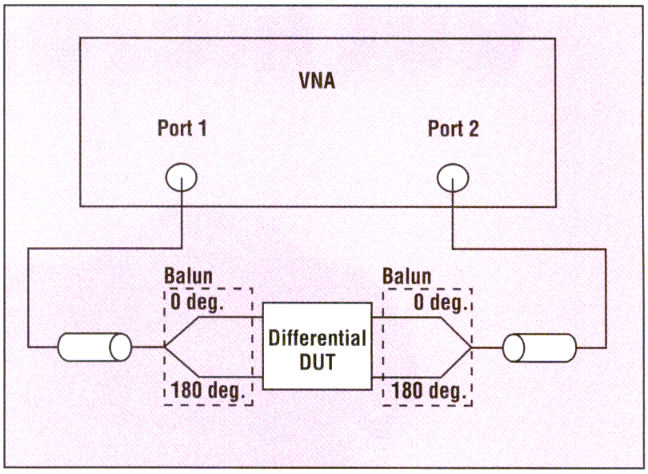
To overcome this problem, a system similar to that used to describe the four transfer gains (A_{cc}, A_{dd}, A_{cd},



3. This example of a differential amplifier shows how balanced lines are used for noise suppression.



4. In a mixed-mode representation of a circuit, the differential and common-mode signals are separated. In reality, both types of signals appear at common ports.



5. In this sample test setup, baluns are employed to measure differential S-parameters.

and A_{dc}) introduced by Middlebrook in ref. 3 is used. This system of S-parameters (known as mixed-mode S-parameters) was introduced by Bockelman *et al.* in ref. 2. It begins by grouping ports one and two together (to form a differential port one) and grouping ports three and four together (to form a differential port two).

The network shown in Fig. 4 is only a tool to help visualize the operation of a differential circuit. In reality, there are only two differential ports with each port having differential and common-mode signals.[2]

Comparing the single-ended voltages and currents in Fig. 3 with the differential voltages and currents in Fig. 4, the differential and common-mode voltages and currents can be defined as:

$$v_{d1} = v_1 - v_2$$
$$v_{c1} = \frac{v_1 + v_2}{2} \quad (5)$$

$$i_{d1} = \frac{i_1 - i_2}{2}$$
$$i_{c1} = i_1 + i_2 \quad (6)$$

$$v_{d2} = v_3 - v_4$$
$$v_{c2} = \frac{v_3 + v_4}{2} \quad (7)$$

$$i_{d2} = \frac{i_3 - i_4}{2}$$
$$i_{c2} = i_3 + i_4 \quad (8)$$

With this conversion between single-ended voltages and currents to differential (and common-mode) voltages and currents, a way to convert from single-ended S-parameters to mixed-mode S-parameters can be found. Before the conversion is given, a review of what has been done in the past to measure circuits differentially will be presented.

In the past, if differential measurements were desired, then a balun (or hybrid coupler) would be needed as seen in Fig. 5. The problems associated with this method are magnitude and phase imbalance of the baluns, no way to measure mode conversion (i.e., from differential to common mode), no rigorous definition of mixed-mode S-parameters, and calibrating the system with the baluns is not well-defined. Due to these problems, a carefully developed system is needed to describe the device differentially.

With the need for mixed-mode S-parameters to be presented, it is now convenient to define the mixed-mode S-parameters. Using the definition for the incident and returning waves provided in Eqs. 3 and 4, a differential and common-mode incident and returning power wave can be defined as:

$$a_{dn} = \frac{v_{dn} + i_{dn} Z_{dn}}{2\sqrt{Re(Z_{dn})}} \quad (9)$$

$$b_{dn} = \frac{v_{dn} - i_{dn} Z_{dn}}{2\sqrt{Re(Z_{dn})}} \quad (10)$$

$$a_{cn} = \frac{v_{cn} + i_{cn} Z_{nc}}{2\sqrt{Re(Z_{cn})}} \quad (11)$$

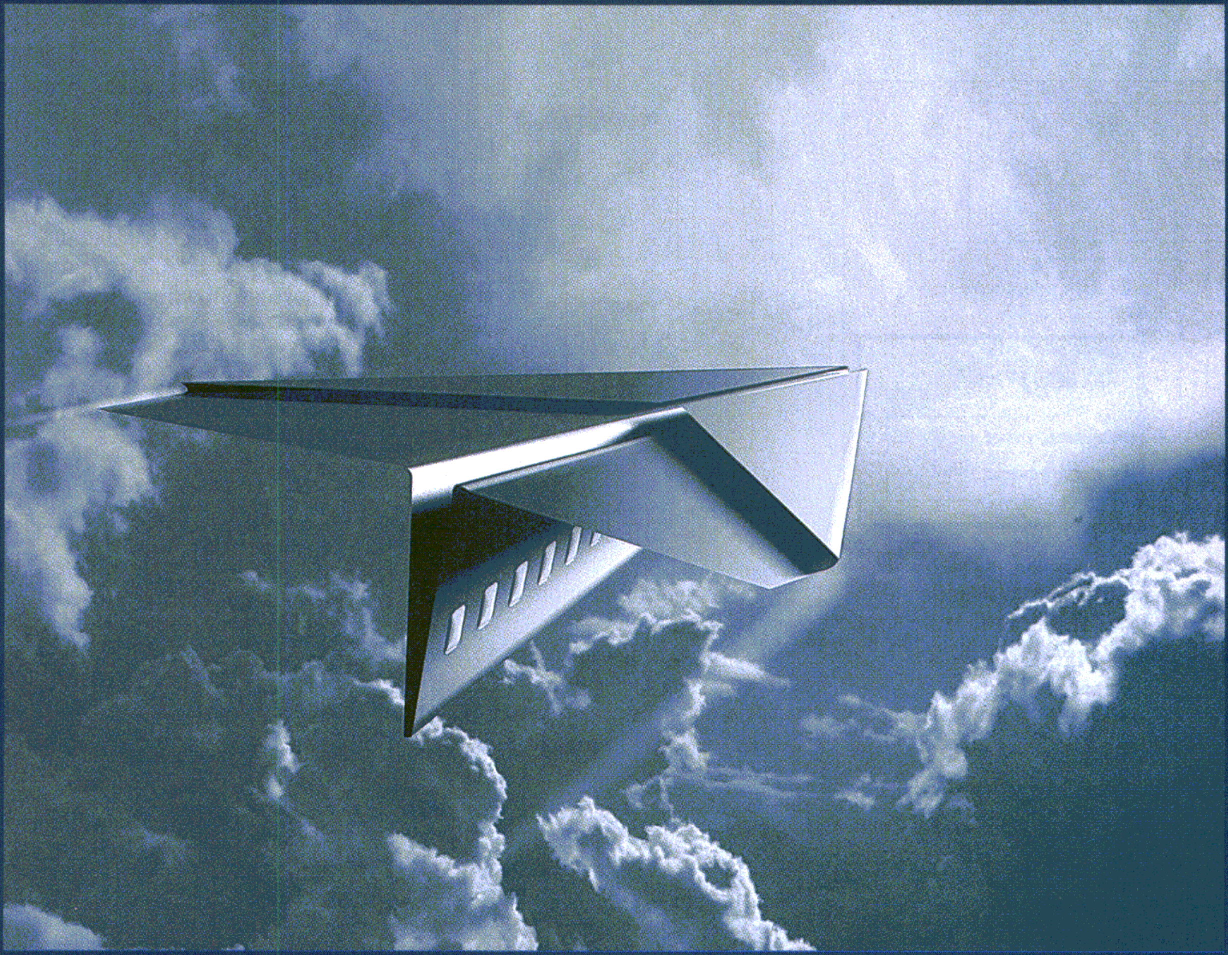
$$b_{cn} = \frac{v_{cn} - i_{cn} Z_{cn}}{2\sqrt{Re(Z_{cn})}} \quad (12)$$

In Eqs. 9 through 12:
v_{dn} = the differential voltage at port n,
v_{cn} = the common-mode voltage at port n,
i_{dn} = the differential current at port n,
i_{cn} = the common-mode current at port n,
Z_{dn} = the differential-mode characteristic impedance at port n (Z_{oo} for a coupled-line system), and
Z_{cn} = the common-mode characteristic impedance at port n (Z_{oe} for a coupled-line system).

To calculate Z_d, it should be remembered that Z = V/I, so in order to find Z_d it is necessary to take v_d, (from Eq. 5) and divide it by I_d (from Eq. 6). A similar method is needed to calculate Z_c. Following these steps yields:

$$Z_d = 2Z_{\infty}$$
$$Z_c = \frac{Z_{oe}}{2} \quad (13)$$

With the definition of the power waves in Eqs. 9 through 12, the mixed-mode S-parameters can be defined as:



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NGA-186	0.1-6.0	4.1	50.0	12.5	14.6	32.9	120
NGA-286	0.1-6.0	4.0	50.0	15.5	15.2	32.0	120
NGA-386	0.1-5.0	4.0	35.0	20.8	14.5	25.8	144
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	0.1-6.0	5.0	80.0	19.9	18.9	39.6	121
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.

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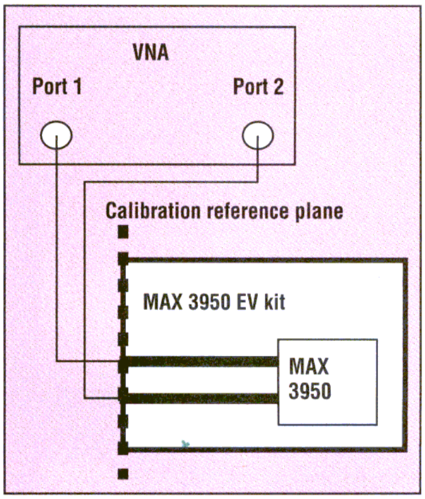


6. This measurement setup is designed to evaluate the return loss of a 10-Gb/s deserializer circuit.

$$\begin{aligned} b_{d1} &= s_{dd1}a_{d1} + s_{dd12}a_{d2} \\ &+ s_{dc11}a_{c1} + s_{dc12}a_{c2} \\ b_{d2} &= s_{dd21}a_{d1} + s_{dd22}a_{d2} + \\ &s_{dc21}a_{c1} + s_{dc22}a_{c2} \\ b_{c1} &= s_{cd11}a_{d1} + s_{cd12}a_{d2} + \\ &s_{cc11}a_{c1} + s_{cc12}a_{c2} \\ b_{c2} &= s_{cd21}a_{d1} + s_{cd22}a_{d2} \\ &+ s_{cc21}a_{c1} + s_{cc22}a_{c2} \end{aligned} \quad (14)$$

where:

$$S_{ghij} = S_{(output\ mode)(input\ mode)(output\ port)(input\ port)} \quad (15)$$

which can be represented as:

$$\begin{bmatrix} b_{d1} \\ b_{d2} \\ b_{c1} \\ b_{c2} \end{bmatrix} = \left\{ \begin{matrix} \begin{pmatrix} S_{dd11} & S_{dd12} \\ S_{dd21} & S_{dd22} \end{pmatrix} & \begin{bmatrix} S_{dc11} & S_{dc12} \\ S_{dc21} & S_{dc22} \end{bmatrix} \\ \begin{pmatrix} S_{cd11} & S_{cd12} \\ S_{cd21} & S_{cd22} \end{pmatrix} & \begin{bmatrix} S_{cc11} & S_{cc12} \\ S_{cc21} & S_{cc22} \end{bmatrix} \end{matrix} \right\} \begin{bmatrix} a_{d1} \\ a_{d2} \\ a_{c1} \\ a_{c2} \end{bmatrix} \quad (16)$$

where:

S_{dd} = the differential S-parameters,

S_{cc} = the common-mode S-parameters,

S_{dc} = the mode conversion that occurs when the device is excited with the common-mode signal and the differential signal is measured, and

S_{cd} = the mode conversion that occurs when the device is excited with a differential-mode signal and the common-mode response is measured.

This mode conversion is unavoidable because (whether intentionally or not) there is a common ground to the entire circuit or there is device mismatch and imbalance.

To make a conversion from single-ended S-parameters to mixed-mode S-parameters, an assumption is made that the DUT is being fed from differential input lines and that Z_{oe} = Z_{oo}} = Z_0. The assumption of differential input lines is not limiting, as one can define the length of the lines to be arbitrarily small. The assumption of $Z_{oe} = Z_{oo} = Z_0$ implies that the differential input lines are not coupled. This is also a valid assumption as the lines of the VNA are coaxial and not coupled.

Taking the definitions of ν_d, ν_c, i_d, and i_c from Eqs. 5 through 8 and plugging them into Eqs. 9 through 12, and taking Z_d to be $2Z_0$ (from Eq. 13), yields the following equations:

$$a_{d1} = \frac{a_1 - a_2}{\sqrt{2}} \quad a_{c1} = \frac{a_1 + a_2}{\sqrt{2}} \quad (17)$$

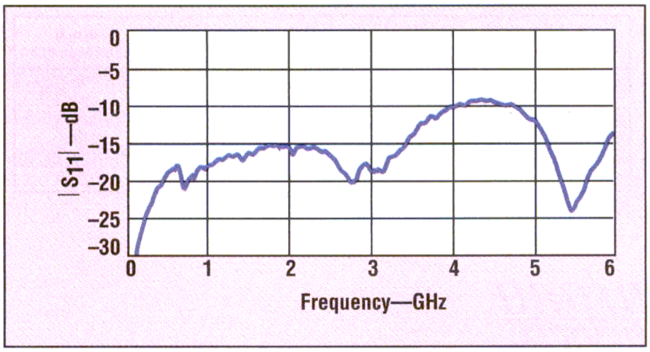
$$b_{d1} = \frac{b_1 - b_2}{\sqrt{2}} \quad b_{c1} = \frac{b_1 + b_2}{\sqrt{2}} \quad (18)$$

$$a_{d2} = \frac{a_3 - a_4}{\sqrt{2}} \quad a_{c2} = \frac{a_3 + a_4}{\sqrt{2}} \quad (19)$$

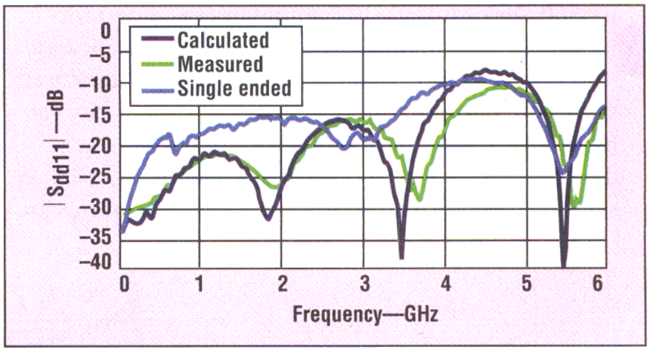
$$b_{d2} = \frac{b_3 - b_4}{\sqrt{2}} \quad b_{c2} = \frac{b_3 + b_4}{\sqrt{2}} \quad (20)$$

A convenient matrix representation of Eqs. 17 through 20 is:

$$\begin{bmatrix} a_{d1} \\ a_{d2} \\ a_{c1} \\ a_{c2} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} \quad (21)$$



7. The single-ended S_{11} response of the 10-Gb/s deserializer was measured with a commercial VNA.



8. The differential S_{11} response of the 10-Gb/s deserializer was measured with a commercial VNA.

$$\begin{bmatrix} b_{d1} \\ b_{d2} \\ b_{c1} \\ b_{c2} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix} \quad (22)$$

More compactly, it can be represented as:

$$a^{mm} = Ma^{std} \quad b^{mm} = Mb^{std} \quad (23)$$

In Eq. 23, the superscript "mm" represents mixed mode and "std" represents the standard parameters and "M" is provided by:

$$M = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \quad (24)$$

Applying the conversion from a^{std} and b^{std} to a^{mm} and b^{mm} provided in Eq. 23) to the definition for single-ended S-parameters shown in Eq. 2 yields:

$$S^{mm} = MS^{std} M^{-1} \quad (25)$$

It is important to follow the port-numbers scheme provided in Fig. 3. If the four ports are not numbered in this fashion, then Eq. 24 for "M" will not be correct. It must be arranged in order for Eq. 25 to work.[4]

To demonstrate this technique, the return loss of the model MAX3950 10-Gb/s deserializer from Maxim Integrated Products (Sunnyvale, CA) was measured using a model 8753D VNA from Agilent Technologies (Santa Rosa, CA). Since this network analyzer only operates to 6 GHz, only these data are presented. The measurement test setup is provided in Fig. 6.

To obtain the measured data, standard short-open-load-through (SOLT) calibration was performed using the model 85033D 3.5-mm calibration kit from Agilent Technologies. The calibration moves the measurement reference plane to the end of the cables (Fig. 6). Since no calibration kit was built to measure the device on its circuit board, all S-parameters presented include the effects of the transmission line and SMA connectors to get from the VNA to the MAX3950. As a result, the actual return loss of the device will be better than that which is presented here. As a comparison, the single-ended return loss is presented in Fig. 7.

To obtain a true differential return loss, apply Eq. 25 to the measured data. This result is given in Fig. 8. To validate the conversion, the differential return loss of the MAX3950 on the MAX3950 EV kit was measured using the ATN-4000 series differential network-analyzer system from ATN Microwave (North Billerica, MA). The results of the differential network analyzer are also presented in Fig. 8.

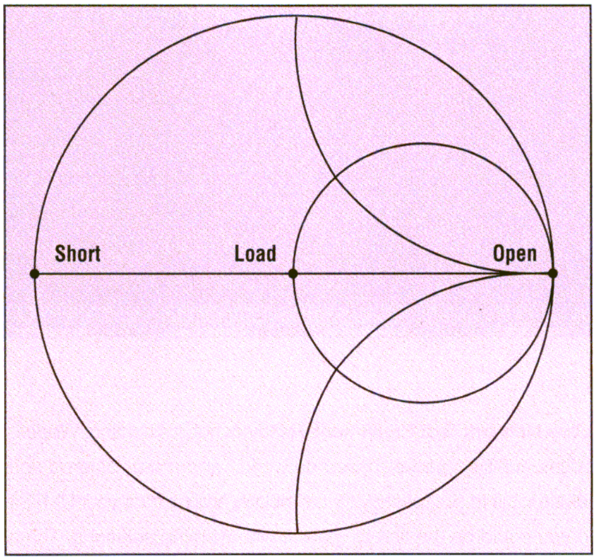
The actual differential return loss is different than the single-ended return loss. Since the DUT is a differential part, the most accurate way to characterize the part is through the use of differential return loss.

The choice of calibration standards depends on the measurement setup. Some possible calibration standards are the SOLT standards provided in the 3.5-mm calibration kit with a VNA or an impedance-standard substrate (ISS) [i.e., as provided by Cascade Microtech (Hillsdale, OR) with their wafer probes] when making on-wafer probe-station measurements. Another option is to define a custom set of standards using a SOLT, through-reflect-line (TRL), line-reflect-match (LRM), or other calibration method.

In a typical VNA measurement system, cables connect the VNA to the DUT (through SMA connectors; a wafer-probe station; or other types of connectors, such as K connectors). The cable and connector combination has a significant effect on the measured data, since it adds its own insertion loss, return loss, and other electrical characteristics to the test system. Without a calibration, the electrical effects of the cables and connectors are added to the responses of the DUT. To remove the cable and connector effects, a calibration is needed.

With a calibration (for example SOLT), one is defining a position on the Smith Chart. The open defines the right edge of the Smith Chart, the short defines the left edge of the Smith Chart, and the load defines the center of the Smith Chart (Fig. 9). The through standard identifies the delay and loss introduced by the cables and connectors.

Parameters S_{11} and S_{22} can be thought of as light reflected by a lens, while parameters S_{21} and S_{12} can be thought of as light transmitted through a lens. A good calibration can be compared with cleaning a camera lens before taking a photograph. Next month, Part 2 of this article series will continue with a closer look at mixed-mode S-parameters. ●●



9. The Smith Chart is a graphical device that is useful for plotting the impedance and admittance of a DUT. This plot shows the locations of three calibration standards relative to 50 Ω at the center.

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3. R.D. Middlebrook, *Differential Amplifiers*, Wiley, New York, 1963.
4. D.E. Bockelman, Ph.D. dissertation, University of Florida, Gainesville, FL, 1997.

Site Reveals Design Of Sigma-Delta Synthesizer

Visitors to this site will find an excellent 130-page tutorial article on the design of a frequency-discriminator-based synthesizer.

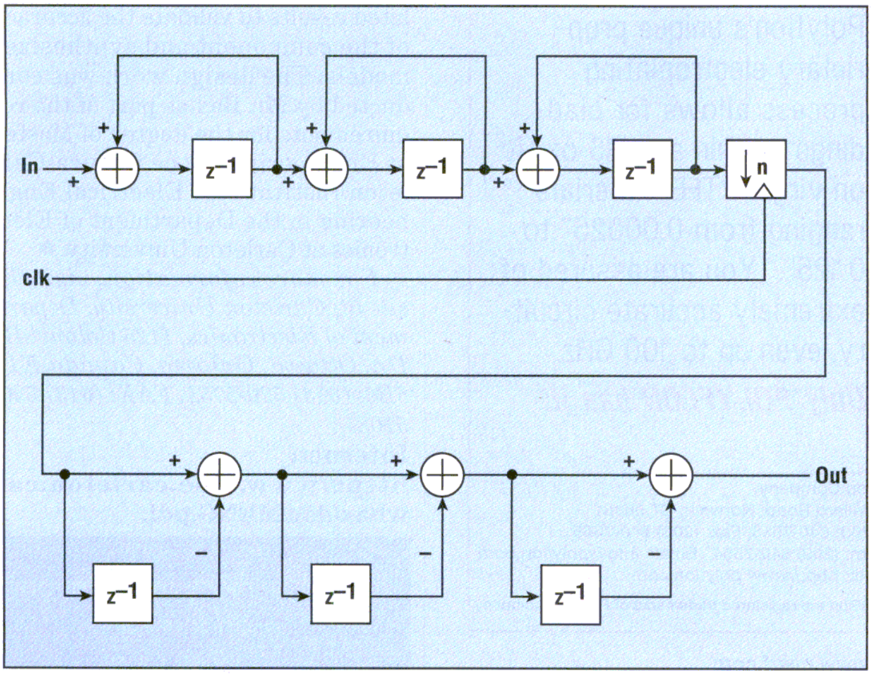
ALAN ("PETE") CONRAD
Special Projects Editor

Frequency synthesizer design offers many challenges due to its complexity. Fortunately, a website sponsored by the Department of Electronics of Carleton University (Ottawa, Ontario, Canada) contains an excellent tutorial article on the design of a frequency-discriminator-based frequency synthesizer. The article also happens to be the Master of Engineering thesis submitted to the University by Walter T. Bax and made available on the school's website at www. doe.carleton.ca/~wbax/doc/MENG.pdf.

The synthesizer design is well-suited for digital mobile radio applications. In fact, the article notes that with the growing use of digital modulation in modern communications systems, digital frequency synthesizers support better channel utilization and noise suppression than analog signal-generation techniques.

The architecture has several advantages over conventional high-resolution fractional-N synthesizers currently used in communications products. The design is based on an oversampled sigma-delta (sum-difference) frequency discriminator that directly converts frequencies from a voltage-controlled oscillator (VCO) to digital form. Additional signal processing can then be performed digitally to eliminate many of the analog noise sources present in conventional fractional-N frequency synthesizers. By processing signals in the digital domain, for example, near-ideal finite-impulse-response (FIR) digital filters can be used to remove unwanted signal artifacts without adding the group-delay distortion associated with analog bandpass filter designs.

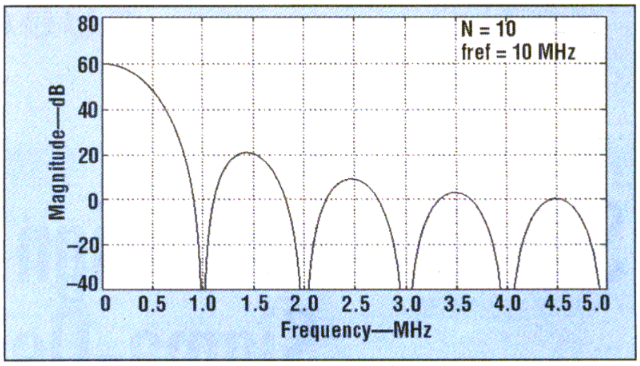
In creating the frequency synthesizer, simulation models were developed to explore the effects of various parameters on the synthesizer phase noise and transient response. A discrete version of the synthesizer was then realized, and experimental testing was used to validate the accuracy of the simulation models. Measured results show that the performance of this frequency-synthesizer architecture rivals that of conventional fractional-N synthesizers while being more suitable for implementation as a very-large-scale-integration



1. This block diagram shows the third-order comb filter designed for the sigma-delta frequency synthesizer.

(VLSI) circuit.

The article found on the Carleton University Web Site contains a total of 72 figures with design information and test results. For example, *Fig. 1* shows a block diagram of the third-order comb filter used in the design of the synthesizer, while *Fig. 2* displays the frequency response of the same comb filter. The two figures are typical of complementary pairs of block diagrams and analysis plots of the circuits involved in synthesizer design. •



2. The frequency response of the third-order comb filter was plotted for a reference frequency of 10 MHz and an integer N value of 10.

The article/thesis provides an overview of different frequency-synthesis techniques, comparing the suitability of each type for implementation in VLSI circuitry in digital radio applications. It also provides full details on the development of frequency-domain and time-domain models for the sigma-delta synthesizer. These models in conjunction with the frequency synthesizer performance parameters are used to explore the effects the parameters have on frequency stability, transient response, and synthesizer phase noise.

The article provides detailed design considerations for realizing the synthesizer, clearly identifying the key parameters needed to define different performance levels. The literature includes experimental results that compare analytical and simulated results to validate the accuracy of the component and synthesizer models. The design work was conducted by Mr. Bax as part of the requirements for the degree of Master of Engineering at the Ottawa-Carleton Institute for Electrical Engineering in the Department of Electronics at Carleton University. •

For more information, visit the site at: Carleton University, Department of Electronics, 1125 Colonel By Dr., Ottawa, Ontario, Canada K1S 5B6; (613) 520-5754, FAX: (613) 520-5708.

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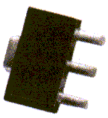

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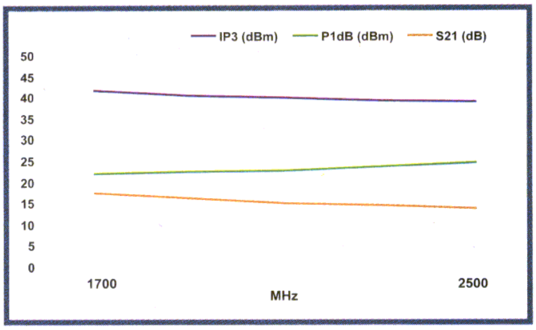

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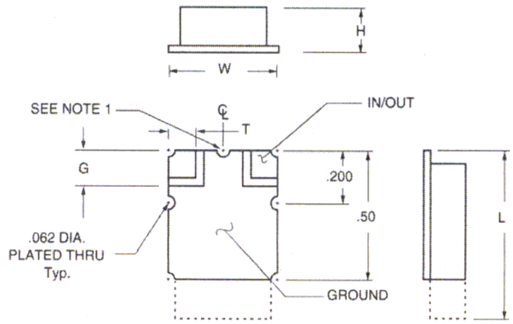

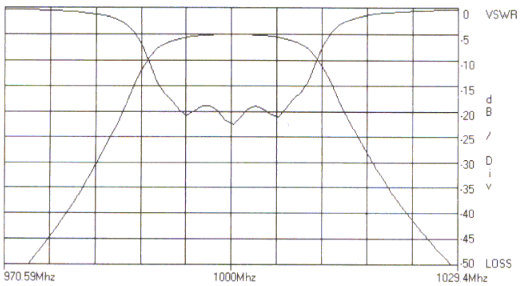

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Website Surveys MathCAD Applications

Fans of the popular mathematical processing program MathCAD will find more than 200 application files on this bountiful British site.

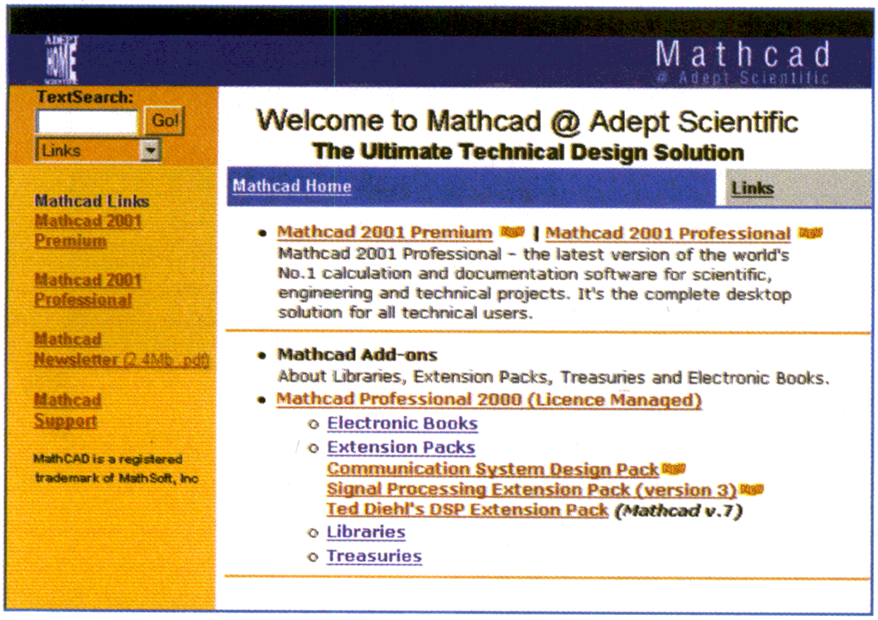
ALAN ("PETE") CONRAD
Special Projects Editor

MATHEMATICS can solve many engineering problems. But rather than working out problems on paper, many engineers over the years have turned to the powerful MathCAD software program for quick answers. The popular program from Mathsoft Engineering and Education, Inc. (Cambridge, MA) can be used for everything from antenna design to waveguide analysis. And recently, many ready-to-use application files have been developed by a variety of sources for use with Mathcad. Just by visiting the British website of Mathcad @ Adept Scientific, at www.mathcad.adaptscience.co.uk, MathCAD users can add more than 200 of these "plug-in" application files to their collections.

MathCAD, of course, is a personal-computer (PC) based software program that simplifies the visualization and calculation of complex equations and functions. The software uses a patented technology to combine rich and interactive content with powerful tools for learning, communicating, and applying mathematics in real-world technical applications. The application files span numerous versions of MathCAD, although the older versions of these files will seamlessly integrate with newer versions. Full descriptions of each application file are provided on the Mathcad @ Adept Scientific site *(see figure)*, along with file sizes.

Applications at the site include astronomy, chemical engineering, chemistry, electrical engineering, industrial engineering, mathematics, navigation, operations research, and physics. Mathematics and statistics files include electromagnetic (EM) scattering of a plane wave by a conducting sphere; two-dimensional (2D) scattering of a plane wave by an infinite, perfect electrical conducting wedge; elliptical integrals; and fractional-order Bessel functions. Other topics include random binary trees through the Galton-Watson branching process, Gauss-Newton nonlinear regression, and Hofstadter's sequence.

Electrical engineering topics include Fourier analysis of amplitude modulation (AM), neural networks, design parameter calculation for an operational amplifier, as well as the analysis of noise from tape recorders.



The MathCAD @ Adept Science site at www.mathcad.adeptscience.co.uk provides hundreds of ready-made applications files for use with the MathCAD mathematics program.

Other files include calculation and Bode plots of transfer functions, the reconstruction of an object from its projections, and plotting the time response directly from a Laplace transfer function, using inverse Fast Fourier transforms (FFTs).

Astronomy and navigation files include calculations for the orbits of Jupiter's moons, equatorial to horizon transformation, cosmological look-back time, and the calculation of times of solstices and equinoxes. Physics files include propagation of a Gaussian beam through two lenses using the FFT transform for data reduction in thermal diffusivity measurement, determination of the thickness and refractive index of non-absorbing films using null-ellipsometry, background subtraction in X-ray photoelectron spectroscopy, and thermal lens effects in diode-pumped laser crystals.

Chemistry and chemical engineering files include calculations of vapor pressure and boiling points from gas laws, calculation of flame temperatures, and simulation of chemical reactions by randomly selecting pairs of molecules. Industrial engineering and operations research topics include modeling drift in a gene pool, analyzing water-pumping test data from unconfined aquifers, finite-difference representation of the advection-dispersion equation, and a numerical solution for the advection-dispersion equation with a tridiagonal matrix.

Civil and mechanical engineering topics include wind loads using American Society of Civil Engineers (ASCE) Standard 7-95, solid and hollow shafts in torsion, elastic bending in a beam, and the design of a staircase. Business and economics files include annual percentage rate, net present value of an investment, home mortgage calculations, and Black-Scholes option pricing.

Technical support files include 2D spline interpolation, X-Y plotting, surface, contour and parametric plots, decimal to binary number conversion, data exchange between MathCAD and Excel, and examples of using FFTs. Other topics include least squares fitting, polynomial fitting, linear and spline interpolation, linear-regression analysis, and bidirectional conversion between matrices and arrays.

MathCAD users number over 1 million worldwide, with wide-ranging interests. Mathsoft' own website at www.mathcad.com features an additional 350 application files for download, includng files for chemistry, chemical engineering, civil engineering, electrical engineering, and physics. Files in the electrical-engineering section cover the Fourier analysis of amplitude modulation, yagi antenna design equations, design-parameter calculations for an opamp, and analysis of a small-signal, common-emitter RF amplifier. ●

For more information on MathCAD @ Adept Scientific, visit the website at **www.mathcad.adaptscience.co.uk.**

Website Hosts EMC Application Notes

Visitors to this test-oriented site will find information about and applications for high-power amplifiers operating from DC to 40 GHz at power levels to 50 kW.

ALAN ("PETE") CONRAD
Special Projects Editor

Amplifiers are widely used in electromagnetic-compatibility (EMC) testing, and Amplifier Research (Souderton, PA) has long been a leader in supplying high-performance amplifiers for EMC testing and other applications. The firm supports its product lines with a well-populated website at www.ar-amps.com, complete with specifications, technical articles, and application notes.

The firm manufactures a wide range of power amplifiers (PAs), from moderately powered solid-state units to massive tube-powered behemoths. The website lists brochures and data sheets for broadband amplifiers operating from 1 to 2000 MHz at power levels up to 2 kW, as well as amplifiers operating from DC to 1 GHz at power levels as high as 50 kW. The company also produces amplifiers with power levels from 400 W to 10 kW at frequencies from 10 kHz to 400 MHz, transient generators, and matched antennas.

The website (*see figure*) also boasts numerous application notes on EMC testing. The application notes include amplifier and antenna combinations for measurements at field-strength levels of 20, 100, and 200 V/m at frequencies from 10 kHz to 1 GHz. The test equipment features setups for generating fields inside a transverse-electromagnetic (TEM) cell, as well as in a shielded chamber at a distance of 1 m from either an electric-field generator or a calibrated antenna operating from 10 kHz to 1 GHz.

Application notes provide equipment selection criteria for International Electromechanical Commission (IEC) IEC 801-3 and IEC 1000-4-3 testing. This testing is particularly relevant for products that are sold in Europe since the EMC directive adopted by the European Union (EU) requires that, for the first time, manufacturers test their product for intrinsic EM immunity.

The site features a conducted immunity testing overview that reviews the concept of EM immunity testing through injecting current into the input and output cables of a system under test. The document for these measurements is the IEC 1000-4-6 specification titled "Immunity to Conducted Disturbances Induced By Radio-Frequency Fields."

An additional application note addresses the use of RF PAs in applications characterized by mismatched loads (see p. 111). The effects of variations in VSWR on immunity testing are covered in the note, and the concept of minimum available power (MAP) is introduced as a quantitative measure of an amplifier's capability to supply power into a poor load VSWR. ●

For more information, contact: Amplifier Research, 160 Schoolhouse Rd., Souderton, PA 18964; (800) 933-8181, (215) 723-8181, FAX: (215) 723-5688.
Internet: http://www.ar-amps.com.

The Amplifier Research website at http://www.ar-amps.com offers a wide range of application notes on high-power amplifiers and EMC testing.

Site Offers Comprehensive IC Information

Visitors to the information warehouse at www.maxim-ic.com can find ICs for commercial and military use, as well as application notes and tutorial articles.

ALAN ("PETE") CONRAD
Special Projects Editor

High-frequency designs often consist of analog, digital, and even fiber-optic components. Rather than search across the wide expanse of the Internet for these parts, engineers can find information on all three types at the website hosted by Maxim Integrated Products (Sunnyvale, CA) at www.maxim-ic.com. The site features 15 different product categories, including amplifiers, analog-to-digital converters (ADCs), components for wireless and video circuits, digital-to-analog converters (DACs), fiber-optic components, filters, and sampling circuits.

Each product category on the Maxim website *(see figure)* expands to a related product tree and parametric search page. Most of these pages contain links to specific design guides and application notes, available as PDF files. For example, the parametric search pages for ADCs contain access to a 494-kb PDF-format ADC design guide; a 1446-kb PDF-format, high-speed ADC and DAC design guide; and links to 12 additional application notes.

The analog filter product tree and parametric page offers a choice of anti-aliasing and post-DAC filters with operating frequencies to 300 kHz. The page includes a 136-kb PDF-format analog filter-design guide, as well as links to nine additional application notes and 20 tutorial articles.

The fiber-optic and cable-communications product tree and parametric search page directs visitors to a variety of components for network hubs and bridges, as well as telecommunications switches for private-branch-exchange (PBX) and central-switching offices. Additional components are suitable for bridges and routers, transport nodes, access nodes, add-drop multiplexers, and digital cross connects. This section of the website includes links for 20 fiber-optic application notes, as well as a 726-kb-long PDF-format fiber-optic design guide.

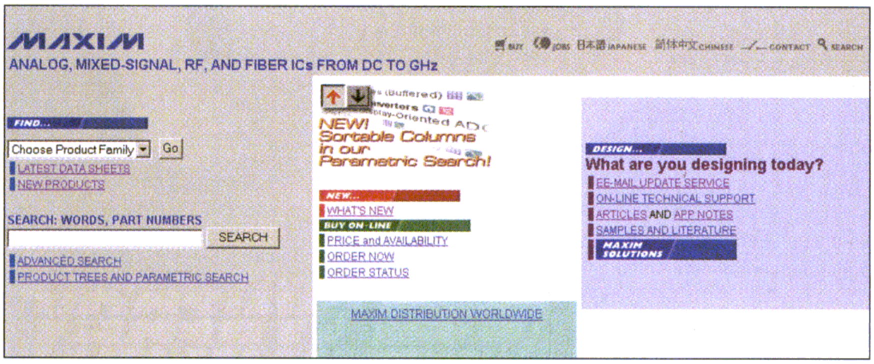
The design and application product tree branch includes links to design guides, technical articles, tutorial articles, application notes by part number, and application notes by category. A total of 29 component application categories covers everything from analog modems and automotive sensors to high-frequency application-specific integrated circuits (ASICs) and cable modems.

Application notes by category include ADC and DAC converters and sampling circuits, amplifier circuits, analog filter circuits, battery-charger and bias-supply circuits, and protection circuits. Other categories include fiber optics, wireless circuits, signal generation, and video circuits.

The site currently lists more than 2694 choices when searching through total applications, although searches can be simplified by the proper choice of keyword or words. ●

For more information, contact Maxim Integrated Products, Inc., 120 San Gabriel Dr., Sunnyvale, CA 94086; (800) 998-8800, (408) 737-7600, FAX: (408) 737-7194.

Internet: http://www.maxim-ic.com.



The Maxim Integrated Products website at http://www.maxim-ic.com features a selection of design guides and application notes for analog, digital, and fiber-optic ICs.

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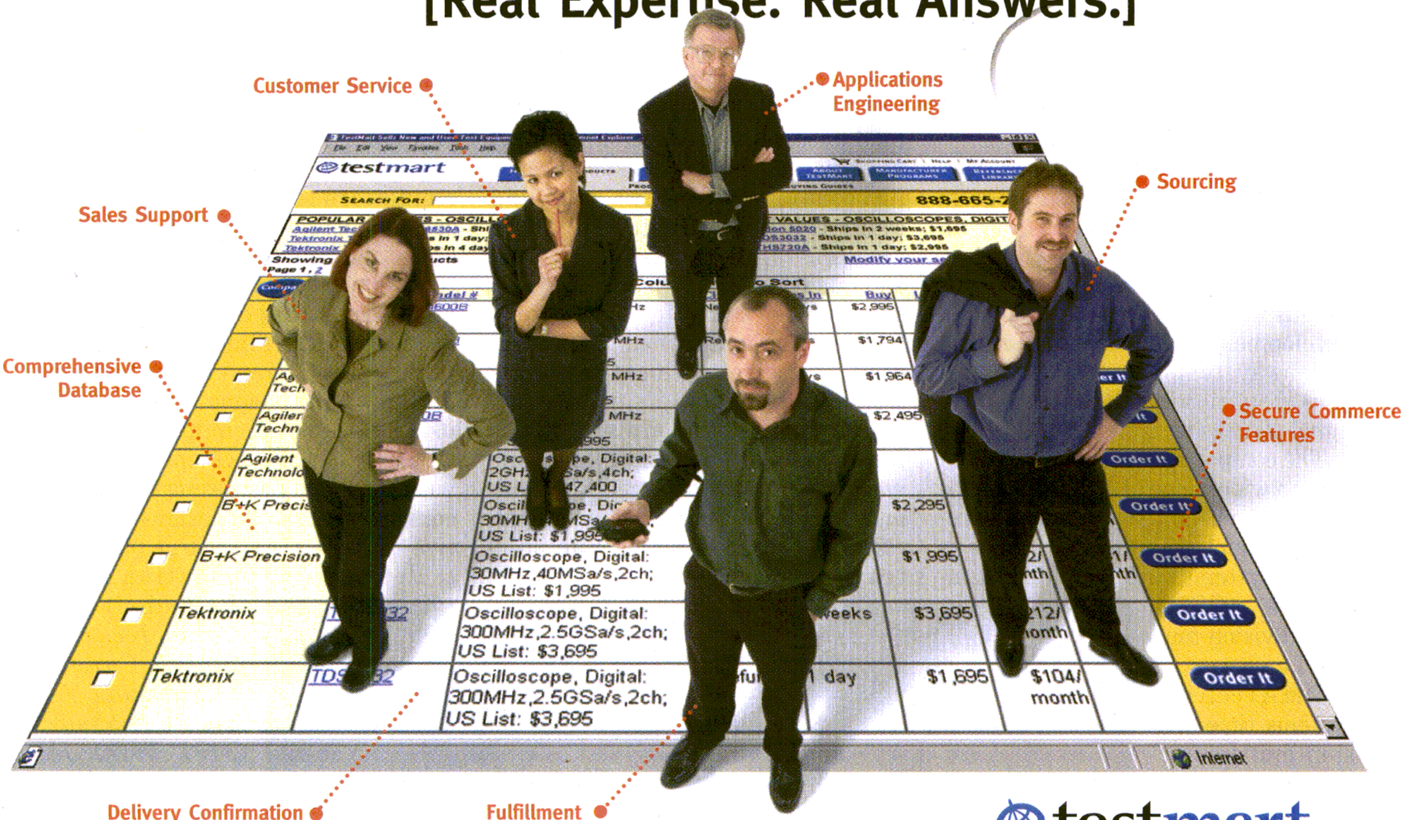

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Site Hosts System-Design Applications And Examples

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ALAN ("PETE") CONRAD

Special Projects Editor

System designers have special software needs. For them, a software tool, such as SystemView from Elanix (Westlake Village, CA) provides the high-level analysis and synthesis needed to create and optimize systems for commercial and military applications. The firm's website at www.elanix.com provides generous support of the software tool through a wide range of design examples and application notes.

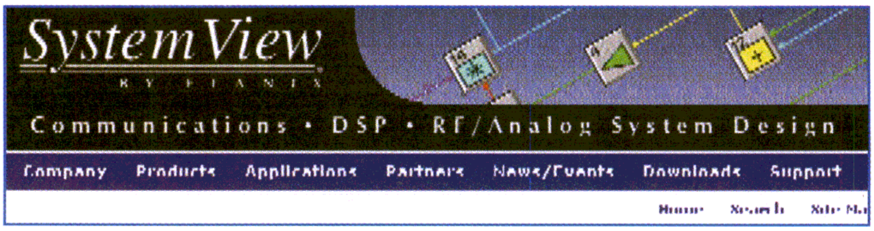
SystemView is a Windows-based design, simulation, and analysis program for advanced communications, digital-signal-processing (DSP), RF, digital, and analog system designs. The software is well-suited for the design and development of end-to-end communications systems, bit-true DSP systems, distortion-true RF systems, and signal-processing systems.

The company's website *(see figure)* offers a wide range of design examples that can be used to model most wireless communications systems, such as Global Systems for Mobile Communications (GSM), code-division-multiple-access (CDMA) cellular systems, time-division-multiple-access (TDMA) cellular systems, high-speed modems, and systems using quadrature-phase-shift-keying (QPSK) modulation, quadrature amplitude modulation (QAM), and frequency-shift-keying (FSK) modulation.

The website also features examples on signal-processing systems, communications systems, and control systems, including analog, digital, and mixed-mode systems. Examples include phase-locked loops (PLLs), frequency-locked loops, modulation, demodulation, channel models, DSP systems, analog-to-digital converters (ADCs), sampling systems including delta-sigma data converters, as well as in-phase (I) and quadrature (Q) systems. Sample categories include Bluetooth, CDMA, communications, digital radios, and wireless local-area networks (WLANs).

The example section also provides information on simulating a feedforward amplifier that cancels second- and third-order output distortion, calculation of cascaded noise figure, spectrum analysis using digital Fast Fourier transform (FFT) techniques, as well as a comparison of two direct-sequence, spread-spectrum (DSSS) systems where the first system uses QPSK for a WLAN and the second system uses two separate carriers with a transmitted reference signal.

Modeling and circuit application notes include baseband simulation of communications systems, baseband pulse shaping for improved spectral efficiency, a methodology for combining system-level and circuit-level simulators to examine trade-offs, second-order effects for wireless designs, and Bluetooth system simulation. Application notes also highlight an interpolating delay line, a GSM receiver (Rx) simulation, QPSK transmitter (Tx) and Rx system simulations with baseband processing using real-world components, and QPSK Tx and Rx system simulation with baseband processing using ideal components and the design of a resistive-capacitve (RC) charge pump. ●



The Elanix website at www.elanix.com features a wide range of design examples and application notes in support of its popular system-level simulation program, SystemView.

For more information, visit the website at: *Elanix, Inc., 5655 Lindero Canyon Rd., Westlake Village, CA 91362; (818) 597-1414, FAX: (818) 597-1427.* **Internet: http://www.elanix.com.**

Since its inception 21 years ago, Metelics has supplied microwave diodes for a vast array of commercial, military, and high-reliability applications. Today, Metelics is in the forefront of technology, with diodes that ride on commercial telecommunications satellites, the space shuttle, and a wide range of fixed and mobile wireless systems and test applications.

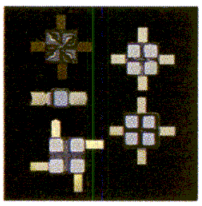
Schottky Diodes

Metelics manufactures a broad range of Schottky diodes for RF and microwave mixers, sampling bridges, limiters, and fast switches.

High-reliability devices can be provided up through S-level. These devices feature

low Rd, very low capacitances, high uniformity, and are 100% tested and visually inspected. Diodes are available in rings, bridges, series T, antiparallel pairs, and singles. Surface mount packages are available in SOT 23, 0805, and epoxy-coated lead packages. Ceramic packages also available.

Pin Diode Chips and Beam Leads for Switch and Attenuator Applications



Metelics provides a wide selection of PIN diodes, SRDs, and varactors in chip, beam lead, and packaged configurations for RF and microwave requirements. Products range from very low-capacitance, high-speed switch devices to long-lifetime, high-power switch and attenuator types.

SRD (Step Recovery Diodes) and Tuning Varactors

Compared to packaged or chip devices, Metelics' silicon mesa beam lead step recovery diodes provide low-capacitance, very fast transition times, and low inductance, along with low parasitic capacitance. Tuning varactors are available from .5 to 20 pF (Cj4) in chips or packages.

RF/Microwave Components and Subassemblies

Metelics' years of experience in microwave diode beam lead and chip assembly are reflected in our enhanced performance, lower cost, and highly reliable state-of-the-art assemblies. Metelics' multi-device components include:

- switches
- detectors: Schottky, tunnel
- limiters
- sampling phase detectors
- tunnel diodes
- drop-in, bolt-down microstrip designs

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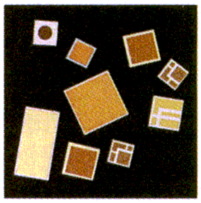
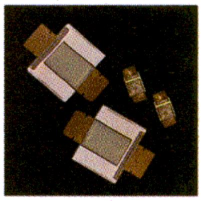
Capacitors



MIS (Metal-Insulating Layer-Silicon) chip capacitors have very high Q and small size for use in microwave hybrid circuit applications. Large bonding pads are supplied on most chips; the contact periphery is typically 2 mils from the edge, allowing wire or ribbon bonding near the edge for the lowest practical inductance. Beam lead MIS caps are also available.



Metelics' capacitors provide better performance than other types of ceramic capacitors, with low loss in supply decoupling circuits and GaAs FET transistor source bypass (providing more gain per stage). They can also be used as tuning elements in filters and matching networks.

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Use junction temperature to figure MMIC reliability

Reliability predictions for all semiconductors depend on how much power is dissipated in the device and how much the heat generated raises its junction temperature. To calculate junction temperature (T_J), a designer must know the ambient temperature, the power dissipation, and the device's thermal resistance from its junction to case (θ_{JC}). Knowing T_J enables a field effect transistor's (FET's) maximum channel temperature to be determined, which should not be exceeded to permit reliable operation and long life of the device. Ambient temperature and power can be measured, but thermal resistance must be supplied by the manufacturer since it is a function of a monolithic microwave integrated circuit's (MMIC's) material, size, spacing between the chip's gates, and other factors.

A one-page application note from Alpha Industries entitled "MMIC Thermal Resistance" is mistitled but useful for providing the theory and equations to calculate the T_J of gallium-arsenide (GaAs) FETs used in MMICs. The reason that the note is mistitled is because it uses what is known as Cooke's method for calculating thermal resistance, but only refers to its derivation in a footnote. The note's main purpose is to show designers how to make rough and precise calculations of T_J. Alpha publishes θ_{JC} values for all of its microwave and millimeter-wave MMICs on its data sheets based on Cooke's method, and these are used to determine T_J. According to the note, they have been found to correlate within 10°C of the maximum channel temperature.

Purists who wish to dig a little deeper into the details of a FET's thermal resistance can find Harry F. Cooke's original article entitled "Precise Technique Finds FET Thermal Resistance" in the August 1986 issue of *Microwaves & RF*, p. 85. An interesting aspect of the theory is that it treats heat flow in a multigate FET as analogous to the capacitances of multiple, coupled transmission lines. A copy of the note can be downloaded from the company's website. **Alpha Industries, Inc., 20 Sylvan Rd., Woburn, MA 01801; (781) 935-5150, FAX: (617) 824-4579, e-mail: sales@alphaind.com, Internet: http://www.alphaind.com.**

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What is all this FBAR technology about?

Approximately a year-and-a-half ago, Agilent Technologies (Santa Clara, CA) introduced film-bulk-acoustic-resonator (FBAR) technology which is similar to, but with major differences from, another acoustic technology—surface acoustic wave (SAW). To provide designers with the basic facts of FBAR, the company recently published a six-page application note entitled "A Brief Overview of FBAR Technology." FBAR has important applications in wireless communications, such as filters, duplexers, and resonators for oscillators. Indeed, the company's first product will be a duplexer intended for wireless handsets that use the personal-communications-services (PCS) code-division-multiple-access (CDMA) air-interface standard.

As the note's name implies, it begins simply with an explanation of each term that makes up the acronym FBAR. In the following section entitled "Performance," the note compares FBAR with the technologies that it hopes to replace—SAW and ceramic resonators. With respect to ceramic devices, FBAR elements are many times smaller. For example, in the aforementioned PCS duplexer, a ceramic type would measure 675 mm^3, while the FBAR equivalent is only 98 mm^3. The note predicts it will be even smaller, only 46 mm^3, once the process is perfected. Obviously, reducing component dimensions has major implications on the cost and size of a handset.

One area where the ceramic devices have an edge on FBAR is in performance, but FBAR is coming on quickly and with its significant size and volume advantage over ceramic, it is capable of eventually replacing it. Compared with a SAW duplexer, FBAR offers size and performance advantages. A clear win for FBAR over ceramic and SAW technology is its compatibility with silicon (Si) and gallium-arsenide (GaAs) processing. The note projects that this ability will lead to integrated solutions that provide active elements and filtering on a single chip.

A copy of the note can be downloaded from the company's website. **Agilent Technologies, Inc., Semiconductor Products Group, 3175 Bowers Ave., Santa Clara, CA 95054; Internet: http://ftp.agilent.com/pub/semiconductor/morpheus/docs/FBARoverview.pdf.**

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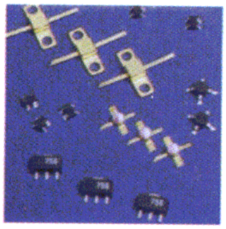


Packaged PHEMTs for Superior Linearity

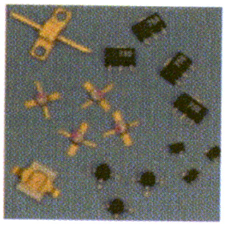
Model	N.F.	Gain	P1 dB	IP3
LP750SOT89	0.7 dB	14 dB	25 dBm	40 dBm
LP1500SOT89	0.8 dB	16 dB	28 dBm	42 dBm
LP3000SOT89	1.0 dB	15 dB	30 dBm	44 dBm

*with optimum IP3 biasing, associated gain @1.8 GHz

FET Chips for Low Noise Amplifier Applications

Model	IDSS	Gain	N.F.
LPD200	60 mA	14 dB	1.1 dB
LP7512	35 mA	9.5 dB	0.7 dB

*optimized for noise



FET Chips for Medium Power Amplifier Applications

Model	P1 dB	Gain	PAE
LP6836	25 dBm	12 dB	55%
LP750	28 dBm	12 dB	55%
LP1500	31.5 dBm	10 dB	50%

*associated gain @ 1 dB compression

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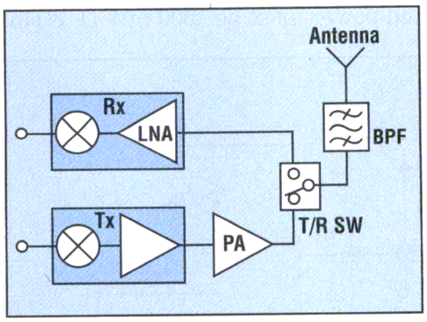
Linear Amplifier Powers 2.4-GHz WLAN Applications

This robust yet low-cost chip-scale amplifier IC provides the high linearity and good spectral purity needed to maintain low error rates in WLAN systems.

Frank Li
Senior Scientist
Walter Lau
Business Manager
Wireless Data Products, Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: http://www.maxim-ic.com.

WIRELESS local-area networks (WLANs) offer a flexible alternative to conventional wired LANs. But to promote the acceptance of WLANs among users comfortable with more traditional networks, low-cost, high-performance components are needed. The MAX2242 linear power-amplifier (PA) integrated circuit (IC) from Maxim Integrated Products (Sunnyvale, CA) is this type of component. With +22.5-dBm output power at 2.4 GHz, the amplifier provides the linear performance needed to maintain good spectral purity in and out of band.

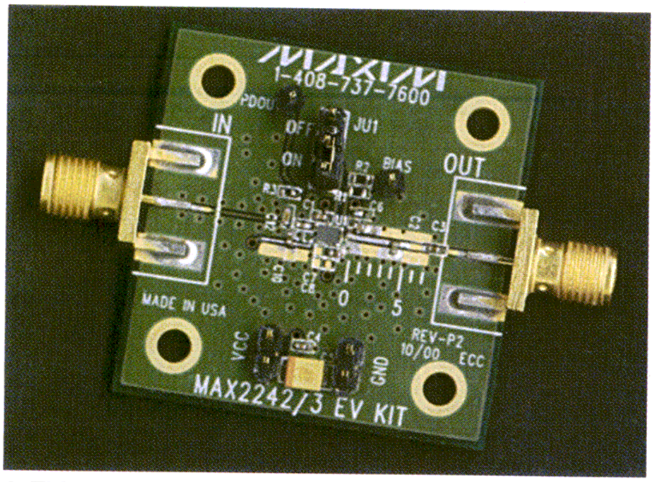
WLANs have come a long way in the past three years since the IEEE 802.11 standard was officially adopted in 1997. Since then, WLAN data rates have risen from 1 to 2 Mb/s to the current standard (for IEEE 802.11b) of 11 Mb/s at 2.4 GHz. In the near future, this speed will increase to 22 Mb/s at 2.4 GHz and 54 Mb/s at 5.0 GHz (for IEEE 802.11a). Meanwhile, the price of a 2.4-GHz 802.11 WLAN personal-computer (PC) card has dropped from the initially high $600 to $800 range to the current price of $129, available from suppliers on the Internet. With multiple vendors offering Wi-Fi-certified (802.11b-compliant) WLAN cards and interoperability established among these vendors, the price of a WLAN card is projected to drop below $100 by the end of 2001, heading towards $50 in the not-too-distant future.



1. This front-end architecture is typical of those used in DSSS WLAN communications systems.

The WLAN market is forecast by several market-research firms to exceed $2 billion in annual revenues by the year 2003. These forecasts will likely be revised upward, as the performance and flexibility of WLAN systems are embraced for offices, homes, and public places, such as airports, hotels, and convention centers. Home networking is expected to play a major role in driving the demand for WLAN cards. Simultaneously sharing a broadband Internet connection via a cable modem or a digital subscriber line (DSL), printing to a common printer, and sharing files among family members are truly compelling applications for an in-home WLAN.

As WLAN applications continue to expand into portable devices, the pressure increases on equipment manufacturers to make WLAN radios that are more compact and less expensive. Next-generation WLAN radios will have to fit on a printed-circuit board (PCB) the size of a compact flash-memory card, approximately 1.7 × 1.4 in. (4.32 × 3.56 cm). This small size makes it possible to integrate WLAN functionality in portable devices such as personal digital assistants



2. This evaluation board was designed and tested for use with the MAX2242 WLAN PA IC.

Bias current control through the DAC

Linear output power (dBm)	I_{idle} (mA)	I_{DC} (mA)
+22	279	303
+20	180	213
+18	134	165
+16	94	128
+14	81	105
+12	61	83
+10	41	63
+6	21	40
0	18	27

(PDAs), digital cameras, MP3 players, webpads, and Internet Protocol (IP) cordless telephones.

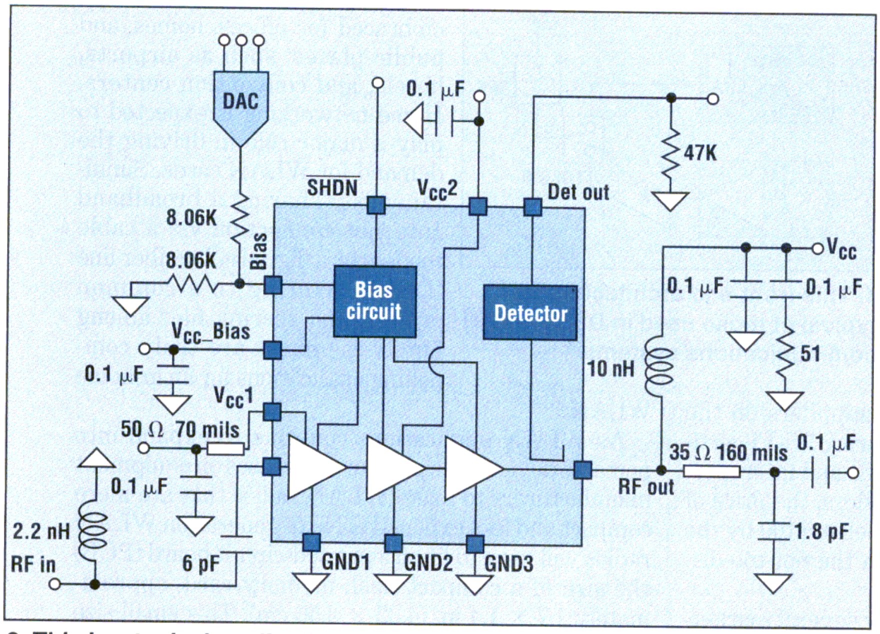
Two major WLAN technologies are currently used in the 2.4-GHz industrial-scientific-medical (ISM) band: direct sequence, spread spectrum (DSSS) and frequency hopping, spread spectrum (FHSS) techniques. To ensure high security and good rejection of interference, DSSS radios generate a redundant bit pattern for each bit to be transmitted. This bit pattern is called a chip (or chipping code). The longer the chip is, the greater the probability is that the original data can be recovered, but at the cost of requiring more bandwidth. FHSS radios use a narrowband carrier that changes frequency or hops in a pattern that is known to the transmitter (Tx) as well as the receiver (Rx).

The widespread acceptance of WLANs depends on industry standardization to ensure product compatibility and reliability among the various manufacturers. The IEEE recently ratified the 802.11b standard (also known as 802.11 high rate) which extends the raw data rate to 11 Mb/s using the 2.4-GHz DSSS system. According to the 802.11b standard and Federal Communications Commission (FCC) rules, the maximum transmitted power must be 1000 mW (1 W) or less for the US, 100 mW or less for Europe, and 10 mW/MHz or less for Japan. The IEEE 802.11b standard also requires the transmission mask to meet the following conditions: the transmitted spectral products should be less than –30 dBr [dB relative to the SIN(x)/(x) peak] in the first sidelobes (f_c – 22 MHz < f < f_c – 11 MHz and f_c + 11 MHz < f < f_c + 22 MHz, where:

f_c = the channel center frequency), –50 dBr in the second sidelobes (f < f_c – 22 MHz and f > f_c + 22 MHz).

The MAX2242 is a low-cost silicon (Si) linear PA designed specifically for 802.11b WLAN applications. It delivers +22.5-dBm linear output power with an adjacent channel power rejection (ACPR) of less than –33 dBc in the first sidelobe and less than –56 dBc in the second sidelobe, providing a margin of 3 and 6 dB, respectively, compared to the 802.11b standard. The +22.5-dBm output power overcomes any insertion loss of the WLAN transmit/receive (T/R) switch and bandpass filter, which typically totals 2.5 dB. As a result, the MAX2242 can be used to deliver an output-power level of +20 dBm at the antenna. Figure 1 shows the block diagram for a typical WLAN transceiver front end.

To demonstrate the performance of the PA, an evaluation board was created and tested. This evaluation board is made from low-cost FR4 circuit-board material, consisting of four metal layers stacked with dielectric thicknesses of 6, 46, and 6 mils. No micro viaholes were used in order to ensure simplicity of the board-level design. Figure 2 shows a photograph of the evaluation board with the PA and all of the neces-



3. This is a typical application circuit using the MAX2242 WLAN amplifier and its evaluation board.

High Performance Drivers

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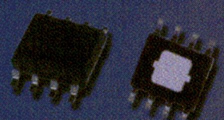
ross the finish line first with the new **SPA** GaAs HBT MIC amplifiers with exceptional linearity, long life and n-chip active bias circuitry keeping performance flat ver process and temperature variation. Operating at 50 MHz, 1950 MHz and 2150 MHz, the SPAs are erfect for driving power amplifiers in cellular, PCS, VLL, UMTS, CDMA and W-CDMA infrastructure quipment.

he SPAs, powered with a single positive supply oltage to reduce part count, offer typical output hird-order intercept points of +48 dBm. These tegrated circuits provide intermodulation erformance previously achieved only through costly iscrete assemblies.

Part Number	Freq (MHz)	Gain (dB, typ.)	P1dB (dBm, typ.)	IP3 (dBm, typ.)	Voltage (VDC)	Current (ImA)
SPA-1108	810-960	17.0	29.5	+48.0	+5.0	320
SPA-1208	1930-1990	12.0	29.5	+48.0	+5.0	320
SPA-1308	2110-2170	11.0	29.5	+48.0	+5.0	320



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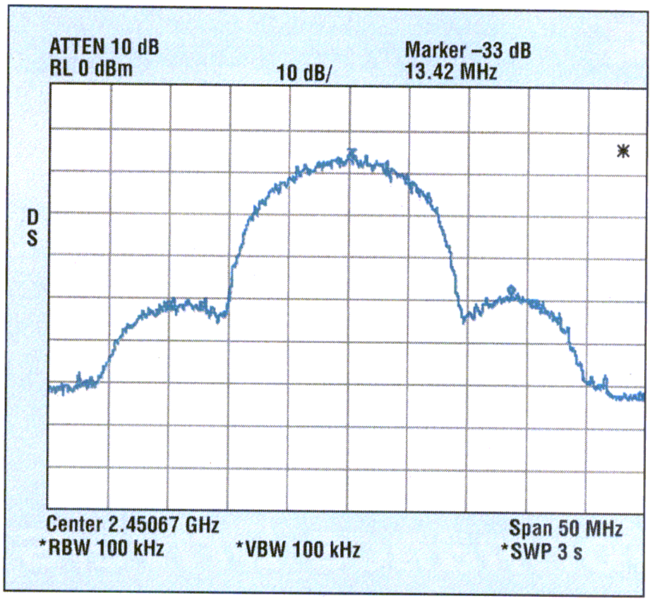
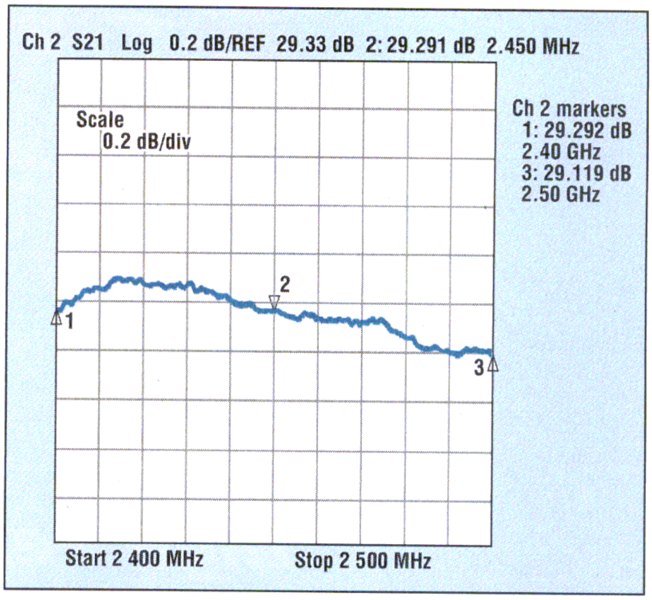
sary passive components installed, while Fig. 3 shows a typical application circuit used on the evaluation board.

Figure 4 shows a spectral plot of ACPR for the MAX2242 at an output-power level of +22.5 dBm. The plot was made at 2.45 GHz by using an IEEE 802.11b-compatible signal source with complementary-code-keying (CCK) modulation and a data rate of 11 Mb/s. The PA consumes approximately 310-mA DC current at its maximum linear

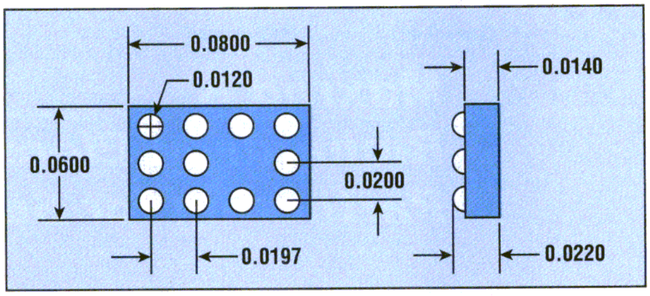


4. The output spectrum of the MAX2242 amplifier IC was measured at 2.45 GHz.



5. The frequency response of the MAX2242 amplifier IC was measured across the WLAN ISM 2.4-GHz band.

output power. Most PA drivers available today can only provide approximately –4-dBm output power, requiring a high-gain PA to follow. MAX2242 cascades three amplifier stages to provide at least 26.5dB gain and ensure an output of +22.5 dBm. Figure 5 is a plot of gain over frequency. The PA provides a flat gain response over the entire 2.4-to-2.5-GHz ISM band.



6. The dimensions (in inches) of the 3 × 4 UCSP package used with the MAX2242 amplifier IC are shown here.

The PA has a power detector coupled to the output port, providing at least 20 dB of dynamic range with ±0.8-dB accuracy at maximum linear output-power level. An accurate automatic-level-control (ALC) function can be easily implemented using the detector circuit. With this detector integrated, the traditional directional coupler and discrete detector are eliminated, greatly reducing overall PCB area and size.

The PA also features an external bias-control pin. Through the use of an external digital-to-analog converter (DAC), the current can be throttled back at lower output-power levels while maintaining sufficient ACPR performance. As a result, the highest possible efficiency is maintained at all power levels. The table shows the linear output power versus idle current and supply current (I_{DC}) with –33 dBc ACPR (unchanged). It can be seen from this table that bias current can be significantly reduced or power efficiency can be mostly maintained by using the external DAC.

The PA has simple input and output impedance-matching requirements. The input-matching circuitry is simply a series capacitor and a shunt inductor, while the output-matching circuitry consists of two capacitors. This "minimalist" approach to matching circuitry further helps to shrink the size of the WLAN PCB.

Most Personal Computer Memory Card International Association (PCMCIA) or PC cards only provide a +3.3-VDC power supply. The MAX2242 PA has been designed to operate from a single supply line from +2.7 to +3.6 VDC. Since time-division duplexing (TDD) is commonly used in WLAN applications which requires that the PA be shut off separately to maximize battery life during receive mode, the MAX2242 is also equipped with an on-chip shutdown feature. In the shutdown mode, the operating current is reduced to a mere 0.5 μA without the need for any external supply switch.

The MAX2242 PA is available in an ultra chip scale package (UCSP) that measures only 1.5 × 2.0 mm, virtually the same size as a 0805 resistor. The small size makes it ideal for WLAN radios built in small PC-card and Compact Flash card form factors. Figure 6 shows the detailed dimensions of UCSP package. The UCSP packaging technology allows the IC to be attached facedown to the PCB (in the manner of flip-chip mounting), with the IC's pads connecting to the PCB's pads through individual balls of solder.

Although it is tiny, the MAX2242 amplifier provides the performance needed to maintain reliable data communications in current and next-generation WLAN systems. The amplifier combines the benefits of low-cost Si IC technology, high output power, an on-chip detector, and external bias control in a compact UCSP housing. P&A: stock. **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: http://www. maxim-ic.com.**

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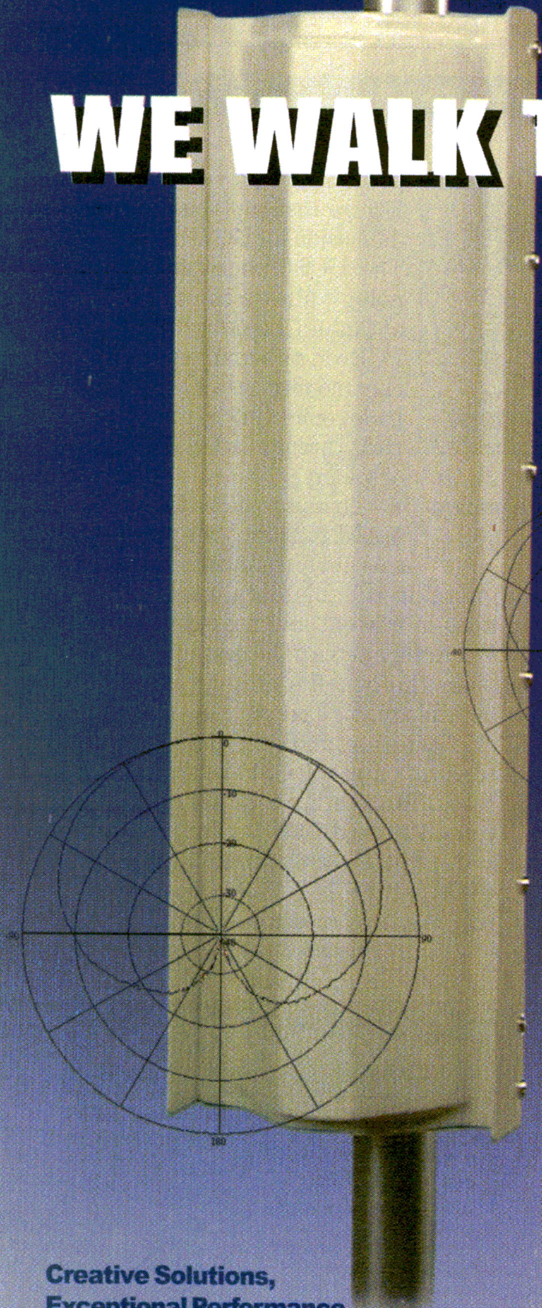

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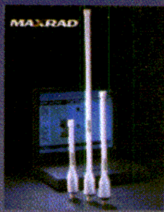

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Introducing Maxrad's new patent pending, 2.4 GHz ISM adjustable sector panel antenna. The MSP24013MB provides field adjustable horizontal beamwidth options of 45, 60, 90 or 120 degrees with a VSWR of less than 1.5:1. This unique design delivers industry-leading front to back ratios with excellent cross pole discrimination. It is the ideal solution for wireless broadband applications where coverage of a geographical sector is needed.

MSP24013MB Specifications

Nominal Gain	Front to Back Ratio	Horizontal Plane	E-Plane Beamwidth	VSWR	Typical Cross Poll Discrimination
13 dBi at 120°	> 32 dB at 120°	120°, 90°,	16° at all	<1.5:1	270° - 0°, 0° - 90° = -20 dB
14 dBi at 90°	> 42 dB at 90°	60° and 45°	horizontal		235° - 270°, 90° - 135° = -28 dB
16 dBi at 60°	> 42 dB at 60°	options	beamwidth		180° - 235°, 135° - 180° = -32 dB
17 dBi at 45°	> 42 dB at 45°		options		

Note: For applications in which adjustability is not necessary, the sector panel antenna can be ordered with fixed horizontal beamwidths of 45, 60, 90 and 120 degrees.

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Transceiver Chip Set Integrates Triband GSM Functions

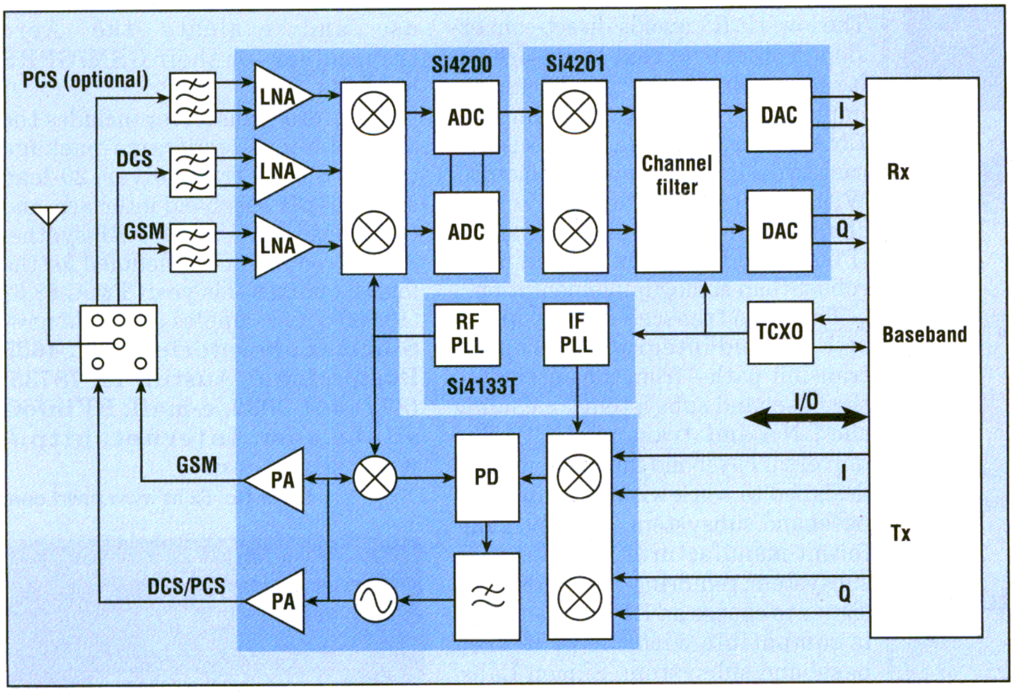
This transceiver provides a complete RF front end for dual- and triple-band GSM digital cellular handsets, while its universal baseband can be used with any supplier's baseband subsystem.

PETER STAVENICK
Managing Editor

CELLULAR technology has come a long way in 10 years, especially in support of Global System for Mobile Communications (GSM) voice and data terminals. The Aero™ GSM transceiver chip set from Silicon Laboratories, Inc.(Austin, TX) is one example of this advanced technology—it provides a complete RF front end for dual- and triple-band GSM digital cellular handsets. This chip set eliminates the intermediate-frequency (IF) surface-acoustic-wave (SAW) filter, external low-noise amplifiers (LNAs) for three bands, and provides transmit and RF voltage-controlled oscillators (VCOs) along with the elimination of more than 60 other discrete components found in conventional GSM handset designs.

In addition to the transceiver eliminating so many components, it takes up less than 66 percent of the board area of other designs, with 80 percent fewer components. The additional benefit is a lower-cost phone. One other benefit is that solutions today use bipolar complementary metal-oxide semiconductor (BiCMOS) or bipolar technologies, but the Aero transceiver is the first cellular transceiver to be designed in CMOS. The transceiver also meets General-Packet-Radio-Service (GPRS) class 12 requirements.

A cellular handset has two primary subsystems—RF and baseband. The Aero transceiver's receive section includes the LNA in a digital low IF architecture and provides a universal analog baseband interface. The digital low IF Rx consists of a dual- or triple-band LNA, an image-rejection downconverter, and a high-performance analog-to-digital converter (ADC). The transmit section of the transceiver is a complete upconversion path from the baseband subsystem to the power amplifier (PA) using an offset phase-locked loop (PLL) with a fully integrated transmit VCO. The offset PLL transmitter features a high-precision in-phase/quadrature (I/Q) upconverter and an integrated transmit VCO. The frequency-synthesizer function of the transceiver is performed using the company's technology—including integrated RF and IF VCOs.



The Si4200 transceiver consists of three LNAs, two ADCs, and five mixers.

Helping to form a complete RF front-end solution when it is coupled with an external PA and switch, the transceiver has a VCO that needs to be carefully designed. The Si4200 transceiver also consists of three LNAs, two ADCs, and five mixers (see figure). The Si4201 baseband interface consists of two mixers, a channel filter, and two digital-to-analog converters (DACs), while the Si4133T RF synthesizer includes an RF PLL and an IF PLL. Operating from +2.7 to +3.3 VDC, the Si433T RF synthesizer measures 5 × 5 mm and uses the company's RF synthesizer technology. As of mid-February, it offers the industry's fastest settling times at 140 µs by using a stable integer-N architecture.

The Rx portion of the transceiver encompasses the top portion of the transceiver along with the baseband interface. Where direct-conversion Rxs provide reduced performance due to local oscillator (LO) self mixing, second-order distortion of blockers, and with DC offsets and 1/f noise, the Aero digital low-IF Rx is a better fit. The low-IF Rx avoids direct-conversion problems in that there are relaxed requirements on difficult-to-implement RF blocks including the LNA, mixer, and PLL. The Rx is also easy to design, use, and manufacture. With its digital IF downconverter, channel filter, and pin-grid array (PGA), the Rx is smaller and more robust than analog implementation.

The Aero transceiver measures 5 × 5 mm and integrates the entire transmit path—from the antenna to the baseband subsystems, including the LNA and transmit VCO. The universal baseband interface itself is designed to work with any supplier's baseband subsystem. Usually, a different manufacturer supplies each subsystem, requiring the handset designer to choose an RF front end that is compatible with the preferred baseband subsystem. Silicon Labs' universal baseband, however, is programmable through simple software commands, enabling it to operate with any baseband solution. Measuring 4 × 4 mm, the baseband interface enables the handset designer to use the Aero transceiver without redesigning the baseband portion of the phone.

THE AERO TRANSCEIVER MEASURES 5 × 5 mm AND INTEGRATES THE ENTIRE TRANSMIT PATH—FROM THE ANTENNA TO THE BASEBAND SUBSYSTEMS, INCLUDING THE TRANSMIT VCO.

All of the company's products (including the transceiver) are implemented in cost-effective CMOS technology. Although it is challenging to implement complicated RF designs in CMOS, it provides a significant cost advantage to customers. Worldwide, the manufacturing capability for CMOS is higher than that for any other process—ensuring that the company can meet customers' growing product demands.

Applications for the transceiver include many cellular applications, including code-division multiple access (CDMA), time-division multiple access (TDMA), third generation (3G), and other low-cost dual-mode multistandard designs. Many cellular-phone manufacturers are looking to use and evaluate the Aero transceiver for their GSM/GPRS handsets.

The Aero transceiver includes the 32-lead micro-leadframe-package (MLP) Si4200 transceiver, 20-lead MLP Si4201 baseband interface, and the 28-lead MLP Si4133T RF synthesizer. Production is scheduled for the fourth quarter this year. P&A: $8.62 (10,000 qty.); samples available now. **Silicon Laboratories, Inc., 4635 Boston Lane, Austin, TX 78735; (877) 444-3032, e-mail: RFinfo@silabs.com, Internet: http://www.silabs.com**

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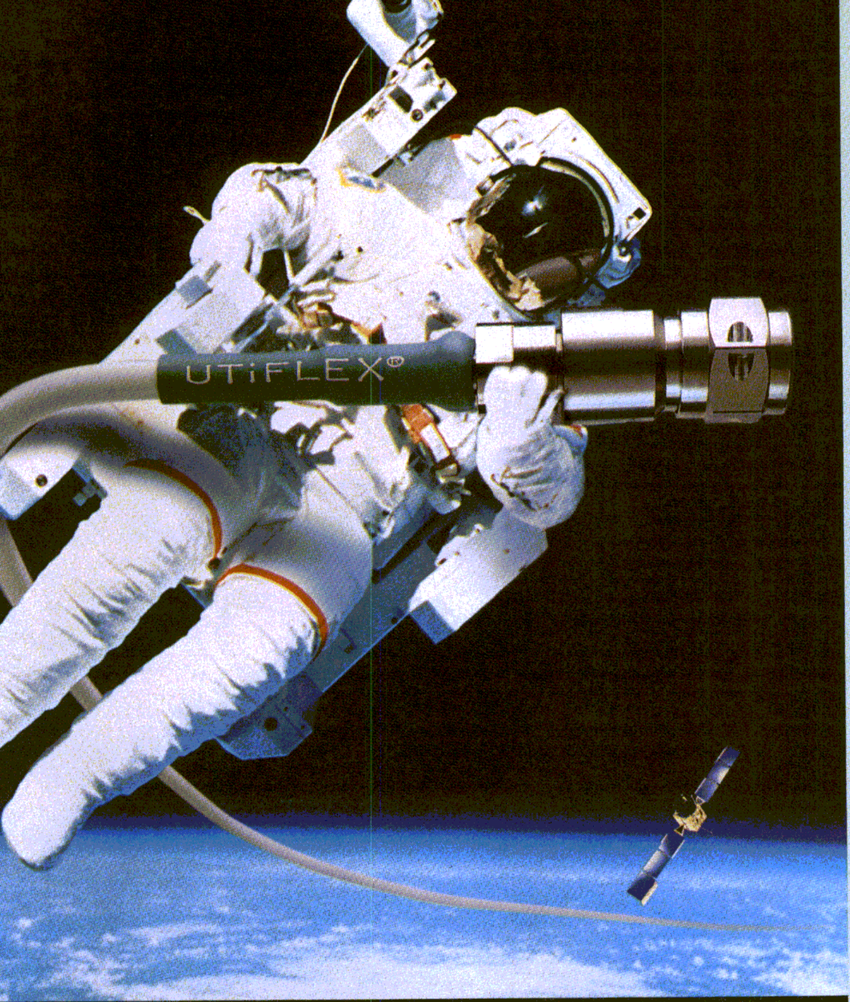
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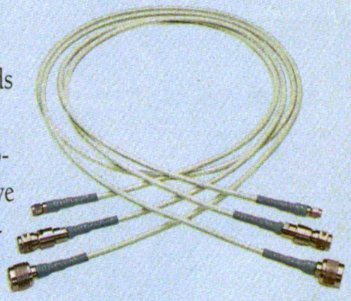



A Perfect Fit!
YF-22

Radio IC Cuts Costs Of Building 2.4-GHz WLANs

This highly integrated device includes a receiver, transmitter, oscillators, and filters in a cost-effective solution that supports data rates to 11 Mb/s.

Craig Conkling

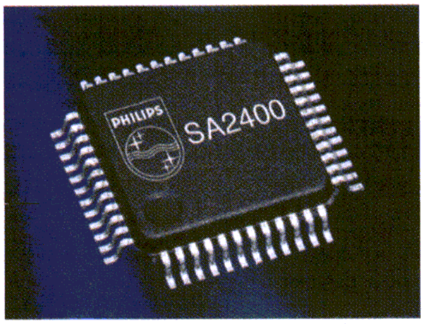
Applications Engineer

Philips Semiconductors, 811 E. Arques Ave, Sunnyvale, CA 94088; (800) 447-3762, (408) 991-2000, FAX: (408) 991-2311, Internet: http://www.semiconductors.phillips.com.

CHANGES to the IEEE's 802.11 standard for wireless local-area networks (WLANs) have been fast and furious in recent years. Originally developed for data rates of 1 to 2 Mb/s at 2.4 GHz, the standard has been revamped (to IEEE 802.11b) for improved data performance of 11 Mb/s at 2.4 GHz. Still, cost is an important consideration in the selling of WLANs, and the SA2400 WLAN integrated circuit (IC) from Philips Semiconductors (Sunnyvale, CA) represents a giant step in making 11-Mb/s WLANs affordable. Using a zero-intermediate-frequency (zero-IF) architecture, the radio chip integrates all of the functions needed for operation: receiver (Rx), transmitter (Tx), synthesizer, voltage-controlled oscillator (VCO), crystal oscillator, and on-chip channel filtering, with only a few external components required to complete the radio bill of materials (BOM). The SA2400 makes a WLAN radio BOM possible that is less than one-half the cost of most competitive solutions.

The SA2400 radio IC (see figure) is backwards compatible with the earlier version of IEEE 802.11 for 1- and 2-Mb/s WLAN systems. The IEEE 802.11 standard was designed to provide the wireless equivalent of wired Ethernet LANs, the IEEE's 802.3 standard. From a user's standpoint, a wired or wireless solution is merely a link or physical transmission medium to send data to a network interface card (or client) from an access point (AP), and vice-versa. The protocol that enables the wired to wireless seamless operation is the IEEE 802.2 logical-link-control (LLC) sublayer.

The IEEE 802.11 standard also defines a medium-access-control (MAC) sublayer, a MAC management and services protocol, and the physical layer (PHY). The MAC is the brain of the operation—it manages the data flow between the transmission interface and upper layers. The management and services are further requirements of operation embedded in the MAC. The PHY is the physical hardware that either prepares data (information) for transmission or extracts the real data from the received bit stream. Three types of PHYs exist in the IEEE 802.11 standard: infrared (IR), frequency hopping, spread spectrum (FHSS); and direct sequence, spread spectrum (DSSS). IEEE 802.11b standard specifies two PHYs: complementary code (shift) keying (CCK) and packet binary convolutional coding (PBCC).



The SA2400 radio IC includes a Rx, Tx, signal sources, and filters in a cost-effective solution that supports data rates to 11 Mb/s.

The firm's first generation of WLAN ICs supported the DSSS modulation scheme. The radio is part of the PHY description of the hardware. The PHY can be generically divided into three parts: radio, modem, and MAC. In modern implementations, the MAC is primarily software and, hence, resides in memory. The first-generation radio solution consists of the SA2420 2.4-GHz front-end transceiver, the SA1630 350-MHz IF transceiver and frequency synthesizer, and the UMA1021 2.2-GHz integer synthesizer.

The SA2400 features a zero-IF architecture, which makes it possible to eliminate many of the external components needed in first-generation WLAN radio designs. The SA2400 integrates a complete receiver and transmitter, complete channel filtering in the Rx, spectrum conditioning filtering in the Tx, a 1.25-GHz fractional-N synthesizer, a fully integrated VCO and doubler, a predriver amplifier with +5-dBm output power, and calibration loops that reduce the LO leakage in the transmitter that set the gain in the Rx.

Both IEEE 802.11 and IEEE 802.11b use three 22-MHz-wide channels in the 2.40-to-2.45-GHz industrial-scientific-medical (ISM) band. These channels are centered at 2.412, 2.437, and 2.462 GHz. Therefore, channel 1 uses the frequency range from 2.401 GHz to 2.423 GHz, channel 6 uses the frequency range from 2.426 GHz to 2.448 GHz, and channel 11 uses the frequency range from 2.451 GHz to 2.473 GHz. For example, when an antenna receives a signal on channel 1, it passes to the receiver through a transmit/receive (T/R) switch, is filtered by a dielectric bandpass filter, and enters the SA2400 via a matching network to the on-chip front-end low-noise amplifier (LNA).

The SA2400's LNA has differential input ports (for reduced line noise), so a balun is needed for single-ended applications. The LNA has two gain states, set internally through digital commands from the automatic-gain-control (AGC) circuitry or manually through a standard three-wire bus or special high-speed serial bus.

Signals boosted by the LNA are downconverted to zero IF in the front-end mixers. By using two tightly matched mixers and driving them with in-phase (I) and quadrature (Q) signals, image suppression is typically better than 30 dB.

This approach supports the use of dielectric bandpass filters instead of more costly surface-acoustic-wave (SAW) filters. The signal then proceeds through the on-chip channel filters and a variable gain amplifier (VGA) before leaving the SA2400's receiver circuitry and connecting with baseband analog-to-digital converters (ADCs).

The I and Q lowpass filters are fully integrated active filters with a bandwidth of 7 MHz. They are designed with high compression points and are tunable to eliminate process spread. A highpass characteristic is integrated into these filters for reducing DC offsets generated by LO leakage to the LNA or mixer inputs or by device mismatches. Since the corner frequency is selectable, it is possible to accelerate the cancellation process without losing too much signal energy needed for the AGC circuitry. Both DC cancellation and AGC are controlled either by a complex algorithm (implemented on-chip) or externally controlled by the serial interfaces. The AGC settling takes less than 8 μs, and after another 5 μs, the offset is completely removed.

As the received signal passes through the AGC, the AGC_RESET command must be provided to the SA2400 by a baseband IC to set the gain based on the actual signal plus noise power level at the Rx input. The on-chip 85-dB gain-adjust-range digital AGC control loop settles to the final output signal level (within ±3-dB dynamic error) in 8-μs after an AGC_RESET command. The AGC controls the LNA gain, active filter gain, and VGA gain, and has an on-chip digital control loop which is frozen at the end of the 8 μs AGC settling time in the receive mode. As previously mentioned, the AGC gain can be manually adjusted by setting the SA2400 into the RXMGC mode through the three-wire bus. The gain setting is determined by the value of the corresponding register word.

The AGC cycle involves a coarse reduction of gain in steps of 30 dB, starting from the maximum value. Gain stepping stops if the signal level at the output of an internal flash ADC appears within its operational window, after which the gain is adjusted in finer steps until the signal reaches a set point. The set point is determined from a received signal strength indicator (RSSI) signal that is coming from a lowpass filter, which itself is driven by an IF signal. This signal reflects the amplitude of the instantaneous-modulated RF signal (envelope) on a log-scale. At the end of the AGC settling time, the AGC_SET digital indication is provided. Ordinarily, the AGC begins from the highest gain and may initially saturate the Rx if a strong signal is present, but at the end of the 8-μs AGC settling time, the Rx will also be settled into its linear operational region.

The DC cancellation occurs simultaneously during the time the AGC is active and reduces a maximum allowable DC offset of –20 to +50 dBc relative to a –76-dBm antenna input signal, for instance, by 8 μs after the AGC_RESET command. The entire DC cancellation process consists of three steps, consistent with the programmed lower cutoff frequency of the AC coupling filter. This filter is programmed for 1-MHz lower cutoff frequency during the AGC settling phase (maximum 8-μs duration), and then is configured for 100 kHz for 5 μs before switching to a final 10-kHz cutoff frequency. The low value of 10 kHz is required for minimizing the signal distortion created by a high-pass function at zero frequency. Whenever there is a frequency change in the DC cancellation AC coupling, the DC offset can change from a very low value to approximately 50 percent (1-MHz ∅ 100-kHz step) or 10 percent (100 kHz ∅ 10-kHz step) of the peak signal level. This DC offset then decays according to the highpass response of the (internal) AC coupling.

Measuring the receive signal strength is a necessity in setting the correct AGC level. The SA2400's RSSI circuitry has a –20- to +10-dBm operational range relative to the nominal signal level that the AGC tries to set at the I and Q outputs. Since the RSSI acts on the modulated RF signal envelope extracted from the I and Q signals, which includes DC offsets, it will therefore show transient decaying errors when the highpass cutoff frequency is changed.

The SA2400 Rx is designed to provide at least –10-dBm RSSI at maximum gain when there is no signal present (i.e., with only thermal noise). However, due to process spreads (e.g., gain, noise figure, I and Q lowpass filter bandwidths, etc.), the RSSI may show higher than {MINUS}10 dBm. In case a calibration is required for setting this noise power to –10 dBc, the AGC's maximum gain can be changed in the range of 85 to 54 dB in steps of 1 dB through the

three-wire programming. The programmed value of maximum gain is never altered by the AGC settling or by forcing the AGC circuitry to maximum gain. Only the SA2400's RXMGC mode can set the AGC gain to higher values than the preprogrammed maximum gain (in case the maximum gain was reduced by programming). The RXMGC mode does not change the value of the preprogrammed maximum gain. As the RSSI signal passes a certain threshold of the baseband IC's Flash ADC ("sniffer"), the MAC "wakes up" and begins to determine if the signal is intended for its reception or not (and if not, it discards it).

There are times when the receive signal is in the presence of interferers and needs to have some level of blocking immunity. The receiver is designed to exceed the IEEE 802.11 specification for the blocking and intermodulation (IM). It can accept continuous or randomly pulsed interfering single-tone or multi-tone signals that are more than 35 dB stronger than the desired signal and up to –10 dBm of interference level. The spurious I and Q outputs are held to less than –20 dBc of the desired signal level. Once the I and Q signals enter the baseband processor, they pass through the ADC, are despread (if DSSS) or decoded (if CCK), demodulated, and finally descrambled.

The local oscillator (LO) is common to the Tx and Rx. The RF VCO is a differential 1.25-GHz oscillator with all the frequency-determining components internal to the IC. The VCO is connected internally through a frequency doubler and a phase shifter to the I and Q upconverters and downconverters. The VCO is internally connected to the synthesizer which can be programmed in steps of 1 MHz to the desired LO frequency. The SA2400 can also accept an external 2.45-GHz LO signal when low-phase-noise performance is required.

IEEE 802.11 systems are designed for half-duplex operation (i.e., it is either receiving or transmitting). Therefore, the same channel used for receiving is also used for transmitting data. The signal is generated in the baseband modem circuit by scrambling the data, spreading (if DSSS) or coding (if CCK) it over a 22-MHz channel, modulating it, and passing the data in the form of I and Q signals through digital-to-analog converters (DACs). These I and Q signals passing into the SA2400 are therefore analog in form. The SA2400 has a digital mode, but requires that digital signals be (pre)filtered in the baseband processor.

The wideband I and Q upconverter includes spectral-shaping reconstruction filters that are driven from the baseband DAC current-source outputs. On the RF side, the SA2400 has two different outputs: a 0-dBm single-ended output level and an AGC level that can be varied from –9 to + 5 dBm. At the second output, +5-dBm maximum output power is available and the out-of-band spurious signal power (in bands designated as forbidden by the Federal Communications Commission) is less than –70 dBc in a 1-MHz or greater resolution bandwidth for the 11-MSymbols/s CCK modulation, taking into account the internal reconstruction filters (which are fourth-order lowpass Butterworth filters with 3-dB upper cutoff frequency of 10.5 MHz). This implies that the spectral regrowth is dominated by any external power amplifier (PA) that may be used to boost the transmission power level. It is also assumed that the input I and Q signals are pulse shaped (e.g., sinusoidal 1-0 or 0-1 transitions) and additionally filtered by a second-order lowpass filter (with 3-dB upper cutoff frequency of 10.5 MHz). To operate in the linear region, the combined Tx chain should have between 1-to-3-dB output backoff from the 1-dB compression point in order to limit spectral regrowth.

For digital-mode operation, the I and Q signals are driven directly by two binary data streams, which are chosen by selecting the digital transmit (T) input mode in register 0x04. In this case, the data stream for channel 'I' is to be applied to TX_IN_I_P/TX_DATA_I pin, pin 36, the stream for 'Q' to TX_IN_I_M/TX_DATA_Q pin, pin 35. Two on-chip finite-impulse-response (FIR) DACs convert the digital signal into an analog signal and feed it into the analog signal path.

The Tx carrier leakage can be reduced to levels far less than required by using the on-chip calibration loop. An on-chip RF power meter detects the LO level, converts it into a digital signal, and a state machine calculates the compensation values which are then fed through a DAC directly to the I and Q inputs. The I and Q gain and phase imbalance, reconstruction filter rolloff, and in-channel noise produce an error vector magnitude (EVM) of less than 15 percent for quadrature-phase-shift-keying (QPSK) modulation at a rate of 11 MSymbols/s. As mentioned earlier, the transmitter has two switched outputs, one with 0-dBm output power and 1-dB backoff, and the other with +5-dBm output power and 3-dB backoff. An input line, TX_OUT_SEL, selects between the two RF output ports.

When switching out of the transmit mode (either into receive mode by transition on TXRX pin, or into another mode by three-wire programming), the reference clock input (pins XTAL_1 and XTAL_2) must be active since a digital timer is being used. The SA2400 switches from transmit to receive mode and vice-versa is far less than 5 μs, thus meeting the IEEE 802.11 requirements. The signal then passes through an external discrete or IC PA.

Typical Rx performance includes 90-dB gain , 6-dB noise figure, –4-dBm third-order intercept point in the high-gain state, –10-dBc I/Q output DC error, less than 8-μs AGC settling time, and less than 5-μs DC cancellation time. The typical transmitter system-level performance includes an output-power range of –15 to +5 dBm that is adjustable in 1-dB gain steps, a carrier leakage of better than typically –40-dBc, sideband rejection of approximately 30 dB, in-band common-mode rejection of 35 dB, and receive-to-transmit and transmit-to-receive switching times of less than 5 μs. **Philips Semiconductors, 811 E. Arques Ave, Sunnyvale, CA 94088; (800) 447-3762, (408) 991-2000, FAX: (408) 991-2311, Internet: http://www.semiconductors.phillips.com.**

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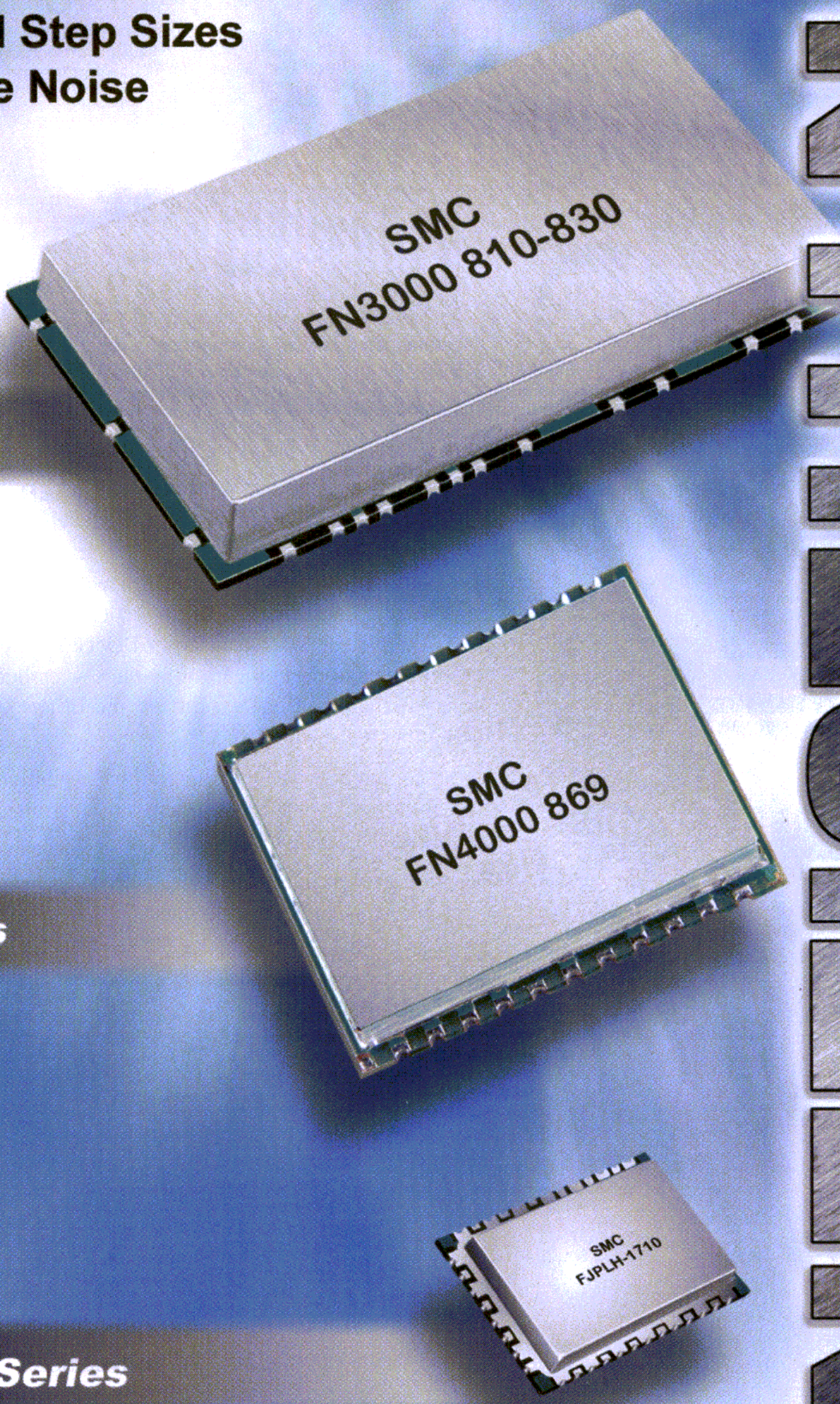

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This four-chip solution brings WLANs to the unlicensed 5-GHz range with enough bandwidth for Internet and video applications.

JACK BROWNE

Publisher/Editor

NETWORKS cry for speed and bandwidth, especially when they are required to pass large amounts of data. Until recently, wireless local-area networks (WLANs) have been limited to data rates of approximately 11 Mb/s. But with the advent of the IEEE 802.11a standard for high-speed WLANs, speeds increase up to 54 Mb/s for wireless networking are obtainable. And thanks to Raytheon Co. (Lexington, MA), a complete chip set is now available for implementing high-speed WLANs according to the IEEE 802.11a standard. The four-chip set, known as Tondelayo, includes a power-amplifier (PA)/switch module, a baseband integrated circuit (IC), an intermediate-frequency (IF) IC, and a frequency-converter/low-noise-amplifier (LNA) IC.

Film buffs will no doubt recognize the Tondelayo reference to Hollywood actress Hedy Lamarr, who played a character by that name in the 1942 film *White Cargo*. Lamarr was also instrumental in the conceptualization and development of spread-spectrum technology (and is credited as one of the original patent holders). Raytheon's version of Tondelayo is a well-matched chip set that is supported by peripheral-component-interface (PCI) and CardBus reference designs and a suite of software drivers. Rather than operating in the congested 2.4-GHz band specified for IEEE 802.11b and Bluetooth WLANs, the Tondelayo chips are designed for use in the 5-GHz Unlicensed National Information Infrastructure (UNII) bands. The three 100-MHz-wide UNII bands are 5.15 to 5.25 GHz, 5.25 to 5.35 GHz, and 5.725 to 5.825 GHz.

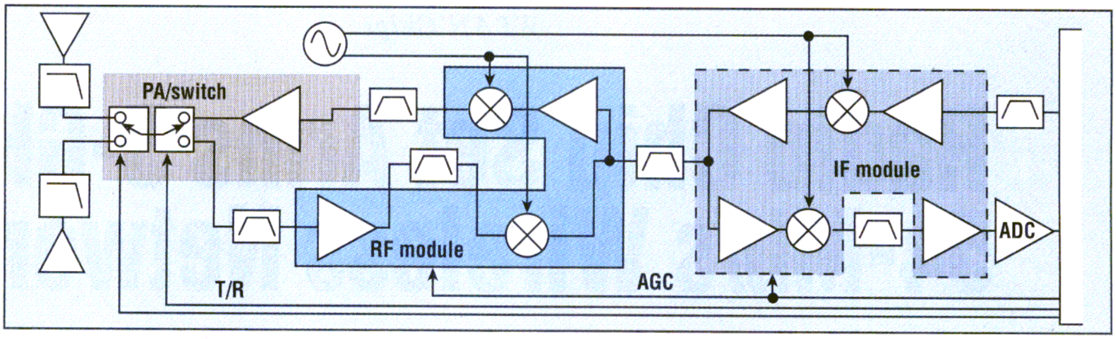
1. The RTCV-5500 frequency converter/LNA and the RTPA-5250 PA/switch module are two of the four devices in the Tondelayo IEEE 802.11a 5-GHz, 54-Mb/s WLAN chip set.

The Tondelayo device set (Fig. 1) includes the model RTCV-5500 frequency converter/LNA, the model RTIF-5500 IF processor module, and the model RTB-5500 baseband IC. The set also includes the model RTPA-5250 PA switch module, which was introduced late last year (see *Microwaves & RF*, October 2000, p. 154). The RTPA-5250, which is fabricated with the company's high-performance 0.5-{LC MU}m gallium-arsenide (GaAs) pseudomorphic-high-electron-mobility-transistor (PHEMT) process, offers small-signal gain of 38 dB from 5150 to 5825 MHz with +16.5-dBm linear output power. The RTPA-5250's two inline switches exhibit insertion-loss performance of 1.5 dB for the pair, which helps to preserve system noise figure. As much as 30-dB typical isolation is available per switch. The PA/switch module is housed in a compact, low-loss low-temperature-cofired-ceramic (LTCC) package.

The RTCV-5500 frequency converter/LNA and the RTIF-5500 IF converter ICs provide the low-noise performance needed for high receiver (Rx) sensitivity. Both devices are fabricated with a high-efficiency silicon-germanium (SiGe) process in order to minimize power consumption. The frequency-conversion circuitry in these two ICs enable the use of off-chip frequency synthesis, which reduces risk and supports a variety of intermediate-frequency choices. Raytheon's reference design will support a 465-MHz IF, although different frequencies may be used.

IF PROCESSOR

The RTIF-5500 IF processor consists of frequency-upconversion/downconversion circuitry, IF and baseband amplification, and a programmable attenuator. The unit, which is designed for operation from a single +3.3-VDC supply, is pack-



2. The four-chip 5-GHz WLAN collection consists of a PA/switch, a frequency converter/LNA, an IF processor, and a baseband processor.

aged in a compact flip-chip assembly. In receive mode, the RTIF-5500 draws 110-mA current typical, while in transmit mode, the current draw is typically 70 mA. Input and output ports are matched on-chip for simple integration to outboard filters, analog-to-digital converters (ADCs), and digital-to-analog converters (DACs). The device's electrical performance can be characterized in terms of its transmit-path performance, receive-path IF performance, and receive-path baseband performance.

The transmit path begins with a 60-MHz baseband signal at an average level of –25.5 dBm typical, provided by a DAC internal to the RTB-5500 baseband processor. The RTIF-5500 provides 18.5-dB small-signal transmit-path gain typical with ±0.5-dB gain variations with temperature (0 to +50°C) and voltage. The transmit spectral regrowth, which is defined as the unwanted signal levels within ±156.25 kHz of the 60-MHz carrier, is –52 dBc or better. The RTIF-5500 provides a transmit IF output signal of 380 MHz and typically –7 dBm with spurious levels of better than –25 dBc.

The RTIF-5500's IF receive path starts with a 465-MHz signal at levels as low as –65.6 dBm (and as high as –40 dBm), and boosts these signal levels through 58.6-dB typical small-signal gain. The built-in attenuator provides 44-dB gain control in 2-dB steps to support precise tuning of the received signal level prior to digitation and baseband processing. The attenuator is surprisingly "clean" in terms of noise figure—it contributes only 0.5 dB to the system noise figure when used in conjunction with the RTCV-5500 at the system's front end.

The IF signal path results in 60-MHz IF output signals which can then be processed by the baseband receive-path section. The baseband section handles input signals of at least –20 dBm, and provides 25-dB typical small-signal gain with ±1-dB variations in gain. The spectral regrowth, measured as unwanted signal levels generated within ±156.25 kHz of 60 MHz, is –52 dBc or better. Harmonically-related spurious signals are no worse than –38 dBc within ±20 MHz of 60 MHz, while nonharmonically-related spurious content is no worse than –51 dBc within ±20 MHz of 60 MHz. The RTIF-5500 provides high receive gain and the means to control signal level through its AGC attenuator circuitry, resulting in a baseband signal that is optimal for low bit-error-rate (BER) data reception.

The RTCV-5500 frequency converter/LNA receives signals from 5180 to 5320 MHz and from 5745 to 5805 MHz with better than –74-dBm sensitivity. The LNA stage includes a pair of in-series 8-dB attenuators to adjust signal levels. Without attenuation, the LNA stage noise figure is typically 3.1 dB. With the full 16-dB attenuation, the LNA stage noise figure is typically 3.9 dB. The small-signal gain without attenuation is typically 28 dB. LNA gain variations are ±1 dB typical, while spectral regrowth (as defined earlier) is typically –52 dBc. In addition to the LNA, the coupled downconverter stage adds 6 dB of small-signal gain.

The RTCV-5500 operates with local-oscillator (LO) signals from 4715 to 4875 MHz and from 5300 to 5360 MHz at a level of –5 dBm typical. The device features a unique LO/4 output port that provides scaled-down versions of the LO input signal for use with inexpensive, low-frequency phase-locked loops (PLLs).

Finally, the RTB-5500 baseband IC contains the modem and the media-access controller (MAC). It also contains a high-resolution DAC, ARM7TDMI microprocessor core, digital-signal-processing (DSP) core, and PCI/cardbus interface. This module also includes custom-designed cells that perform decoding, automatic gain control (AGC), and other functions required by the IEEE 802.11a standards. The IC, which enables full 54-Mb/s operation, is supported by software drivers for a wide range of operating systems. The RTB-5500 is built with a 0.18-μm complementary-metal-oxide-semiconductor (CMOS) process and housed in a 180-pin ball-grid-array (BGA) package.

Together, these chips and modules represent the first complete solutions for IEEE 802.11a 5-GHz WLAN development (Fig. 2). The devices represent a careful selection of process technologies (GaAs, SiGe, and Si CMOS), each chosen for optimum performance. **Raytheon Commercial Electronics, 1001 Boston Post Rd., Mail Stop 1-1-1172, Marlborough, MA 01752; (508) 490-1552, FAX: (508) 490-3007, Internet: http://www.tondelayo.com.**

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Synthesizers Shave Noise In Receivers And Test Equipment

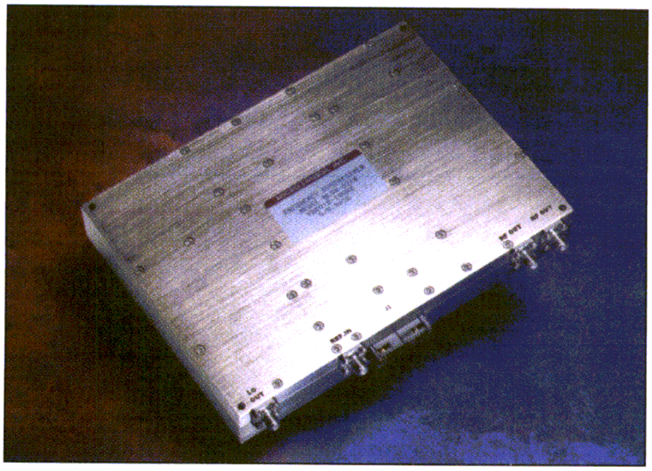
These YIG-based PLL sources can be specified in wideband and narrowband configurations for carrier frequencies through 18 GHz.

Scott Wettenkamp
Director of Engineering
Micro Lambda, Inc., 48041 Fremont Blvd., Fremont, CA 94538; (510) 770-9221, FAX: (510) 770-9213, e-mail: mcrolambda@aol.com, Internet: http://www.micro-lambda.com.

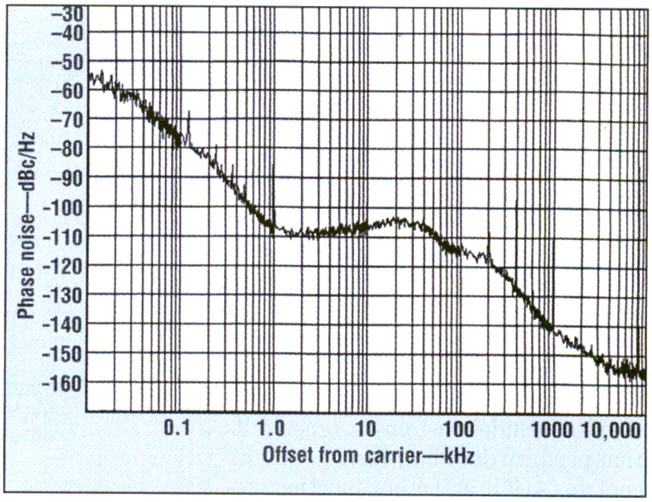
SIGNAL generation is critical to all modern communications systems, with good source performance marked by signal purity and stability. Since modern systems often employ an advanced form of phase modulation (PM), source signal purity is often judged by phase noise. And when low phase noise is important, many system integrators specify yttrium-iron-garnet (YIG)-based sources. For those in the market for YIG-based frequency synthesizers, Micro Lambda, Inc. (Fremont, CA) has just launched a line of phase-locked synthesizers with noise floors dropping below −150 dBc/Hz for carrier freqencies through 18 GHz.

Micro Lambda's MLSx series of low-phase-noise frequency synthesizers (Fig. 1) is suitable as the main local oscillators (LOs) in receiving systems, as well as in test equipment. They achieve 1-Hz frequency resolution in narrowband models covering any 2-GHz portion of the 2-to-18-GHz frequency band or in wideband models such as the MLSW synthesizer, which tunes from 2 to 10 GHz (see table). The sources uniformly deliver more than +10-dBm output power with maximum output-power variations as a function of temperature and frequency falling within a 3-dB window.

Building upon the company's heritage of low-noise YIG-based oscillators, these synthesizers add phase-locked-loop (PLL) circuitry that stabilizes the internal YIG oscillator to the phase of an internal 100-MHz crystal-reference oscillator. This internal voltage-controlled crystal oscillator (VCXO) can also be locked to an external crystal-reference oscillator in the range of 1 to 50 MHz (and nominal level of 0 dBm) for improved stability. For those applications requiring extremely low phase noise



1. The MLSx series of high-performance YIG-based frequency synthesizers can be specified as wideband or narrowband units with more than +10-dBm power over a total frequency range of 2 to 18 GHz.



2. The measured phase noise of a 5-GHz MLSx series frequency synthesizer drops rapidly for offsets of 1 kHz and further out from the carrier.

The MLSW-xxxx frequency synthesizer at a glance

Tuning range	2 to 10 GHz
Tuning step size	1 Hz
Output power	>+10 dBm
Output-power variations	3 dB
Switching speed	<500 μs + 1 ms/GHz
Harmonic levels	–12 to –15 dBc
Spurious levels	–60 dBc
Phase noise	
Offset 100 Hz	–80 dBc/Hz
Offset 1 kHz	–107 dBc/Hz
Offset 10 kHz	–107 dBc/Hz
Offset 100 kHz	–110 dBc/Hz
Offset 1 MHz	–140 dBc/Hz
FM bandwidth	100 kHz (3 dB)
Size	5 × 7 × 1 in.

and good stability, the firm can also provide the MLSx series synthesizers with an internal, high-performance 10-MHz oven-controlled crystal-reference oscillator.

In addition to the frequency-generation circuitry, the MLSx series synthesizers incorporate a low-power microcontroller which helps to simplify the user interface, coordinates temperature compensation, and provides the calculations that are needed by the various synthesizer subsections, such as the loop-filter circuitry. Operators can command the microcontroller (and the synthesizer) through a standard four-wire serial bus. Frequency commands can be in the form of a straight binary interface with the least-significant bit (LSB) representing 1 Hz, or through a binary-coded-decimal (BCD) format where the user simply sends the desired frequency in megahertz as an American Standard Code for Information Interchange (ASCII) character string. With the inclusion of the microcontroller, the synthesizer can report on its own internal temperature, and whether it is maintaining phase lock.

Besides simplifying and improving the performance of the MLSx frequency synthesizers, the internal microcontroller adds a certain amount of operating flexibility to the sources. For example, the microcontroller is equipped with enough nonvolatile memory to store up to 400 synthesizer frequency configurations, should a user need to rapidly step through a sequence of frequencies.

Although it employs signal-generation technology (YIG sources and PLLs) not normally associated with fast switching speed, the frequency synthesizers are designed to minimize delays between frequency steps, with switching speed of better than 500 μs + 1 ms/GHz. So, for a tuning step of 5 to 7 GHz, the switching speed is approximately 2.5 ms. As might be expected from a multioctave source, the harmonic levels are moderately controlled, at –12 to –15 dBc. Yet it is in the areas of spurious and phase noise that these synthesizers excel. The spurious levels are generally at –60 dBc or better for all frequency offsets. The single-sideband (SSB) phase noise (Fig. 2) is approximately –80 dBc/Hz for a 100-Hz offset from the carrier, dropping to –107 dBc/Hz for a 100-kHz offset from the carrier, and continuing downward to a noise floor below –150 dBc/Hz at offset frequencies beyond 1 MHz from the carrier.

These YIG-based frequency synthesizers can be ordered with an optional L-band synthesizer based on an inexpensive inductive-capacitive (LC) oscillator. Useful as a second LO in receiving subsystems, the L-band synthesizer can be specified for any suboctave range from 500 to 2500 MHz. Typical frequency resolution is 10 to 50 kHz, although other values are available.

The MLSx frequency synthesizers are supplied in a compact package measuring 5 × 7 × 1 in. (12.70 × 17.78 × 2.54 cm) with female SMA connectors for RF output. A 20-pin connector is also included for power supply, clock input, data input, lock status, narrowband and wideband frequency modulation (FM), as well as ground connections. Standard models are equipped with a single RF output port, although units can be supplied with a wideband power splitter when dual RF output ports are required. The frequency synthesizers are designed to operate into maximum load VSWR of 1.50:1 and

THE MLSx SERIES SYNTHESIZERS INCORPORATE A LOW-POWER MICROCONTROLLER WHICH HELPS TO SIMPLIFY THE USER INTERFACE AND PROVIDES THE CALCULATIONS THAT ARE NEEDED BY THE VARIOUS SYNTHESIZER SUBSECTIONS.

handle operating temperatures from –20 to +70°C. Power-supply requirements are 1.5 A at +15 VDC and 0.7 A at +5 VDC.

The company's sources are widely used in instruments such as signal generators and spectrum analyzers. In addition to the synthesizer line, the firm offers a wide range of YIG-tuned fundamental-frequency oscillators from 0.5 to 30 GHz, YIG-tuned multipliers through 20 GHz, and YIG-tuned bandpass filters from 0.5 to 46 GHz. **Micro Lambda, Inc., 48041 Fremont Blvd., Fremont, CA 94538; (510) 770-9221, FAX: (510) 770-9213, e-mail: mcrolambda@aol.com, Internet: http://www.micro-lambda.com.**

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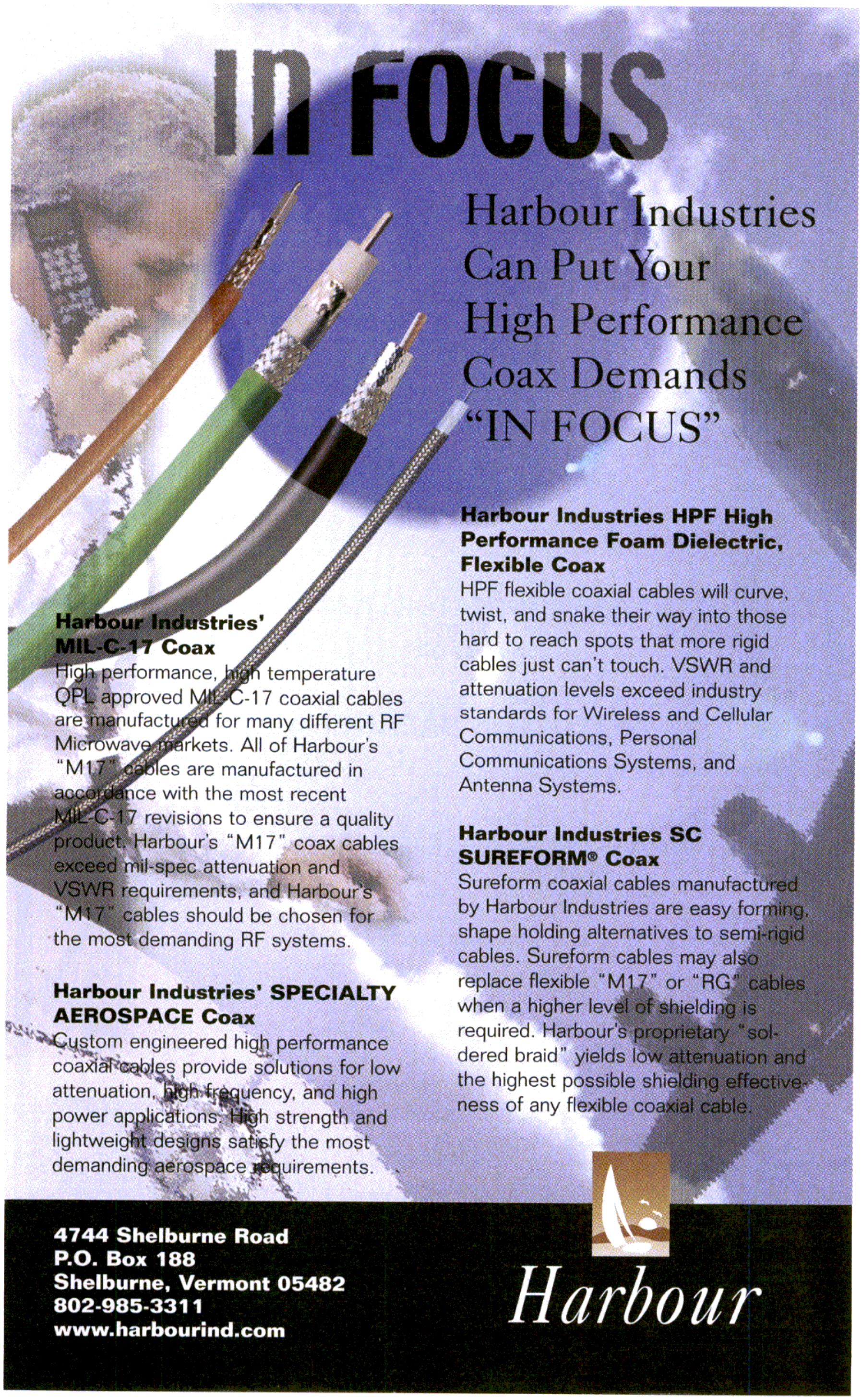
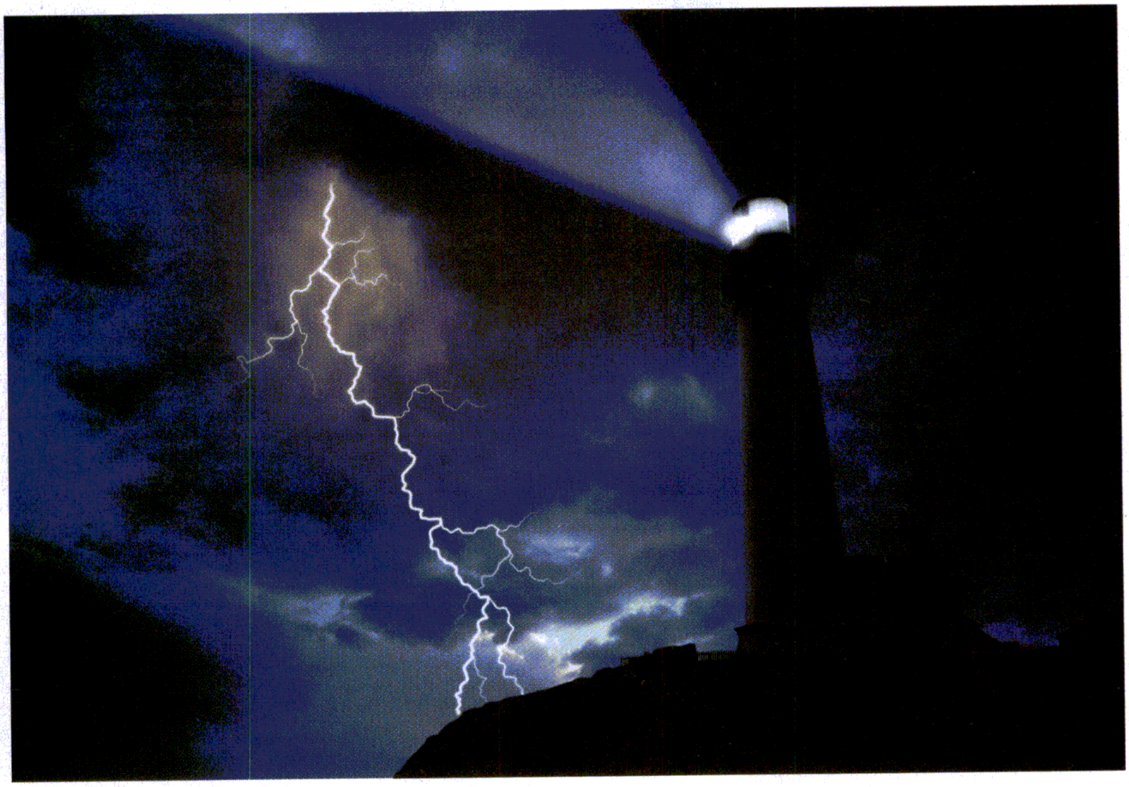


When you need Clarity and Power



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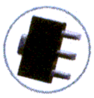
SPECIFICATION MATRIX

	SGA-6286 SGA-6289	SGA-6386 SGA-6389	SGA-6486 SGA-6489
Frequency (GHz)	DC-3.5	DC -3.0	DC-1.8
Gain (dB)	13.8	15.4	19.7
TOIP (dBm)	34.0	36.0	34.0
P1dB (dBm)	20.0	20.0	20.0
N.F. (dB)	3.9	3.8	2.9
Supply Voltage (Vdc)	4.2	5.0	5.2
Supply Current (mA)	75	80	75

All data measured at 1GHz and is typical. MTTF @ 150C T_j = 1 million hrs. (R_{TH} = 97C/W typ)

SiGe HBT MMIC features include:



SOT-89 package

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- High output intercept
- +20dBm 1dB Compression Point
- Low current draw
- Low noise figure

86 package

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Waveform Generator Creates Complex Modulation Formats

This simple-to-use function/waveform generator provides enough bandwidth and control to emulate the phase-based modulation formats of next-generation wireless systems.

JACK BROWNE
Publisher/Editor

MODULATION is critical to modern communications. As demands for information bandwidths increase, modulation formats grow more complex, using phase and amplitude to convey ever-growing amounts of data over relatively narrow communications channels. The model 9302 dual-channel synthesized function/arbitrary waveform generator from Protek (Allendale, NJ) allows engineers to emulate these complex modulation formats—in the laboratory and in the field—to evaluate the performance of communications systems and their components. The 9302 (which is also available as a single-channel model) offers a wide range of waveforms from 0.01 μHz to 31 MHz.

The 9302 can be used as a stand-alone instrument or under the control of an external personal computer (PC). Waveforms can be defined by front-panel data-entry buttons, or downloaded as a file from the PC. The 9302's internal memory supports waveforms comprised of as many as 16,384 data points. A wide range of waveforms is available as a result of the 9302's 40-MSamples/s sampling rate and 12-b amplitude resolution. The generator can produce sine and square waves from 0.01 μHz to 31 MHz with 0.01-μHz resolution, as well as ramp and triangle waveforms from 0.01 μHz to 2 MHz with 0.01-μHz resolution. The instrument can also function as a noise generator with a maximum bandwidth of 10 MHz.

For all of these waveforms, the instrument yields output levels of 50 mV to +10 VDC peak-to-peak into a 50-Ω load. DC offsets can be set over a range of 0 to ±5 VDC into a 50-Ω load.

The 9302 offers high accuracy in all of its formats. For example, for sine waves through 20 MHz, the accuracy for all amplitude levels (at a 0-VDC offset) is better than ±0.5 dB, with an accuracy of ±0.9 dB for all amplitude levels through 31 MHz. For all amplitude levels, the square-wave accuracy is ±5 percent for frequencies through 100 kHz, ±8 percent or better for frequencies approaching 20 MHz, and ±16 percent for square-wave frequencies from 20 to 31 MHz. The accuracy for triangle, ramp, and arbitrary waveforms is better than ±9 percent for all levels and frequencies through 2 MHz.

The spectral purity of sine waves generated with the 9302 is better than –50 dBc/Hz when measured in a 30-kHz band. Spurious levels are better than –50 dBc while subharmonic levels are also better than –50 dBc. Harmonic levels are better than –55 dBc from DC to 100 kHz, better than –45 dBc from 0.1 to 1 MHz, better than –35 dBc from 1 to 10 MHz, and better than –25 dBc from 10 to 31 MHz.

The 9302 can be used to generate phase resolution over a range of ±9999.99 deg. with 0.01-deg. resolution; phase modulation (PM) can be generated at rates from 0.001 Hz to 10 kHz. Similarly, amplitude modulation (AM) and frequency modulation (FM) are available at rates from 0.001 Hz to 10 kHz using the internal source. The AM is available at depths to 100 percent, while the FM can be applied to spans as wide as 31 MHz. The 9302 can also perform frequency sweeps across the full 31-MHz span (depending on the type of modulation applied). The 9302 includes a trigger generator with TTL-level outputs.

Data entry is fairly routine using the front-panel controls, with operating parameters clearly visible on a two-line, backlit, liquid-crystal-display (LCD) screen. The controls are intelligently grouped, largely on the righthand side of the front panel. Functions, such as sine wave, square wave, or noise, can be selected by pushing increment or decrement buttons. A large keypad on the righthand side simplifies numerical entry, with a choice of hertz, kilohertz, and megahertz for terminating frequency entries and choice of decibels per meter, voltage root mean square (RMS), and voltage peak-to-peak for terminating amplitude entries. For those who may have trouble understanding the 9302's straightforward user interface, the instrument is shipped with an easy-to-follow 52-page operator's manual. **Protek Test & Measurement, 40 Boroline Rd., Allendale, NJ 07401; (201) 760-9898, FAX: (201) 760-9888, Internet: http://www.protektest.com.**

Interconnects span 10 MHz to 1 GHz

The MIT/MIS series of matched-impedance microinterfaces on 0.025-in. (0.635-mm) pitch features 38, 76, 114, 152, 190, 228, and 266 input/outputs (I/Os). A discrete ground plane with through-hole leads on 0.100-in. (2.54-mm) pitch can be used in order to replace more expensive alternatives without the need for board-relay outs. These high-speed interconnects are fully tested for 50- and 75-Ω systems for impedance, VSWR, attenuation, crosstalk, propagation delay, as well as rise time at frequencies ranging from 10 MHz to 1 GHz. They provide a range of spacings of 0.197 in. (5 mm), 0.315 in. (8 mm), and 0.433 in. (11 mm) between boards. Edge-mount, elevated, as well as cable versions are available. **Samtec, Inc., P.O. Box 1147, New Albany, IN 47151; (800) SAMTEC-9, (812) 944-6733, FAX: (812) 948-5047, e-mail: info@samtec.com, Internet: http://www.samtec.com.**

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Supplies boast ±2-percent accuracy

The RPGM series of high-performance power supplies features remotely programmable control by external voltage and resistance. Features include isolated inputs and outputs, ±0.2-percent accuracy, three-digit light-emitting displays (LEDs), and rear-panel manual operation. Specifications include typical constant voltage, ripple and noise of ±0.5 mV, 5-mV constant voltage-load regulation, ±10-mA typical constant current-load regulation, and ±3-mA line regulation. Three selectable line voltages of 100, 120, 220, and 230 VAC are offered. **Protek, 40 Boroline Rd., Allendale, NJ 07401; (201) 760-9898, FAX: (201) 760-9888, e-mail: hcprotek@hcprotek.com, Internet: http://www.protektest.com.**

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Transformers cover –40 to +85°C

Models S558-5999-T5 and S558-5999-U5 are surface-mount magnetic transformer modules that boast an extended temperature range of –40 to +85°C. The modules are said to provide an isolation voltage of +1500-VDC root mean square (RMS). The components are designed to interface with all transceivers meeting industrial Ethernet temperature specifications. The modules facilitate fast Ethernet transmission over UTP-5 cabling, though the S558-5999-U5 affords maximum electromagnetic-interference (EMI) noise suppression because it features an additional auto transformer to support termination of the unused twisted pair. **Bel Fuse, Inc., 198 Van Vorst St., Jersey City, NJ 07302; (800) BEL-FUSE, FAX: (201) 432-9542, e-mail: belfuse@belfuse.com, Internet: http://www.belfuse.com.**

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Transceiver integrates into industrial systems

The model PKLR 200-mW transceiver is designed for integration into industrial systems. Employing frequency-hopping, spread-spectrum (FHSS) technology, the device is said to provide interference-resistant communication even in RF hostile environments. To facilitate integration, the package measures 1.65 × 2.65 in. (4.19 × 6.73 cm). The device contains software for implementing a variety of network configurations (point-to-point, point-to-multipoint, multiple-collocated non-interfering networks). The unit ships completely assembled and connection is achieved using an RS-232 or TTL-level serial interface. **Aerocomm, 13256 W. 98th St., Lenexa, KS 66215; (800) 492-2320, FAX: (913) 492-1243, Internet: http://www.aerocomm.com.**

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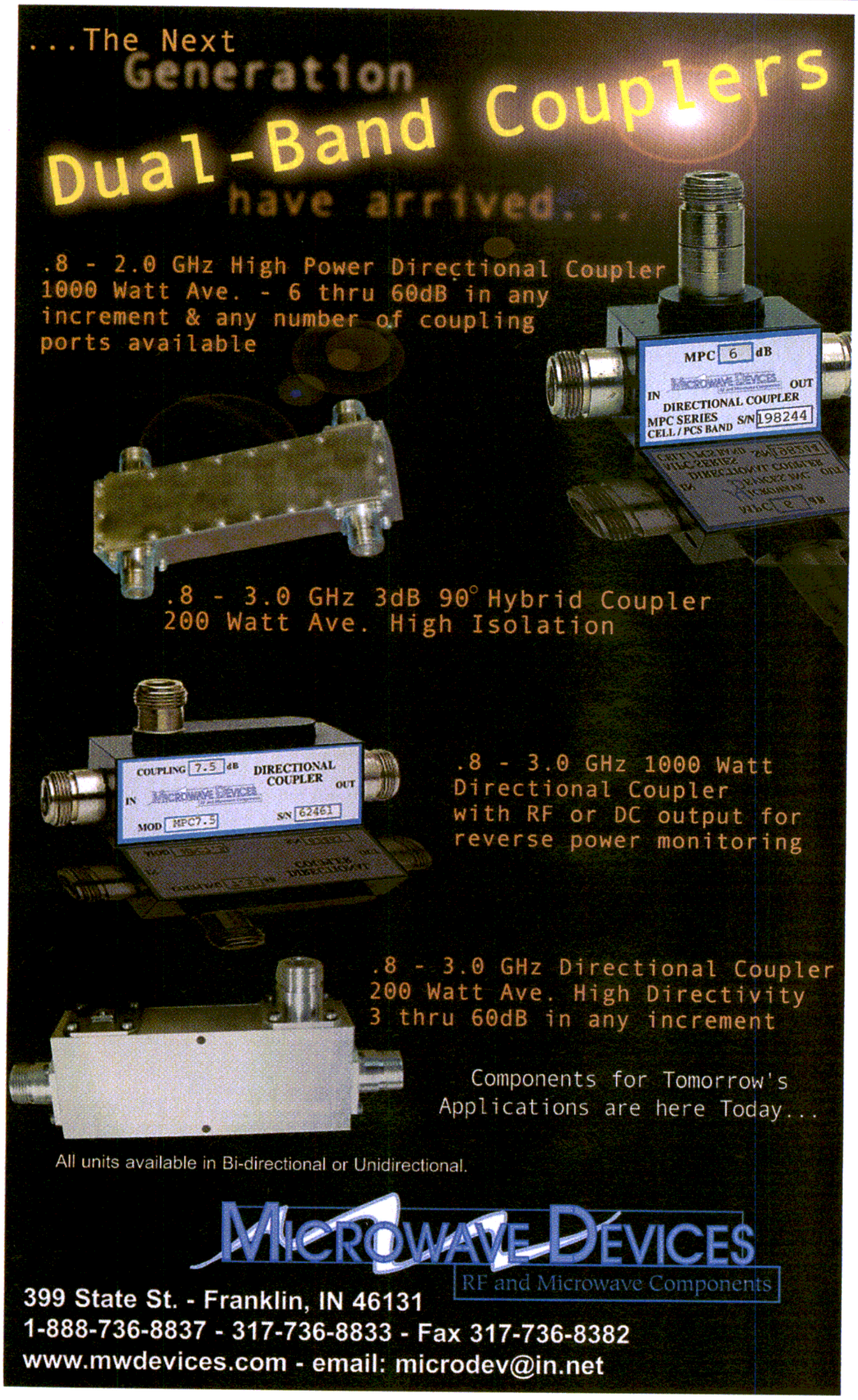

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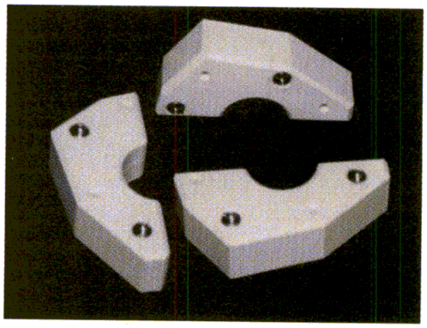
Ceramic targets applications to 1100°F

The Aremcolox™ 502-600 is an machinable glass-ceramic developed for electrical, electronic, and high-temperature applications to 1100°F (593°C). Compressive strength is 32,000 psi, flexural strength is 14,000 psi, dielectric strength is 380 V/mil, dielectric constant is 6.8 at 1 MHz, and thermal conductivity is 4.08 BTU-in./hr-ft^2-°F. Applications include connector housings, instrument and appliance insulators, coil forms and bobbins, resistor supports, capacitor insulators, and arc barriers. **Aremco Products, Inc., P.O. Box 517 707-B Executive Blvd., Valley Cottage, NY 10989; (914) 268-0039, FAX: (914) 268-0041, e-mail: aremco@aremco.com, Internet: http://www.aremco.com.**



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Power-conversion architecture delivers 75 W

Powerstick™ is a power-conversion architecture designed for low-profile, high-density board-mounted DC-to-DC converters. The unit delivers up to 75 W per module and up to 900 W in fault-tolerant arrays. The device's through-the-board mounting results in a power-conversion density of 188 W/in.^{3} **Vicor Corp., 25 Frontage Rd., Andover, MA 01810; (978) 470-2900, FAX: (978) 475-6715, Internet: http://www.vicr.com.**

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Connectors offer push-on mating

The BMA series of blind-mate connectors is qualified to MIL-PRF-31031 with the interface in accordance with MIL-STD-348. The devices offer the advantage of push-on mating and provide miniaturization through modular design by eliminating cumbersome cable assemblies. Configurations include semirigid and flexible cable connectors, hermetic versions and adapters, fixed and floating versions, low-profile styles, high-power versions, along with stripline and microstrip launchers. Adapters between series and terminations are other configurations. **SV Microwave, Inc., 3301 Electronics Way, Suite D, West Palm Beach, FL 33407; (561) 840-1800, FAX: (561) 844-8551, Internet: http://www.svmicrowave.com.**

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Kit speeds products to market

The KH series basic evaluation/development kit includes tools for the integration of KH modules into an end product. The KH modules combine an optimized RF link with an onboard decoder or encoder. A pair of modules is capable of transferring the status of up to eight parallel inputs and 3^{10} addresses over distances in excess of 300 ft. The module development system features fully assembled evaluation boards, supporting visual and audible testing of the KH module's performance in various environments. An onboard prototyping area is also provided to support rapid product development. Antennas, extra KH modules, and full documentation are included. **Linx Technologies, 575 SE Ashley Pl., Grants Pass, OR 97526; (541) 471-6256, FAX: (541) 471-6251, Internet: http://www.linxtechnologies.com.**

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Cable resists chemical erosion

The GX series subgrouping fiber-optic cable is double jacketed for chemical resistance in industrial environments. The cable will not degrade with continuous long-term exposure to most volatile chemicals, such as fuels, oils, liquids, cleaning agents, and acids. The cable consists of an inner cable jacket of PVC and an outer fluoropolymer cable jacket in order to provide the chemical resistance. The fiber count for the cable can range from 2 to 144 optical fibers within a single cable jacket. The cable can mix multimode and single-mode optical fibers within a single cable. **Optical Cable Corp., 5290 Concourse Dr., Roanoke, VA 24019; (800) 622-7711, (540) 265-0690, FAX: (540) 265-0724, Internet: http://www.occfiber.com.**

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Generator boasts jitter of <1-ps RMS

The model SCG 450 is a synchronous clock generator used in various telecommunications and datacommunications applications where designs must conform to a Stratum synchronization or Synchronous Optical Network (SONET) architecture. The device is a digital phase-locked loop (PLL) that generates 155.56-MHz low-voltage-positive-emitter-coupled-logic (LVPECL) outputs from a low-jitter voltage-controlled crystal oscillator (VCXO) with two 8-kHz inputs. Features include two selectable references, switching capability between references without introducing a phase transient, disable capability on LVPECL outputs, jitter <1-ps root mean square (RMS) in the 12-kHz-to-20-MHz band, and low jitter-clock source for high OC-N framers. P&A: $463.05 each; 4 to 6 wks. **Conner-Winfield Corp., 2111 Comprehensive Dr., Aurora, IL 60505; (630) 851-4722, FAX: (630) 851-5040, e-mail: info@conwin, Internet: http://www.conwin.com.**

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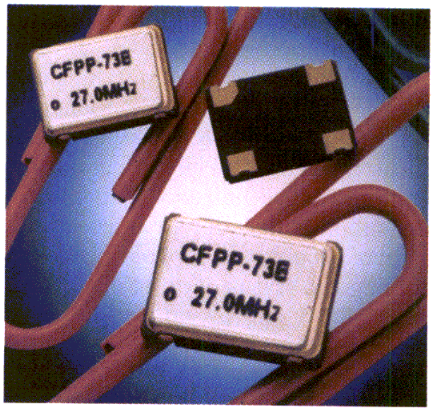
Oscillators operate between 1 and 133 MHz

The models CFPP-72 and CFPP-73 are a range of one-time factory programmable oscillators available in any frequency between 1 and 133 MHz. The CFPP-72 series operates from a +5-VDC supply and covers the entire 1-to-133-MHz frequency range, while the CFPP-73 series takes a +3.3-VDC supply and offers frequencies up to 100 MHz. Both

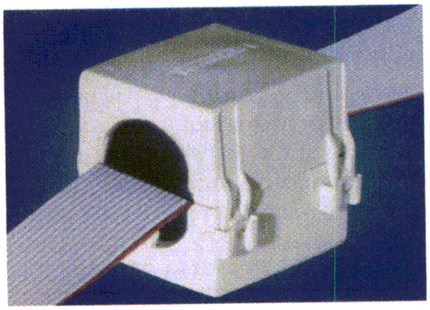


variants can be specified for operating temperature ranges from 0 to +70°C or from –40 to +85°C, with frequency stabilities down to ±50 PPM in each case. All devices operate in tri-state mode and provide high-speed-complementary-metal-oxide-semiconductor (HCMOS) output, while the CFPP-72 series also offers TTL output. Applications include telecommunications transmission systems and process equipment. P&A: $4.10 (depending on quantity). **C-MAC MicroTechnology, 4222 Emperor Blvd., Suite 300, Durham, NC 27703; (919) 941-0430, FAX: (919) 941-0530, Internet: http://www.cmac.com.**

Enter No. 89 at www.mwrf.com

Suppressor offers 1-GHz shielding effectiveness

A nylon outer case with a pair of ferrite halves clamps over flat-ribbon cables in order to provide electromagnetic/RF-interference (EMI/RFI) suppression. The device offers shielding effectiveness up to 1 GHz, while allowing data signals to pass unimpeded. Four sizes accommodate



cables with up to 64 conductors. Assembly options include direct clamping of the cable, as well as adhesive and hardware mounting. **FerriShield, Inc., 350 Fifth Ave., Suite 7310, New York, NY 10118; (212) 268-4020, FAX: (212) 268-4023, e-mail: info@ferrishield.com, Internet: http://www.ferrishield.com.**

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Relay spans DC to 8 GHz

The coaxial RF 1P2T pulse-latching "RDT" relay series features design-enhanced surface-mount technology (SMT) and provides a low-cost option from DC to 8 GHz. These coaxial SMT devices boast 50-Ω impedance with pulse-latching actuation, and are available with standard operating voltages of +12, +24, and +28 VDC. The relays are intended for high-volume, high-performance commercial wireless and industrial applications requiring small size with typical insertion loss of 0.07 dB at 900 MHz and 0.12 dB at 1900 MHz. This series of relays boasts typical isolation of 85 dB at 900 MHz and 75 dB at 1900 MHz. P&A: stock to 6 wks. **RelComm Technologies, Inc., 610 Beam St., Salisbury, MD 21801; (410) 749-4488, FAX: (410) 860-2327, e-mail: sales@relcomm tech.cor.**

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Via fills achieve 2°C/W thermal resistance

With circuit designers achieving thermal resistance as low as 2°C/W, a series of solid, copper-plated via fills is used in the fabrication of metallized ceramic substrates, chip carriers, and packages. Along with their high thermal conductivity, solid via plugs have an electrical resistance as low as 0.38 mΩ. By combining this thermal management with thin-film circuitry, multilayer patterns, integrated resistors, capacitors and inductors, designers can increase the performance in a miniaturized package. **Remtec, Inc., 100 Morse St., Norwood, MA 02062; (781) 762-9191, FAX: (781) 762-9777, e-mail: sales@remtec.com, Internet: www.remtec.com.**

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Retainer targets SMT applications

A low-profile coin-cell retainer has been designed for high-density surface-mount-technology (SMT) applications and features a flow-hole soldertail that increases joint strength. Dual-spring contacts ensure low-contact resistance and are designed to hold the cell securely to withstand shock and vibration. With polarity being clearly marked, the retainer is balanced and lightweight for reliable pick up and placement. **Keystone Electronics Corp., 31-07 20th Rd., Astoria, NY 11105; (800) 221-5510, FAX: (718) 956-9040, e-mail: kec@ keyelco.com, Internet: http:// www.keyelco.com.**

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Service handles variable passive loads

A custom-built load offers service for power supply, telecommunication, industrial-equipment manufacturers, and other companies that require passive loads. The service specializes in designing and manufacturing variable passive loads based on customer specifications. **OHM LOADS, Inc., 313 Evans Ave., Etobicoke, Ontario, Canada M8Z 1K2; (416) 503-0123, FAX: (416) 503-1546, Internet: http:// www.ohmloads.com.**

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Heat sink cools 1.5-GHz processor

The model TS-12088-AA is designed to cool the Intel "Williamette" processor up to 1.5 GHz. The unit is driven by a +12-VDC high-speed fan that generates 24 CFM. The 5000-RPM ball-bearing fans sits atop an extruded aluminum (Al) heat sink. The device is equipped with an attachment clip and factory-applied interface material. **Thermshield, P.O. Box 1641, Laconia, NH 03247; (603) 524-3714, FAX: (603) 524-6602, e-mail: info@therm shield. com, Internet: http:// www.therm shield.com.**

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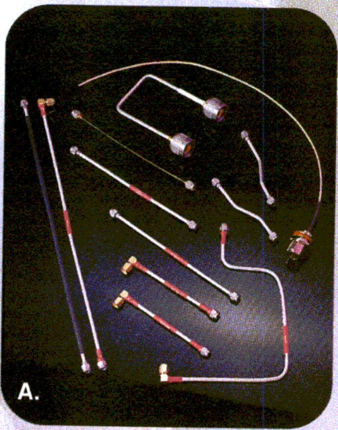
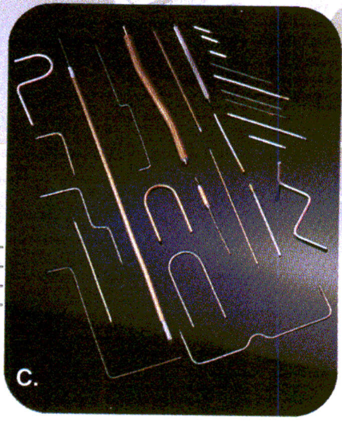
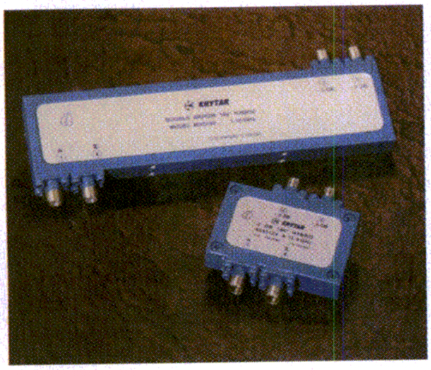




Coupler spans 1 to 18 GHz

Model 4010180 is a double-arrow-designed 180-deg. hybrid four-port coupler with dual-input and output ports. Signals supplied to the difference ports provide signals that are 180 deg. out of phase. The unit operates over the entire frequency range of 1 to 18 GHz. With 3-dB coupling, amplitude imbalance is ±0.6 dB maximum and phase imbalance is ±12



deg. maximum. Isolation is 15 dB minimum while maximum VSWR is 1.7:1. Insertion loss is 2.9 dB maximum and maximum power ratings are 20 W average and 3 kW peak. **Krytar, 1292 Anvilwood Ct., Sunnyvale, CA 94089; (408) 734-5999, FAX: (408) 734-2017, Internet: http://www.krytar.com.**

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Switch works from 3 to 24 GHz

The model MSN-6DR-06-standard option No. 1524, B02, AL is an ultra-broadband reflective single-pole, six-throw (SP6T) solid-state switch. The device operates from 3 to 24 GHz with an insertion loss of < 1.8 dB at 3 GHz to <4.5 dB at 24 GHz. Switching speed is ≤45 ns on and ≤35 ns off. Video transient is ≤225 mV peak-to-peak at 20-MHz bandwidth with an isolation of 50 dB minimum, VSWR is 2.2:1 typical. Power supplies are +5 VDC at 180-mA current as well as –15 VDC at 40-mA current. **American Microwave Corp., 7311-G Grove Rd., Frederick, MD 21704; (301) 662-4700, FAX: (301) 662-4938, e-mail: amcpmi@aol.com, Internet: http://www.amwave.com.**

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Antenna turret feed covers three bands

Model 0009-800 is a three-band turret-style feed system. The unit features a rack-panel controller to remotely select polarization and frequency band. The panel also indicates feed status. The dual-polarized S-band frequency range is 2.2 to 2.8 GHz, while the linear- rotatable C-band frequency range is 3.4 to 4.2 GHz. The linear-rotatable Ka-band frequency range is 18 to 21 GHz. **Seavey Engineering Associates, Inc., 28 Riverside Dr., Pembroke, MA 02359; (781) 829-4740, FAX: (781) 829-4590, Internet: http://www.seaveyantenna.com.**

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RF calibration

A brochure describes a company's RF and microwave calibration services. The brochure discusses the calibration of dipole-like antennas, calibrations of microwave antennas and probes, calibrations of power-flux density probes, and field-strength sensors, microwave power sensors, attenuators, and signal generators. Other services include characterization of electromagnetic (EM) materials, vector-network analysis, as well as the measurement of noise sources, phase noise, and amplifier-noise parameters. **National Physical Laboratory;** *020 8943 6880, FAX: 020 8943 6458.*

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Attenuators/switches

A 22-page product catalog presents data sheets for microwave integrated components. In-phase/ quadrature (I/Q) vector modulators, quadrature-phase-shift-keying (QPSK) modulators, phase shifters, and attenuators are covered. Specifications include frequency range, DC power consumption, attenuation, insertion loss, and switching speed. **G.T. Microwave, Inc.;** *(973) 361-5700, FAX: (973) 361-5722, e-mail: gtmicrowav@aol.com, Internet: http:// www.GTmicrowave.com.*

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Fixed attenuators

A brochure focuses on a company's capabilities. The brochure contains five pull-out sections that are dedicated to the company's manufacturing subsidiaries in the coaxial isolator and circulator, coaxial-fixed-attenuator, power resistor and termination, base-station, military-diode and capacitor, and programmable step-attenuator markets. A description of the company's facilities and brief discussions of its products and services, are included. **MCE Companies, Inc.;** *(734) 426-1230, FAX: (734) 426-1510, e-mail: info@mcecompanies.com, Internet: http:// www.mcecompanies.com.*

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Laser diodes

Fiber-optics and optical instrumentation are the subject of a 314-page catalog. Lenses, beamsplitters, filters, waveplates, mounts, plates, stages, apertures, laser diodes and pointers, illuminators, targets, objectives, and measuring devices are specified. A series of application notes is included. **Edmund Industrial Optics;** *(800) 363-1992, FAX: (856) 573-6295, Internet: http://www.edmundoptics.com.*

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Temperature monitoring

Data-logging instruments are featured in a 15-page catalog. Temperature and humidity data loggers and indicators, remote monitoring systems, temperature- and pressure-chart recorders, moisture indicators, universal input recorders, along with temperature- and humidity-chart recorders are offered. Specifications include velocity range, volume range, accuracy, ambient operating conditions, measurement ranges, weight, and power supply. **Dickson;** *(800) 323-2448, FAX: (800) 676-0498, Internet: http://www.dicksonweb.com.*

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Production testing

Solutions for optoelectronic-component production testing are covered in an eight-page brochure. An industrial solution for laser-diode testing, high-speed programmable laser drivers, light-intensity measurement solutions, temperature control, photodetector characterization, along with switching and data acquisition (DAQ) are presented. Application information is provided. **Keithley Instruments, Inc.;** *(888) KEITHLEY, (440) 248-0400, FAX: (440) 248-6168, Internet: http:// www.keithley.com.*

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Relays and switching

A 26-page brochure (No. 1307764) focuses on connectors, relays, switches, printed-circuit boards (PCBs), terminal blocks, circuit protection, electronic modules, battery packs, wires, cables, and touchscreens. The telecommunications, automotive, wireless, tooling and fiber-optics industries are covered. Application information is provided. **Tyco Electronics;** *(800) 522-6752, e-mail: newproducts@tycoelectronics.com, Internet: http://www.tyco electronics.com.*

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Suppression filters

A 15-page brochure discusses suppression-filter systems. Integrated-suppression-bus technology™, product testing, surge-current capacities, and product features are covered. Filter systems for low-, medium-, medium-to-low-, and high-exposure applications are offered. Product specifications, such as filtering attenuation frequencies, surge-current capacities, operating voltage, and clamping-voltage data are included. **Current Technology;** *(800) 238-5000, FAX: (972) 252-7705, Internet: http://www.currenttechnology.com.*

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Transceiver ICs

A 26-page cross-reference brochure is designed to assist engineers in selecting local-area-network (LAN) isolation transformers for optimizing the performance of transceiver integrated circuits (ICs). The catalog focuses on magnetics which interface with chip sets for HomeLAN, Gigabit Ethernet, 10/100 Base-Tx, and 10Base-T applications. More than 450 part numbers, cross-referenced to over 180 transceiver chip sets are offered. **Bel Fuse, Inc.;** *(800) BEL-FUSE, FAX: (201) 432-9542, e-mail: belfuse@belfuse.com, Interent: http:// www.belfuse. com.*

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EMI shielding

A 42-page design guide covers electromagnetic-interference (EMI) shielding theory, standards, and application data. The guide offers approaches to solving EM-compatibility (EMC) problems and assists in the selection of EMI shielding products for particular solutions. Flow charts that guide the user from a perceived EMC problem to a solution with EMI material recommendations are included. **Tecknit;** *(908) 272-5500, FAX: (908) 272-2741, e-mail: tecknit@tecknit.com, Internet: http:// tecknit.com.*

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NEW LITERATURE

Test probes

A catalog and sourcebook focuses on spring-contact probes. In-circuit test probes, high-current probes, and semiconductor probes are discussed. The sourcebook section is designed to help customers specify and order the correct probe for their application. Guidance on coaxial fixturing and battery-contacting mounting is also covered. **Interconnect Devices, Inc.;** *(913) 342-5544, FAX: (913) 342-7043, e-mail: info@idinet.com, Internet: http://www.idinet.com.*

Enter No. 73 at www.mwrf.com

LED lamps

Direct incandescent replacement light-emitting-diode (LED) lamps are the focus of a 32-page catalog (datasheet log UT005). The product offerings are organized by base type and subdivided by LED color. Mechanical specifications and application information are included. A reference chart shows the available LED hues, wavelengths, forward voltages, intensities, viewing angles, as well as dye materials. A cross-reference table for incandescent lamps is provided to accompany each LED lamp listing. **LEDtronics, Inc.;** *(800) 579-4875, (310) 534-1505, FAX: (310) 534-1424, Internet: http://www.ledtronics.com.*

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Interconnect solutions

A 100-page source book is designed in order to expose product designers and engineers to many proven interconnect concepts. The book is divided into five sections—multicycle test connectors, product connectors, board-to-board connectors and interfaces, high-performance test sockets, and source book. The sections include descriptions of customer challenges, detailed descriptions of solutions, and a review of the results. Technical drawings for each interconnect solution are included. **Synergetix;** *(913) 342-0404, FAX: (913) 342-6623, e-mail: info@synergetix net.com, Internet: http://www.synergetixnet.com.*

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NEW LITERATURE

Data conversion

A product-selection guide focuses on analog signal conditioning and data-conversion components. Product offerings include analog-to-digital converters (ADCs), digital-to-analog converters (DACs), video-line drivers, track-and-hold amplifiers, and comparators. Specifications such as resolution, sample rate, power dissipation, linearity, and pack information are included. **Signal Processing Technologies;** *(800) 643-3778, FAX: (719) 528-2370, e-mail: sales@spt.com, Internet: http://www.spt.com.*

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Logic analyzers

Test equipment is available from an 18-page catalog. Pulse generators, logic analyzers, plotters, TV and video devices, meters, RF signal generators, inductance-capacitance-resistance (LCR) analyzers, spectrum analyzers, precision sources, and oscilloscopes are specified. Frequency counters, RF measurement equipment, impedance analyzers, network analyzers, power supplies, audio analyzers, semiconductors, signal generators, and data-acquisition (DAQ) equipment are offered. **Test Equipment Connection Corp.;** *(800) 615-8378, (407) 804-1780, FAX: (800) 819-TEST, (407) 804-1277, Internet: http://www.TestEquipmentConnection.com.*

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Magnet-wire terminations

A six-page brochure (No. 1308516) highlights the AMP-application tooling equipment available for machine-applied open-barrel through-splice terminals, AMPLIVAR pigtail splices, and direct-connect terminals, as well as MAG-MATE insulation-displacement contact termination of copper (Cu) and aluminum (Al) magnet wire. The brochure guides the reader through the appropriate application equipment for low-volume, intermediate-volume, high-volume, and maximum-volume production of magnet-wire terminations and splices. **Tyco Electronics;** *(800) 522-6752 option 3, FAX: (717) 986-3611, Internet: http://www.amp. com.*

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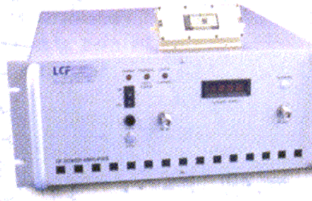

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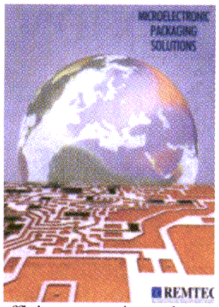

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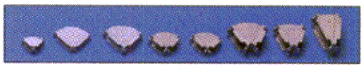

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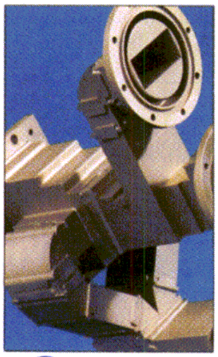

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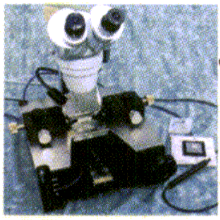

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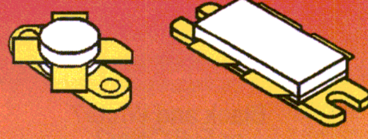

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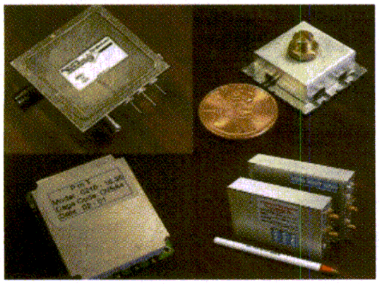

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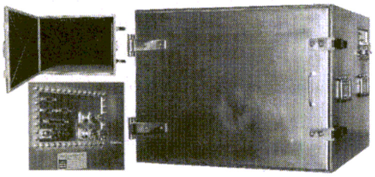

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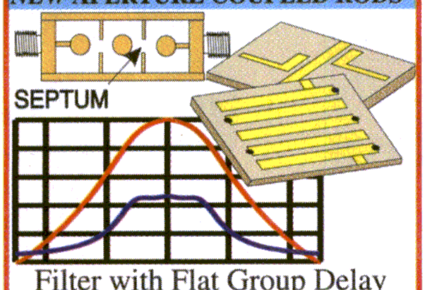

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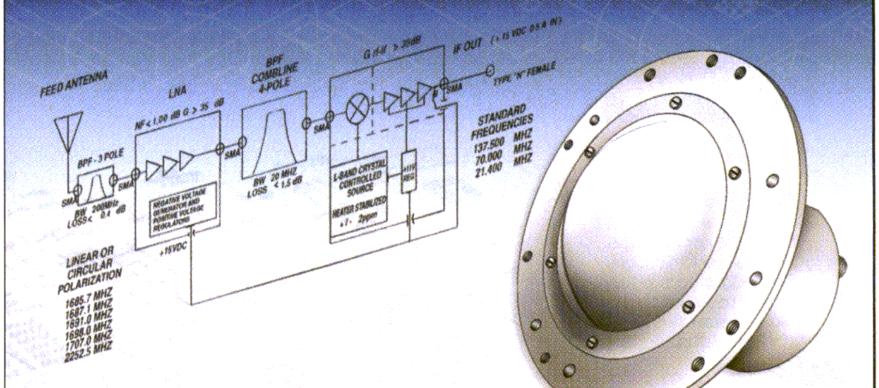

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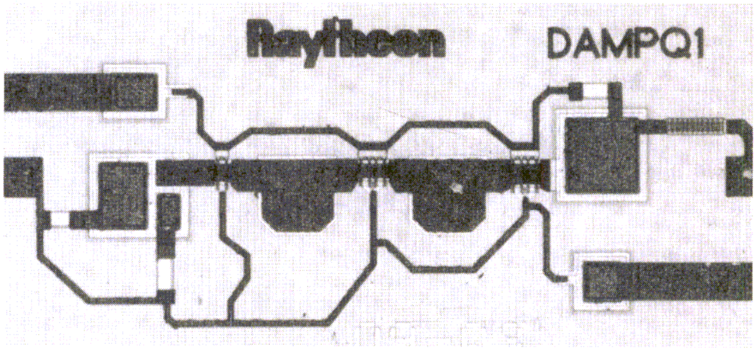


Nearly 15 years ago, an inside look at major defense contractor Raytheon Co. (Lexington, MA) revealed considerable capability in gallium-arsenide (GaAs) monolithic microwave integrated circuits (MMICs), including this distributed amplifier for use from 20 to 40 GHz. Using three field-effect transistors (FETs), the amplifier achieved 6-dB gain across its wide frequency range.

Microwaves & RF April Editorial Preview

Issue Theme: Military Electronics

News

The Military Electronics Show (MES) has been created for designers of military systems. This conference and exhibition, scheduled for April 25-27, 2001 at the Baltimore Marriott Waterfront Hotel (Baltimore, MD), is for engineers and companies dedicated to the advancement of military electronics. The April issue will preview the first-ever Military Electronics Show with coverage of technical sessions on all levels of military component and system design.

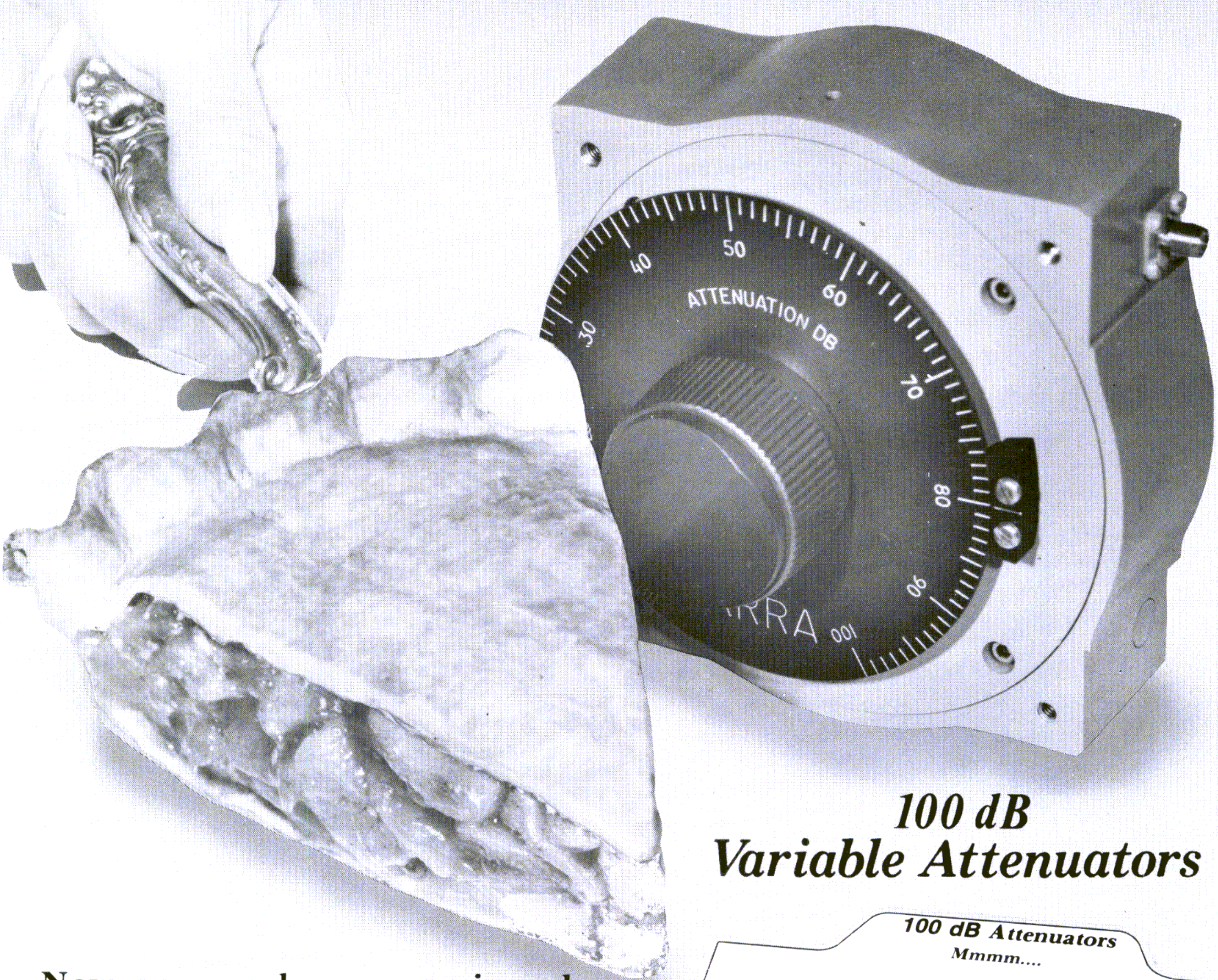
Design Features

The April issue of *Microwaves & RF* offers several articles with dual-use significance for military and commercial applications. For example, an author from the People's Republic of China introduces a new version of very-minimum-shift-keying (VMSK) modulation, a biphase technique with extremely high-bandwidth efficiency. Also, an author from the Ukraine explores techniques for designing broadband injection-locked Impatt oscillators for pulsed millimeter-wave applications.

Product Technology

April's Product Technology section will uncover a growing trend in the high-frequency industry, that of traditional RF and microwave manufacturers moving to the design and development of components for high-speed fiber-optic communications systems. Additional articles will detail a line of circuit-laminate materials well-suited for antennas, and a low-noise enhancement-mode, pseudomorphic high-electron-mobility-transistor (E-PHEMT) device ideal for cellular amplifiers.

Get a piece of the ARRA pie...



100 dB Variable Attenuators

100 dB Attenuators
Mmmm....

Freq Range	Atten vs Freq dB	Model #
500 - 1000 MHz	1.5	2952 - 100
900 - 1300 MHz	0.75	2-3952 - 100
1000 - 2000 MHz	1.5	3952 - 100X
2000 - 4000 MHz	1.5	4952 - 100 X
4000 - 8000 MHz	1.5	5952 - 100X

Insertion loss - 6 dB
VSWR - 1.5
Power - 15 cw
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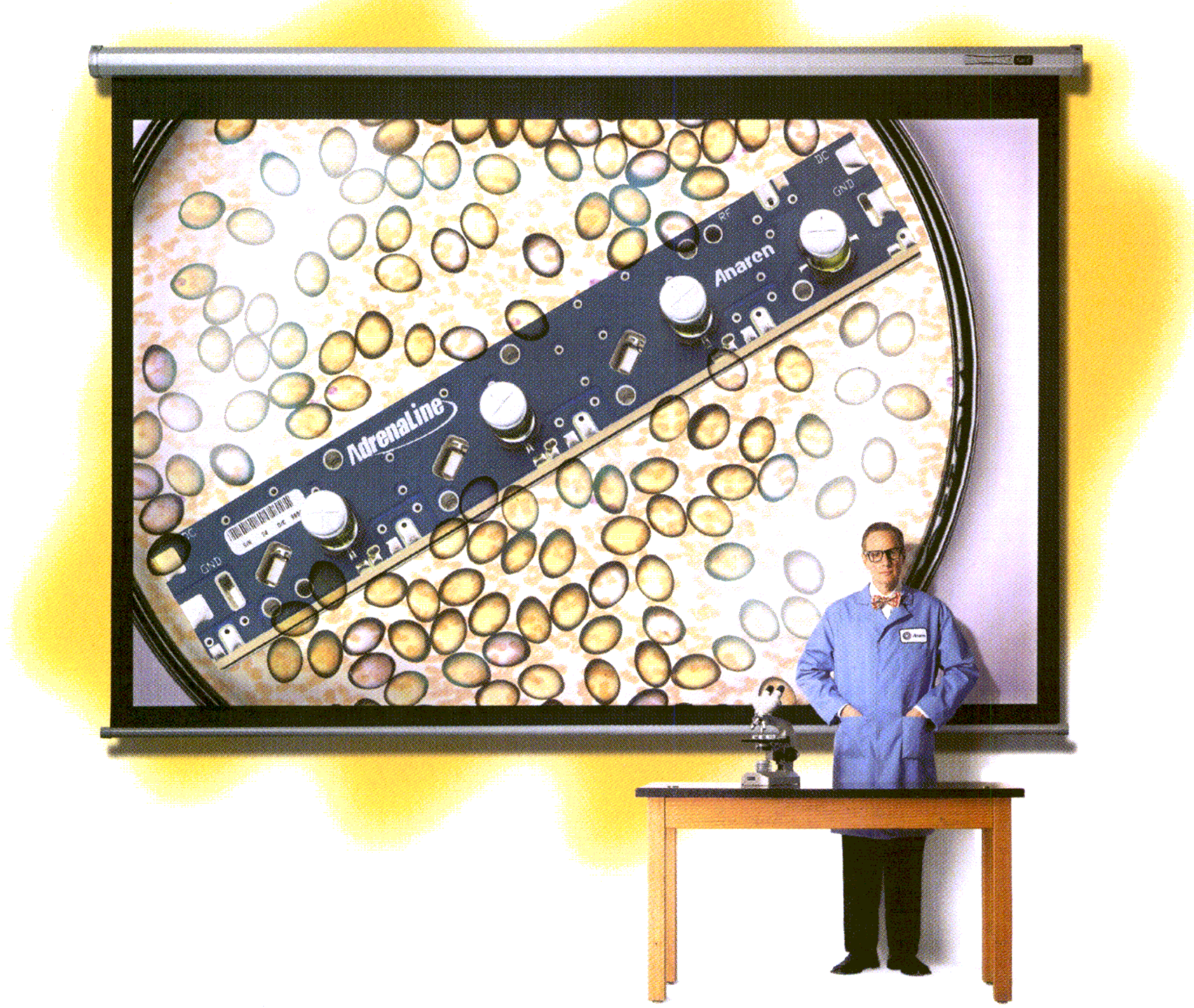
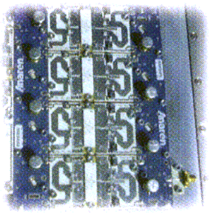
Warning: The benefits of our splitter/combiner are larger than they appear.



AdrenaLine

Today's lesson: Small footprint. Big benefits. Anaren's AdrenaLine™ high-power splitter/combiner takes the science out of designing and manufacturing single- and multi-channel amplifiers. Its unique, patented multilayer-stripline packaging and modular design increase capacity — and functionality — for greater performance in a slim-and-trim package.

Ideal for GSM, PCS, and WCDMA applications, AdrenaLine's three- through eight-way power modules can be tested or replaced individually for even greater amplifier manufacturing and field efficiency. Its unique splitting scheme produces four equal power divisions that make non-binary splits a snap for plug-and-play convenience — and the lowest loss possible.



AdrenaLine includes space to accommodate additional RF or DC functions creating a high-performance, low-profile, and low-cost interconnect solution. And it's so versatile, you can launch a connector or go connector-less altogether.

Give your amplifier design a closer look — then give it a shot of AdrenaLine! Exclusively from Anaren.

Questions? Contact Anaren at adrenaline@anaren.com

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