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Microwaves & RF

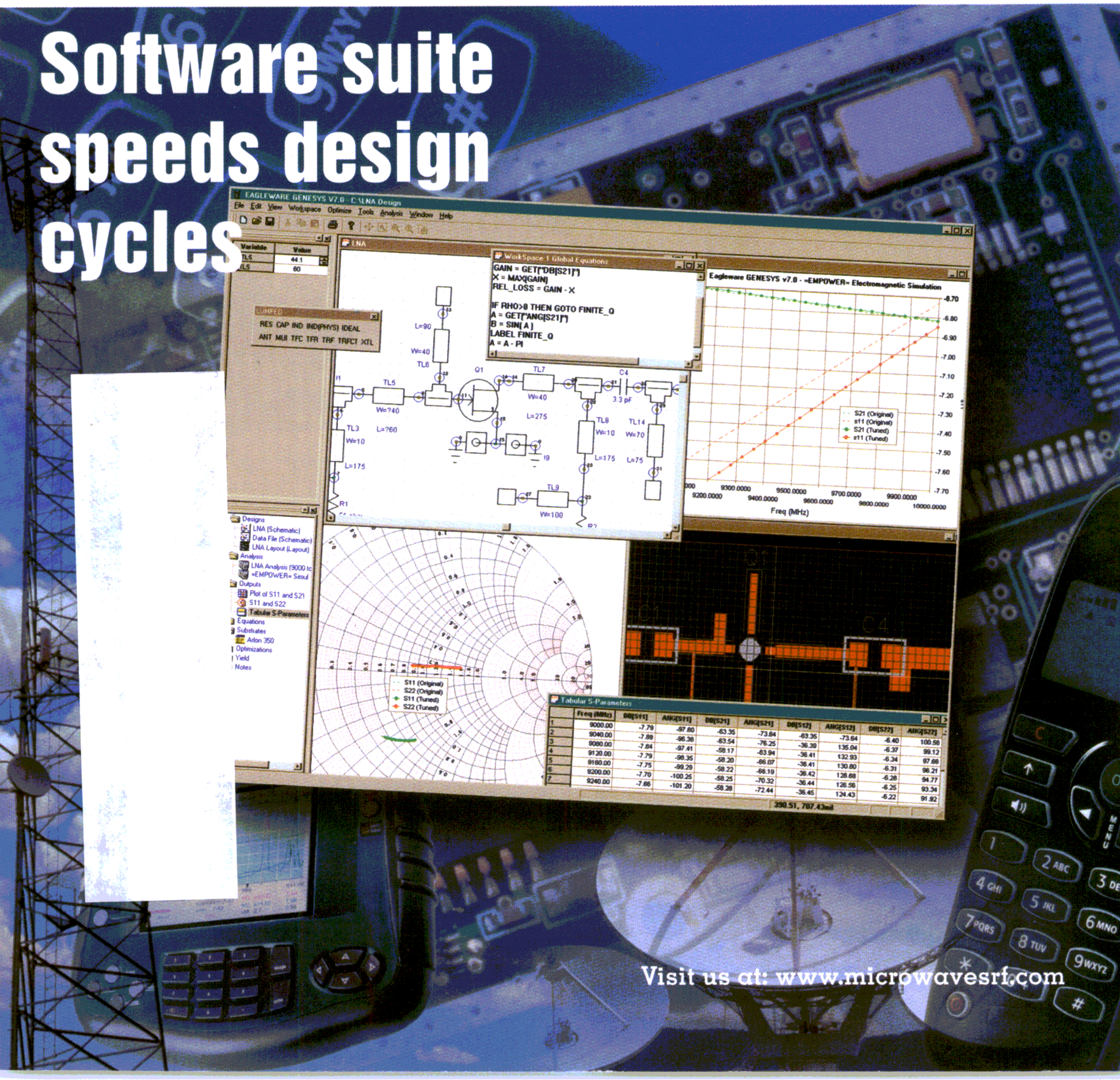
Wireless Applications Issue

NEWS
Extracting the truth about Bluetooth

DESIGN FEATURE
Advantages of array antennas

PRODUCT TECHNOLOGY
Chip set channels CDMA signals

Software suite speeds design cycles



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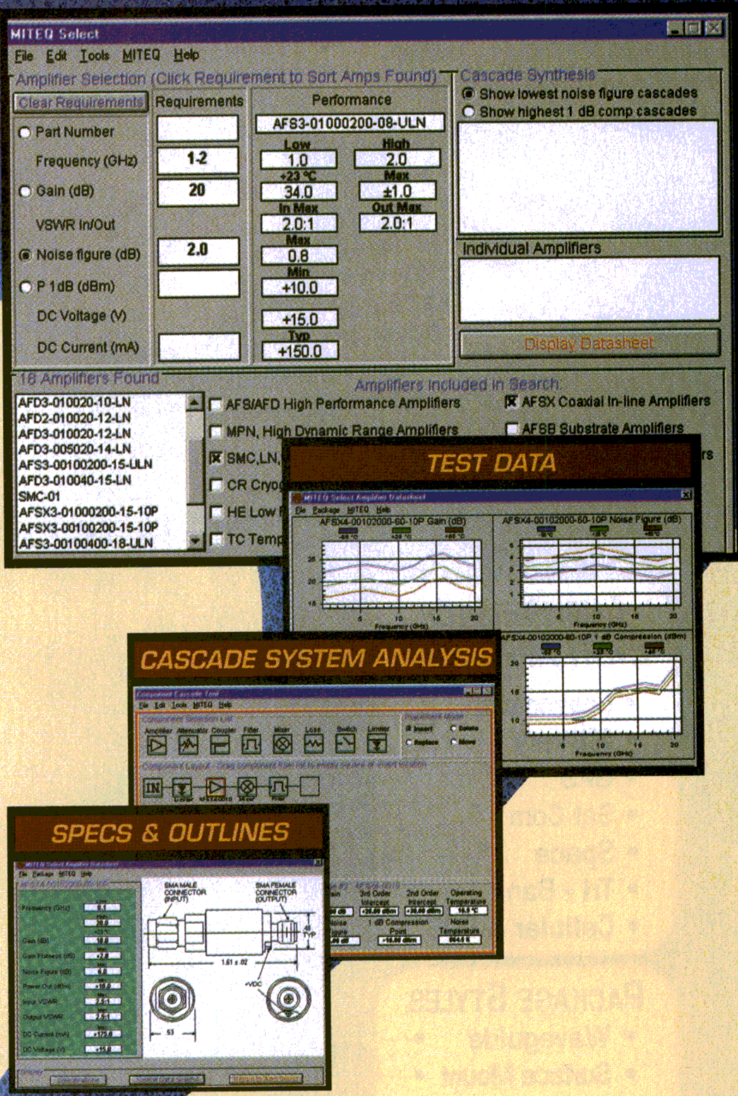

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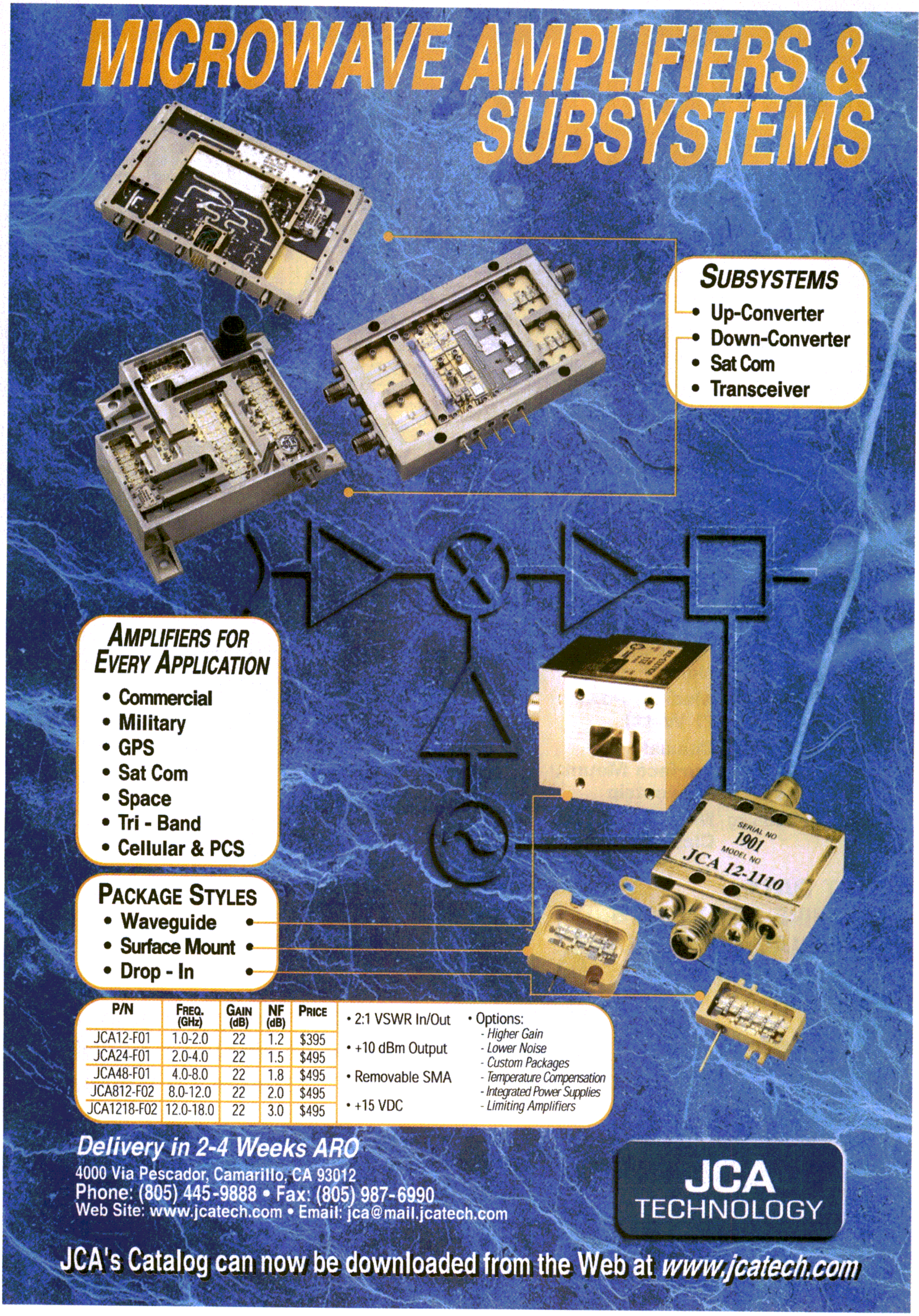

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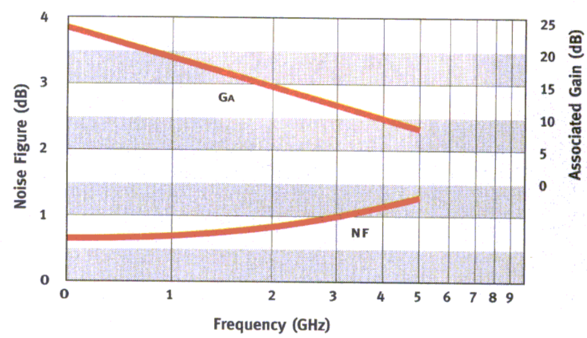

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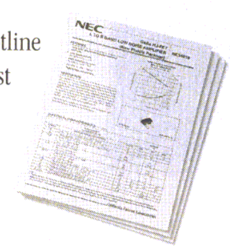

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AUGUST 1999 VOL. 38, NO. 8

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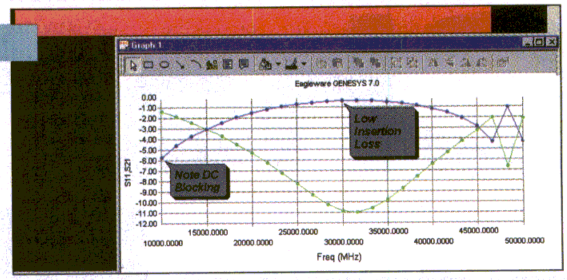
141
Low-Cost CAE Suite Adds Power And Speed
The latest version of a PC-based CAE package combines electromagnetic and circuit co-simulation with additional speed and ease of use.

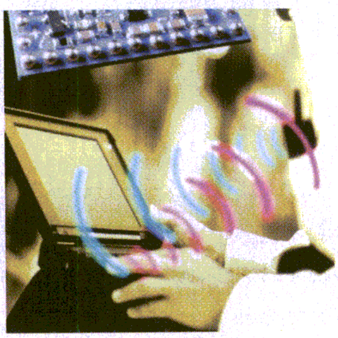


DEPARTMENTS

13 Feedback
17 Editorial
21 The Front End
48 Editor's Choice
50 Financial News
52 People
54 Educational Meetings
56 R&D Roundup
96 Bookmark
139 Application Notes
174 New Products
187 New Literature
195 Infocenter
196 Looking Back
196 Next Month

NEWS

31 Wireless Ushers In The Era Of Personal Connectivity



44 Quadrature Hybrid Couplers Serve Narrowband Applications

SPECIAL REPORT

130 New Orleans To Host Fall Wireless Symposium

DESIGN FEATURES

59 Novel Multiple-Beam Antenna Array Serves Mobile BTS
69 FSK Modulator Boasts High DC Accuracy
77 Design Interdigital Bandpass Filters Using LTCC Circuits
88 Novel Coaxial Connector Aids In-Vehicle Phone Users
98 Perform Production Testing On Millimeter-Wave MMICs
105 Fractional-N Synthesizers Meet HSCSD And GPRS Demands
123 Synthesis + Simulation = Enhanced Design Process

PRODUCT TECHNOLOGY

147 CDMA/AMPS Chips Enable Dual-Band Transceivers
151 Splitters/Combiners Bond High-Power Amplifiers
152 EM Simulator Is Free Of Charge
154 Schottky Mixers Feature High Dynamic Range
157 Signal Generators Offer Enhanced Spectral Purity
159 Spectrum Analyzers Geared To Production Testing
160 Software Simplifies IR Communications
164 Doublers Drive YIG Sources To 44 GHz

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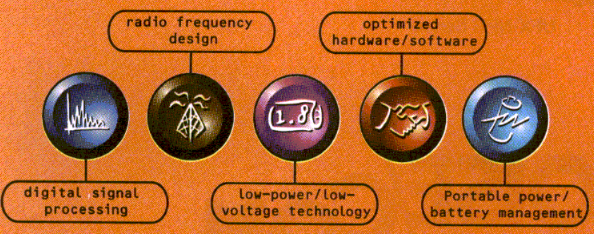

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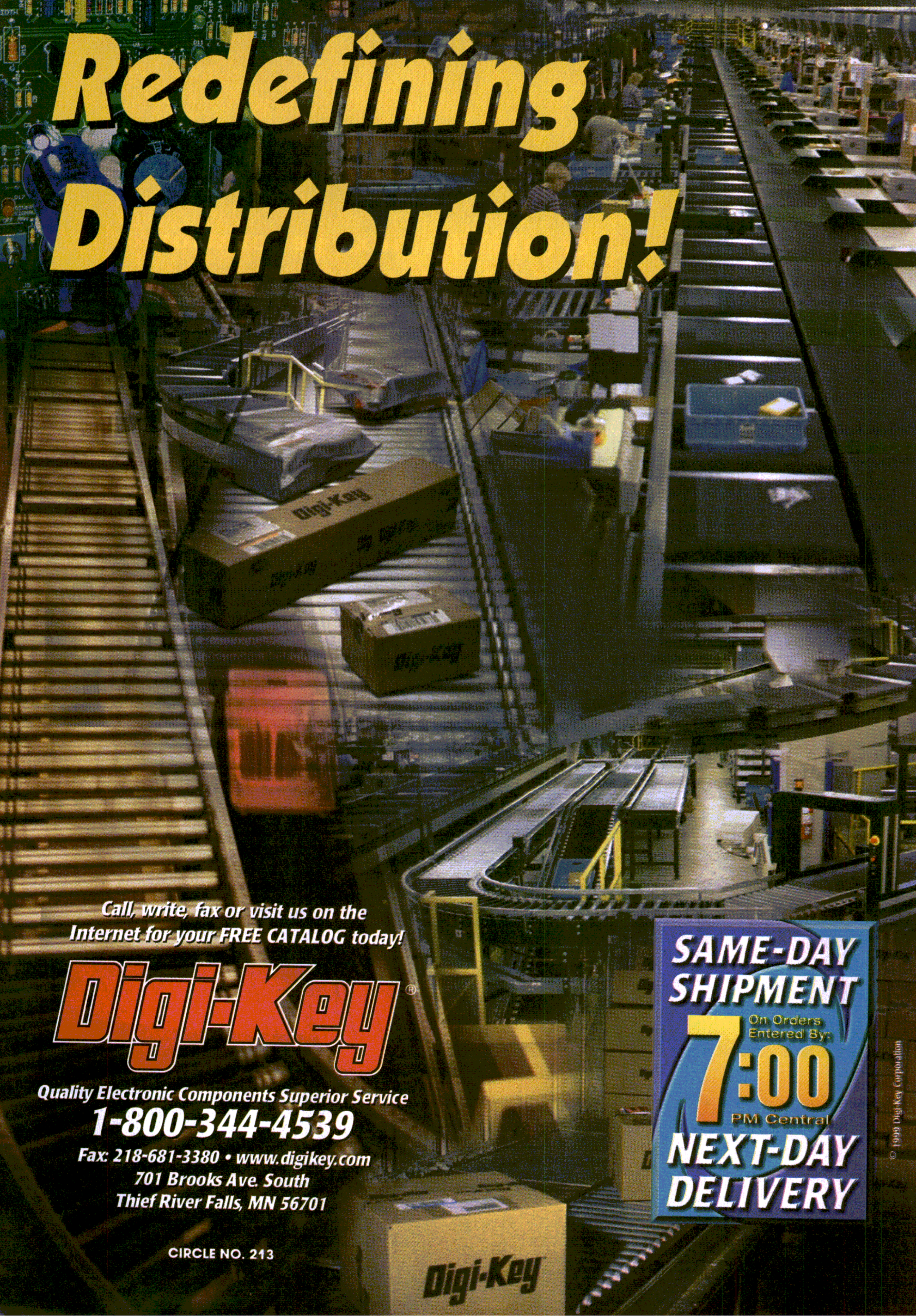
in communications



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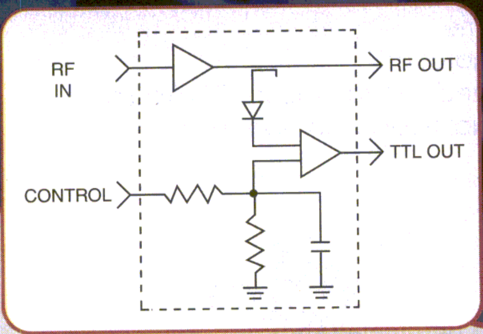

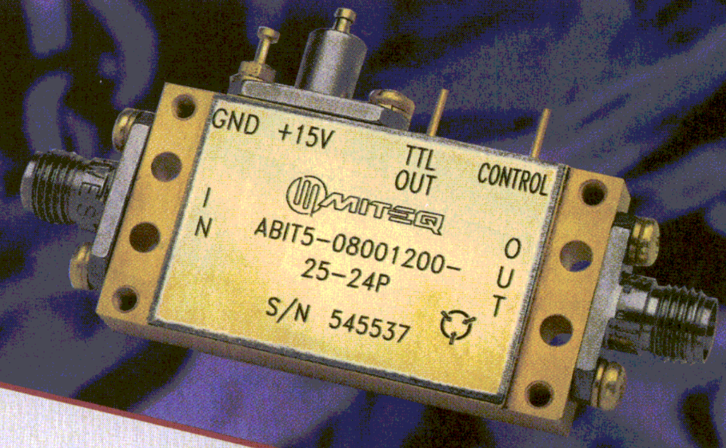

Features

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- Independent TTL output
- Up to ½ Watt CW power output
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Typical Model Performance

Model number	ABIT5-08001200-25-24P	ABIT5-04000800-25-25P
Frequency range	8–12 GHz	4–8 GHz
Gain	30 dB minimum	30 dB minimum
Noise figure	2.5 dB maximum	2.5 dB maximum
1 dB gain compression	+24 dBm minimum	+25 dBm minimum
BIT detector threshold	<+20 dBm *	<+20 dBm *
BIT detection format	TTL single ended	TTL single ended
Output power	Logic 1 = +3.7±1.3 VDC Logic 0 = +0.4 ±0.4 VDC	Logic 1 = +3.7±1.3 VDC Logic 0 = +0.4 ±0.4 VDC

*Other levels available via adjustment to the threshold control.

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CIRCLE NO. 234

ALBALLOY RESPONSE

To the editor:

I would like to respond to John Zorzy's letter on white bronze and the true name of tri-alloy (Alballoy) that appeared in May's Feedback (p. 13). We are a plating company that has been plating RF connectors for more than 40 years and providing service for many of the companies that advertise in your magazine. Our finish is known as Tri-M3™. Currently, there is no standard that exactly governs the way alballoy should be plated or tested as is the case with gold (Au), silver (Ag), and nickel (Ni). This is good and bad in that it allows plating companies to have freedom in how they plate alballoy, but it promotes a market saturation of trade names.

The unfortunate byproduct of this is that there are a lot of "alballoy"-plated parts out there and no one really knows what the alloy concentrations are or if customers are truly receiving what they have asked and paid for. This has led to some *Microwaves & RF* company variations of the trade names that are out there. So in this sense, I agree with Mr. Zorzy.

However, I must also disagree with him, because underneath this convoluted view of alballoy, there is also another reason. While I won't dispute that there are some plating companies out there that come up with a trade name for competitive purposes, there are others that have been plating alballoy for years and have developed variations of this type of plating, specifically with their customers' parts in mind. We have been using alballoy in some variation for many years to provide a solderable surface on traditionally unsolderable metals or for corrosion resistance. Since alballoy is a ternary alballoy, platers can manipulate the properties to provide the desired characteristics.

It is this variation that we present a trade name to identify the very particular characteristics that this version offers. Zinc (Zn), one of the constituents to the alballoy, has a very favorable oxidation potential. If a plater manipulates the deposit so that more Zn is plated out of the bath, then it will yield better shelf life and corrosion resistance. Tin (Sn), another constituent, has excellent anti-seizure properties (lubricity) and solderability. If a plater manipulates the deposit so that the concentration of Sn in the deposit is higher than normal, there will be a more solderable part that exhibits excellent wear resistance. Finally, if it is conductivity that a person is after, a plater can manipulate the deposit so that it is higher in copper (Cu). Therefore, alballoy can be broken down into other variations depending on the desired properties. It offers many possibilities that can be "tailored" to a person's needs and this capability lends to the names that are associated with it.

Jeff Smith
President/CEO
Electro-Spec, Inc.
Franklin, IN

Silicon Germanium (SiGe), Stanford Microdevices' latest RF semiconductor process, offers benefits not attainable by conventional silicon-bipolar technologies: lower noise figures, lower power consumption, high output power at high efficiency, and high integration level.

As part of a series of Stanford Microdevices' initiatives to apply silicon germanium technology to a broad spectrum of communications applications, we are now offering the wireless market devices built using a patented silicon germanium manufacturing process. As these devices enter the marketplace, consumers will benefit from cellular phones, pagers, and other wireless communications devices that have extended battery life, carry out multiple functions, and are smaller, lighter, and less expensive.

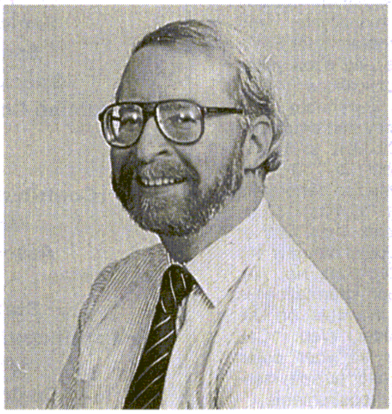
PRODUCT SELECTION GUIDE

General Purpose Amplifiers

Part Number	Vd (V)	Id (mA)	3dB BW	P1dB (dBm)	IP3 (dBm)	Gain@ 1 GHz	Gain@ 2 GHz	NF 50 Ohm
SGA-2186	2.2	20	DC-5.0	+7.0	+20.0	10.5	10.2	4.1
SGA-2286	2.2	20	DC-3.5	+7.0	+20.0	15.0	14.0	3.2
SGA-2386	2.7	20	DC-2.8	+7.0	+20.0	17.4	16.4	2.9
SGA-2486	2.7	20	DC-2.0	+7.0	+20.0	19.6	18.0	2.5
SGA-3286	2.7	35	DC-3.6	+12.0	+26.0	14.8	13.4	3.5
SGA-3386	2.5	35	DC-3.6	+12.0	+25.0	17.4	16.2	3.0
SGA-3486	2.9	35	DC-2.0	+12.0	+25.0	21.5	19.4	2.6
SGA-4186	3.2	45	DC-6.0	+15.0	+29.0	10.4	10.2	4.6
SGA-4286	3.2	45	DC-3.5	+15.0	+29.0	13.8	12.6	3.3
SGA-4386	3.3	45	DC-2.5	+15.0	+29.0	17.0	15.2	2.8
SGA-4486	3.2	45	DC-2.0	+15.0	+29.0	19.0	16.8	2.5
SGA-5286	3.5	60	DC-4.0	+17.0	+30.0	13.5	12.7	4.1
SGA-5386	3.6	60	DC-3.2	+17.0	+31.0	17.3	16.0	3.5
SGA-5486	3.5	60	DC-2.4	+17.0	+31.0	19.7	18.0	2.8
SGA-6286	4.2	75	DC-3.5	+20.0	+34.0	13.8	12.4	3.9
SGA-6386	5.0	80	DC-3.0	+20.0	+34.5	15.4	13.8	3.8
SGA-6486	5.2	75	DC-1.8	+20.0	+34.0	19.7	16.7	2.9

SGA 2000 through 4000 series are also available in SOT-363
SGA 5000 and 6000 series are also available in SOT-89 & SOT23-5

OF COMMUNICATIONS AND INFORMATION OVERLOAD



Communications is now the fastest-growing segment of the electronics market. And those who read this magazine are probably hoping that the wireless segment of communications, which is based on the use of RF, microwave, and millimeter-wave frequencies, captures its fair share of this expanding market. Yet, the days of being an RF "specialist" are over, replaced by the need to be a multifaceted design engineer, well versed in analog, digital, microwave, and even optical technologies. Those who can command the greatest set of complementary design skills will benefit the most from the growth in communications markets.

The blending of technologies is evident in almost every modern communications system. Most community-antenna-television (CATV) systems, for example, are a combination of copper (Cu) cable, fiber, wireless links, and satellites. Telephone networks are likewise a combination of wire and wireless. Ironically, the very engineering skills that have built these systems will be made obsolete as the systems mature. As information is made more accessible through more-efficient communications systems, engineering teams will be pushed to increase data rates, to increase bandwidth efficiency, to reduce costs. The pressure on high-frequency engineers to keep current is enormous, brought on by shrinking design cycles and increasing competition (for those communications markets). Eventually, limits will be reached, and next year's cellular telephone will look very much like this year's model.

Fortunately, there is help in the battle against information overload. Through Internet classes and compact-disc-read-only-memory (CD-ROM)-based educational courses, engineers can fill the holes in their training on their own terms. Some computer-aided-engineering (CAE) software suppliers have responded to complaints about the long learning curves for their tools by developing engineering templates. And many trade shows now offer educational programs based on specific technologies or applications, providing a much-needed filter for their attendees.

Global communications can be a wonderful thing, but not all the time. A constant flow of information can only decrease the value of that information, with no time to digest it or even comprehend it. Rue the day when cellular handsets are designed without an on/off switch. ••

Editor's Note: *Attentive readers (and those who read from the back of the magazine forward) may have noticed several new names among the stories of this issue. One is that of an old friend, Allen Podell, who has graciously agreed to share his design ideas as part of a somewhat regular column called Designer's Diary (see p. 44). Allen, who is Chief Technology Officer for Besser Associates (Mountain View, CA), will no doubt stir the imaginations (and sometimes the tempers) of more than a few readers with his provocative ideas.*

The other name is that of Senior Editor Don Keller. A skilled writer with a strong background in general electronics, Don will be making his way through this industry as he learns more about the capabilities of microwave electronics. Please welcome him to our part of the electronics industry!

Jack Browne

Publisher/Editor

Microwaves & RF

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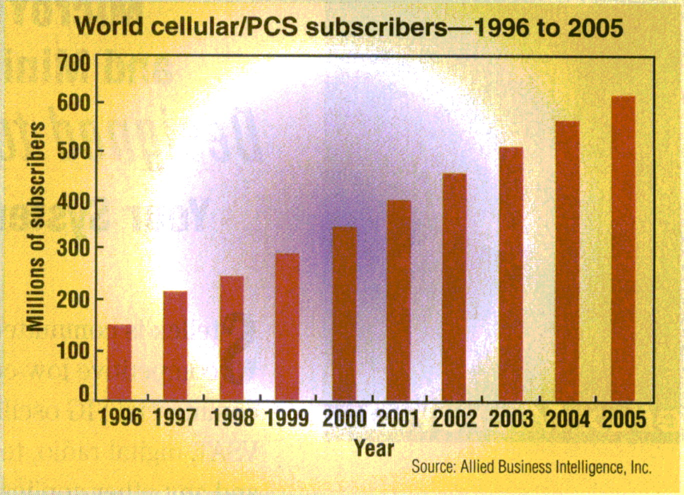
Wireless Market Expanding Rapidly

OYSTER BAY, NY—A report published by Allied Business Intelligence, Inc. examines key wireless communications technologies by assessing current market status, market potential, and competitive pressures. The report, *Wireless 99*, considers the market position of the following systems groups and where they might be in 2005 and beyond—cellular/personal communications services (PCS), wireless local loop (WLL), wireless local-area network (WLAN), very-small aperture terminal (VSAT), Global Positioning System (GPS), and satellite television. Satellite broadband, local multipoint distribution system (LMDS), multichannel MDS (MMDS), HALO (HALE), specialized mobile radio (SMR), and microwave radio are also covered.



Over the next five years, the expansion of connectivity will accelerate as wireless communications move toward non-telco media that incorporate video, telephony, and data. Enhanced information services and e-commerce will make today's information environment seem primitive by comparison. In many parts of the world, wire-line technologies will yield to cheaper and quicker implemented wireless solutions. World communications revenue for products and services is approaching the trillion-dollar mark and is growing at a rate of 5 to 6 percent per year. Much of that growth is derived from fixed and mobile wireless communications and is on the order of $25 to $30 billion annually, with the likelihood that it will continue increasing through 2005 and beyond (see figure).

Leading the charge is cellular/PCS telephony, where 80 million subscribers in the US are generating close to $35 billion in revenue per year. On a greater scale, LMDS will provide a broadband pipe for corporate and business users across the US.

CTIA Outlines Flaws In "Strongest-Signal" Proposal

WASHINGTON, DC—For more than two years, the Federal Communications Commission (FCC) has considered mandating the use of "strongest-signal" technology in cellular telephones. This mandate would require cellular phones operating in the analog mode to scan analog and digital systems and lock on to the strongest signal available when the person operating the phone dials 911 for emergency services. The Wireless Consumers Alliance, the group that proposed the mandate, claimed that the technology would increase the chances that emergency service would receive the call, making cellular 911 calls more reliable. But the Cellular Telecommunications Industry Association (CTIA) opposes the proposal for several reasons.

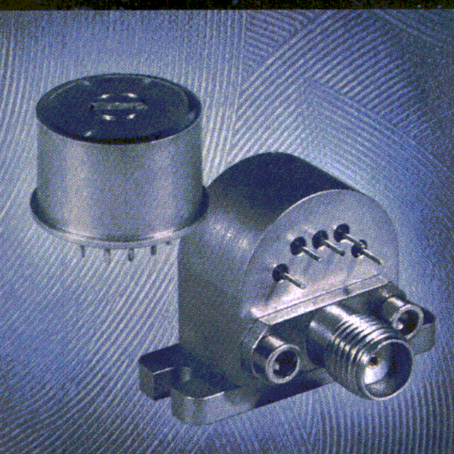
In a letter to the FCC, CTIA Vice President Michael Altschul contends that "strongest-signal" technology would not lead to more emergency calls being completed, and might actually cause call blockage. The proposed technology would make cellular phones scan analog and digital systems for the strongest control channel when 911 is dialed. But the availability of a control channel does not necessarily mean that a voice channel is available. Altschul also says that the technology might actually decrease the reliability of 911-call completion because it is likely to place all emergency calls on one system, increasing the likelihood of blockage.

Another reason why the CTIA opposes the proposal is that it would require cellular-phone manufacturers to purchase a license from the technology's patent holder.

As an alternative to "strongest-signal" technology, the CTIA supports a technology called "automatic A/B roaming." In the event of a failed 911 call attempt, automatic A/B roaming would cause the cellular phone to scan all channels until it makes a voice connection.

The Stellex YIG Advantage:

Low Noise and Low Cost



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The MicroYIG™ is designed for applications where small size and cost combine with low phase-noise demands. An ideal replacement for DROs.

- Very low cost (as low as $99 in 10K quantities for board mount config.)
- Low phase noise performance
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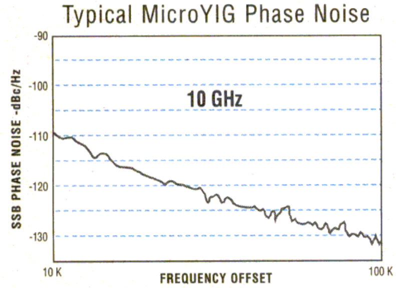
  - *-125dBc @ 100kHz*
- Small package (footprint is smaller than a dime. TO-8 style)
- Through-hole board mount or SMA connectorized configuration
- Heaterless design
- ±50MHz tuning range from 2-10 GHz with permanent magnet construction

Typical MicroYIG Phase Noise



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Stellex is committed to providing competitive low-cost, high quality commercial YIG oscillators for LMDS, VSAT, digital radio, test equipment and any other application where low phase noise is critical. Low cost is achieved through extensive assembly automation and the use of molded metal cases. Stellex has invested in state-of-the-art Metal Injection Molding (MIM) technology to dramatically reduce cost over traditionally machined packages. This in-house capability yields low-cost, high quality products unmatched in the industry.

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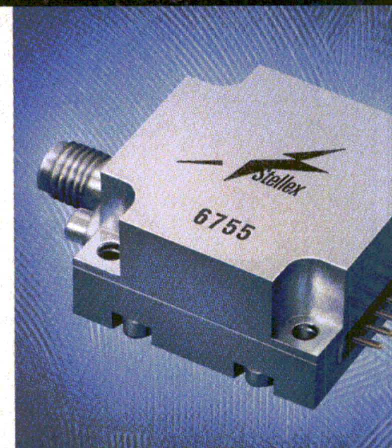

Stellex MiniYIG

The MiniYig excells where low phase-noise, broad tuning range, and low tuning power consumption are required.

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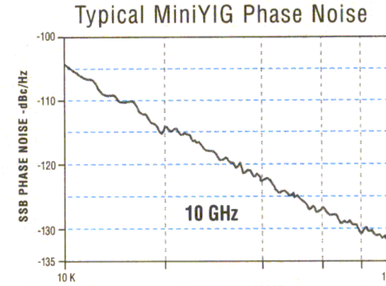
- Low Noise Performance:
  - *-95dBc @ 10kHz*
  - *-120dBc @ 100kHz*
- Tunable to ±1GHz from 2-14 GHz (permanent magnet configuration)
- Also available in multi-octave tuning range (electromagnet tuned)
- Standard 1" X 1" footprint
- SMA Connectorized
- Heaterless design

Typical MiniYIG Phase Noise



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CIRCLE NO. 271

Technology Uses Public Networks

WASHINGTON, DC—Several telecommunications companies recently teamed up with US Government agencies to demonstrate the first operational fiber-optic network for advanced voice, video, and data transmission. The optical ring network linked three government sites in Washington DC: the Defense Information Systems Agency (DISA), the Defense Intelligence Agency (DIA), and the Defense Advanced Research Projects Agency (DARPA). The ring successfully carried data and full-motion video, including secure high-definition television (HDTV), at speeds of 2.5 GB/s. The demonstration as part of a program called Multiwavelength Optical Networking Technology (MONET), commissioned by DARPA, defines the best way to achieve optical networking that will serve government and commercial applications on a national scale.

Commercial participants in the MONET program included AT&T, Bell Atlantic, Telcordia Technologies, BellSouth, Lucent Technologies, SBC/TRI, and Tellium, Inc. Tellium provided three Aurora-32 optical cross-connects, six dense wave-division multiplexers (DWDMs), and four line-wavelength amplifiers. "We are honored to be participants," said Mike Hodges, President and CEO of Tellium. "What we have seen here is the launch of a new era in high-performance communications that not only supports our national-defense system securely, but has far-reaching commercial applications," he said.

AIA Urges Removal Of Barriers To Commercial Space Industry

WASHINGTON, DC—If US companies are to compete successfully with foreign companies in the commercial space industry, Congress must remove the barriers. That was the contention of John W. Douglas, president of the Aerospace Industries Association (AIA), in his recent testimony before the Senate Subcommittee on science, technology, and space. Douglas stressed the need for what he called "an enlightened national space program that combines public and private investment in synergistic ways." He cited three areas where the government needs to remove barriers blocking the growth of the US commercial space industry.

The first and most critical barrier is the lack of a five-to-10-year renewal of the indemnification provisions of the Commercial Space Launch Act. These provisions allow the US Government to subsidize the insurance required by commercial launch providers. But the provisions are due to expire on December 31, 1999, and if they are not renewed, launch costs in the US would become prohibitive and drive clients overseas.

The second barrier is the lack of modern facilities in America's national launch ranges. The time to reconfigure facilities between launches is too long for commercial needs, and any glitch in the process delays the launch schedule even further. The third barrier is the current time-consuming export licensing process. "If our US export system is too slow and cumbersome," says Douglas, "our customers will simply purchase satellites from our European competitors."

Anritsu Selects Broadband Calibrated Noise Source

PARAMUS, NJ—Anritsu Co.'s Microwave Measurement Division recently announced that it has selected Noise Com's NC346 series broadband calibrated noise source for the new Anritsu MS462X Scorpion™ Vector Network Measurement System.

The Anritsu MS462X Scorpion Vector Network Measurement System is the first instrument that has the ability to make error-corrected noise-figure measurements on active devices used in wireless communications. Four basic models are available in the MS462X family. Models MS4622A and MS4623A are equipped with non-reversing transmission/reflection test sets with frequency ranges of 10 MHz to 3 GHz and 10 MHz to 6 GHz, respectively. Models MS4622B and MS4623B incorporate reversing test sets for automatic forward and reverse S-parameter measurements from 10 MHz to 3 GHz and 10 MHz to 6 GHz, respectively.

"We are pleased to be chosen by Anritsu to supply one of our signature products for this state-of-the-art instrument. The Anritsu MS462X Scorpion Vector Network Measurement System clearly represents a breakthrough in the integration of test functions enabling the user to test noise figure quickly and accurately without a separate costly instrument. We are excited to be a partner on this project and believe that collaborating with leading-edge companies such as Anritsu will be a key factor in future Noise Com successes," states Edward Garcia, chief executive officer of Noise Com.

RFID Market To Reach $800M This Year

NATICK, MA—A study performed by technology market-research firm Venture Development Corp. (VDC) shows that the global market for RF-identification (RFID) equipment and systems is expected to reach approximately $800 million in 1999. This market has been growing approximately 30 percent per year for a number of years, and is expected to grow between 25 and 30 percent per year through 2002.

But this growth is not ensured. The study by VDC highlights the primary barriers to RFID market development and recommends solutions for exploration by RFID suppliers.

Company To Build Multichip Modules

GREENSBORO, NC—RF Micro Devices, Inc. recently announced the establishment of an integrated multichip-module (MCM) assembly facility to complement the company's current wafer-fabrication and testing capacity.

This assembly facility is expected to enhance current supply services, add much-needed capacity, reduce costs, and improve cycle times while maintaining high-quality standards.

The automated production line will contain all of the required technologies to assemble MCMs, including surface-mount-device (SMD) attachment, die-attach, wire-bond, encapsulation, singulation, and marking. MCMs combine the chip and supporting package, which dramatically reduces the external parts that are required in the customer's application circuit.

"Vertical integration gives us control of every detail from start to finish and should help us reduce the product-cycle times that are critical to our customers," says David A. Norbury, president and chief executive officer. "Adding module packaging to our current capabilities will help our customers increase their own production capacity as well, due to the reduced component count in the final assembly."

Base-Station Interface Is Introduced

REDMOND, WA—Metawave Communications Corp., a provider of smart-antenna systems for cellular networks, recently announced that the SpotLight® 2000 smart-antenna system is now compatible with the Motorola SC 4812 and SC 4812T cellular code-division-multiple-access (CDMA) base stations. The new SpotLight 2000 configuration has been successfully integrated with the SC 4812 base station in the field and several systems are expected to carry commercial traffic by the end of the second quarter.

SpotLight 2000 connects with a CDMA base station to exploit a cell site's unused capacity. Using the system's sector synthesis capabilities, operators can match a site's antenna pattern to its traffic patterns. Traffic loads can be more evenly balanced across sectors, with more lightly loaded sectors reconfigured to carry more traffic, putting their idle capacity to use.

Kudos

The Cellular Telecommunications Industry Association (CTIA) recently announced the 1999 winners of the VITA ("life") Wireless Samaritan Awards, honoring 61 individuals whose use of a wireless phone in an emergency resulted in a safer community, a prevented crime, or a rescue...The National Association of Broadcasters Education Foundation and Bonneville International Corp. have begun a new annual program to recognize and encourage outstanding community service by broadcasters and their community partners. The symposium and evening awards banquet will take place this month at the Ronald Reagan Building and International Trade Center in Washington, DC. General Colin Powell will present the opening remarks...Every mother who had a baby on Mother's Day in 10 cities across the US received a little extra bonus this year. As part of its new "Point of Contact" brand-promotion campaign, Sprint delivered special packages to mothers to help them on their big day and make it easier for them to stay in contact with friends and loved ones. Every new mother received a care package that included three 10-minute prepaid calling cards, a classical-music compact disc (CD), a disposable camera, a sterling-silver baby charm, lotion, a stuffed animal, a soft rattle, and bubble gum cigars. Sprint also helped families at selected hospitals to take a digital photo of their new arrival and e-mail it to friends and relatives across the country. Additionally, Sprint provided Sprint personal-communications-services (PCS) phones for free wireless calls.

NEWS

Bluetooth Update

First came portable phones, and now a slew of personal electronic "appliances" will communicate wirelessly with each other using a radio technology called Bluetooth.

Wireless Ushers In The Era Of Personal Connectivity

GENE HEFTMAN
Senior Editor

SOME years back, the then New York Telephone Co. used the phrase, "We're all connected" in an advertising campaign to bring attention to a multitude of wired telephone services that customers could use to communicate with one another. Flash ahead approximately a decade to today's wireless technology and the phrase takes on an entirely new meaning as the era of personal connectivity dawns. Not only will people soon have a wide array of voice and data services available with the emerging wireless connectivity, but they will be able to communicate using virtually every electronic "appliance" known to man—portable phones, laptop computers, personal digital assistants (PDAs), fax machines, digital cameras, etc. There will also be some non-electronic appliances one would have never believed such as refrigerators and irons. It will all be made possible over the next few years through Bluetooth, a wireless connectivity standard using short-range radio that has captured the imagination of almost everybody associated with the communications industry. A Bluetooth special-interest group (SIG) formed a few years ago by five founding members—IBM, Intel, Ericsson, Nokia, and Toshiba—to develop an open specification for the technology has attracted so many members that it was recently closed to further entrants. Although the 900-plus SIG members have yet to manufacture a single Bluetooth-enabled product, optimism about user acceptance is running so high that few doubt that the technology will turn out to be a big hit in business and consumer markets.

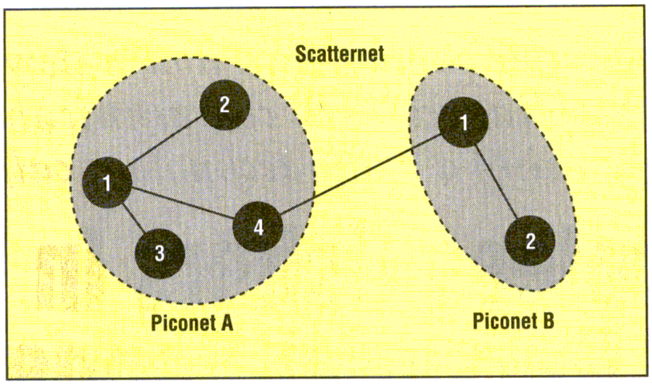
The original concept behind Bluetooth was to enable a wireless connection between a mobile telephone and a laptop computer (from a mobile device to a fixed device). But that basic idea has been expanded upon to include applications that sound like science fiction. For example, picture a Bluetooth-enabled refrigerator in one's home sending a shopping list over the telephone network to a supermarket which then calls the customer on a mobile phone to find out when he or she wants the order delivered. That scenario is probably not around the corner, but neither is it out of the question a few years after the technology makes its debut early in 2000.

Most SIG members figure that the early adopters of Bluetooth will be mobile professionals, business users who can benefit from a wireless connection between their laptop and cellular or digital phone, and who may not pay for it out of their own pocket. According to Warren Allen, Senior Product Planner and Program Manager for the Bluetooth SIG for Toshiba America Information Systems (Irvine, CA), the company is planning to implement Bluetooth in their line of notebook computers, starting out with the high-end types. That's because the cost of the Bluetooth radio can be absorbed more readily in a high-priced machine than a low-cost one. But, says Allen, "The ultimate goal is deploy Bluetooth across the entire notebook line, as costs drop and acceptance of the technology occurs." For that to happen, Bluetooth hardware will have to have a bill-of-materials cost of approximately $5 per implementation. That will not be the case early on because implementing and certifying a Bluetooth radio to Federal Communications Commission (FCC) specifications is not a trivial task and the design and testing of this device can be quite challenging.

NETS OF NETS

The primary goal of Bluetooth technology is to free communications and computer users from the burdensome cabling that is now needed for equipment to send information back and forth by replacing it with a short-range radio link. This radio link, as presently specified, can cover a distance as little as 10 cm and as great as 10 m depending on the radio's output power. It will also probably replace infrared (IR) communications links in many short-distance (line-of-sight) applications due its higher-speed data capability. Bluetooth is a global standard that will ensure compatibility of systems anywhere in the world.

The Bluetooth radios contemplated for this task operate in the unlicensed 2.4-GHz industrial-scientific-medical (ISM) band that is noted as being the same band used for IEEE 802.11 wireless local-area networks (WLANs), and serves as a comparison point. Bluetooth employs spread-spectrum technology, but the simpler frequency-hopping (FH) type as opposed to the direct-sequence (DS) type of 802.11. The Bluetooth data rate is in the range of 432.6 kb/s to 1-Mb/s, while 802.11 is much faster, already at 2 Mb/s and moving into its second generation at 10 Mb/s. In general, 802.11 can cover more distance. It is more performance oriented, faster, and more expensive than Bluetooth, and is not considered a competitive technology for the same applications.



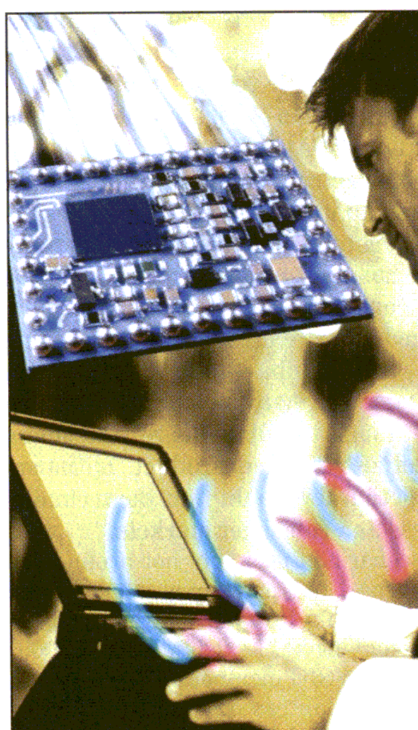
1. Just two devices need to be connected to form the simplest Bluetooth network called a piconet. Two or more piconets—up to eight devices each—make up a scatternet.

In its simplest network configuration, Bluetooth requires only two devices to establish a communications link, known as a piconet. The two devices—a laptop personal computer (PC) and a mobile phone, for example—need not have any prior knowledge of one another and can simply establish an ad-hoc network. Up to six more devices—for a total of eight—can join in a piconet (Fig. 1). All devices in the piconet are identically configured, making them peers. But once a piconet is established, one device becomes the master and the others slave for the duration of the connection. Multiple piconets can communicate with each other in a scatternet, which is a group of piconets that are linked together in a non-synchronized fashion. Each of the piconets in a scatternet is identified by a different FH sequence. The radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet of information. By hopping faster and using shorter data packets than other systems operating in the same frequency band, Bluetooth can avoid interference from microwave ovens and transmissions from other systems.

With the first Bluetooth-enabled products scheduled for early next year, prospective manufacturers need to get up to speed quickly to gain a foothold in what promises to be a very competitive market.

NEW DEVELOPMENTS

Many members of the SIG can find themselves short on the RF and software backgrounds necessary to equip products with the radios, so they must turn to outside sources such as manufacturers of development kits or combinations of hardware and software to gain the expertise to get on the Bluetooth bandwagon.



2. Development kits such as this one from Ericsson Microelectronics contain the hardware and software necessary to design a prototype Bluetooth communications system for a variety of electronic appliances.

A recently announced development kit comes from Ericsson Microelectronics (Richardson, TX) intended for early adopters who want to integrate Bluetooth into a variety of information appliances. Rex Siefert, Market Manager for Microelectronics, says the kit "can be used for proof of concept to show that Bluetooth is a viable product, and demonstrates a basic stack, which is the software that interfaces between the RF physical layer and applications." The complete Bluetooth protocol stack is complex because the radio must be able to handle a variety of information including audio, multimedia, and packet data. The stack is an essential element of any Bluetooth development process since it provides successive layers of software which control the radio, baseband functions, the link manager, logical link control, and on up to the application-program layer. Siefert believes that the current basic stack in the development kit will be extended to the higher layers when the kit begins shipping in the fall. Other Bluetooth development-kit manufacturers already make use of the Ericsson stack in their own products.

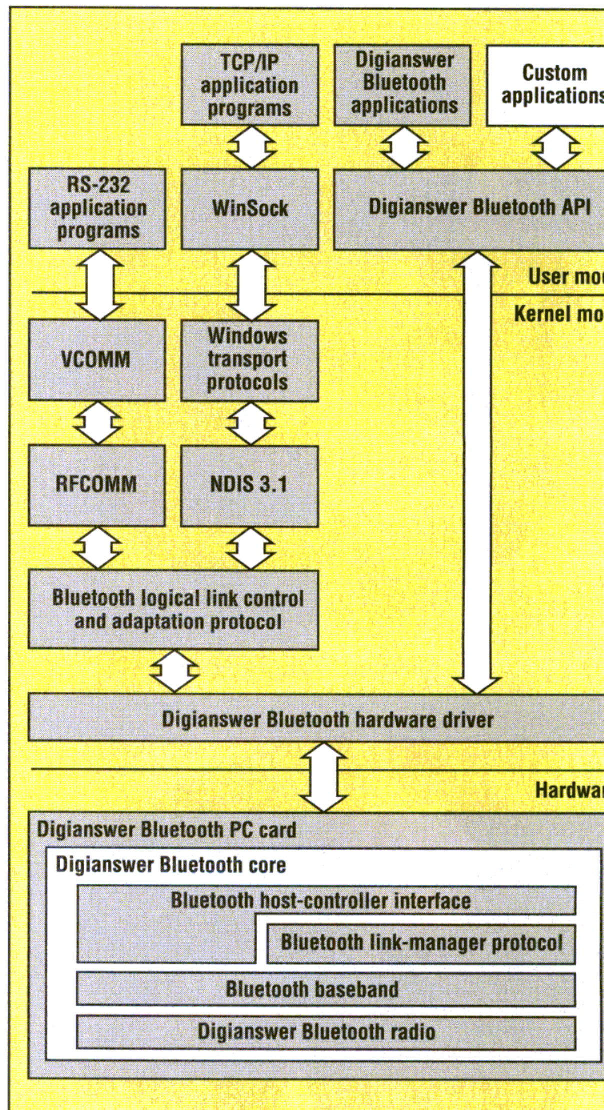
The kit contains two development boards that each have a complete functional radio for proof-of-concept demonstrations and application-software testing (Fig. 2). Also included is documentation that runs the gamut from an introduction to wireless connectivity to application examples and a comprehensive description of the Bluetooth packet structure, link type, and protocols. The kit sells for $15,500 and is available 10 to 12 weeks after receipt of order.

A similar development kit, aptly named the Bluetooth Development Kit, or BTDK, is offered by VLSI Technology (San Jose, CA). The company says that the BTDK can be used

with its Rapid Silicon Prototyping methodology to create complete solutions for system-on-chip (SOC)-based Bluetooth devices. Included in the kit are the company's Bluetooth radio module that has 79 channels, each with 1-MHz bandwidth, the VWS-26001 baseband processor with reusable intellectual property that can be integrated into custom integrated circuits (ICs), and a protocol stack containing the link-controller and host-controller interface. The BTDK is configured as a development board and a pair of daughter boards. On a daughter board is the VWS-26001, which handles functions such as the link controller, universal asynchronous receiver/transmitter (UART), and interfaces such as USB. It also executes the protocol stack through its ARM7TDMI microprocessor. The processor itself and the stack have been developed to Ericsson specifications, and since Ericsson is a charter member of the Bluetooth SIG, users of the kit be ensured that devices developed with it will comply to the Bluetooth standard.

The BTDK's daughter boards can run in a stand-alone mode or with the Velocity Rapid Silicon Prototyping Development Board. In the latter mode, designers can develop core-based SOC ICs, develop hardware and software concurrently, and debug and verify the operation of complex embedded systems. Use of the Velocity platform with the Ericsson baseband processor will also yield application-specific-IC (ASIC) devices compliant to the Bluetooth standard.

From Digianswer A/S (Dublin, Ireland) comes a development and demonstration toolkit based on a digital-signal-processing (DSP) implementation of the Bluetooth specification. The type II PC-card version incorporates a +20-dBm radio (for the 10-m range version of Bluetooth) together with a full software stack and Windows-compatible applications software that enables a user to see Bluetooth devices within RF proxim-



3. The Type II PC Card Development System from Digianswer incorporates the software—a full Bluetooth prototype stack—and hardware—a DSP-based Bluetooth core that contains a radio module—for demonstrating, testing, and developing a product.

ity and establish data and/or audio connections between selected devices. Part of the PC-card version is the Digianswer Bluetooth Core which is a DSP implementation of the Bluetooth Baseband, Link Manager Protocol (LMP), and the Bluetooth Host Controller Interface (HCI). The Core also includes a Bluetooth Radio Module with +20-dBm or 0-dBm output power (Fig. 3). Protocols in the present kit are subsets of the 0.8 version of the protocol but the 1.0 Bluetooth protocol (the final release) will likely be available to developers in the next month or two. A free upgrade program is available with the kit to access periodic updates, applications, and documentation on the Internet until the 1.0 release is finalized.

THE CHIP RACE

Anticipating a rush for Bluetooth devices that can be integrated quickly into personal-connectivity appliances, IC manufacturers are prepared with devices that incorporate many of the features that will be required in this application. However, in most situations, designers will need the support of a development kit together with these devices to implement a workable Bluetooth solution.

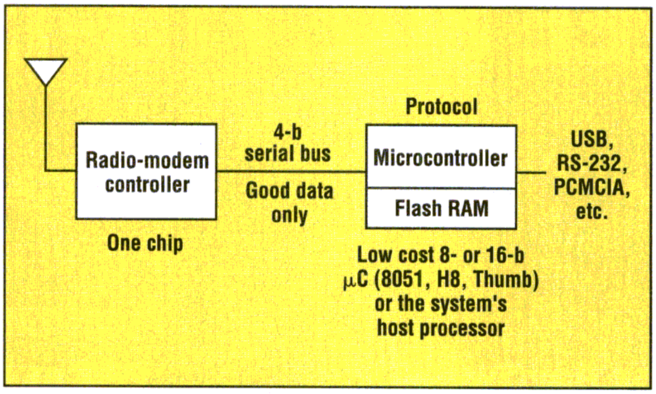
National Semiconductor (Santa Clara, CA), for example, introduced a few months ago a single-chip radio transceiver for wireless voice and data in the 2.4-GHz band. The LMX3162 contains all of the transmit and receive functions of a complete radio front end, and suits the low-power networking applications using FH spread spectrum that make up the Bluetooth specification. The IC is aimed at 2.4-GHz Digital Enhanced Cordless Telecommunications (DECT) cordless phones used extensively in Europe. National has designed two other devices that work with the LMX3162—the SC14402 baseband processor for DECT handsets and the SC14422 integrated baseband processor with embedded echo cancellation for base stations. Complete DECT and 2.4-GHz development kits are supplied by the company's system-integration partner, RTX Telecom A/S, which include schematics, layout, software, and documentation. A 48-lead, plastic-quad

flat-pack (PQFP) version of the LMX-3162 is priced at $5.60 in 1000-piece quantities.

A complete single-chip Bluetooth transceiver fabricated in bipolar-complementary-metal-oxide-semiconductor (BiCMOS) silicon-on-insulator (SOI) technology from Silicon Wave, Inc. (San Diego, CA) will be on the market in late summer. The company claims that BiCMOS SOI offers a better technology than straight CMOS for implementing analog, digital, and mixed-signal functions on the same substrate. High-quality passive components (inductors and capacitors) for radio circuits can be fabricated in the process and the insulating layer of silicon dioxide (SiO_2) between circuits and the Si substrate prevent noise from being coupled between RF elements. Silicon Wave's transceiver, called the RMC (radio, modem, and controller functions) chip, operates in a partitioned mode with a low-cost microprocessor in a Bluetooth system (Fig. 4). This scheme conserves power because the RMC contains the logic to decode incoming data packets and passes on only good ones addressed to the host. The host microprocessor can remain in a sleep mode most of the time, awakening only to handle a "good" packet, thus conserving system power.

Although ostensibly an IC company, Silicon Wave acts like a systems company in that it will soon offer its own development system including a protocol stack to customers. As Chairman and CEO David Lyon puts it, "We try to take a partnering approach with customers because Bluetooth is such a new technology. Virtually none of the organizations we're working with is self-sufficient at this time."

Indeed, obtaining a workable Bluetooth solution could be a tedious chore for many companies according to Jim Zyren and Bruce Kraemer, Senior Marketing Managers in the Wireless Products group of Harris Corp. (Melbourne, FL). They point out that phones already have most of the



4. Single-chip transceivers such as this Silicon Wave RMC (radio, modem, and controller) device will be critical in building inexpensive, small-size, low-power Bluetooth solutions.

intelligence onboard to implement the link-controller function in the protocol stack. Therefore, they would need only a physical-layer (PHY) device to provide a complete Bluetooth solution. But appliances such as laptops and PDAs are another story since they are not inherently Bluetooth ready, and do not have any communications capability. These products would need a link-controller function in addition to the PHY. To support users at the physical level, the company is developing a single-chip FH-PHY solution which it hopes to demonstrate late this year and sample in the first half of next year. It will also have applications in other wireless systems such as 802.11 and HomeRF.

Although Bluetooth radios are low power—0 dBm or 1 mW for the 10-cm range and +20 dBm or 100 mW for the 10-m range—they will require some form of FCC certification as transmitting devices. This creates another potential problem for computer companies seeking to implement Bluetooth since they are not RF experts say Zyren and Kraemer. These companies should seek modularized solutions where the company who manufactures the module obtains the FCC radio approvals. When the module is installed in a computer or other electronic appliance, that product does not need FCC certification since the module is already approved.

In addition to its development kit mentioned earlier, Ericsson is introducing a pair of devices to enable faster development times. The PBA-31301/2 is a short-range radio transceiver fabricated as a BiCMOS ASIC that, with an antenna, provides a complete Bluetooth radio solution. A user must provide the antenna, baseband, host-processor hardware, and the software for a complete Bluetooth solution. Also available is a Bluetooth module, the ROK101007/1, with more functions integrated for users who need even faster turnaround times.

Mitel Semiconductor (Kanata, Ontario, Canada) and Philsar Electronics, Inc. (Ottawa, Ontario, Canada) have joined forces to develop a low-power Bluetooth solution to be released early next year. Mitel's contribution is its WAVE chip set, a 1-Mb, 2.4-GHz FH radio system built in CMOS technology, while Philsar has developed a unique radio-signal processor technology for software-configurable radios. The companies plan to offer radio and baseband ICs, a development kit, an example platform, software, and application information. The goal is to enable early adopters of Bluetooth to test product ideas, develop prototypes quickly, and develop their own applications software. ••

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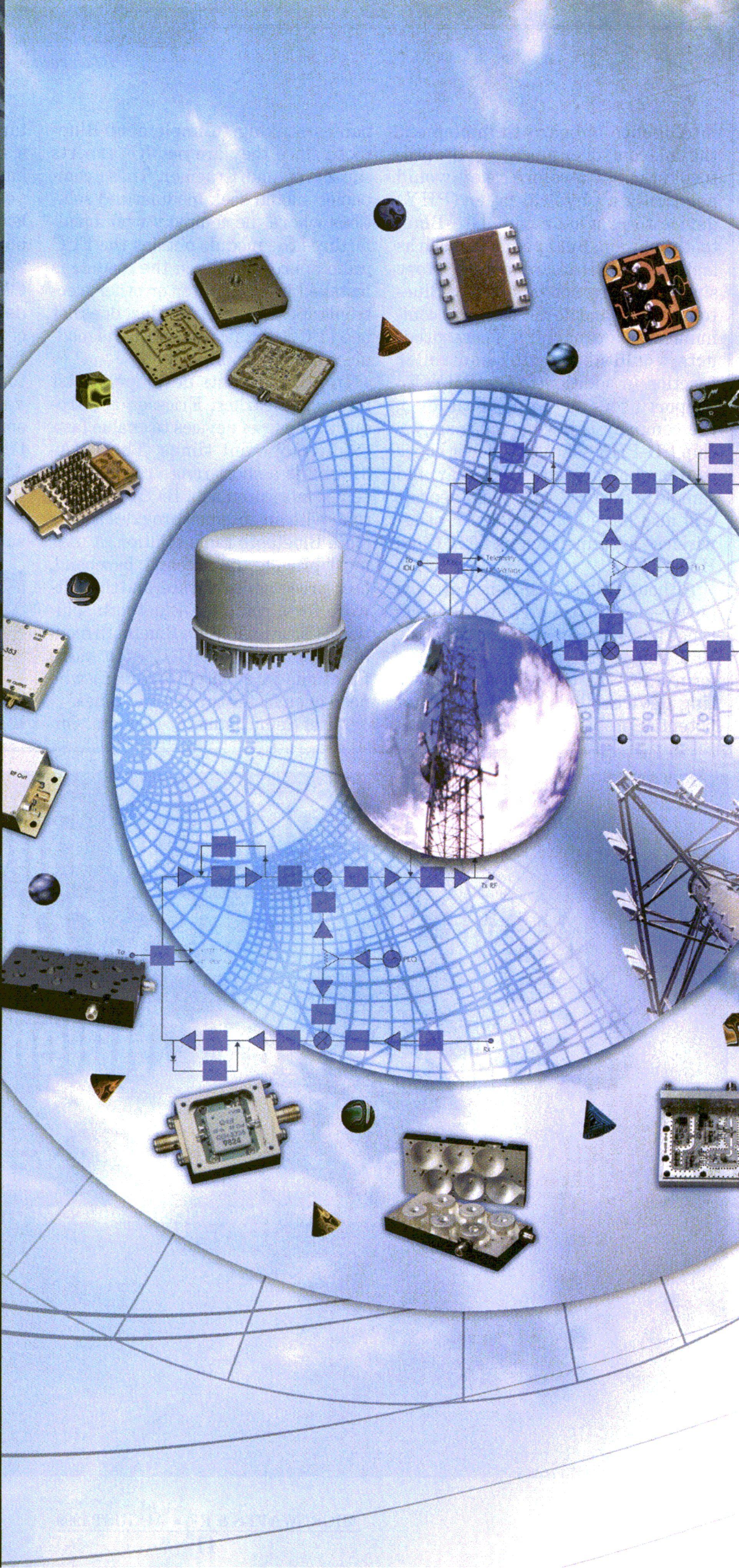

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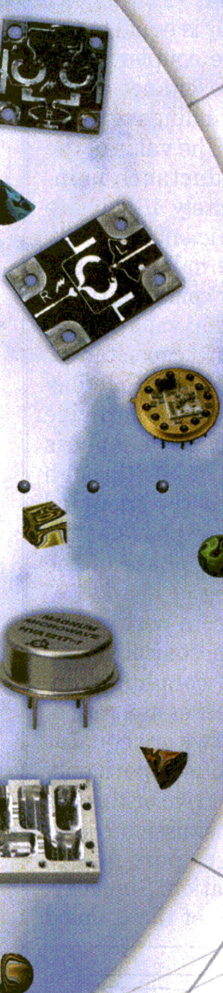

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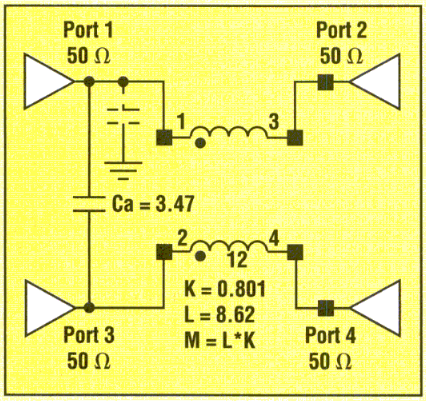
CIRCLE NO. 388

Quadrature Hybrid Couplers Serve Narrowband Applications

The quadrature hybrid coupler is useful for adding and subtracting signals.

ALLEN PODELL
Contributing Editor

QUADRATURE hybrid couplers sound exotic, but they are actually quite simple in design and extremely useful in a wide range of signal-processing applications. They can add or subtract signals vectorially and split a signal into multiple outputs. They can be used to sense transmitter power, deliver power to two loads with high isolation, and split and combine signals from RF/microwave mixers. With currently available surface-mount bifilar coils, a designer needs to only add a capacitor to create an effective narrowband coupler.



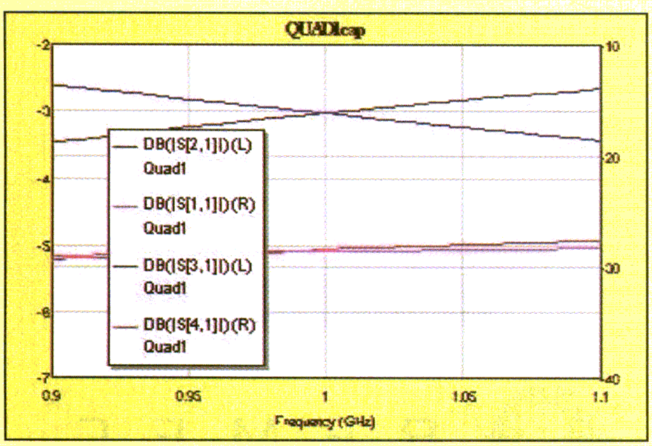
1. This coupler can be fabricated with a pair of surface-mount bifilar inductors and a capacitor.

Simple narrowband couplers designed in this manner can achieve better than 20-dB return loss and directivity over a ±10-percent bandwidth, with dissipation loss on the order of 0.1 to 0.2 dB. The bifilar inductor can be etched onto a circuit board or included as part of an integrated circuit (IC).

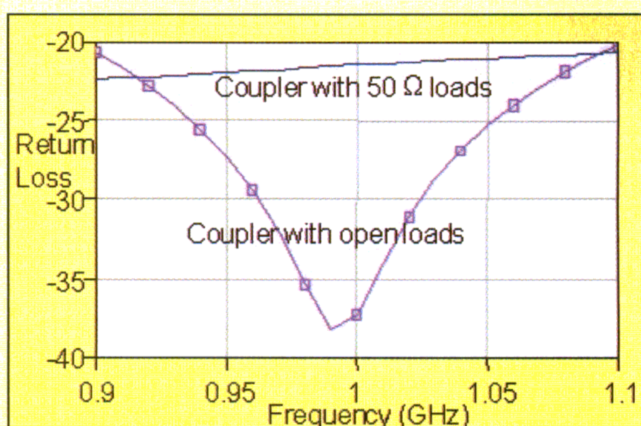
Figure 1 shows a narrowband four-port coupler. Since parasitic values are not considered, the magnitude of the reactance of the capacitor or one winding of the inductor is equal to the port impedance of the coupler. With an actual inductor, capacitance exists between the bifilar windings and the coupling is imperfect. The value of the required winding inductance is increased by approximately 1/k, where k is the coupling coefficient, typically greater than 0.8 for a multi-turn air- or ceramic-core bifilar coil. Additional capacitance is reduced in value by the amount of the inter-turn capacitance.

In this design, the 8.62-nH inductor and the 3.47-pF capacitor provide 3-dB coupling at 1 GHz. The input is connected to port one, the "through port" is port two, and the "coupled port" is port three. The phase of the coupled port leads the phase of the through port by 90 deg.

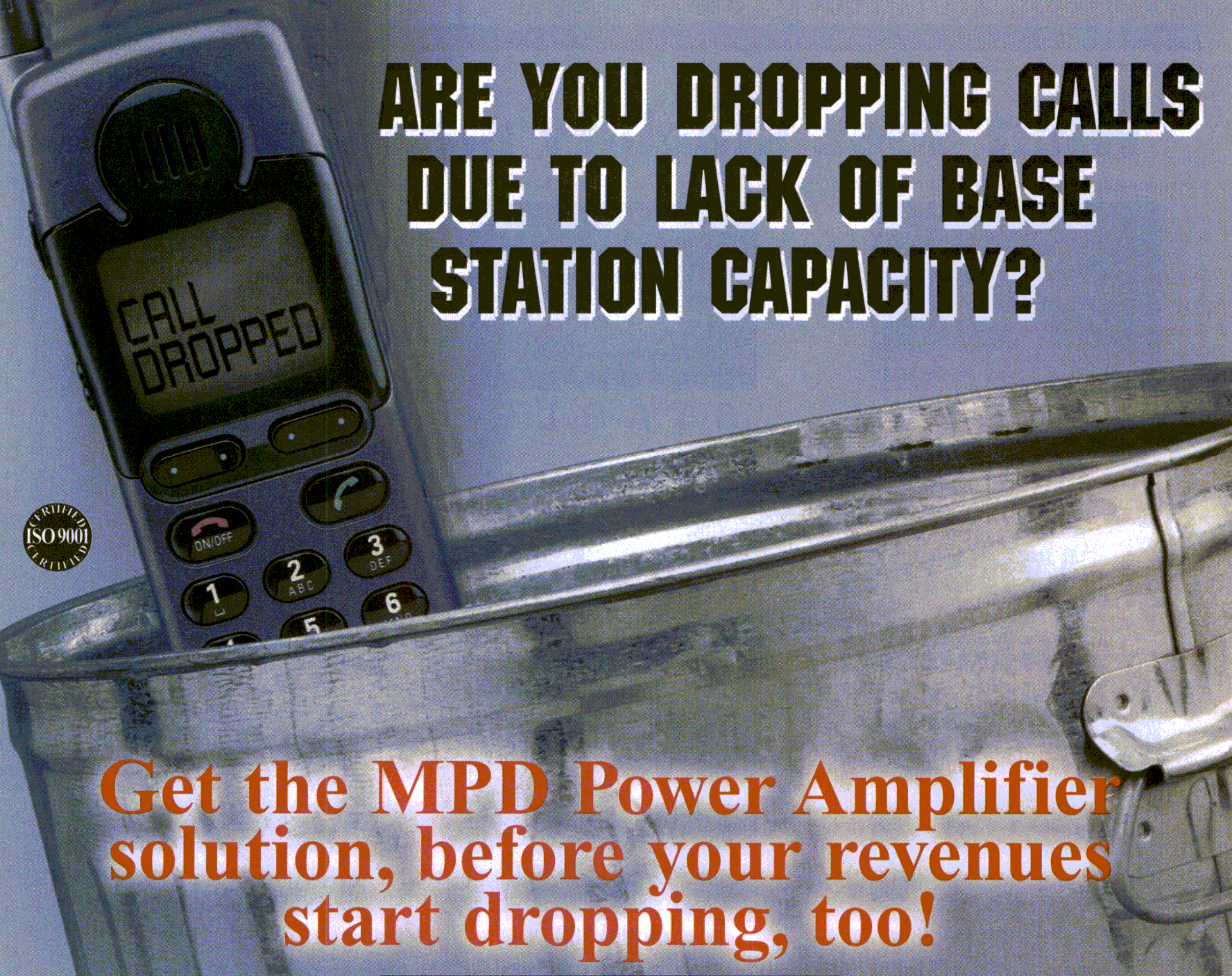
The transmission from port one to port two falls off monotonically with frequency, while the coupling from port one to three increases at a rate of 6 dB/octave, until the two are equal at 3-dB coupling. The fourth port only receives a signal if port two or three is mismatched. The transmission coefficient from port one to port four is equivalent to the isolation. Similarly, directivity is the ratio of the coupled



2. The performance of the quadrature hybrid coupler is plotted close to its 3-dB coupling frequency (approximately 1 GHz).



3. The return loss is plotted with the through and coupled ports open. All of the reflected power is sent to the port that was previously isolated.



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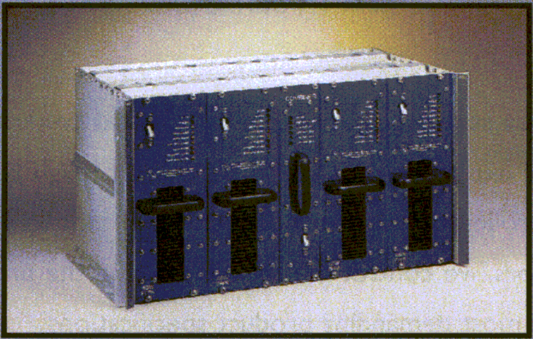
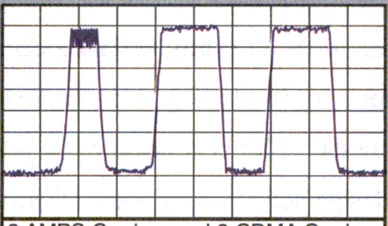


Nothing annoys a customer more than a dropped call. In fact, it can lead to churn, which can cost you big money in lost revenues.

With MPD multi-carrier feed forward power amplifiers, you'll increase capacity and coverage – reducing dropped calls. MPD power amplifiers can transmit multiple AMPS, TDMA or CDMA signals simultaneously. And, integration is seamless, so you can easily upgrade your expanding analog network to your expanding digital network.

What's more, our power amplifiers are designed for the long-term. As your needs increase, you simply add digital carriers. You can even expand to cdma2000 – providing unmatched flexibility.



8 AMPS Carriers and 2 CDMA Carriers Transmitted Simultaneously

Engineered for just about any base station, a single MPD amplifier can produce 60 watts of output power. Multiple amplifiers can also be combined to achieve 100, 150, or 200 watts and more.

For more information about the superior performance and reliability of MPD multi-carrier power amplifiers, call today. And, increase your base station capacity before you drop another customer.

MPD TECHNOLOGIES, INC. MPD a subsidiary of Microwave Power Devices, Inc.

49 Wireless Boulevard, Hauppauge, NY 11788 • Phone: 516-231-1400 x452 • Fax: 516-434-1725 • E-mail: sales@mpd.com • Web site: www.mpd.com.
MPD is an EEO employer (M/F/D/V). For career opportunities, please visit our web site.

CIRCLE NO. 384

signal to the isolation signal.

A signal fed into port four is split between ports two and three, but with the roles of ports two and three reversed. Port three is now the through port and port two is the coupled port. Connected in this way, a four-port coupler can feed two isolated loads with two isolated sources. A hybrid is a four-port device, unlike a three-port isolator. It is not unidirectional like an isolator, but it can be used in similar ways.

The two closely coupled inductors can be fabricated as an etched spiral on a printed-circuit board (PCB), as a twisted or bonded (bifilar) pair of wires wound on a coil form, or just looped from one pair of terminals (one and two) to the second pair (three and four). At 1 GHz, a 0.4-in. (1.016-cm) length of #37 bifilar wire works well. Approximately two turns would be required if the coupler is etched on PCB, and multilayer is essential. This is due to the effect of the ground on the PCB reducing the coupling between the pair of wires.

Figure 2 shows the performance of the coupler close to its 3-dB coupling frequency. The parasitic effects of the nonideal inductor are apparent in the return loss and isolation (coupling to the fourth port from the input). The results are for k = 0.8. For k = 1, return loss and isolation could be better than 40 dB, and the coupling response would remain unchanged.

Figure 3 shows the return loss for this coupler with the through and coupled ports open. All of the reflected power is sent to the formerly isolated port. In this way, two couplers can combine the power of two identical devices with poor impedance match. Low-noise transistors, common-base transistors, and power amplifiers (PAs) are examples of these devices. At frequencies below the 3-dB coupling frequency, the magnitude (S_{41}) decreases faster than the coupling (S_{31}). This shows that this coupler works with high directivity down to a very-low frequency.

The frequency slope of coupling for this design is approximately 6 dB/octave. This slope is excessive for broadband applications, but adequate for narrowband applications. For narrowband, less than 20-dB couplers, a short length of bifilar wire, and a capacitor can be used. These couplers are so electrically short that their loss is nearly zero. Since the coupling response exhibits a sharp slope, it is important that there be little harmonic content in the input signal, or a two-diode peak-to-peak detector which minimizes the effect of second harmonic, should be used for automatic-gain-control (AGC) applications. ••

Editor's Note: *This article sets off a regular series by Allen Podell, recently named Contributing Editor to* Microwaves & RF *and Chief Technology Officer for Besser Associates, 201 San Antonio Circle, Building E, Suite 280, Mountain View, CA 94040; (650) 949-3300, FAX: (650) 949-4400, Internet: http://www.bessercourse.com.*

Front-end SiGe IC serves DECT applications

The model U7006B integrated circuit (IC) uses silicon-germanium (SiGe) technology to integrate several front-end RF circuits on one chip for Digital European Cordless Telecommunications (DECT) applications. Included on the chip are a 50-Ω internally matched low-noise amplifier (LNA), power amplifier (PA), and transmit (Tx)/receive (Rx) switch driver. The amplifiers cover DECT frequencies from 1.88 to 1.94 GHz. The noise figure (NF) of the LNA is typically 1.8 dB and its typical power gain is 19 dB. The PA has a typical gain of 28 dB and its power-added efficiency (PAE) is typically 40 percent. The use of SiGe technology enables the chip to be powered by a single voltage of +2.7 to +4.3 VDC. In case of higher supply voltages, an internal ramp-control function controls and optimizes the output power. **TEMIC Semiconductor GmbH, P.O. Box 3535, D-74025 Heilbronn, Germany; 49 (0) 7131 67 2594, FAX: 49 (0) 7131 67 2423, Internet: http://www.temic-semi.com.**

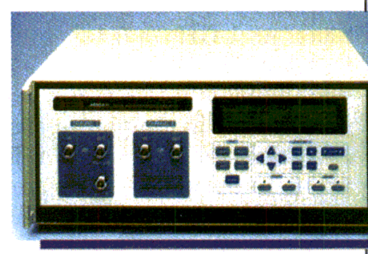
CIRCLE NO. 63

Distributed antenna aids in-building wireless systems

The RadWire distributed antenna system enhances wireless coverage inside high-rise buildings, transportation terminals, shopping malls, campuses, warehouses, and similar structures. It replaces radiating coaxial cable, standard coaxial cable, and individual antennas with a single-wire transmission line that serves as a high-efficiency distributed antenna. The system converts signals into a surface wave that is simultaneously guided and radiated by the wire. Its most basic configuration consists of a transition cone, which creates the surface wave on the wire, followed by a length of RadWire and a Terminating Load. The system is band specific, entirely passive, and rated for plenum environments. Four band-specific systems are available—cellular/specialized mobile radio (SMR)/paging, distributed communication systems (DCS), personal communications services (PCS), and 2.4-GHz industrial-scientific-medical (ISM) band. **Rubytron, 70 West Red Oak Lane, White Plains, NY 10604; (914) 937-6376, FAX: (914) 697-4888, Internet: http://www.rubytron.com.**

CIRCLE NO. 65

Noise/interference emulator extends coverage to 2.5 GHz

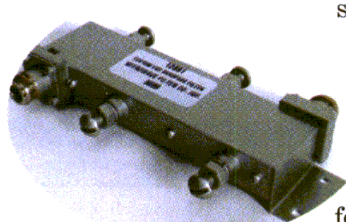


Model 4600AH noise and interference emulator reaches carrier frequencies to 2.5 GHz for testing next-generation wireless equipment for applications such as personal-communication-services (PCS), IMT-2000, and industrial-scientific-medical (ISM) bands. The 4600AH accurately measures the power of an incoming RF signal, then adds a specified amount of noise or interference to obtain a desired carrier-to-noise (C/N) and carrier-to-interference (C/I) ratio. It is available in single- and dual-channel configurations and includes TASKIT/4600-for-Windows software. The software includes pre-defined configuration files based on industry test standards. **Telecom Analysis Systems, Inc., 34 Industrial Way East, Eatontown, NJ 07724-3319; (732) 544-8700, FAX: (732) 544-8347, Internet: http://www. taskit.com.**

CIRCLE NO. 64

Bandpass filter handles ENG services

Single-channel bandpass filter model 12861 passes frequencies from 1990 to 2110 MHz and is ideal for use in electronic-news-gathering (ENG) applications. The filter has a bandwidth of 8 MHz and an insertion loss of less than 3.5 dB at center frequency. It offers more than 25-dB rejection at ±7 MHz from the center frequency, providing substantial selectivity to remove undesired frequencies. The filter offers 50-Ω, type-N female connectors and is designed for indoor applications. It is available with a 16-MHz bandwidth, and can be provided with other connectors and modified for outdoor use. **Microwave Filter Co., 6743 Kinne St., East Syracuse, NY 13057; (800) 448-1666, FAX: (888) 411-8860, Internet: http://www.microwavefilter.com.**



CIRCLE NO. 66

Harris Focuses On Communications

After spending much of its life as a broad-based technical company—communications, semiconductors, and office business products—Harris Corp. (Melbourne, FL) is pulling in its horns and focusing on one of its core competencies, communications, with an emphasis on its wireless, broadcast, government systems, and network-support groups. The company announced recently that it is selling its semiconductor operations and is in the process of spinning off its Lanier Worldwide Office Products business. These moves will reposition Harris as a company devoted exclusively to providing communications infrastructure for voice, video, and data worldwide.

The main buyer of the semiconductor operations is Sterling Holding Co. LLC, a Citicorp Venture Capital Ltd. investment-portfolio company. Also participating in the buyout is Credit Suisse First Boston Corp., individual investors, and Harris itself, which will retain a 10-percent ownership of the business. Harris will pull in $700 million in cash, notes, retained receivables, and contingency payments, in addition to its equity in the business. The proceeds will go toward reducing corporate indebtedness and other general corporate purposes.

Another result of the divestiture will be a streamlining of the company's organizational overhead structure from its present sector-based form to a slimmer one that will have five divisions with approximately 11,000 employees. Last year, Harris had more than 28,000 employees worldwide and sales of $3.8 billion.

By selling the semiconductor sector, the company parts with over $500 million in annual sales and more than 6200 employees. The power-semiconductor operation, based in Mountaintop, PA, is a key coup for the buyer of this sector since it boasts the world's only 8-in. power wafer-fabrication facility. Other group locations include fabrication and assembly operations in Florida and Ohio, and a major test and assembly facility in Kuala Lumpur, Malaysia. The semiconductor operation has been a technology innovator in analog and digital technology dating back over 30 years.

In its new incarnation, Harris will still be a diversified technology company, but on a smaller playing field. Its product line ranges from airborne, spaceborne, and ground-based communications and information systems to wireless-market digital microwave radios, wireless-local-loop (WLL) telephony systems, and secure radio. Recently, Harris has played a leading role in the development of wireless local-area-network (WLAN) technology with the creation of a radio chip set that enables high-speed data transfers. The company has a long history as a military supplier and last year, 20 percent of sales were to the US government. ••

Contracts

Sprint—Has signed a $120 million contract with MasTec, Inc., a Hispanic-owned telecommunications infrastructure construction firm. MasTec will perform a variety of construction projects, including the installation of copper (Cu) and fiber networks and providing network technicians to support service installation and maintenance activities, initially at Sprint sites in Fort Myers, FL and Las Vegas, NV, and their surrounding metropolitan areas.

Sanders—Was awarded an indefinite-delivery, indefinite-quantity (IDIQ) contract by the US Army Communications and Electronics Command (CECOM) for its AN/ALQ-144A(V)1/3/5 countermeasures set with a not-to-exceed value of $30 million.

Microelectronic Modules Corp. (MMC)—Has acquired Switch Power, Inc. (SPI). The purchase caps a two-year licensing agreement where MMC has developed its board-level high-density, low-voltage (HDLV) DC-to-DC converters incorporating SPI's patented V^2® control architecture.

CTS Corp.—Announced that its custom microcircuits manufacturing operation, CTS Microelectronics, has been awarded a contract by Harris Corp.'s ASD to provide three custom optical data-link multichip modules (MCMs) in support of the F-22 Raptor Aircraft.

Watkins-Johnson Co.—Announced that its Telecommunications Group received the award of two contracts totaling $8.2 million for electronic receiving equipment from Sanders, a Lockheed Martin Co.

Diversified Technologies, Inc. (DTI)—Has received a contract valued at more than $750,000 from the US Navy to build advanced solid-state radar transmitters. The transmitters will use the company's patented PowerMod™ modulator technology.

Boonton Electronics Corp.—Has received a $250,000 contract to supply 70 of its model 1130 distortion analyzers to the French Army.

Fresh Starts

Sprague-Goodman Electronics, Inc.—Announced the appointment of Brothers Electronics, Inc. as a franchised distributor of Sprague-Goodman's trimmer capacitor, specialty, and surface-mount inductor lines.

QUAKE Wireless, Inc.—Has entered into a strategic alliance with WABCO Railway Electronics, a division of Westinghouse Air Brake Co. (WABCO). The companies will jointly develop a rail-specific interface card and customized onboard software designed to work with QUAKE's satellite-communications hardware, LEOLink™.

Texas Instruments—Announced that its digital signal processors (DSPs) have been selected by Exide Electronics as the control platform for the Powerware Plus™ 750 uninterruptible power systems (UPS). Exide Electronics is the first UPS manufacturer to implement a DSP-based UPS.

Berkeley Varitronics Systems, Inc.—Announced the appointment of Safco Technologies, Inc. of Chicago, IL as Berkeley's international distributor for Israel, Japan, South Korea, and Turkey. Safco will sell Berkeley's standard product line of portable wireless test and measurement products throughout these four countries.

Northrup Grumman Corp.—Has signed a definitive agreement to acquire the Information Systems Division (ISD) of California Microwave, Inc. This division of California Microwave specializes in airborne reconnaissance and surveillance systems, government ground-based satellite-communications systems, and mission-planning systems.

Ericsson, Inc. Components Group—Announced the establishment of the new design center based in Phoenix, AZ. The new design center will focus on the development of highly reliable, gold (Au)-metallized products including state-of-the-art laterally-diffused-metal-oxide-silicon (LDMOS) RF integrated circuits (RF ICs), advanced bipolar products, and replacements for devices that are phased out by other RF power-transistor manufacturers. The Phoenix Design Center will work in concert with and will also be a complement to the Morgan Hills, CA; Norristown, PA; and Kista, Sweden design centers.

ISTAR—Announced the creation of an American subsidiary, ISTAR Americas, Inc., that will reinforce technical and commercial operations throughout North and South America.

Continental Microwave and Tool Co., Inc.—Announced that it will be relocating to a newly constructed 90,000-sq.-ft. facility in Exeter, NH.

Tellabs—Recently introduced the TITAN 4500GS global-services delivery system, a flexible platform that enables service providers to seamlessly deliver high-bandwidth global services over Synchronous Optical Network (SONET) and synchronous-digital-hierarchy (SDH)-access networks.

SaRonix—Signed a distribution agreement with Sterling Electronics. Sterling will offer SaRonix's complete line of frequency-control products, including programmable oscillators, to a broad spectrum of customers in telecommunications, wireless process-control automation, computer peripherals, as well as the medical and industrial markets.

Rohde & Schwarz GmbH & Co. KG—Has concluded a far-reaching sales agreement with X-Net of Finland. Under the designation "Nethawk," X-Net produces plug-in cards and software to enable analysis and simulation in communication networks. With products from X-Net, Rohde & Schwarz will be able to add portable measurement solutions for wired data transmission to its wide range of communication-test products.

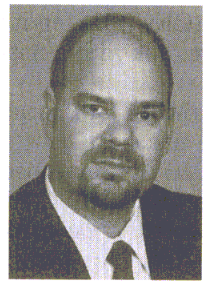
Intertek Testing Services (ITS)—Purchased the assets of Electrohome Ltd.'s electromagnetic-compatibility (EMC) testing facility, known as Wellington Labs. With this acquisition, ITS complements its existing EMC testing services for clients throughout Canada.

Gabriel Electronics, Inc. and Hite Electronic Sales Co.—Have entered into an agreement for Hite to represent Gabriel's terrestrial microwave point-to-point and point-to-multipoint antenna products, transmission-line systems, and pressurization equipment.

Boldt Metronics International (BMI)—Peter Spaulding to vice president and general manager of the Boldt Metronics business unit; formerly president of the Wilton Tool Group.

Filtronic Solid State—James M. Miller to vice president of sales and marketing; formerly western regional sales manager.


MILLER


MORTENSEN

Quad Systems Corp.—Derek Mortensen to director of international sales; formerly manager of international sales.

Microtune—Vincent Birleson to vice president of systems engineering; formerly director of systems engineering.

American Technical Ceramics—Mike Giacalone to vice president of advanced product operations; formerly worked at Electro-Technik.

Palomar Technologies—Robert W. Ott to Asian regional sales manager; formerly regional manager for Sym-Tek Systems.

ADC Telecommunications, Inc.—P.G. Narayanan to vice president and chief technology officer; formerly executive vice president of Osicom.

Communication Solutions, Inc.—James A. Andem to director of sales and marketing; formerly worked in business development in the signals-intelligence industry.

Boonton Electronics Corp.—Ron Zukowski to director of operations; formerly manufacturing manager at the Phillips/Lucent Technologies New Product Introduction Center.

GHz Technology—Anthony J. Riemma to western regional sales manager and wireless marketing engineer; formerly worked for Rockwell-Collins.

Reed Exhibition Companies (REC)—Cynthia Holloway to director of industry development for the NEPCON portfolio of trade events; formerly director of industry development for association exposition and services (AE&S) international security shows.

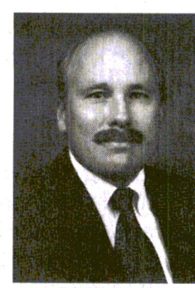
Current Technology, Inc.—Toni Mihalic-Watson to vice president of sales and marketing; formerly marketing manager for Matco Tools.

Sanders—Walter P. Havenstein to president and acting president of the electronics sector's aerospace electronics systems; formerly executive vice president. Also, Albert E. Smith to president of Lockheed Martin's Energy and Environment Sector; formerly president of the electronics sector's aerospace electronics systems.

Synergetix—Alan Niesel to eastern regional sales manager; formerly worked in sales and marketing of high-end test equipment.

Lawrence Behr Associates, Inc.—Bill Frazier to manager of signal measurements and analysis; formerly national program coordinator of the signal measurements and analysis division with Crown Communications, Inc.


FRAZIER


BUCHANAN

Watkins-Johnson Co.—Scott G. Buchanan to executive vice president, chief financial officer, and treasurer; formerly worked in finance and management positions with Watkins-Johnson.

TriPoint Global Communications—John T. Russell to vice president of international sales for RSI; formerly director of business development for Media4, Inc.

I-Bus, Inc.—James Falasco has been appointed director of business development.

EDUCATIONAL MEETINGS

Short Courses

Advanced Electronic Warfare Principles
September 14-17 (Atlanta, GA)
Continuing Education, Georgia Institute of Technology
Atlanta, GA 30332-0385
(404) 894-2547, FAX: (404) 894-7398
e-mail: conted@gatech.edu
Internet: http://www.conted.gatech.edu

Satellite Communications: Systems Planning, Design, and Operation at C- and Ku-Bands
September 14-17 (Washington, DC)
The George Washington University
Continuing Engineering Education Program
Washington, DC 20052
(800) 424-9773, FAX: (202) 872-0645
Internet: http://www.gwu.edu/~ceep

Microwave Radio Systems
September 21-24 (Washington, DC)
The George Washington University
Continuing Engineering Education Program
Washington, DC 20052
(800) 424-9773, FAX: (202) 872-0645
Internet: http://www.gwu.edu/~ceep

The 1999 Ansoft HFSS User Workshop
September 23-24 (Baltimore Marriott Inner Harbor, Baltimore, MD)
Ansoft Corp.
Four Station Square, Suite 200
Pittsburgh, PA 15219-1119
David DiOrio
(412) 261-3200 ext. 158, FAX: (412) 471-9427
e-mail: diorio@ansoft.com

Practical RF/Microwave Design
September 27-October 1 (University of Oxford, Oxford, England)
International Electronics and Communications Courses 1999
University of Oxford Department for Continuing Education, Linda Tonge
CPD Centre, 67 St. Giles
Oxford OX1 3LU, England
+44 (0)1865 288170, FAX: +44 (0)1865 288163
e-mail: linda.tonge@conted.ox.ac.uk
Internet: http://www.conted.ox.ac.uk/ousep.html

Digital Signal Processing Applications in Wireless Communications
September 29-October 1 (Los Angeles, CA)
UCLA Extension, Department of Engineering
10995 Le Conte Ave., Suite 542
Los Angeles, CA 90024
(310) 825-3344, FAX: (310) 206-2815
e-mail: mhenness@unex.ucla.edu
Internet: http://www.unex.ucla.edu/shortcourses

Meetings

AUTOTESTCON 99: Test Technology for the New Millennium
August 30-September 2 (Henry B. Gonzalez Convention Center, San Antonio, TX)
Institute of Electrical and Electronics Engineers (IEEE)
Internet: http://www.AUTOTESTCON.com.

Computer Telephony Expo Fall 99
September 13-16 (Jacob K. Javits Center, New York, NY)
Miller Freeman, Inc.
12 West 21st St.
New York, NY 10010
(212) 691-8215, FAX: (212) 691-1191
Internet: http://www.ctExpo.com

PCS '99-Personal Communications Showcase
September 21-24 (Ernest N. Morial Convention Center, New Orleans, LA)
PCIA
Registration
P.O. Box 561
Brookfield, IL 60513-0561
(800) 759-0300, FAX: (708) 344-4444
Internet: http://www.pcs99.com

Wireless Symposium/Portable by Design (in conjunction with PCS '99)
September 21-24 (Ernest N. Morial Convention Center, New Orleans, LA)
Penton Media, Inc.
611 Route 46 West
Hasbrouck Heights, NJ 07604
(888) 974-3734, FAX-back service: (800) 561-7469
Internet: http:/www.WirelessPortable.com

M+RF 99 (Microwaves and RF Conference and Exhibition)
September 21-23 (Wembley Conference & Exhibition Centre, London, England)
Nexus Media Ltd.
Nexus House, Swanley, Kent BR8 8HU, England
+44 1322 660070, FAX: +44 1322 661257
e-mail: M+RF@nexusmedia.co.uk

Internet Device Builder Show and Conference
October 4-8 (Jacob K. Javits Center, New York, NY)
Penton Media, Inc.
611 Route 46 West
Hasbrouck Heights, NJ 07604
(201) 393-6259, FAX: (201) 393-6297
e-mail: tcusumano@penton.com
Internet: http://www.iDeviceBuilder.com

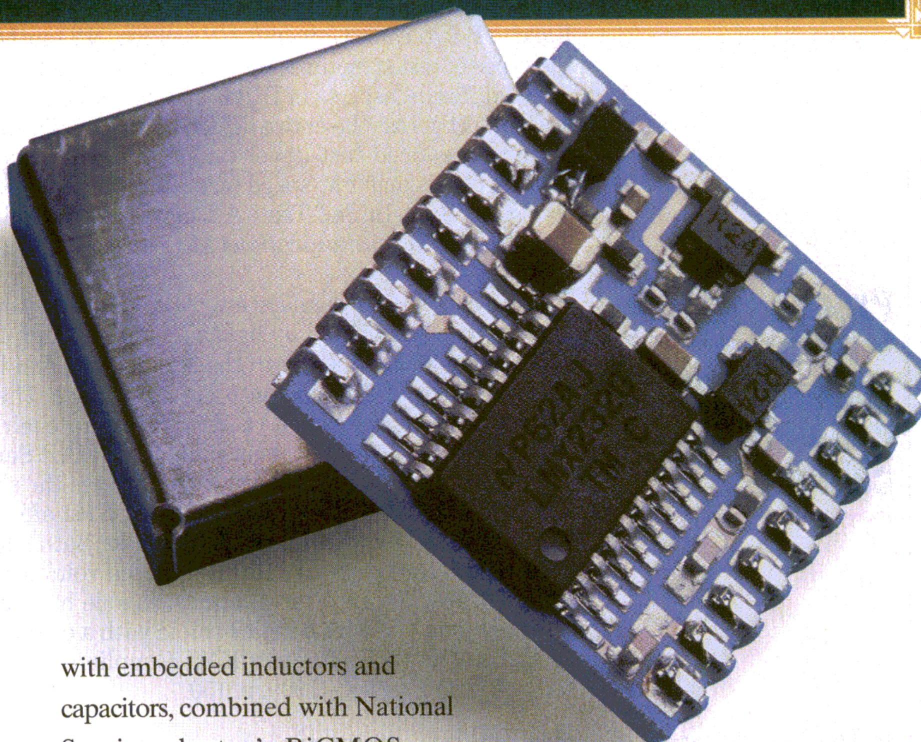
Call for Papers

International Conference and Exhibition on High Density & Systems Packaging
April 26-28, 2000 (Adam's Mark Hotel, Denver, CO)
International Microelectronics and Packaging Society (IMAPS)
1850 Centennial Park Drive, Suite 105
Reston, VA 20191-1517
(888) 464-6277, FAX: (703) 758-1066
e-mail: imaps@imaps.org
Abstract deadline: October 1, 1999

4th European Symposium on Electromagnetic Compatibility (EMC Europe 2000)
September 11-15, 2000 (Brugge, Belgium)
TI-KVIV, Mrs. R. Peys
Desguinlei 214
B 2018 Antwerpen, Belgium
+32/(0)3 216 09 96, FAX: +32/(0)3 216 06 89
e-mail: johan.catrysse@kh.khbo.be
Internet: http://www.ti.kivi.be/conf/emc2000.htm
Abstract deadline: December 1, 1999

Application Profile

DuPont Green Tape™ Shrinks Wireless Communications Devices.



National Semiconductor chose DuPont Green Tape™ materials to integrate passive components into circuit substrates used in wireless communications devices, improving performance and reducing circuit size and cost.

The Challenge: Small-Size, High-Performance Circuits for Wireless Telecom

In wireless communications devices such as cellular telephones, wireless LANs and satellite global positioning systems (GPSs), the ratio of passive to active components may be more than 100:1, which increases circuit size, weight and cost. National Semiconductor engineers needed to address the problem of integrating the necessary passive components, while still meeting circuit size and cost-reduction goals.

In addition, the new circuit had to meet complex performance requirements. Portable wireless components typically operate in the 900 MHz–2.4 GHz range, and require high efficiency (or high Qs) to meet stringent power and signal integrity requirements.

The Solution: Dupont 951 Green Tape™ System

The new circuit substrates use the DuPont 951 Green Tape™ system with embedded inductors and capacitors, combined with National Semiconductor's BiCMOS frequency synthesizer ICs.

The combined technology was first used on a VCO/synthesizer designed to embed the resonator and several passive circuit elements of a loop filter in a frequency control module. The embedded technology reduced circuit size by a factor of four and cut costs by half. The circuit has eight conductive layers, 200-micron lines and spaces, and 150-micron vias. It contains two buried inductors and four buried capacitors. Each substrate master produces 64 individual circuits.

The embedded functions of the substrate eliminate many interconnections with poorly controlled impedance, which traditionally require additional components to control the effects of parasitics and impedance mismatches. Concurrent design of active RF ICs with substrates containing embedded passives simplifies IC design and improves circuit efficiency to reduce power consumption, improve battery life, or reduce battery size.

For more information, call DuPont at 1-800-284-3382, press 3, or visit the DuPont Microcircuit Materials Web Site (http://www.dupont.com/mcm/).

DUPONT®

CIRCLE NO. 256

BIST solves many telecom-test problems

Built-in self test (BIST) offers a test methodology for all types of electronic systems whereby the test functions are embedded into the circuit itself. It can be particularly useful in telecommunications systems which must operate at high reliability to ensure uninterrupted network service to customers. To familiarize engineers with BIST concepts and how they apply to the testing of telecom systems, Nilanjan Mukherjee and Tapan J. Chakraborty of Bell Laboratories of Lucent Technologies (Princeton, NJ) and Ramesh Karri of Polytechnic University (Brooklyn, NY) authored a tutorial on BIST that explains the types of test structures required at the circuit and system levels. The tutorial focuses on the different aspects of BIST and how it can be used effectively to achieve complete system test across the entire design hierarchy. The advantages for large systems are numerous—reduced test-development time, elimination of very-high-speed hardware testers, provision for at-speed tests, in-field test capability, and high fault coverage are a few. See "Built-In Self-Test: A Complete Test Solution For Telecommunication Systems," *IEEE Communications Magazine*, Vol. 37, No. 6, June 1999, p. 72.

Proper shielding termination reduces EMI coupling in cables

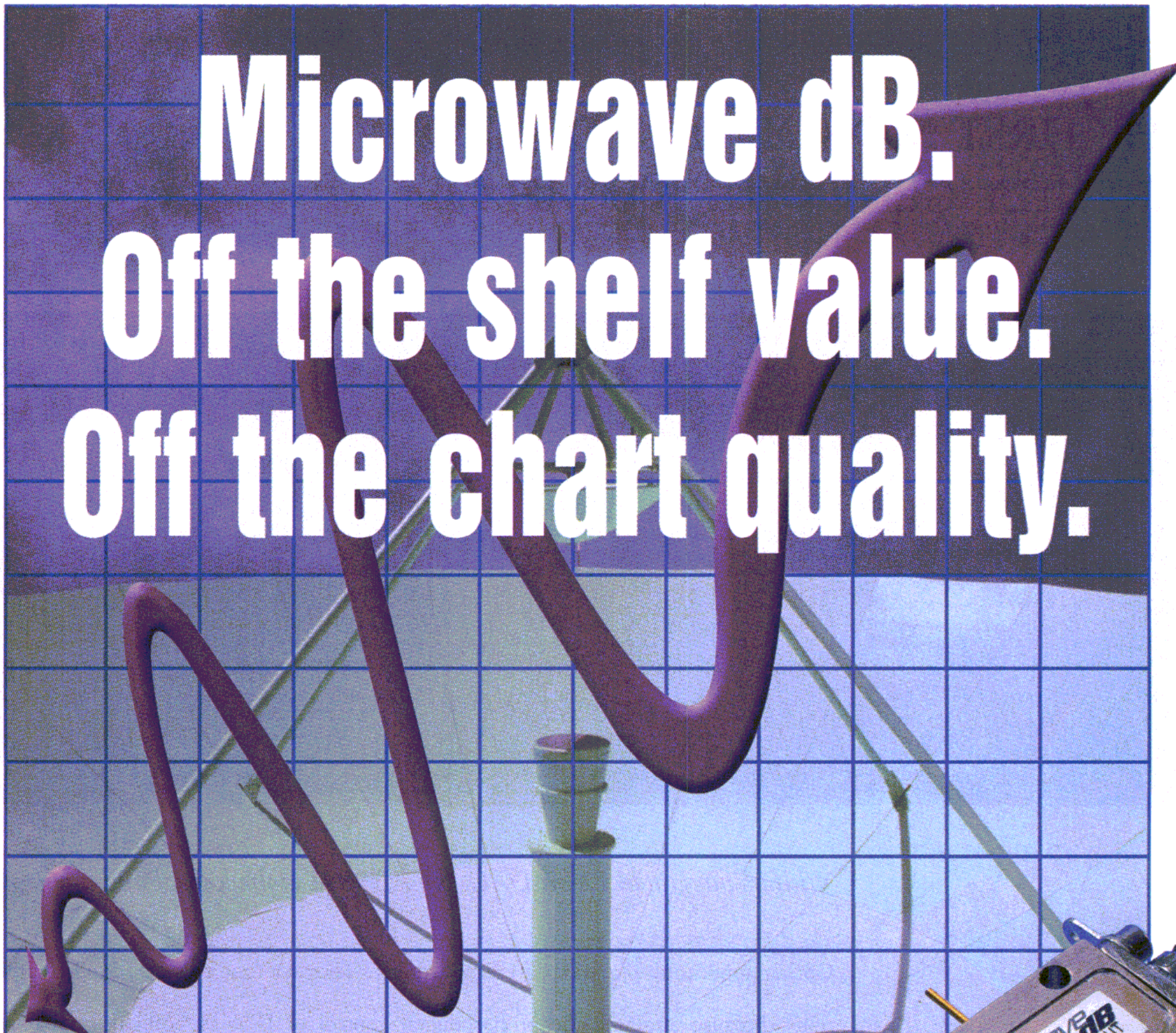
Long cables that connect low-voltage data systems such as RS-232 interfaces or modems can be affected by lightning surges, high-frequency interference that propagates along a shield and into the signal lines, and low-frequency interference caused by shield current coupling onto the signal lines. There are methods to reduce the electromagnetic-interference (EMI) effects in each of these situations according to Richard Meininger and Robert Blouch of CHAR Services, an EMI consulting company (Lebanon, PA). Much of the solution involves the shield around multiconductor cables and its method of termination. Reduced EMI effects can be achieved for existing cables by proper termination of the shield for both high- and low-frequency effects while a bleed path can be created for the induced voltages due to lightning that result in damaging surges. For new installations, a cable having braided shield or thick-foil shield is better than one with a mylar shield with a drain wire. See "Impedance Termination Of Cable Shield To Reduce EMI Coupling," *The International Journal of EMC (ITEM 1999 Edition)*, 1999, p. 150.

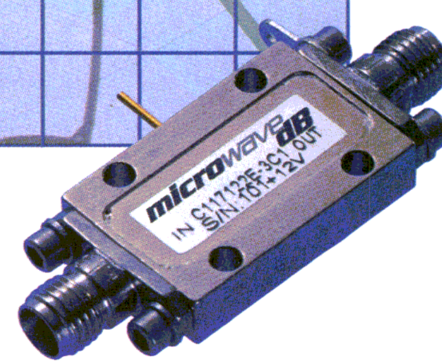
VXIbus overhaul adds new test capabilities

The VXIbus (VME eXtensions for Instrumentation) is a primary open-system standard in the test and measurement arena that has undergone tremendous expansion in this decade. A new version of the VXIbus standard, called VXI-1 Revision 2.0, was released recently with a number of enhancements and features, a summary of which are described by Greg Hill of Hewlett-Packard's Measurement Systems Division (Loveland, CO). The major contribution, from the VME64 specification, is the increase to 64-b data transfers. This doubles the available bandwidth for both the VMEbus and VXIbus, without any backward compatibility problems. Another enhancement derived from VME64 is the retry capability. This enables a slave device to backoff a transaction it is not ready to complete and perform it at a later time. Some features of VME64 are not included in Revision 2.0 because they would add little to the bus's capability while increasing cost to the user. See "VXIbus Revision 2.0-What's New," *IEEE Instrumentation & Measurement Magazine*, Vol. 2, No. 2, June 1999, p. 19.

Microstrip equivalent circuits derived from algorithm

Discontinuities in microstrip lines and microwave circuits such as planar inductors and parallel-plate capacitors are represented by S-parameters when measured by conventional instruments such as network analyzers. But such parameters cannot be handled by circuit simulators such as SPICE, which require conventional, lumped-parameter equivalent circuits for proper simulation. A technique for extracting an equivalent circuit from its S-parameter form was created by P.L. Werner, R. Mittra, and D.H. Werner of the Department of Electrical Engineering of Pennsylvania State University (University Park, PA). The technique is based on the application of the genetic algorithm (GA) to extract the equivalent circuit. The GA works by taking a large population of randomly selected component values and guiding it toward better solutions through repetitive applications of reproduction, crossover, and mutation operators. See "Extraction of Equivalent Circuits for Microstrip Components and Discontinuities Using the Genetic Algorithm," *IEEE Microwave and Guided Wave Letters*, Vol. 8, No. 10, October 1998, p. 333.





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CIRCLE NO. 251

Novel Multiple-Beam Antenna Array Serves Mobile BTS

Multiple-Beam Antennas, Part 1

This environmentally sound, multiple-beam, direct-radiation array antenna can help boost the capacity of existing wireless systems.

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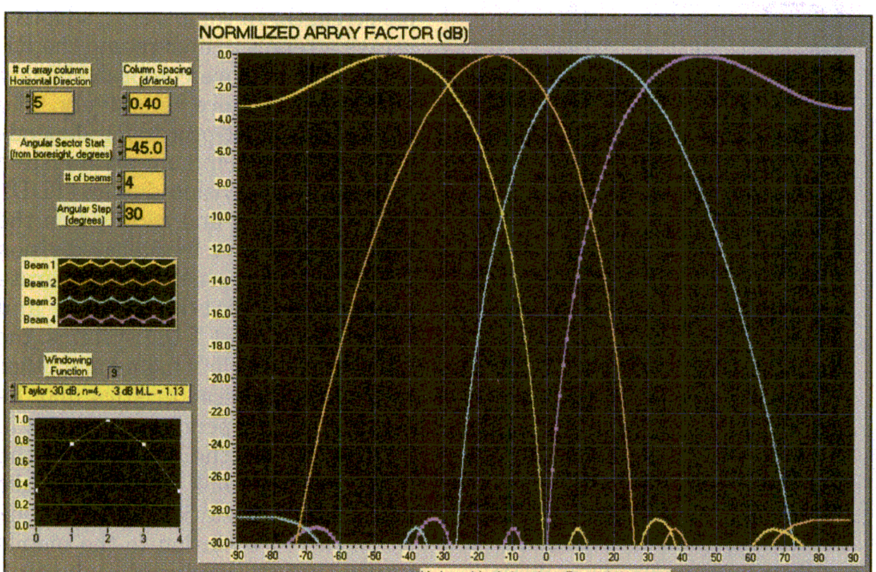
MULTIPLE-BEAM (direct radiation) array antennas have been successfully used for more than a decade in military and satellite systems. This type of antenna offers a novel means of fulfilling conflicting wireless base-transceiver-station (BTS) design requirements, such as boosting system capacity while being attentive to health and environmental issues.

Sector antennas are commonly used in a mobile communications BTS, with typically one transmitting and one or more receiving antennas per cell, depending on the diversity scheme. The same pole usually hosts the antennas of several cells and these 'objects' are now very common in the skyline of an urban environment. In general, as the sector size is made narrow, the potential for frequency re-use increases, and higher capacity can be achieved with lower power levels. But narrower sectors also increase the number of sector antennas needed. In addition, the physical dimensions of BTS antennas depend on the sector size. Usually they have the shape of a rectangular panel whose height depends on the beamwidth in the vertical plane. Narrower sector/beamwidth sizes (either in the vertical or horizontal plane) translate into larger antenna panels.

Clearly, large antenna systems have a greater environmental impact on the landscape. But the visual impact is also accompanied by a public awareness of low-level RF radiation. Even though there is no persuasive evidence that 'low-level' RF radiation can produce significant health risks, international bodies are recommending more and more prudential limits to the emissions from personal phones and BTS (especially those located in residential areas). The use of multiple-beam array antennas can make it possible to boost network capacity by upgrading an existing infrastructure, to reduce the environmental impact on the landscape by the BTS antennas, and to reduce the



1. This x-axis cut was made for the array factor of a direct-radiating multiple-beam antenna with four beams evenly covering a span of approximately 120 deg. in the horizontal plane. The array antenna contains five columns of radiating elements spaced 0.4 wavelength units.

level of RF radiation associated with mobile telephones.

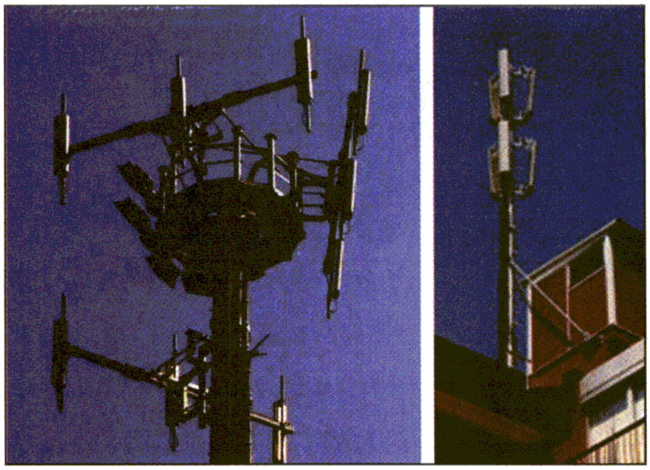
Several strategies and technologies are available to build up capacity in stages that pay back quickly and try to make full use of the investment over the network lifetime.

The current trend is an evolving combination of powerful software solutions that increase network capacity by making more-efficient use of the available frequency band without resorting to massive investments for new infrastructures.

In conjunction with advanced network planning and optimization techniques, an intelligent underlay-overlay approach has also been successfully implemented in several macrocellular and microcellular networks. The basic two-layer network structure of the underlay-overlay technique provides seamless coverage on one layer (macrocell) and high capacity on the other (microcell). The approach can improve network capacity by enabling reuse of frequencies more aggressively than with traditional planning methods. The most-aggressive frequency-reuse strategies, however, require smart antennas.

A smart antenna would appear to be ideal for a BTS. This type of antenna can automatically change its radiation pattern in response to the signal environment. Smart antennas consist of an array of elementary radiating elements, a 'beam-former' that combines the signals to/from the elements, and a digital signal processor (DSP) that calculates the beamformer coefficients.

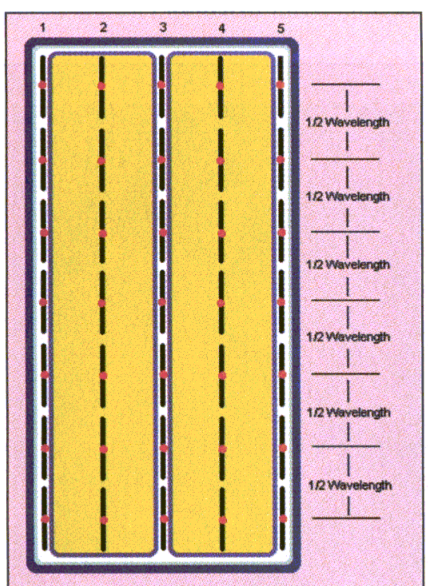
In fact, the desired antenna pattern can be synthesized by adjusting the amplitude and phase/delay of the signals feeding the array elements. The array acts as a spatial filter, which can enhance or reject signals based on their direction of arrival. Employing a smart antenna at cellular BTS sites enables "customized" beams to be dynamically generated for each mobile unit or group of mobile units. This may be regarded as a more-sophisticated spatial-diversity system. It is even possible to reuse frequencies within a single cell through spatial-division multiple access (SDMA). The table summarizes the main features and benefits of smart-antenna systems, which are best suited for fully digital implementation.



2. In a typical antenna system for a clover BTS for GSM (left), a common pole hosts the antennas for three adjacent 120-deg. sectors. A low-environmental-impact antenna is shown (right) for contrast.

Unfortunately, current digital technology does not yet appear mature to support the wide instantaneous bandwidth and the processing power necessary to deal with cellular radio spectrum. In addition, smart-antenna technology does not exactly match the technology of existing BTS and it requires massive capital investments to upgrade the infrastructure. However, a near-term alternative to smart antennas is available—analog synthesis of multiple beams using an array antenna. This approach retains most of the benefits of smart antennas, with considerably less complexity and cost than an all-digital solution.

The technique enables the synthesis of multiple simultaneous narrow beams by using a single array of approximately the same size of a standard sector antenna with comparable beamwidth. The approach is compatible with existing infrastructures, and enables service providers to trade a potential significant increase of the network capacity in exchange for a moderate upgrade investment in BTS equipment.

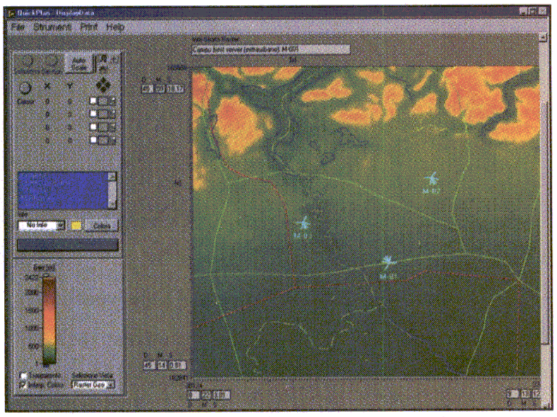


3. This is an example of a multiple-beam, direct-radiation array antenna with radiating elements arranged in a rectangular pattern with five columns and seven rows.

The task of transmitting in a spatially selective manner is the major basis for differentiating between multiple-beam and adaptive-array systems. As described below, multiple-beam systems communicate with users by changing between preset directional patterns, on the basis of signal strength. In comparison, adaptive arrays attempt to understand the RF environment more comprehensively and transmit more selectively. The type of downlink processing depends on whether the communication system employs time-division duplex (TDD), which transmits and receives on the same frequency or frequency-division duplex (FDD), which uses separate frequencies for transmitting and receiving. In most FDD systems, the uplink and downlink fading and other propagation characteristics may be considered independent, whereas in TDD systems, the channels of the uplink (i.e., the link from the mobile user to the base station) and downlink (from the base station to the mobile unit) can be considered reciprocal. Hence, in TDD systems, uplink channel information may be used to achieve spatially selective transmission. In FDD systems, the uplink channel

information cannot be used directly and other types of downlink processing must be considered.

In terms of radiation patterns, multiple-beam antenna technology is an extension of the current sectoring method of splitting a typical macrocell, making it fully compatible with existing wireless infrastructures. However, instead of using as many panel antennas as the number of the new (narrower) sectors, the multiple-beam array synthesizes all the new beams by the same antenna.



4. This display from the Quick_Plan software shows a cellular territory in northern Italy. The existing infrastructure is shown in terms of three clover BTS sites labeled M-01, M-02, and M-03.

Much like current sectoring methods, the multiple-beam approach further subdivides macrosectors into several microsectors or microcells as a means of improving range and/or capacity. Each microsector contains a predetermined fixed beam pattern with the greatest sensitivity located in the center of the beam. The multiple-beam system selects one of several predetermined fixed-beams with the greatest output power in the remote user's channel.

When a mobile user enters a particular macrosector, the multiple-beam system selects the micro-sector (e.g., the cell) containing the strongest signal. Throughout the call, the system monitors signal strength and switches (makes a handoff) to other adjacent beams (cells) as required.

An array antenna has an aperture assembled from many similar radiating elements such as slots over a metal plane, dipoles, patches, or horns.

When the elements are directly radiating in space (with no shaped reflector on the signal path), the array is called "direct radiating." Direct-radiating arrays are very compact and, by suitable amplitude and phase control of the individual radiating elements, can achieve high efficiencies with accurately predictable radiation patterns and beam-pointing directions.

It should be noted the same aperture generates all the beams of the array antenna.

With the elements spaced by one-half wavelength (or less, to avoid the generation of multiple beams, called grating lobes), the number of radiating elements, N, for a pencil beam, is related to the beamwidth:

$$\theta_B,\ by\ \theta_B \approx 100/N^{0.5} \qquad (1)$$

where:

θ_B= the 3-dB beamwidth (in deg.)

The corresponding gain, G_0, when the beam points broadside to the aperture (i.e., along array boresight) is:

$$G_0 \approx \pi N \qquad (2)$$

When the beam is pointed to an angle θ_0 from boresight, the gain of a planar array is reduced to that of the projected aperture:

$$G\theta_0 \approx \pi N \cos\theta_0 \qquad (3)$$

and the beamwidth is somewhat greater than θ_B.

Practical extreme values of θ_0 are in the region of 60 to 70 deg.

The radiation pattern of an array is the product of the element pattern and the array factor. The array factor is determined by the geometric disposition of the elements, and their amplitude and phase weighting, on the assumption that the elements are isotropic and there is no mutual coupling. The element pattern depends on the radiation patterns of all the individual elements, actually taken in the array, in the presence of

Features and benefits of smart-antenna systems

Feature	Benefit
(BTS) receive signal gain Inputs from multiple elementary receive antennas are combined at the base station to limit the RF power required to the portable handset to establish connection.	**Reduced health risk** • Focusing (at the base transceiver station) on the energy received from a mobile terminal (for a particular range) reduces the power transmitted from the user terminal (which is very close to the user's head or body) and, thus, the health risks. • Lower power requirements also enable greater battery life and smaller/lighter handset size.
(BTS) transmit signal gain Inputs from multiple elementary transmit antennas are combined to optimize available power required to establish a particular level of coverage.	**Better range/coverage** • Focusing at the base station, the energy sent out into the cell (with equality of transmitted power) increases BTS range and coverage while controlling interference in other directions.
Interference rejection Antenna (null) pattern can be generated toward co-channel interference sources, improving the signal-to-interference ratio of the received signals.	**Increased capacity** • Both precise control of signal nulls quality and mitigation of interference combine to reduce distance requirements for frequency reuse (or cluster size), hence improving capacity. • Certain adaptive technologies (such as SDMA) support the reuse of frequencies within the same cell.
Spatial diversity Composite information from the array is used to effectively minimize fading and other undesirable effects of multipath propagation and delay spread of the channel, allowing higher bit rates to be supported without an equalizer.	**Low environmental impact** • The "minimal" dimensions of the array (when compared to a typical antenna diversity installation) help to reduce the environmental impact on the landscape of the antenna systems associated with mobile BTS to an absolute minimum.

all other array elements and taking into account all coupling effects and mismatches. The radiation patterns of the array elements must clearly be broad enough to support the maximum pointing angle θ_0 (from boresight) of the design.

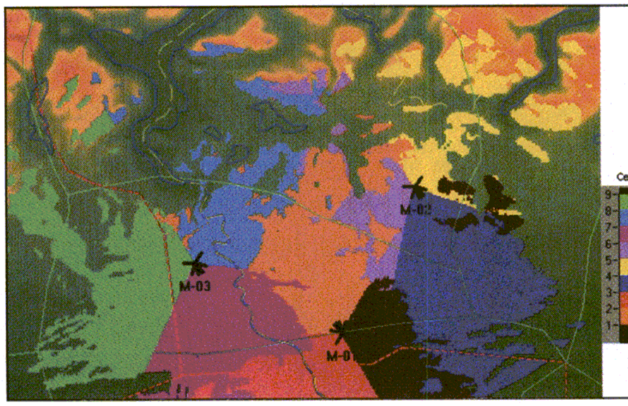
Multiple-beam-forming antennas consist also of networks that generate or receive the simultaneous beams of the array, with each beam having the gain and beamwidth of the whole antenna. The complexity, cost, and implementation loss of such analog networks is directly related to the number of simultaneous beams and their isolation.

Practical values for the number of simultaneous beams range between 4 and 16.

In the case of antenna systems for mobile BTS units, in order to double the effective frequency reuse, the more-appropriate number of beams appears to be in the region of 4 to 6.

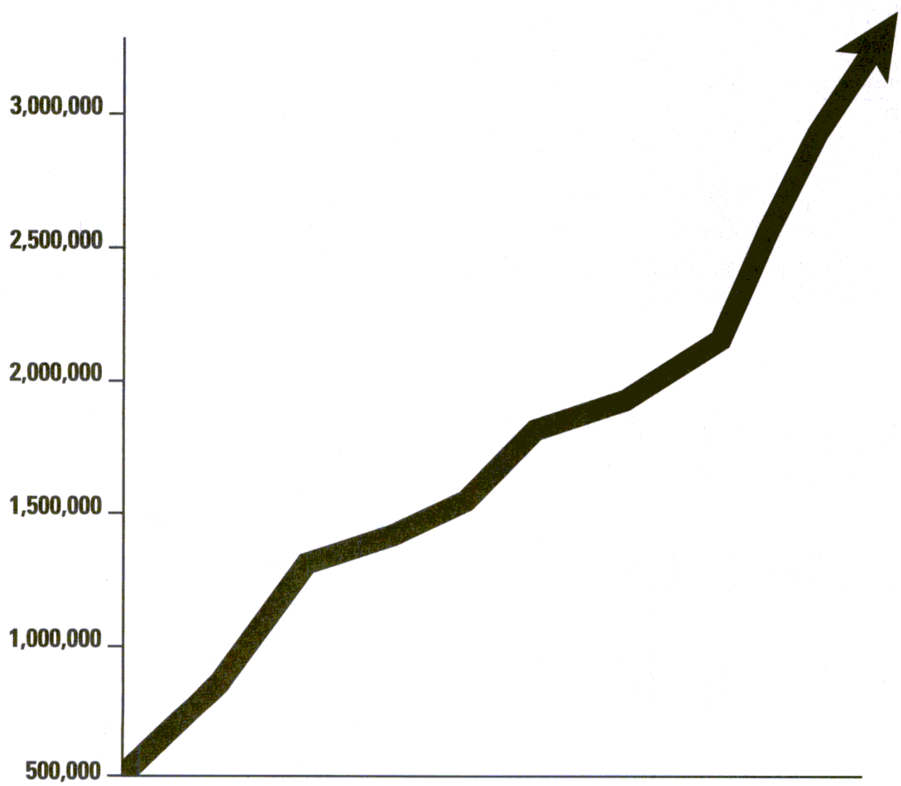
For the sake of clarity, consider the rough preliminary design of a sort of reference antenna of this kind, with the radiating elements arranged in a rectangular pattern with five columns and up to seven rows. Figure 1 shows the array factor (horizontal axis cut) of such a rectangular array with five identical vertical columns of radiating elements. Each column is made of up to seven radiating elements spaced approximately one-half wavelength from each other and the columns are spaced 0.4 wavelength units. Each column of radiating elements is in charge of forming the pencil beams in the vertical plane and it resembles the shape of the standard vertical panel antennas currently used in mobile base (transceiver) stations. The theoretical array factor cut along the horizontal plane of four simultaneous beams can be seen. Four beams may enable a times-two frequency reuse among odd (1-3) and even (2-4) beams. This implies a nominal doubling of the capacity with respect to the case of a single fan beam over the same horizontal sector.

Figure 2 (left) depicts the typical antenna arrangement



5. This "best server" display of the area in northern Italy is based on nine cells corresponding to the three existing clover BTS (three 120-deg. sectors or cells each). Each color shade corresponds to a different cell, with individual pixels corresponding to received field levels.

3 Million & Growing*



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of a Global System for Mobile Communications (GSM) BTS in a clover configuration. The BTS covers three 120-deg. adjacent sectors (cells) by one transmit and two receive antennas (due to spatial diversity) per cell. The three antennas for each cell are mounted horizontally in this case but they could also be mounted vertically.

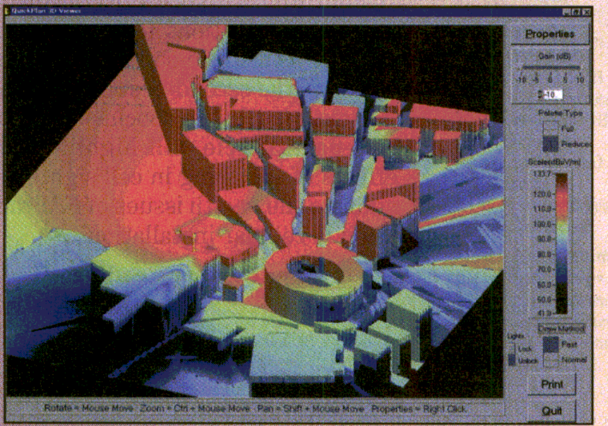
Figure 2 (right) shows the typical configuration of the same three sectors (clover) BTS when low environmental impact is mandatory. In this case, there is only one transmit and one receive antenna per cell (no spatial diversity) and the antennas are mounted vertically.

In the case of a clover BTS, the current sectoring method (case of four beams, that is, four new micro-cells over the original 120-deg. cell) would require the installa-

MORE ON QUICK_PLAN

In 1998, Space Engineering S.p.A. spun off a separate company called Teleinformatica e Sistemi (TeS) s.r.l. (Rome, Italy) to focus almost exclusively on software solutions for the cellular market. The company has developed an effective planning and analysis tool for mobile networks called Quick_Plan®. The software tool is suitable for both cellular operators and environmental agencies. It helps analyze base-station coverage and interference, supports the timely development of frequency plans, and can display the electromagnetic (EM) pollution due to a BTS.

The EM engine for the prediction of the macrocell coverage in Quick_Plan is based on the latest analysis algorithms (including the Okumura-Hata model). The software includes a Geographic Information System (GIS) relational data base powered by ORACLE× software. Quick_Plan can run on a laptop computer for portability to remote locations, and can support the necessary data exchange while maintaining the highest standards for data integrity, security, and consistency. The powerful analysis tool can even analyze levels of EM pollution in a given area (see figure) around an emitter, such as a cellular BTS.



The Quick-Plan analysis software was used to plot the levels of EM pollution for a BTS located near the Colosseum in Rome, Italy.

tion of 24 antennas (no spatial diversity) or 36 antennas (with spatial diversity).

Under the same assumptions, only six (three transmit and three receive) multiple-beam (direct radiating) array antennas (Fig. 3) would suffice. They could be mounted vertically (as in Fig. 2, right) while retaining the inherent spatial diversity benefits of all array antennas. As far as the size of each multiple-beam array antenna (Fig. 3) is concerned, the vertical height is approximately the same as the standard antenna panels—this size depends only on the desired vertical plane beamwidth.

The horizontal width, under the assumptions of Fig. 1, is on the order of four times a one-half wavelength unit (i.e., two wavelength units, approximately 66 cm at 900 MHz or 33 cm at 1800 MHz). In practical terms, the width of the multiple-beam array antenna is more or less comparable to two times the width of a standard antenna panel (Fig. 3, with 900-MHz antenna panels having a width on the order of 35 cm). The total area occupied by 24 standard panel antennas is approximately twice the area of six multiple-beam array antennas.

In the previously depicted sectoring case of a clover BTS, the use of multiple-beam array antennas may give a remarkable 50-percent saving in terms of pure antenna area. Taking also into account the necessary guard distance among 24 standard panel antennas installed on site, the effective area saving might even be higher.

This simplified analysis clearly shows the potential of multiple-beam array antennas to guarantee a very low environmental impact.

To visualize the potential for increase in capacity due to sectoring with a multiple-beam array antenna, analyses were performed with Quick Plan™, a planning software tool for mobile networks (see sidebar) developed by TeS Teleinformatica e Sistemi s.r.l. (Rome, Italy). Figure 4 shows an area in northern Italy with a hypothetical arrangement of several existing (clover) BTS. For simplicity, traffic is assumed to be evenly spread among the cells so that the existing frequency plan is in line with the theoretical frequency reuse pattern corresponding to the cluster size of the system. Figure 5 shows the calculated best-case conditions for coverage of the nine cells. The software can also calculate the second-best conditions.

Next month, the conclusion of this two-part article will highlight the effects of sectoring in cell sights and address the health issues of EM radiation in cellular installations. ••

For Further Reading

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FSK Modulator Boasts High DC Accuracy

A low-cost transmitter integrated circuit can be used as the basis for an FSK modulator for low- and medium-data-rate wireless systems.

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Applications Engineer

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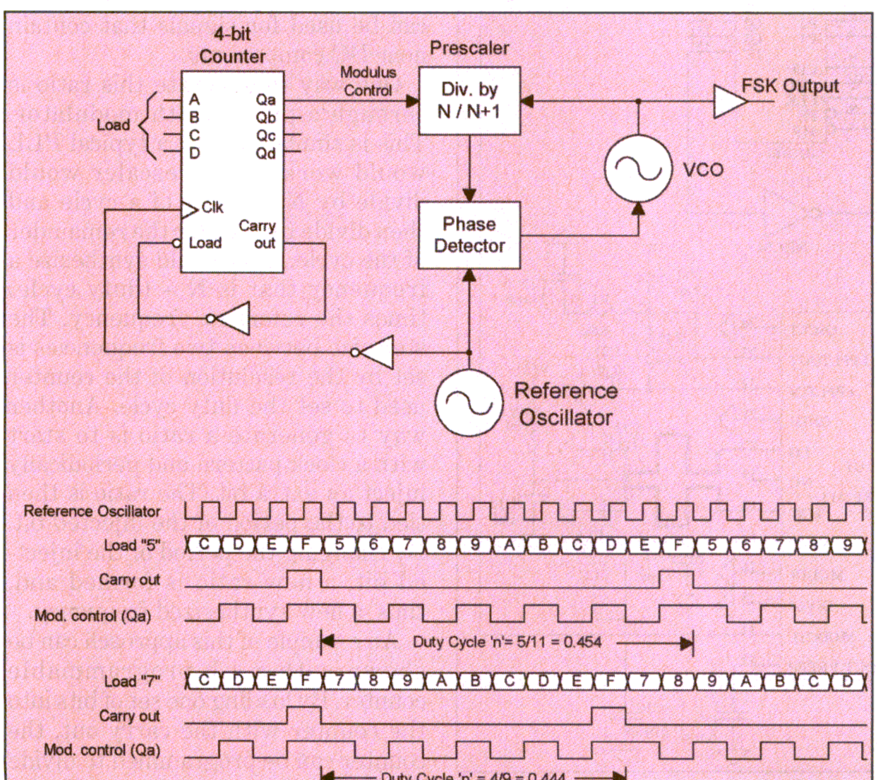
MODULATORS for frequency-shift-keying (FSK) communications systems require high-frequency accuracy. An approach has been developed that is relatively immune to the effects of phase-locked-loop (PLL) filtering.

A typical, low-cost FSK modulator is implemented by injecting the modulation voltage into the carrier synthesizer's PLL. This can be performed by summing the modulation voltage and the loop-error voltage together and applying the combination to a voltage-controlled-oscillator's (VCO's) tuning port or by using a separate tuning port usually having lower sensitivity to voltage changes. The modulating data would change the carrier frequency by a predetermined amount (deviation). This, however, causes a frequency error within the PLL that the loop begins to correct. The effect of the loop correcting for the frequency errors caused by the modulation is analogous to passing the modulating signal through a highpass filter. Lower-frequency components of the modulation signal get filtered off (or even eliminated). The result is unreliable communications for random data streams, especially for long strings of non-changing digital bits.

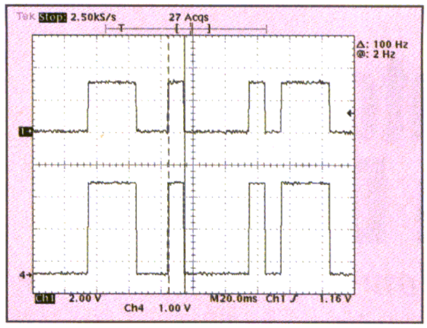


1. This block diagram shows the components of a DC-accurate FSK modulator.

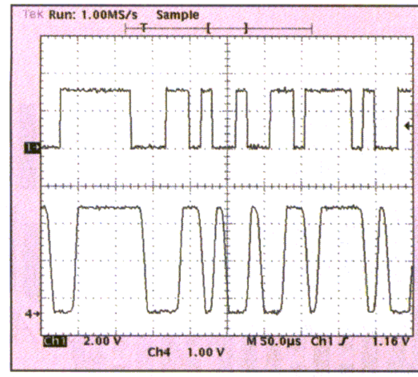
Several solutions have been developed and implemented to address this problem. One approach is to predistort the modulation signal to compensate for the effects of the PLL. This has limited results and a finite frequency range. Another commonly used method is to encode the data stream with techniques such as Manchester coding or split-phase coding. The basis of this coding is to send two complementary symbols for every data bit, thus a transition is guaranteed for every data bit. This approach is effective since it fixes the lowest-frequency component of the modulation signal so that a loop bandwidth can be designed to have a minimal effect on the coded data. Unfortunately, this means that the effective data rate is doubled, increasing the required channel bandwidth. The encoding procedure is rather simple (EXCLUSIVE OR the data and clock together). The decoding is more complicated, requiring some synchronization to guarantee that the correct two symbols are used to decode the data bit.

Other approaches avoid the entire problem by performing modulation outside the PLL. This can be performed by modulating the reference crystal oscillator, for example. Since modulation occurs outside the loop, the PLL does not try to correct the modulation signal, it simply tracks the changes in the reference frequency. The pullability of the crystal resonator or oscillator limits the achievable frequency deviation. Another method would be to generate the reference frequency with a direct digital synthesizer (DDS) and perform modulation of the DDS. This is an accurate, but expensive solution.

Another type of approach is to program the mark and space frequencies in the PLL. There are several ways to do this depending on the programmability of the PLL divider registers. A new technique takes advantage of low-cost integrated circuits (ICs) that contain simple PLL and VCO functions. These ICs are typically designed to be multipliers of a reference crystal to generate a local-oscillator (LO) frequency, although they can also be modulated for FSK transmitters.



3. The accuracy of recovered data (bottom) compared to transmitted data (top) demonstrates the effectiveness of the modulator for a data rate of 100 b/s.

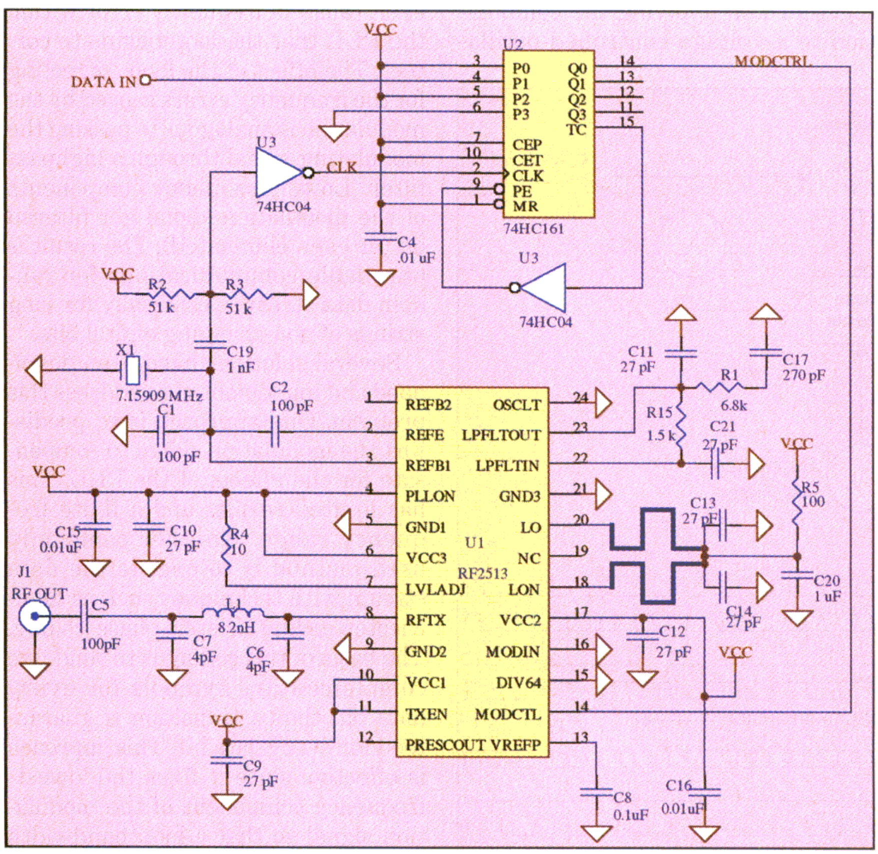


4. The data integrity can be evaluated for the modulator at 72 kb/s by comparing data recovered with an IC receiver (bottom) to the original transmitted data (top).

The prescaler is a PLL component that divides the VCO frequency down to the reference crystal frequency. It usually has dual division rates (N and N + 1) and, as such, is referred to as a dual-modulus prescaler. By controlling the ratio of the two rates, the VCO frequency can be set to a desired frequency. Using one ratio for logic level 1 and another ratio for logic level 0 can effectively generate FSK modulation that is not affected by the PLL and, therefore, can be used for signals that contain near DC components.

One way to generate this ratio is through a pulse-width modulator. This is similar to how a typical PLL would work. The prescaler would divide by N for part of a cycle and then divide by N+1 for the remainder of the cycle. This would synthesize a frequency that is N + (duty cycle) times the reference frequency. The step size between two frequencies is set by the resolution of the counter used to set the duty cycle. Another way to generate a ratio is to start with a clock pattern and periodically inject an extra bit. The ratio is then tied to the period of the injected bit. By changing the period of the injected bit, a new ratio is formed and, thus, a new synthesized frequency.

An example of this approach can be shown with a 4-b programmable counter. By loading one set of bits into the counter with the carry out, the counter can be programmed to divide the clock frequency, F_{clk}, by s (F_{clk}/s), resulting in a cycle rate of s/F_{clk} sec-



2. The DC-accurate FSK modulator is represented by these circuit elements and single integrated circuit.

onds. The first divider output, Q_a, normally looks like F_{clk} divided by 2. If the programmed value s is chosen so that a logical 1 is loaded into the a divider (an odd number), then the Q_a output stays at 1 from the previous state. This puts one more 1 than 0 in the Q_a output for every cycle of the counter. This unequal number of 1s and 0s will define a fractional number over the cycle rate of the programmed bits. Different programmed bits can generate different fractional numbers and, thus, different synthesized frequencies. If b is the number of bits in the counter and s is the programmed word, then the fractional number generated is:

$$\textit{Number of } Q_a \textit{ states per cycle} = 2^b - s \qquad (1)$$

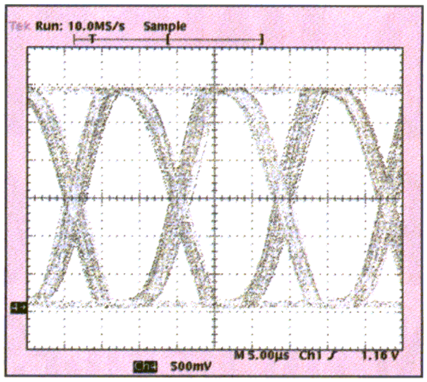
$$\textit{Number of 0s per cycle} = \frac{2^b - s - 1}{2} \qquad (2)$$

$$\textit{Then fractional } n = \frac{2^b - s - 1}{2\left(2^b - s\right)} \qquad (3)$$

The synthesized frequency can then be calculated as $F(ref) \times (N+n)$. If s and $n(s)$ represent the space frequency and m and $n(m)$ represent the mark frequency, then the peak-to-peak frequency deviation can be calculated as $F(ref) \times [n(s) - n(m)]$. This method can produce smaller deviations with fewer dividers than the previous method but offers fewer selections to chose from.

A simple form of this technique is described in Fig. 1, implemented with a 4-b counter. The values of s and m are chosen so that only one of the four bits is different. Therefore, the data to be modulated onto the carrier are used to set or clear that divider every cycle. An infinite numbers of cycles can occur at either the mark or space frequency without correction by the PLL, thereby making this modulator accurate down to DC.

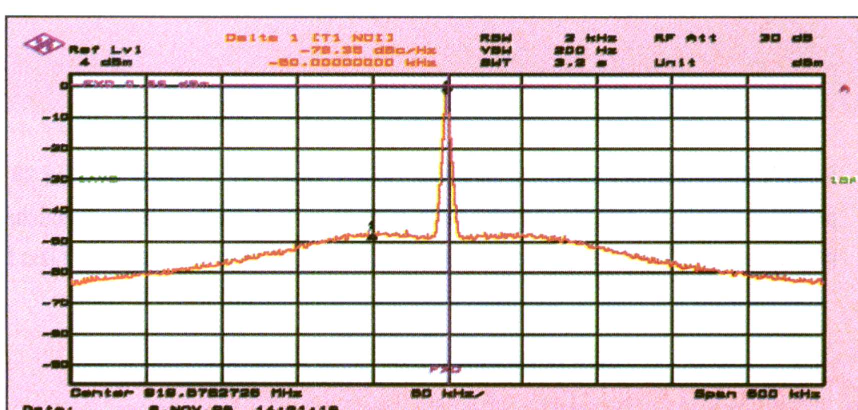
In this example, a 4-b counter is used to control the divider ratio of the prescaler in a PLL synthesizer. The Q_a output toggles high and low except when the carry out is asserted. Then the Q_a output stays high with the correct load value. For a loaded value of 5, the Q_a output will be low for 5 out of the 11 states of the counter [(16 – 5 – 1)/2]. This sets up a ratio or duty cycle of n = 0.454. The B bit of the counter can be changed from a 0 to a 1 to change the load value from 5 to 7. In this case, the Q_a output is low for four out of nine states, [(16 – 7 – 1)/2] for a duty cycle of n = 0.444. The ratios modify the prescaler to produce an output frequency with a fractional divide-by ratio, that is, 128.454 or 128.444. Therefore, the output frequencies differ by (128.454 – 128.444) times the reference oscillator. The rate of change on the modulus control pin is very high relative to the PLL bandwidth so the changes are averaged or smoothed out over time.



5. This eye diagram was measured and plotted for the modulator operating at a data rate of 72 kb/s.

A simple hardware implementation of a radio link using this method is described here. A family of transmitter or transceiver ICs RF Micro Devices (Greensboro, NC) offers the internal PLL and dual-modulus prescaler which can be used in this design. The RF2513 IC from RF Micro Devices was chosen to demonstrate a simple low-cost transmitter for US industrial-scientific-medical (ISM) band applications. The RF2513 contains all of the active circuitry necessary to implement a single IC FSK transmitter—a reference crystal oscillator, PLL, dual-modulus prescaler, VCO, transmitter-buffer amplifier, and power amplifier (PA). The IC also contains an internal varactor diode for tuning the VCO. By using printed inductors for the resonators, the external component count is minimized. A 74HC161 4-b counter from Motorola (Phoenix, AZ) is used to implement the counter and a 74HC04 is used for the necessary inversion to load the counter and to buffer the reference oscillator used for the clock. The schematic of the final circuit is shown in Fig. 2.

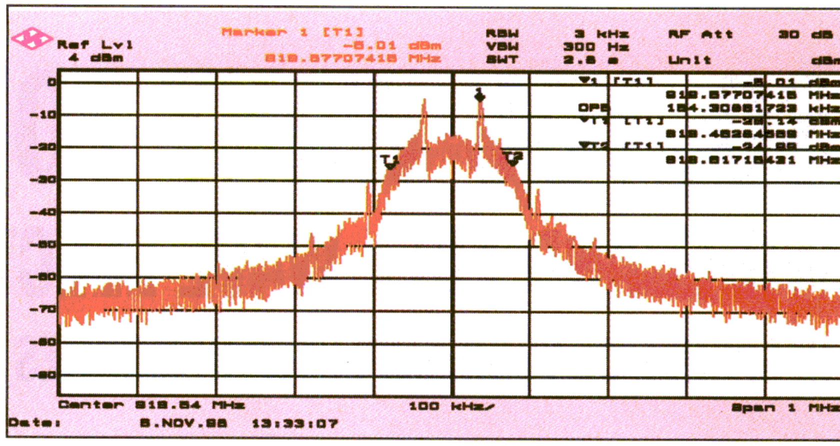
The reference crystal oscillator, which is supplied with the evaluation board for the RF2513, operates at 7.15909 MHz. This normally produces a transmit frequency of 916.4 MHz for a divide-by-128 setting. Other values could easily be substituted. Since the divider ratios are 128.454 and 128.444, the output frequencies are 919.6137 MHz for a logic level 0 and 919.5421 MHz for a logic level 1 input. Thus, the peak-to-peak frequency deviation is fixed at 71.6 kHz. Since the deviation is derived by numerical means as a fraction of the crystal frequency, it is very accurate and repeatable without additional tuning. This deviation supports a wide range of data rates, from 1 b/s to 100 kb/s by using different modulation indices. The upper



6. The phase noise of the RF2510 transmitter IC was measured for a loop bandwidth of 50 kHz.

limit is actually set by the PLL's loop bandwidth to the point where the modulation index becomes too small. In Fig. 3, a pseudorandom data pattern clocked at 100 b/s is shown as an example of the low-data-rate capability. The recovered data maintain their DC level through several consecutive data bits, providing evidence of the modulator's DC accuracy. In Fig. 4, the same pseudorandom data pattern at 72 kb/s is shown. In each instance, an RF2917 evaluation board tuned for 919.578 MHz was used to demodulate the data.

The PLL bandwidth is designed to be reasonably wide and yet still provide reasonable spurious rejection. The loop bandwidth is one factor that determines the rate at which the VCO changes from one frequency to the other and, thus, the upper data rates. As data rates exceed the loop bandwidth, the modulation waveform becomes bandlimited and takes on the appearance of intersymbol interference (ISI). Figure 5 shows the eye pattern of this modulator as seen at the output of a model RF2917 receiver IC. The flatness of the eye pattern attests to the modulator's immunity to random data patterns. The slew rate due to the PLL bandwidth is also evident. The high-loop bandwidth offers several advantages. First, the close-in phase noise of the VCO is corrected by the PLL, at best to that of the crystal. More important, the PLL synthesizer will have a faster lock time due to the higher bandwidth. This is useful for systems that burst a packet of data and then shut down to conserve battery life. Burst-type systems are also affected by load pulling when the PA is turned on. The faster loop response can minimize or eliminate out-of-band spurs due to turn-on transients that would be problematic for low-data-rate systems that use lower-loop bandwidths.

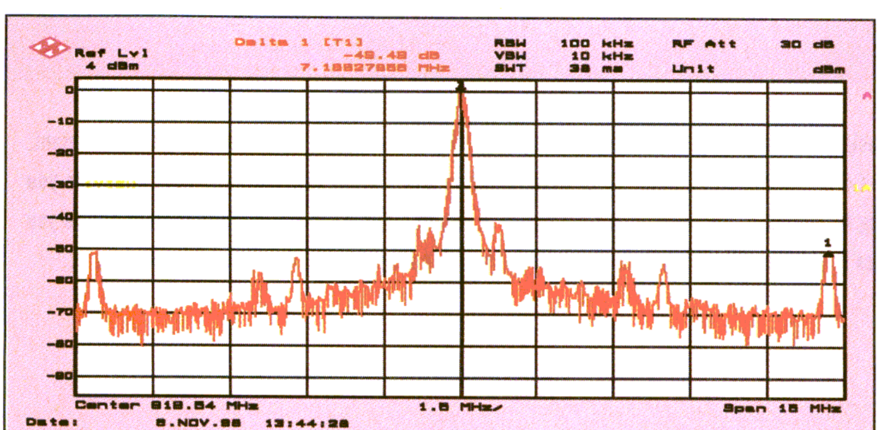


8. The modulated (with 72-kb/s pseudorandom data) spectrum of the RF2510 transmitter IC was measured at a carrier frequency of 819.54 MHz.

For this design, the loop bandwidth is set at 50 kHz and a type two, third-order loop is used to help with suppression of the crystal-reference spurious products. (Additional information on designing the loop filters is available in the *1999 RF Micro Devices* catalog, technical article TA-0031.) Figure 6 provides a look at the close-in phase noise while Fig. 7 shows the spurious performance. Modulation spurious signals resulting from the counter cycles are also evident in Fig. 7. The primary source for these modulation spurs are voltage spikes caused by the gates and flip-flops changing states during the carry over which then get coupled into the VCO. Careful isolation and decoupling are needed to get the best suppression of these spurs. Figure 8 shows the spectrum of a modulated signal, with an occupied bandwidth (99 percent) of 150 kHz for the 72-kb/s data rate. The loop filter acts to smooth the data and helps shape the frequency spectrum even though the input signal is digital. This bandwidth works well with a receiver using low-cost 180-kHz ceramic intermediate-frequency (IF) filters.

The RF2513 transmitter IC provides a counterpart single-IC receiver, the model RF2917, for low-cost frequency-modulation (FM) or FSK simplex links. The RF2917 incorporates the reference oscillator, PLL, VCO, low-noise amplifier (LNA), downconverting mixer, 94-dB limiting IF amplifiers, frequency discriminating demodulator, and data slicer in a single chip. With the addition of a few external, discrete components, a complete FSK receiver can be built.

With so many new applications that require low-to-moderate data rates at low cost, a modulator has been presented that provides a low-cost, easy-to-implement alternative to existing schemes. This modulation scheme is being patented and will be incorporated into a new IC which can further reduce the overall cost of the transmitter. ●●



7. The spurious output products of the RF2510 transmitter IC can be seen in this plot of an 819.54-MHz carrier.

Acknowledgment
The author would like to acknowledge and thank Dan Habecker for his assistance in the lab with assembly and testing.

Design Interdigital Bandpass Filters Using LTCC Circuits

Low-temperature-cofired-ceramic (LTCC) circuit technology offers great promise for multifunction, multilayer microwave designs with high performance in compact housings.

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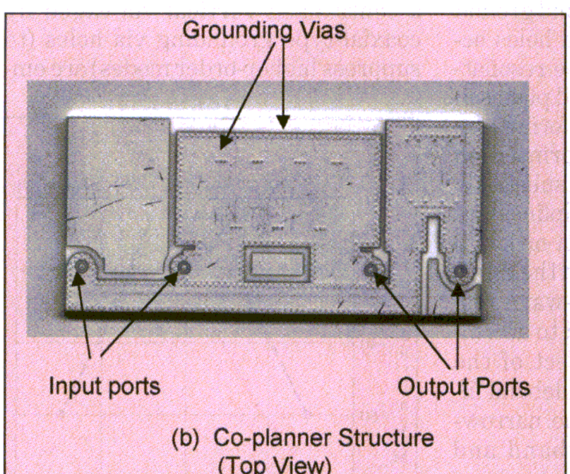
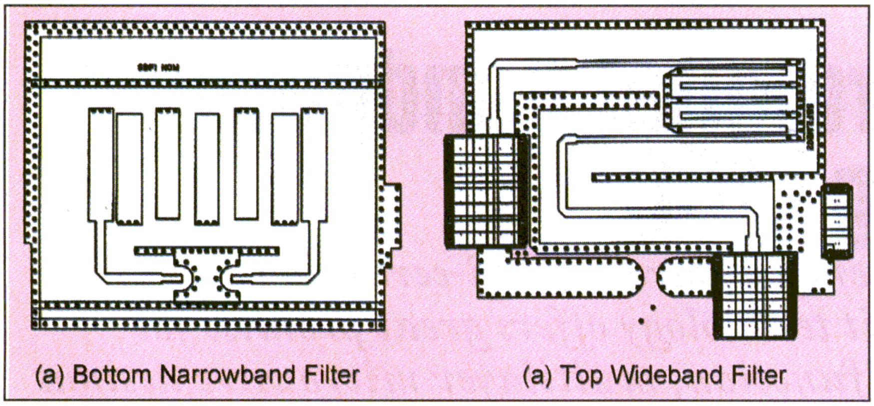
INTERDIGITAL bandpass filters using low-temperature-cofired-ceramic (LTCC) technology offer great potential in multilayer designs. These filters can be made small with low insertion loss and high isolation (approximately 85 dB). They can even be made as low-cost designs, three-dimensional designs with via-hole ground connections, and reduced bond-wire interconnections. The report that follows offers simulated versus measured results at S-band for narrowband and wideband filters fabricated together side-by-side or stacked on LTCC.

The advantages of using LTCC for microwave applications include the ability to use architecturally embedded device structures for high-density packaging, insertion-loss performance that compared favorably with standard microwave and millimeter-wave techniques, and the opportunity to use a cost-effective circuit medium and simplified sealed housing with improved isolation and rejection. LTCC can reduce costs by lowering total part counts. The impact is most pronounced in microwave and millimeter-wave applications with tight constraints on the size and weight of circuit elements. Moreover, a multichip module (MCM) using LTCC offers potential improvements in channel bandwidth and isolation.

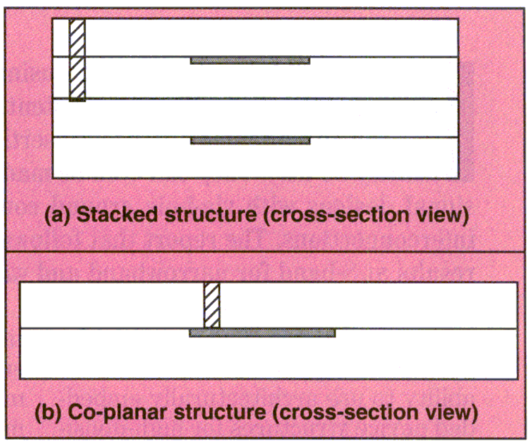
Interdigital bandpass-filter applications using parallel-coupled shorted lines have been found useful in terms of their compact size and low cost.[1-3] To demonstrate the effectiveness of LTCC technology, two interdigital bandpass filter types were simulated, designed, and tested. The two filters feature two approaches—stacked and coplanar configurations. LTCC not only acts as a circuit medium for a filter but also provides a three-dimensional buried stripline format useful in realizing circuit elements for the filter. Narrowband and wideband filters were



1. This top view shows the prototype of the co-planar interdigital bandpass filter realized with LTCC. The input and output ports for the co-planar structure are in vertical transition forms.



2. The stacked-filter configuration includes a narrowband filter on the bottom (left) and a wideband filter (right) on the top.



3. This cross-section view shows the layer configurations for both structures: (a) the stacked structure and (b) the coplanar structure.

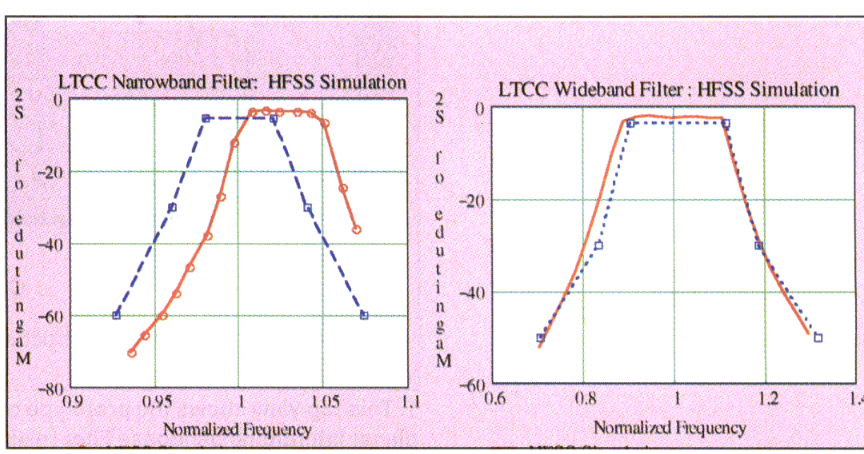
fabricated using each structural type.

Both types of filters have a center frequency at around 4 GHz. Both structures are made with Ferro A6 LTCC, a material with a dielectric constant of 5.9 ±0.15. The material is a 0.074- or 0.037-in.-thick post-fired layer. The input and output ports for the stacked and co-planar structures are in microstrip and vertical transition forms, respectively. Figure 1 offers a top view of the co-planar filter structure. Figure 2 shows the filter layers for the narrowband [Fig. 2 (left)] and wideband [Fig. 2 (right)] filters fabricated with the stacked approach. Both types of stacked filters are fifth-order designs, initially with a Butterworth response.

Shorting the ends to top and ground planes through stagger via holes accomplishes grounding of the resonators in the filters. The ground planes in the structures are simply formed by two silver layers screen-printed on the top and bottom of the substrate. The input/output (I/O) striplines are channelized by via holes in order to guide the RF wave through the filter. The length of the quarter-wave resonator is slightly shortened to accommodate the inductive effect of the grounding via holes. The wideband filter is situated on top of the narrowband filter. The narrowband and wideband filters are designed to have 35- and 60-Ω internal impedances to reduce insertion loss and to relax dimensional constraints, respectively. Since the narrowband filter is buried underneath the wideband filter, two 50-Ω vertical transitions consisting of a centralized vertical via caged by coaxial-type grounding via holes (to suppress higher-order modes) are employed to provide RF feedthroughs for the input and output lines of the narrowband filter.

The top and bottom ground planes are connected by caging via holes surrounding the filters to form the grounding housing. Additional via holes are added in the housing to suppress any undesired modes. The formation of the grounding structure minimizes radiation loss as long as the operating frequency is below the waveguide cutoff frequency. It is possible that propagation modes above the cutoff within the housing can significantly perturb the circuit response. Therefore, the filter housings are designed in such a way as to exclude any half-wave and quarter-wave resonances to avoid radiation at higher frequencies. Moreover, the grounding via holes provide a shielding barrier which increases the isolation between the two filters. For the stacked structure, a center ground plane is sandwiched between the top and bottom filter layers in order to isolate the interference between those filters. In addition, sectional ground planes are provided for the vertical transition and the I/O lines on different substrate layers to guide the microwave signals.

The co-planar structure is similar to the stacked structure except that the filters are placed next to each other on the same LTCC layer. Unlike the fifth-order filters of the stacked configuration, these are fifth- and seventh-order filters, however. The filters employ a vertical



4. The HFSS EM simulator generated these results for the narrowband (left) and wideband (right) LTCC filters.

launching scheme at the input and output ports in order to isolate cross-talk between those ports and improve rejection. Fuzz buttons were used to launch microwave signal through the vertical transitions to the filters in the coplanar structure.

Figures 3a and 3b show the cross-sectional views of the stacked and co-planar filter structures, respectively. The stacked structure consists of 32 separate 3.7-mil LTCC layers where each filter occupies sixteen layers (Fig. 3a). The co-planar structure, on the other hand, consists of eight 7.4-mil LTCC layers (Fig. 3b). For both cases, the input and output vertical transitions are half way up to the top ground-plane layers.

SIMULATING PERFORMANCE

A three-dimensional electromagnetic (EM) simulator, the High-Frequency Structure Simulator (HFSS) from Hewlett-Packard Co. (Palo Alto, CA), was used to simulate the performance of the filters. Simulated results are plotted alongside the design specifications for the narrowband and wideband filters, respectively, in Fig. 4 left and right. The results are normalized to a center frequency of approximately 4 GHz. The simulations are based on a dielectric constant and the loss tangent of 5.9 and 0.0007, respectively. A metal thickness of 0.4 mils was used in the simulations. Resonators were approximately one-quarter-wavelength long.

To confine the microwave energy through the stripline, a coaxial form of surrounding via holes was included in the simulations. With the help of the HFSS simulator, the via-hole feedthroughs were then matched to the input and output lines by adjusting the diameter of the coaxial via holes. Quarter-wave transformers and vertical launchers were also included in the simulations.

For the narrowband LTCC filter simulation, there is an upward shift in frequency for the simulated values compared to the design specifications. However, the specification envelope of the narrowband filter could overlap on top of the HFSS simulation if the HFSS result was down-shifted in frequency by 90 MHz. This

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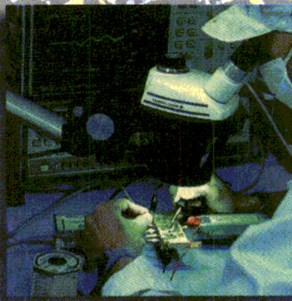

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is equivalent to extending the length of the resonators by 8 mils. Since the frequency shift depends on the length of the resonators, increasing the length of the resonators can restore the narrowband-filter passband closer to the design specifications. The initial filter design was thus modified, but the HFSS simulation was not repeated due to the long computation time required. Although the frequency shift was sensitive in the narrowband case, the performance of the wideband filter was insensitive to frequency shift (Fig. 4b). For the wideband filter, the HFSS simulation provides a close match with the design specifications.

BOTH FILTERS SHOW HIGHER SELECTIVITY THAN THE DESIGN SPECIFICATIONS DUE TO THEIR HERMETICALLY VIA-SEALED CONFIGURATIONS, WITH GREATER THAN 80-dB REJECTION FOR NARROWBAND AND WIDEBAND FILTERS.

EXPERIMENTAL RESULTS

The prototype of Fig. 1 was tested with an HP 8510C vector network analyzer (VNA) from Hewlett-Packard Co. (Palo Alto, CA). Fuzz buttons were used to launch the microwave signal to the filter through the vertical transition in the co-planar structure. Measurements were performed at room temperature. The design performance of the filter is best described by comparing the simulation results, the measurement results, and the filter specifications. Figure 5 shows the performance of the narrowband filter in the stacked structure with frequency normalized to the center frequency. The measured results show good agreement with the simulation in the passband, except that the passband is narrower

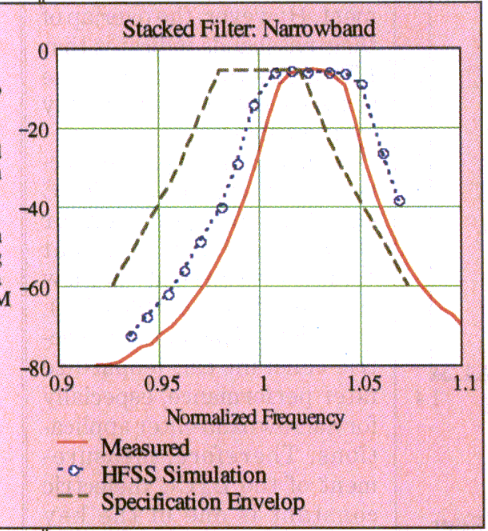
than expected and shifted upward in frequency.

These discrepancies can likely be overcome by increasing the length of the resonators and reducing the width of the filter in order to downshift and widen the filter passband, respectively. The measured insertion loss agrees well with the simulation and design specifications.

Figures 6a and 6b present the transmission and reflection performances of the wideband filter in the stacked structure. Although there is a slight offset in frequency compared to the HFSS simulation and the design specifications, the measurement results show good performance levels in the passband and band-reject regions. The off-resonance isolation or band rejection goes beyond 80 dB (Fig. 6a).

TUNING THE FILTERS

By adjusting the length and width of the resonators in both filters, their passbands can be re-tuned to meet their design specifications (Fig. 7). Figure 7 reveals that the band skirts of both filters have higher selectivity than the design specifications. The linearized phase performance levels of the narrowband and wideband filters were measured and found to be quite linear in the vicinity of the center frequency.

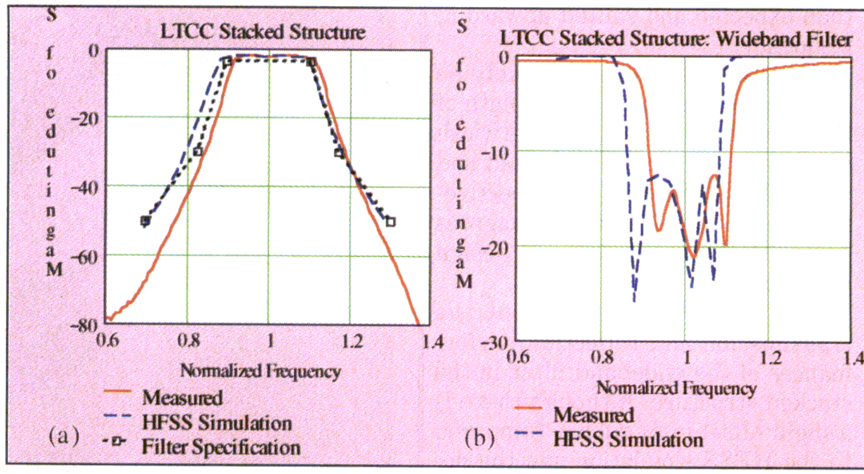


5. The measured performance of the narrowband filter in the stacked structure was compared with the design specifications and the HFSS simulated results.

The off-resonance spurious responses of narrowband and wideband filters were also measured. Even though the stripline configurations of the interdigital filters have the same even- and odd-mode propagation velocities, which in general eliminate the even-order spurious responses at the passband frequency, such filters do have odd-mode spurious responses at higher frequencies.[1,4] These odd-order spurious modes have been observed in both filters as expected in any filter stripline structure. Despite the existence of the odd spurious modes, off-resonance even-order spurious responses have also been observed in both filters. The occurrence of the off-resonance even-mode spurious responses is believed to be caused by the grounding via holes at the end of the resonators where their phases are mismatched due to the inductive effects of the grounding via holes. There is a small amount of additional insertion loss in the passband caused by the impedance mismatch at the input and output lines and possibly by the passband spurious response.

Both filters show higher selectivity than the design specifications due to their hermetically via-sealed configurations. For the stacked and coplanar structures, the narrowband and wideband filters have band rejection greater than 80 dB. In addition, the steepness of the band skirts is sharp and quite favorable in both cases, especially at the 60-dB band rejection.

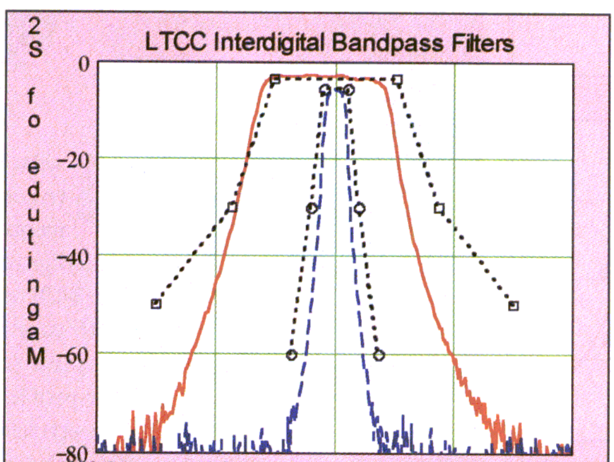
By measuring the bandwidth and insertion-loss performance of the narrowband filters, the unloaded Q-factors of the narrowband bandpass filters for the fifth- and seventh-order filters are estimated[4] to have values around 185 and 288, respectively.



6. The measured transmission and reflection performances of the wideband filter in the stacked structure were evaluated compared to the simulated results for (a) insertion loss and (b) return loss.

After the filter was fired, the two major factors that dictate the filter performance are the consistences of the shrinkage and the dielectric constant of the LTCC substrate. It has been seen that the response of the narrowband filter is very sensitive to the changes of the resonator lengths and the dielectric constant of the substrate. The manufacturer's claimed firing shrinkage percentage of the LTCC is typically 15.6 percent. However, the actual shrinkage percentages measured in these applications were observed to vary between 14.1 and 14.6 percent. Since the shrinkage of the LTCC can impact the performance of the filters, it will be interesting to find out the reproducibility of the filters in terms of their performance, especially for the narrowband filter. Using the same lot of LTCC material, the narrowband filter in the co-planar structure was reproduced on a second wafer to compare its performance to that of the first wafer. Figures 8a and 8b describe the reproducibility of the narrowband filters in terms of their performance. It can be observed that the narrowband filter of the second wafer has a little dip in the passband with less off-resonance isolation (approximately 65 dB compared to the first filter, which is approximately 85 dB). These discrepancies are mainly due to the mismatch between the testing fixture and the input and output lines of the filter during measurement. However, the overlap of their passbands indicates that LTCC filters, which use the same lot material, are highly reproducible.

Although the typical dielectric constant of the LTCC supplied by the vendor (Ferro) is 5.9 ±0.15, that value is measured at very low frequencies (to 100 kHz). Such deviations in the dielectric constant can jeopardize filter performance, especially for narrowband-filter applications. Therefore, measurement of the LTCC dielectric constant is one of the key steps in the LTCC filter-design process. Based on the so-called waveguide cavity-filling approach,[5] the dielectric constant of the LTCC materi-



7. This comparison shows the measured performance of the narrowband and wideband LTCC coplanar filters relative to their design specifications.

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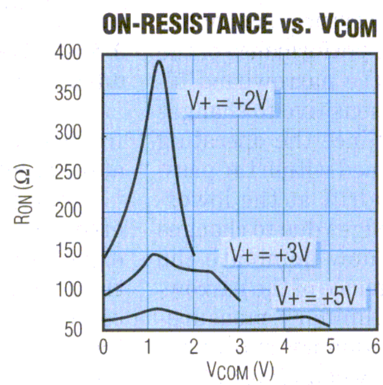

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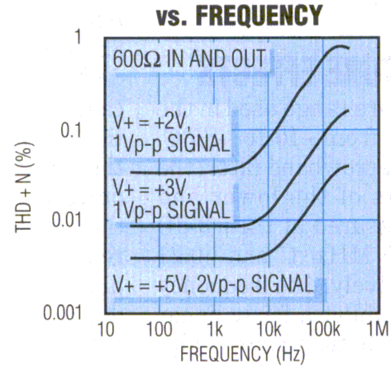

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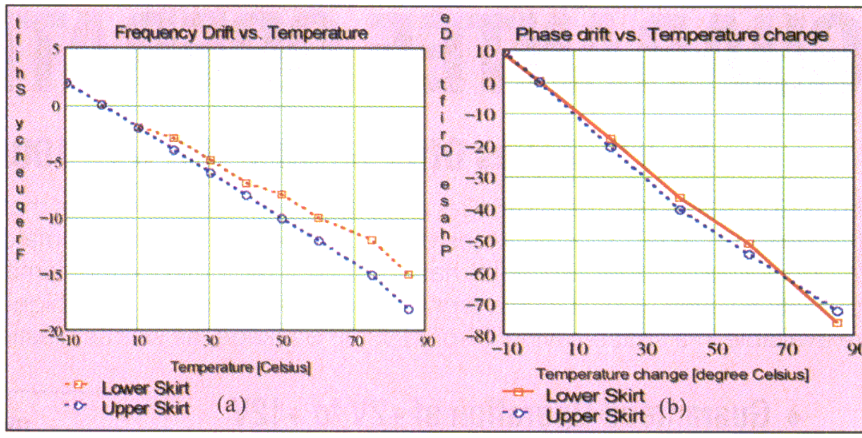
al was found by the frequency shift of the resonance mode when the cavity is filled with the LTCC material. Calibrated by the use of several predetermined materials and adjusted by the system-setup error, the measurement of the LTCC dielectric at 8.5 GHz appears to be around 6 to 7 percent below the vendor's value obtained at 100 MHz. The discrepancy may be due to the different frequency ranges used in both measurements and, possibly, different system factors in both measurement setups.

Although temperature change has little effect on the performance of the wideband filter, the narrowband filter's passband is sensitive to changes in temperature. Since the operating frequency is confined within the passband, frequency drift at the lower- and upper-band edges due to changes in temperature now dominate the passband performance of the narrowband filter. Preliminary measurements on the frequency and phase drifts of the narrowband filter at the band skirts, due to temperature changes, were made referenced to 0°C (Fig. 9).



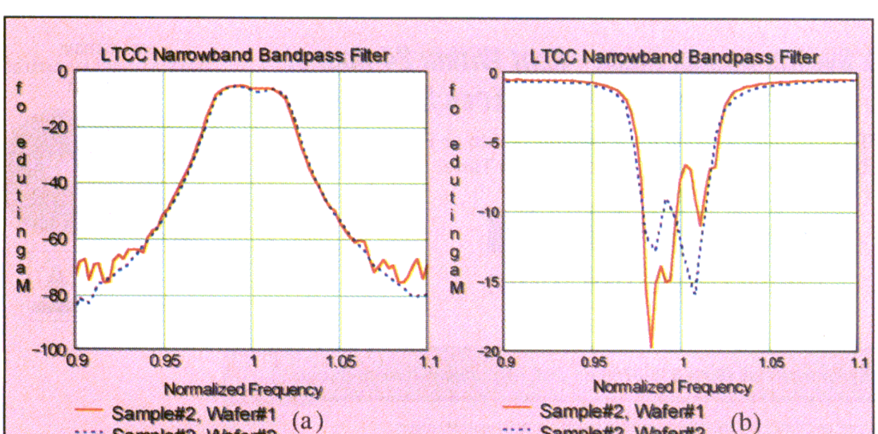
9. Preliminary measurements were made on the frequency (a) and phase (b) drifts of the narrowband filter at the band skirts due to temperature changes.

TEMPERATURE EFFECTS

The temperature range used in the measurement is from –10 to +85°C. For the LTCC narrowband filter, the frequency shifts of the lower and upper skirts measured at their 3-dB points are –0.15 MHz/°C and –0.21 MHz/°C, respectively. The frequency drifts for both exhibit a fairly linear relationship with temperature. Judging by differences in their slopes, the frequency at both skirts are shifted at different velocities.

Among the many factors considered, such as dielectric constant, size expansion, and substrate thickness, the major physical parameter that contributes to the frequency drift is the dielectric constant due to temperature variation. According to vendor data, the variations of the dielectric constant and device dimensions due to temperature change could contribute 81.5 and 13.3 percent of the frequency drifts, respectively. The rest may be caused by other factors such as variations of the substrate thickness and the gap coupling between the resonators and the caging via holes. Similarly, the measured phase shift is linearly related to changes in temperature. A phase drift of approximately –0.88 deg./°C at the 3-dB points was measured. In addition, it was observed that an extra 1 dB was added to the insertion loss in the temperature range being measured. Therefore, it is recommended that the center frequency of the LTCC bandpass filter be designed at a higher temperature (in this case the temperature is approximately +47°C) to ensure that the specification parameters of the LTCC filters are met for the overall temperature range.

In conclusion, interdigital bandpass filters based on LTCC technology for multilayer microwave circuits can be constructed with high performance in compact sizes. By employing the vertical transition approach, the LTCC filters demonstrate a band rejection of ~85 dB with high selectivity due to their inherent sealed grounding configurations. The narrowband and wideband filters show comparable insertion losses with standard techniques for microwave applications. Despite the complex arrangement of the grounding via holes, LTCC interdigital filters show great promise for future three-dimensional microwave designs. ••



8. The reproducibility of the narrowband filters was evaluated in terms of insertion-loss (a) and return-loss (b) performance levels.

Acknowledgments

The author would like to thank all of his teammates in this project for their valuable support and advice. Especially, I would like to thank Paul Setzco who reviewed the filters and provided valuable suggestions; John Odonnell who fabricated the LTCC devices; Yanina Kisler who measured the LTCC dielectric constant; and Steve Huettner who helped in all aspects. This work was supported by Raytheon Systems Co.

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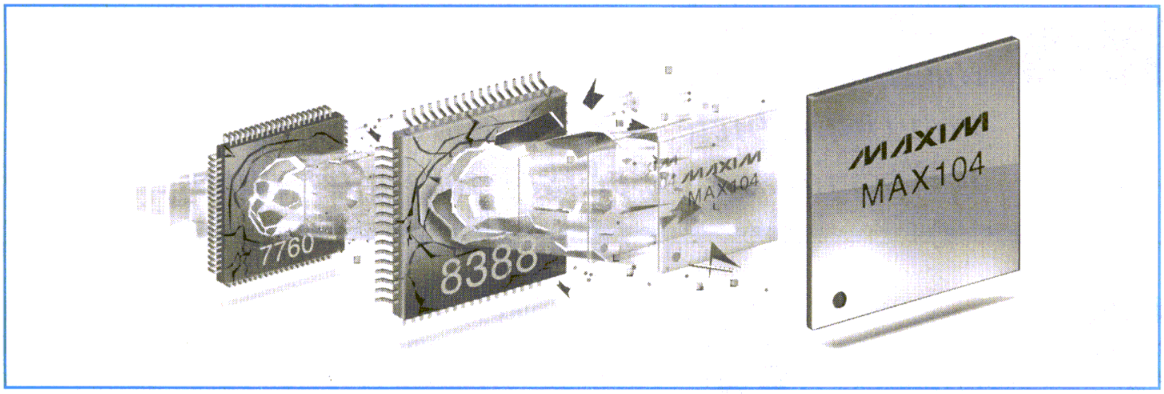

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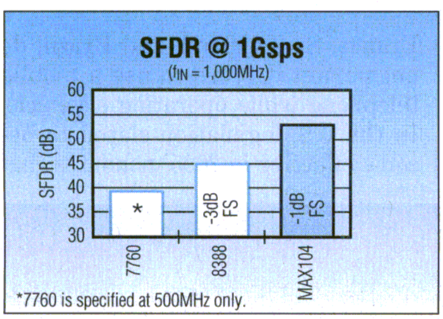

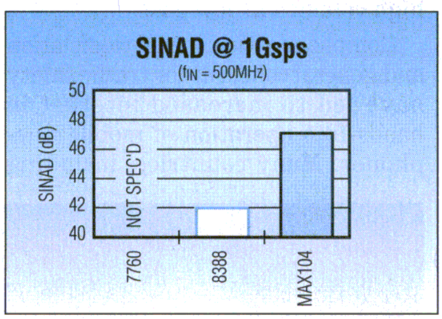

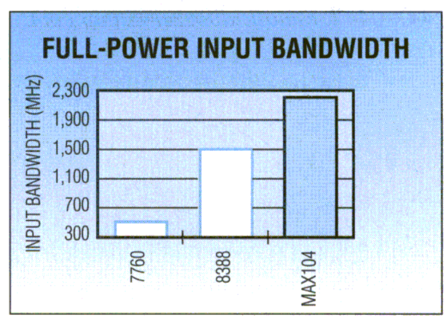

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CIRCLE NO. 386

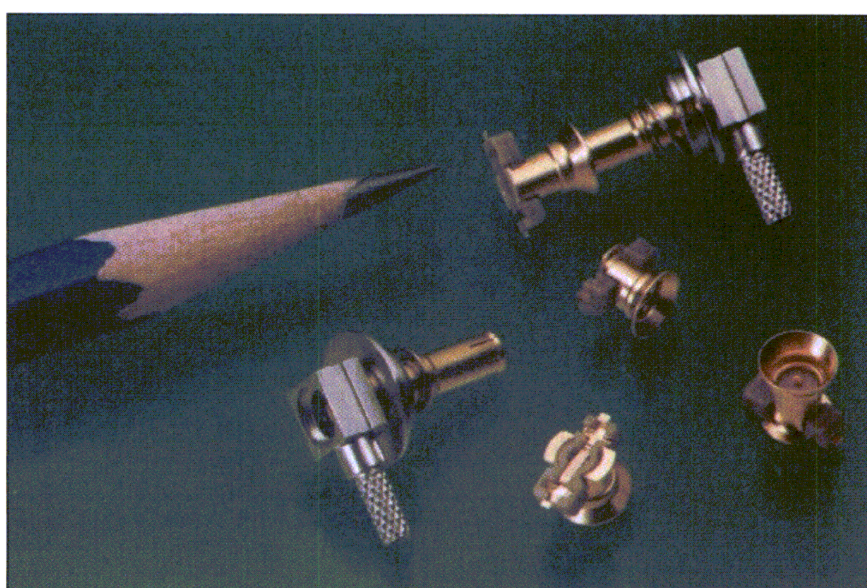
Novel Coaxial Connector Aids In-Vehicle Phone Users

A new coaxial connector enables the safe use of a wireless handset in a moving vehicle, while improving the RF performance of the mobile telephone.

Patrick Duquerroy
Product Manager
AMP Deutschland GmbH, Postfach, Carl Benz Str. 12-14, 64625 Bensheim, Germany; (49) 6251-1330, e-mail: pduquerroy@amp.com
Dieter Bozzer
Engineering Supervisor
AMP (Schweiz) AG, Loading Dock H, Amperstrausse 3, Amperstrausse 9323, Steinach 932, Switzerland; (41) 71-447-0447, e-mail: dbozzer@amp.com.

CONNECTORS play a humble but important role in the design of a wireless system. For example, concerns over safety issues related to the in-vehicle use of mobile telephones have been well documented. But a new high-performance coaxial connector design can help to alleviate these concerns. The novel connector permits hands-free use of a mobile telephone with improved signal gain and signal integrity. The new connector interface switches the signal of a mobile telephone from its own internal antenna to a vehicle's external antenna for hands-free operation with enhanced performance. The connector design accommodates significant misalignment between a mobile unit and its cradle, while occupying minimum space within the telephone. The connector can be produced in high volumes at low cost.

Compliance with specific legislation and general concerns for traffic safety have led to increased interest in hands-free operation of mobile telephones. Many countries, including France, Switzerland, and Brazil, do not permit drivers to use a mobile telephone while operating a vehicle. In the US, legislation slated to become effective in 2005 mandates that



1. This photograph shows the new connector system in mated and unmated configurations.

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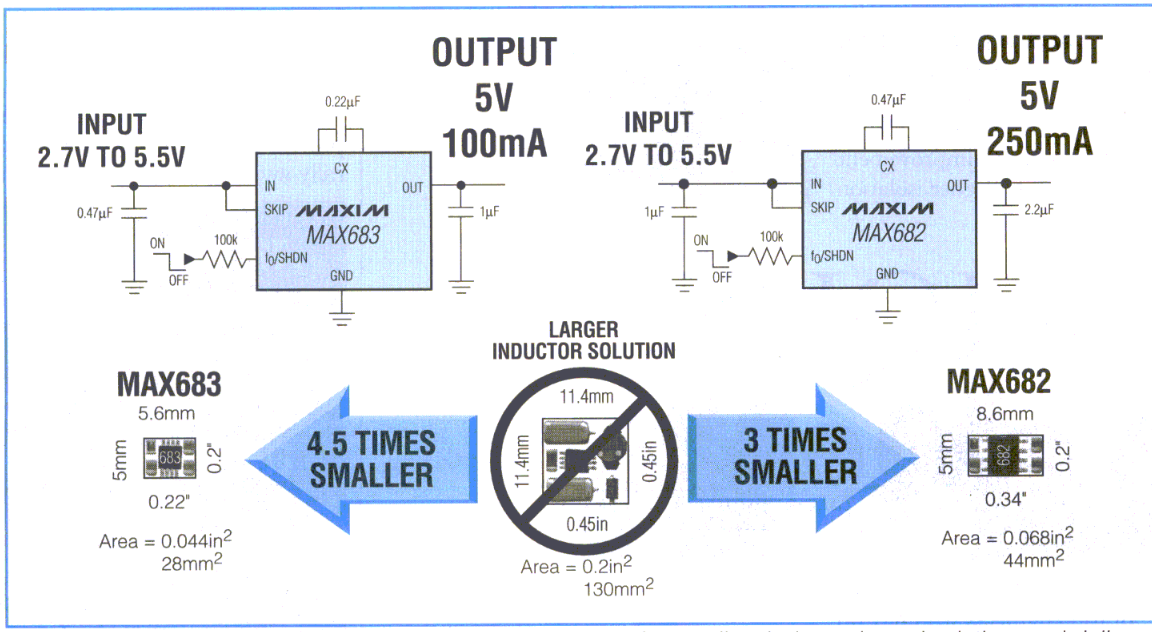
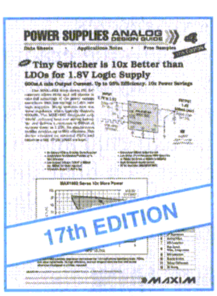


The MAX682 circuit occupies 3-times less board area than the smallest inductor-based solution, and delivers up to 250mA. The MAX683, in a 1.1mm-high µMAX, is 4.5-times smaller and delivers up to 100mA.

- **Regulated 5V Output:**
  250mA for MAX682 (8-SO)
  100mA for MAX683 (µMAX)
  50mA for MAX684 (µMAX)
- **2.7V to 5.5V Input Range**
- **User-Set 50kHz to 2MHz Operation**
- **0.1µA Shutdown Current**
- **Shutdown Disconnects Output**



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cars accommodate a hands-free connection for using mobile telephones.

Regardless of legislation, hands-free operation promotes personal safety and helps to avoid the prospect of litigation if an accident does occur. Additionally, using an antenna external to the vehicle provides improved signal gain (compared to the mobile unit's own antenna), with improved reception and signal clarity.

Mobile-telephone and car-equipment makers are responding with kits that permit drivers to place their mobile phones in a cradle while driving. The action of placing the telephone in the cradle automatically:

- Passively switches the telephone from its internal antenna to the vehicle's external antenna.
- Attaches the telephone to an audio microphone and speaker system installed in the car.
- Enables the telephone to draw power from the vehicle's battery.

The new 50-Ω RF connector system (Fig. 1) offers excellent electrical efficiency through 2 GHz. State-of-the-art production technologies assure high quality at low cost. The connector's durable design is specified for 30,000 connect/disconnect and switching cycles.

The RF jack is a small (typically 5 mm high) surface-mount connector designed to be mounted on the mobile telephone's printed-circuit board (PCB). It mechanically switches from one state to another when engaging or disengaging the connector plug. This low-profile jack requires a minimum amount of real estate on the PCB. Designed for pick-and-place operation, it comes in standard tape-and-reel packaging to accommodate high-volume manufacturing environments.

THE NEW LOW-COST, 50-Ω CONNECTOR SYSTEM OFFERS EXCELLENT ELECTRICAL EFFICIENCY THROUGH 2 GHz, WITH A DURABLE DESIGN SPECIFIED FOR 30,000 CONNECTOR/DISCONNECT AND SWITCHING CYCLES.

The RF plug mounts to the cradle of the car kit, where it may be terminated to a coaxial cable (e.g., RG 174 cable), leading to the external antenna. The RF plug employs a float design, which helps to correct for relatively large misalignments.

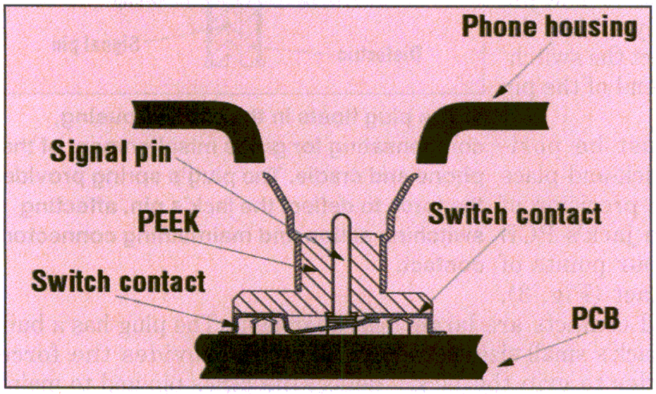
SWITCHING JACK

The connector's switching mechanism resides in the base of the connector (Fig. 2). When the mobile telephone operates independent of the car, RF signals pass to and from the telephone's internal antenna through the normally closed contacts of the switch.

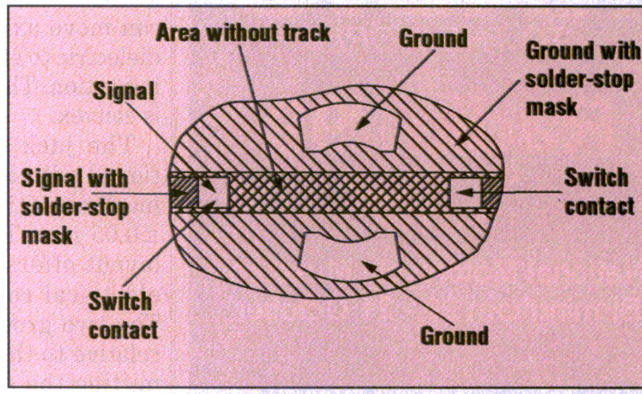
The jack has a bell-like entrance to help guide the plug into position. The base material of the shell is either deep-drawn brass or steel and is gold (Au) plated. Since the bell entrance must be flush with the telephone housing, the jack is manufactured in heights ranging from 3.5 to 6 mm to accommodate various distances from the PCB to the telephone-housing surface.

The dielectric material selected for the jack is polyetheretherketone, commonly known as PEEK. The PEEK injection-molded part has an upside-down tee shape in cross section (see Fig. 2). The stainless-steel switching contacts in the jack's base are embedded in the PEEK dielectric.

PEEK is a high-end, semi-crystalline thermoplastic with exceptionally high strength and good high-temperature characteristics. Its strength and wear resistance contribute to the connector's 30,000 disconnect and switching-cycle specification. Its ability to handle high temperatures helps the jack withstand the rigors of sol-



2. The jack's bell-like entrance accommodates misalignment. A switch in the base changes the path of the RF signal.

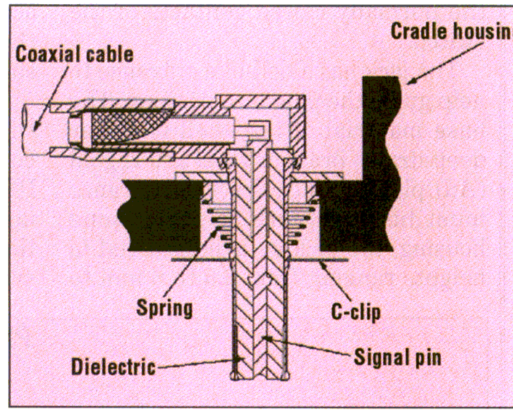


3. As indicated in this layout of the surface-mount contacts, the large ground contacts permit the solder to forcefully grip the jack and hold it to the PCB.

dering operations typical of surface-mount manufacturing. The plastic's mechanical stability aid the jack in meeting surface-mount coplanarity requirements.

The central signal pin of the jack runs coaxially through the PEEK dielectric and makes contact with the switch in the base. The pin can move axially within the dielectric to effect the switching action. The end of the pin is convex.

The jack must be positioned with a pick-and-place machine with a precision of ±0.05 mm. The jack's PCB layout offers four points of electrical contact (Fig. 3). The two ground contacts are large relative to the jack's small size, permitting the solder to grip the jack forcefully. The other two contacts connect to each side of the switch within the jack.



4. The plug floats in the cradle housing, compensating for gross misalignment of the phone and cradle. The plug's spring provides the force to deflect the jack's pin, affecting switching action and maintaining connector contact.

PLUG DESIGN

The RF plug attaches to the plastic housing of a cellular telephone's cradle kit, held in place by a C-clip. The plug has a right-angle design (Fig. 4). Its materials are typical of those used in RF connectors.

The mated-pair design accommodates significant misalignment of the jack and plug. Placing the handset into the cradle kit essentially constitutes blind mating of the antenna jack and plug. The plug floats freely in the plastic cradle housing, permitting effective engagement with the jack despite gross misalignment. In addition, narrow slots cut into the plug's barrel permit slight movements of the resulting splines, further facilitating compensation for misalignment. The plug has a built-i spring that provides the force t deflect the jack's pin and to maintai connector contact.

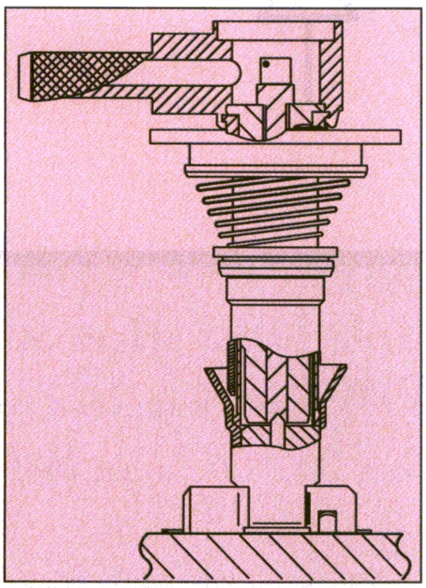
The RG-174 coaxial cable connect to the plug. The stripped center con ductor of the cable slides into a slot a the back end of the plug's pin, and i then soldered into place. The cabl braid is positioned over a knurle tube, and a ferrule is slid over th braid. This is attached by crimpin These attachment methods provid the ground connection and strai relief.

THE MATED-PAIR DESIGN ACCOMMODATES SIGNIFICANT MISALIGNMENT OF THE JACK AND PLUG, INCLUDING A BUILT-IN SPRING IN THE PLUG THAT PROVIDES THE FORCE TO DEFLECT THE JACK'S PIN AND MAINTAIN CONNECTOR CONTACT.

When a drive places the handse in the cradle ki the plug's signa pin makes a sha low entrance int the jack (Fig. 5 pushing agains the jack's pin. Th action deflects th jack's pin slightl mechanically op ening the switc contacts in th base, and isolatin the phone's inter nal antenna. Th RF signal trans mits at a right an gle through th jack's pin to th plug. The plug o fers a signal pat to the car's exte nal antenna.

The design of the plug and jack affords smooth engagement, minimizing contact forces and wear of the Au plating. The spring of the plug exerts a force of 1 to 3 N on the jack's center pin, which has a concave end to accept the jack's convex pin end. The center contacts of the jack and plug simply butt against each other, held in position by the spring. The spring constant was selected to maintain contact regardless of vehicle vibration.

Comprehensive testing has been performed by AMP on the mobile-telephone jack and plug coaxial-connector system. Tests included evaluation of mechanical-, environmental-, and electrical-performance levels. Mechanical tests examined connector durability (cycle life) and resistance to shock and vibration. One mechanical test measured the amount of lateral applied force necessary to make the surface-mount jack break away from the PCB. The lateral force required to tear away from the PCB was found to be 30 N.



5. When mated, the plug makes a shallow entrance into the jack, deflecting the switch contacts in the base of the jack.

Environmental performance tests checked the connector's ability to resist extreme and rapidly changing temperatures, humidity, artificial perspiration, and industrial atmospheres.

A key RF connector electrical parameter is voltage standing-wave ratio (VSWR). This measurement indicates the efficiency of signal transmission through the connector at selected frequencies. The frequencies of interest are 1.770 to 1.990 GHz for Digital Communications System (DCS) and personal-communications-services (PCS) bands and 0.824 to 0.960 GHz for Global System for Mobile Communications (GSM) and cellular bands. Generally, degradation in RF signal transmission is caused by signal reflections resulting from discontinuities in the signal path.

The tests indicated excellent VSWR performance for mated and unmated configurations of the new RF connector system (see table). The values were 1.15:1 at 1 GHz and less than 1.20:1 at 2 GHz.

Another basic electrical performance parameter is insertion loss. In a connector, insertion loss has three major components—losses through contacts, losses through dielectric, and losses due to reflections. As the table also indicates, the total mated insertion loss for the new connector system is below 0.30 dB at 1 GHz and below 0.45 dB at 2 GHz. This represents excellent RF performance for a mobile-telephone connector.

The production methods used for making the new connector are unusual for coaxial systems, but relatively common otherwise. The outer brass shell of the jack is deep drawn in multiple stages. The stainless-steel switch contacts are stamped and then embedded in the PEEK molded part. The central coaxial pin is screw machined. These production methods provide extremely low manufacturing costs.

Production of the jack is fully mechanized with little human intervention. Automatic machines and controls assemble the jack and package it in tape-and-reel format for surface-mount PCB assembly. Currently, the primary site for manufacturing is Switzerland. Production capacity for these new connectors is expected to ramp up to 40 million pieces by the end of 1999.

In short, the new mobile-telephone-connector system offers a low-cost and effective solution to passive switching between an internal and external phone antenna. When imple-

mented in a cradle kit, the connector helps to make possible hands-free operation of the mobile phone within a vehicle, enhancing safety and permitting compliance with a growing body of legislation. Connection to the external antenna also enhances signal gain and clarity.

The connector design accommodates gross misalignment between a cellular telephone and its cradle, which is extremely important when blind mating is necessary. The new switching coaxial connector system meets all performance objectives, including 30,000 connect/disconnect and switching cycles over the life of the connector.

PRODUCTION CAPACITY FOR THESE NEW CONNECTORS IS EXPECTED TO RAMP UP TO 40 MILLION PIECES BY THE END OF 1999.

Designing the connector for this type of durability ensures a long operating life for the cradle set and the cellular telephone, since both are subject to abuse during normal operation in a moving vehicle. Although the environment within the passenger area is not as hostile as that underneath the hood, the connector is also built to withstand the extremes of temperature and humidity that are common to the inside of a vehicle. The fact that the RF plug is designed with a float mounting approach allows cellular-telephone operators to be less than precise with their replacement of the handset to the cradle, allowing good electrical connections under less-than-ideal conditions. ••

A sampling of connector performance

Maximum values		Mated VSWR	Mated insertion loss (dB)	Unmated VSWR	Unmated insertion loss (dB)	Unmated isolation SMD-Jack (dB)
Frequency	Part					
DC to 1 GHz	Requirement (Number)	≤ 1.177	≤ 0.30	≤ 1.15	≤ 0.21	≥ 30.6
	1	1.090	0.189	1.028	0.151	33.799
	2	1.091	0.205	1.065	0.132	33.303
	3	1.094	0.224	1.056	0.145	33.461
	4	1.103	0.211	1.036	0.144	33.453
	5	1.092	0.199	1.056	0.148	33.736
	6	1.075	0.190	1.052	0.158	33.357
	7	1.079	0.208	1.038	0.142	33.566
	8	1.089	0.222	1.027	0.150	33.482
	9	1.072	0.223	1.021	0.165	33.576
	10	1.078	0.186	1.049	0.179	33.611
	11	1.099	0.253	1.064	0.167	33.500
	12	1.067	0.186	1.041	0.122	33.545
	13	1.078	0.177	1.065	0.160	33.555
	14	1.081	0.247	1.028	0.140	33.584
	15	1.094	0.224	1.053	0.158	33.756
	16	1.098	0.234	1.064	0.168	33.408
1 to 2 GHz	Requirement (Number)	≤ 1.25	≤ 0.45	≤ 1.22	≤ 0.35	≥ 25.4
	1	1.135	0.283	1.064	0.215	28.606
	2	1.140	0.301	1.110	0.204	28.365
	3	1.151	0.316	1.096	0.221	28.335
	4	1.154	0.301	1.082	0.222	28.313
	5	1.148	0.289	1.094	0.222	28.675
	6	1.159	0.291	1.084	0.240	28.237
	7	1.130	0.305	1.070	0.200	28.298
	8	1.142	0.335	1.058	0.236	28.370
	9	1.146	0.346	1.037	0.242	28.307
	10	1.133	0.294	1.062	0.263	28.207
	11	1.151	0.380	1.102	0.254	28.291
	12	1.143	0.292	1.069	0.188	28.348
	13	1.143	0.285	1.113	0.238	28.414
	14	1.132	0.382	1.086	0.205	28.387
	15	1.145	0.320	1.088	0.244	28.935
	16	1.155	0.352	1.107	0.247	28.582

Note: Measurements were made with an HP 8510B vector network analyzer (45 MHz to 26.5 GHz) from Hewlett-Packard Co. (Santa Rosa, CA), using an HP 8515A S-parameter test set and an HP 8350B sweep oscillator. For test ports 1 and 2, 3.5-mm flexible test cables were used.

FEEDFORWARD LINEAR POWER AMPLIFIERS

Nick Pothecary

RF power-amplifier (PA) designers looking for a good general reference on the subject of PA technology in general, and feedforward types in particular, will find this relatively short (204 pages) text a welcome and handy addition to their bookshelves. As author Nick Pothecary states in the preface, "The general subject of this book is linear amplification for radio frequency transmitters." Not only that, but each chapter of *Feedforward Linear Power Amplifiers* begins with a review of basic theory that relates to linear amplifier design.

Chapter 3, for example, Power Amplifiers and System Design, opens with short discussions of amplifier efficiency, gain-bandwidth product, and the various classes of amplifier operation (classes A, B, AB, etc.) and the different power transistors used in amplifier designs. And Chapter 1, titled Overview, recaps all of the basic RF theory involved in PA design, from the definitions of dB, dBm, and dBc to the use of directional couplers for combining or dividing the output power of a feedforward amplifier.

In Chapter 5, Feedforward Analysis, the author gets down to the central thesis and reason for writing the book. That is the growing importance of feedforward techniques in wireless communications as new digital air-interface standards such as wideband code-division multiple access (WCDMA) get ready to play a major role in the next-generation-International Mobile Telecommunications 2000 (IMT2000). These wireless systems will be capable of handling voice and data, now made possible by practical and cost-effective RF PAs that can be designed to be very linear.

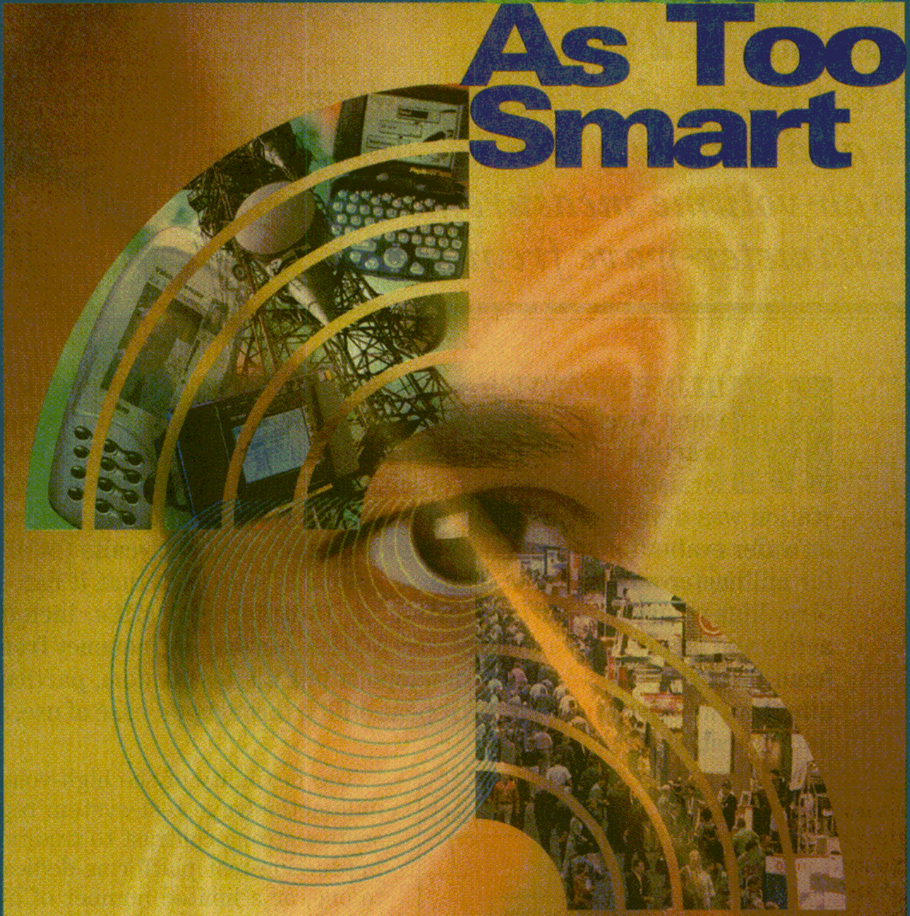
Linear amplifiers are extremely flexible. They can amplify single- or multicarrier signals, analog or digital, and constant-envelope or non-constant-envelope signals. They have not been popular up to now due to their very-low efficiency and need for precise definition of circuit characteristics over the frequency band of interest. On the other hand, their high linearity is a necessary ingredient for modulation formats such as quadrature phase-shift keying (QPSK), which might well be the most-efficient modulation method for WCDMA-based wireless networks that seek to optimize capacity. Another advantage of feedforward techniques is that they support ultra-linear operation over a wide bandwidth.

Linearization techniques, as covered in Chapter 4, begin with feedback theory which was created in the 1920s by the late Harold Black, one of the true pioneers of the electronic age. Interestingly, Black also invented the feedforward technique in 1928 and received a US patent for his discovery. Linearization techniques were developed to eliminate or reduce the amount of distortion added by an inherently nonlinear PA. Negative feedback, as originally described by Black, is commonly used for correcting distortion, but it is inherently bandwidth limited and unsuitable for wideband wireless applications such as WCDMA, as Pothecary points out. The class AB amplifier with feedforward linearization is gaining favor as the wideband amplifier architecture that offers the best compromise between linearity and power consumption for future wireless communications systems.

The chapter treats linearization techniques from a bandwidth point of view—amplifiers are either wideband or narrowband. Predistortion and feedforward are used for wideband systems while feedback, RF synthesis, and envelope elimination and restoration are illustrative of narrowband techniques.

The chapter on feedforward analysis—like the other chapters—starts with a basic level by showing how to derive the gain, followed by the importantance of impedance matching (input and output) to minimize power losses. The chapter concludes with various methods of loop control to compensate for changes in device characteristics with time, temperature, voltage, and signal level. (1999, 204 pp., hardcover, ISBN: 0-1-58053-022-2, $75.00.) **Artech House Publishers, 685 Canton St., Norwood, MA 02062; (800) 225-9977 (Continental US only), FAX: (781) 769-6334, e-mail: artech @artech-house.com, Internet: http://www.artech-house.com.**

In Wireless There's No Such Thing As Too Smart



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CIRCLE NO. 383

Perform Production Testing On Millimeter-Wave MMICs

This test system demonstrates how speed and accuracy can be combined for high-volume measurements even at millimeter-wave frequencies.

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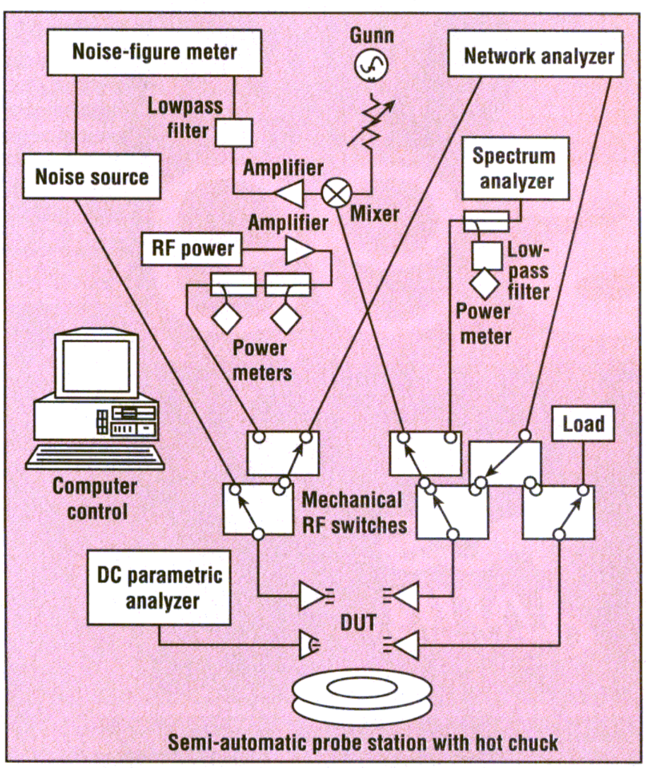
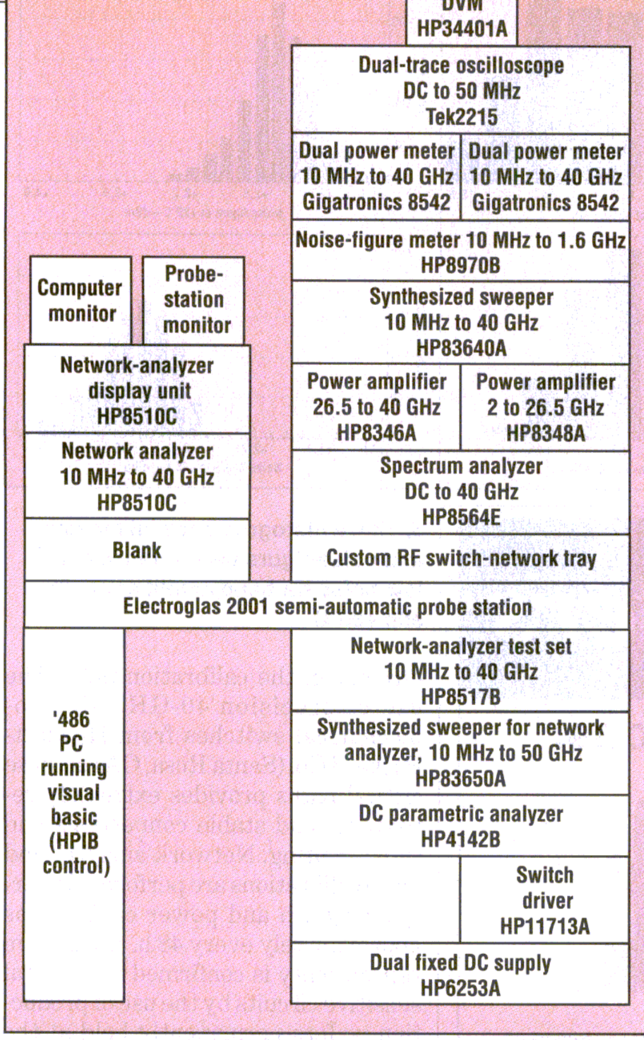
MILLIMETER-WAVE frequency bands offer effective solutions for many wireless communications applications. In order to develop practical millimeter-wave products, however, testing must be performed accurately and efficiently. For this reason, a special test station was developed at Alpha Industries (Woburn, MA) for production on-wafer evaluation of monolithic microwave integrated circuits (MMICs) for millimeter-wave systems. The test system is unique in that it can perform high-volume production testing on 13 different MMICs, including active and passive two- and three-port MMICs ranging in frequency from L-band through Ka-band. In the development of the test system, particular attention was given to accuracy, repeatability, throughput, ease of use, and data traceability.

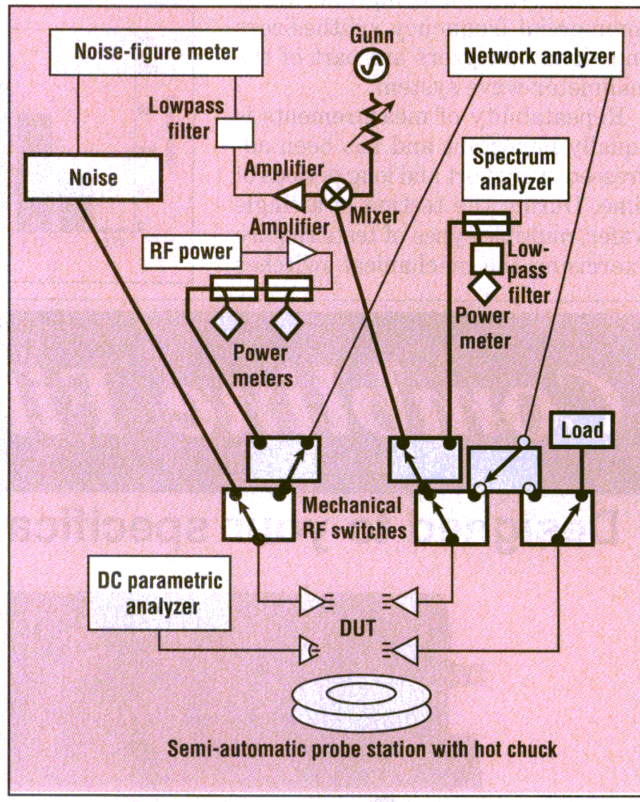


1. The high-volume-production millimeter-wave MMIC test system employs mechanical switches for signal routing.

The flexibility of the high-volume, millimeter-wave test system represents a strong contrast to traditional production-test platforms dedicated to one, or a limited number of high-volume RF chips.[1] The test system is designed to perform 100-percent on-wafer testing of 13 different circuits. Figure 1 is a simplified block diagram of the test station. All switches, sources, and measuring devices are fully automated, enabling single touchdown measurements of DC characteristics, S-parameters, noise figure (NF), power response, and frequency conversion. The system's probe station also features a thermal chuck, enabling measurements over a temperature range from +25° to +125°C. Figure 2 shows in detail the physical arrangements and specific types of equipment used in this system. The table offers a summary of the 13 GaAs MMICs, which currently have been tested on this station. These chips span five types of production processes fabricated at Alpha Industries. Also indicated in the table



2. The production MMIC test system includes network analyzers, synthesizers, and power meters.

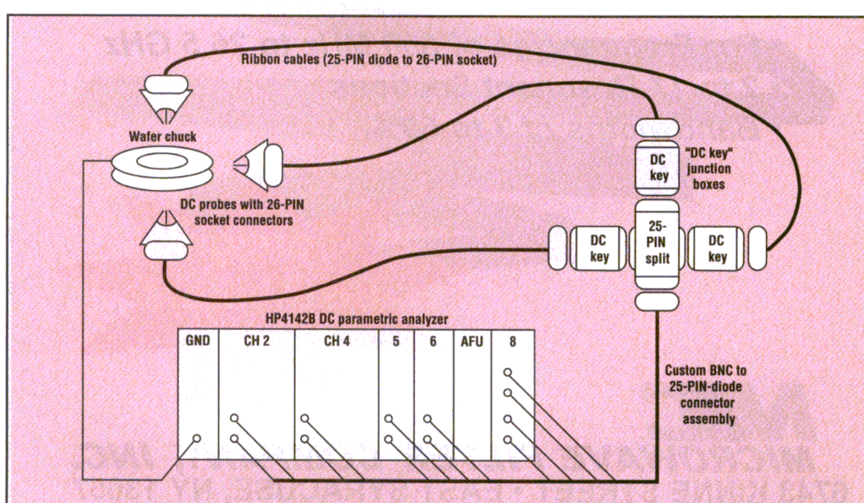


3. The physical layout of the millimeter-wave test system shows how interconnections were kept as short as possible.

is the average monthly volume of chips during two years of operation. During the first year, testing was performed on a single eight-hour-shift basis. During the last year, testing was performed in two shifts. The average test times indicated do not include setup and calibration times, which vary widely due to the complexity of the MMIC, the number of frequencies evaluated, and number of different test types required for each frequency. The setup times vary from zero to two hours.

SYSTEM DESCRIPTION

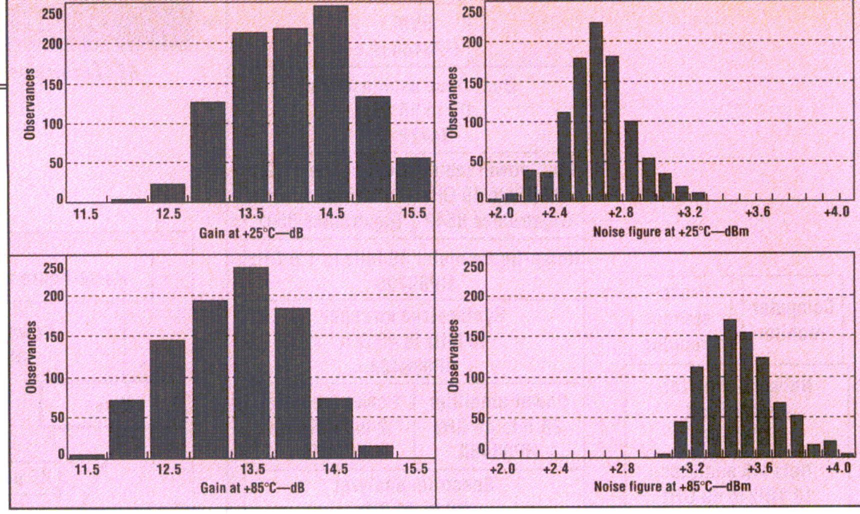
Accuracy is extremely important in this test system. Due to the complexity of the test system, many issues have been addressed in order to attain accurate calibrations. To minimize system loss, for example, all RF equipment is positioned so that interconnections are as short as possible—where all cables between RF components are 12 in. (30.48 cm) or less (Fig. 3). The test cables are short, semirigid sections of K- or 2.4-mm cables, except those leading to the RF probes which are 12-in. (30.48-cm) flexible K-type cables. Figure 4 is a view of the switching matrix located directly behind the probe station where multiple short interconnects are used. In general, a minimum number of cables and adapters are used to minimize reflections. Standard commercial calibra-



4. A custom DC cable configuration was used to reduce test-system and DUT setup times.

tion substrates and high-accuracy commercial frequency synthesizers and signal analyzers are part of the millimeter-wave system.

Repeatability of measurements is equally important and has been addressed over short and long periods of time. During the testing of a single wafer, multiple types of tests require exercising the mechanical switches directly in the calibration path. The use of precision 40-GHz electromechanical switches from Hewlett-Packard Co. (Santa Rosa, CA) in these critical paths provides extremely repeatable and stable connections and signal routing. Network-analyzer and noise calibrations are performed nearly every 4 h and power calibrations approximately every 48 h. Long-term repeatability is confirmed for several sensitive circuits by the use of production wafers permanently held at the station as "golden standards."



5. These histograms reveal the gain and noise-figure performance of a low-noise Ka-band amplifier at +25 and +85°C.

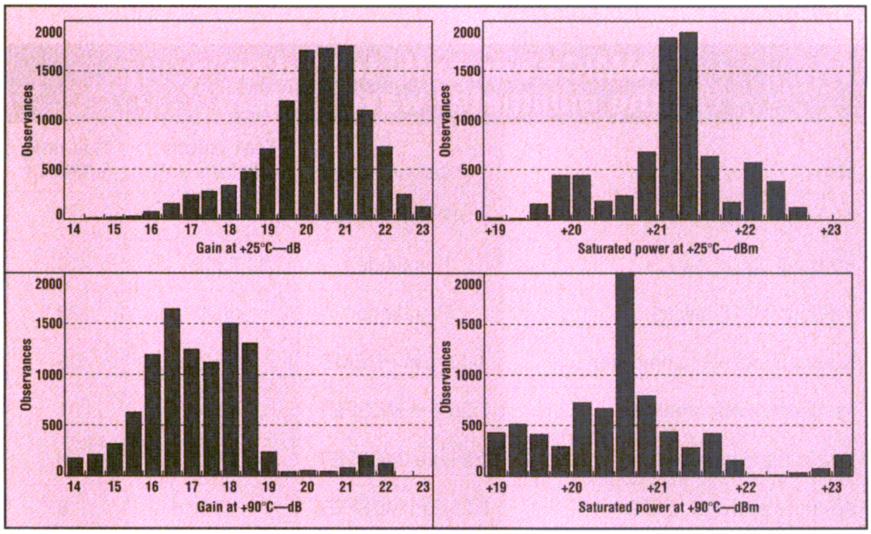
Throughput is also a concern, and was a major motivation for the development of the millimeter-wave test system. In general, this single test station replaces three single-function test stands, in turn, eliminating the extra setup times, wafer-handling, and data screening associated with multiple test stations. The specific high-speed features of the millimeter-wave test system include quick diode-based power sensors and a high-throughput Electroglas semiautomatic probe station. An additional feature that reduces setup times is the custom DC cable system (Fig. 5). With this cable system, a 25-pin junction box is wired once for each type of MMIC to be tested. A technician simply selects the junction box for the current MMIC being tested along with its associated DC probe card, and a consistent, quick, and error-proof DC setup is provided.

Ease of use is an important issue that directly effects throughput by reducing setup, calibration, and data analysis times. Several personal-computer (PC) Windows™-based programs have been written using Visual

Basic™ programming code to aid in the automatic operation of the millimeter-wave test system. A semiautomatic setup and calibration program steps the user through the configuration and calibration specific to the type of MMIC being tested. Advanced calibration types include mixer and three-port S-parameter configurations. Dated calibration files are created and stored for use with the production-test software. Test-equipment debugging and individual control of mechanical switches is also provided in the setup program. The production-test software reads in text files containing a test-plan sequence for a specific IC as well as wafer-mapping information. Tests are performed automatically across the wafer with the ability for intelligent conditional testing based on real-time measurement results. Finally, raw data are screened to the test specifications and a summary of passing chips is generated along with a graphical wafer map. One- to two-page flow

MMICs currently tested on the millimeter-wave system

MMIC	Process type	Test volume (MMICs/month)	Test time (s/MMIC)
Ka-band mixer	Schottky diode	876	17
Ka-band SPDT switch	PIN diode	2298	16
Ka-band DPDT switch	PIN diode	2777	20
Ka-band low-noise amplifier	0.25-µm PHEMT	542	33
Ka-band power amplifier	0.25-µm MESFET	1884	21
Ku-Ka-band multiplier	0.25-µm MESFET	1142	26
Ku-band power amplifier	0.25-µm MESFET	599	18
L-band power amplifier	0.50-µm MESFET	1767	10
L-band low-noise amplifier	0.50-µm MESFET	1178	10
L-band SPST switch	0.50-µm MESFET	433	3
L-band SPDT switch	0.50-µm MESFET	601	8
L-band 4-b attenuator	0.50-µm MESFET	504	3
L-band 0/180-deg. hybrid	Passive	280	9



6. These histograms reveal the gain and saturated output-power performance of a Ka-band driver amplifier evaluated at +25 and +90°C.

documents describe all that is needed for a technician to receive a wafer and produce a summary of good MMICs.

On these data summaries, traceability is provided back to each MMIC. Imprinted on every chip is a unique set of numbers that identifies the type of circuit and its exact location on each wafer. A significant data base of on-wafer DC and RF data are accumulating for all 13 types of MMICs. The data are summarized wafer by wafer and analyzed periodically over the history of each chip. Figures 5 and 6 are examples of data collected with the millimeter-wave test system. Figure 5 shows gain and NF distributions in histogram form for a Ka-band low-noise amplifier (LNA) evaluated at +25 and +85°C. Figure 6 shows the gain and saturated output-power distributions for a Ka-band driver amplifier at +25 and +90°C.

In summary, the automated millimeter-wave test system provides measurements of DC, noise, power, and S-parameter results with a single pass across a wafer. The system provides high accuracy and repeatability while maintaining good throughput, ease of use, and data traceability. The results provided by the test system have helped make system integration of the evaluated MMICs more efficient and cost-effective. ●●

Acknowledgments
The author would like to thank Rick Saulnier, Rob Acres, Hong Pham, and Van Pho of Alpha Industries for operating and maintaining the test station.

Reference
1. P. Wallace *et al.*, "High Volume Testing of RF & Analog GaAs Integrated Circuits," 1996. International Conference on GaAs Manufacturing Technology Digest of Papers.

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CIRCLE NO. 246

Fractional-N Synthesizers Meet HSCSD And GPRS Demands

Good phase noise and fast switching speeds make fractional-N frequency synthesizers suitable for wireless high-speed-data applications.

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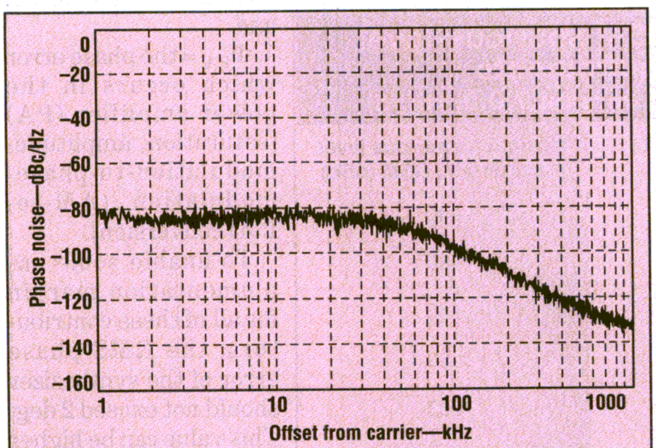
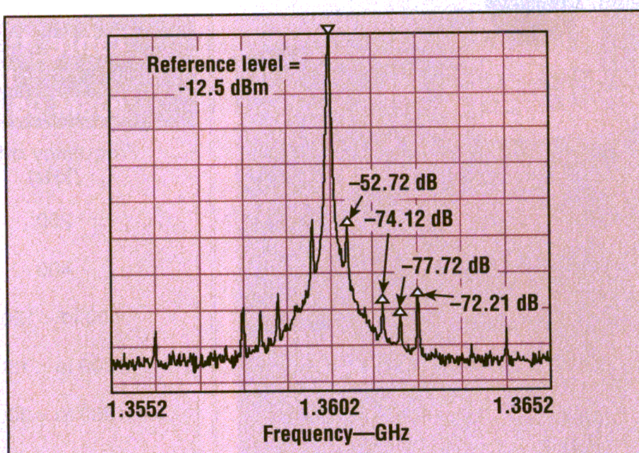
FRACTIONAL-N frequency synthesizers loom large as solutions for emerging fast switching Global System for Mobile Communications (GSM) multislot standards, including high-speed circuit switched data (HSCSD) and general-packet-radio service (GPRS). Fractional-N synthesizers can provide the frequency agility that is necessary for these new standards while maintaining low spurious levels and good close-in phase-noise characteristics.

Three performance parameters are critical for synthesizers that are used in GSM terminal radios—phase noise close to the carrier, spurious levels, and switching speed. The close-in phase noise specifies the noise contributions of the GSM frequency synthesizer, which is part of the system's overall phase errors. This must be less than 5-deg. root-mean square (RMS). Prior to the introduction of HSCSD and GPRS, low phase error and fast switching times were not vital. Often it was phase error that was improved. Now the new multislot classes require faster switching times while keeping up with other performance demands. Meanwhile, much progress has been made in fractional-N technology, leading to improved performance on close-in noise and spurious levels. The use of high comparison frequencies in fractional-N synthesizers contributes to the fast frequency-switching speeds.

Power consumption is also a critical parameter because the receiver in a mobile phone has to listen to the pag-

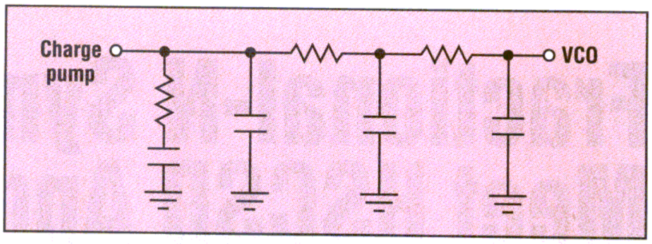


1. The SSB noise of the SA8026 fractional-N frequency synthesizer IC was measured at 1360 MHz.



2. The output spectrum of the SA8026 fractional-N synthesizer was evaluated with a fractional divider.

ing and synchronization channels continuously even in the idle mode. This leads to periodically on and off switching of the receiver, which includes the frequency synthesizer for channel selection. Thus, the synthesizer has a major impact on the standby time of the phone. In the future, the trend toward lower-supply voltages will eventually be limited by the required signal-to-noise ratio (SNR). Power consumption will not be discussed in this article because the demand is very simple—the lower the better, as long as other performance criteria are fulfilled. Nevertheless, power consumption is one of the most important parameters for any integrated circuit (IC) targeting the wireless telecommunication terminal market.



3. This is an extended PLL filter structure for enhanced performance with the SA8026.

Following a brief discussion of synthesizer noise performance, this article will explore the demands for emerging HCSCD and GPRS systems as they relate to switching time. The applicability of a new line of fractional-N synthesizers from Philips Semiconductors (Sunnyvale, CA) for these GSM multislot terminal applications will be demonstrated by a series of measurements.

PHASE NOISE

Phase noise is a key parameter in systems that use complex digital-modulation schemes. An evaluation of phase-noise performance is based upon the type of modulation used. For example, either error vector magnitude (EVM) or phase error can be used. The Gaussian minimum-shift-keying (GMSK) modulation scheme used for GSM requires a phase error of less than 5-deg. RMS and 20-deg. peak of the transmitted signal.[1-6] The phase noise of a phase-locked-loop (PLL) frequency synthesizer can be described by the RMS phase error of the synthesizer, Φ_{PLL}, where Φ_{PLL} is only one of the contributors to the phase error in a GSM terminal.

The total RMS phase error, Φ_{total}, can be calculated by taking into account the four main contributors as follows:

$$\Phi_{total} = (\Phi^2_{PLL} + \Phi^2_{bb-mod} + \Phi^2_{RF-mod} + \Phi^2_{PA})^{0.5} (RMS) \quad (1)$$

where:

Φ_{PLL} = the phase error of the frequency synthesizer,

$\Phi_{bb\ mod}$ = the phase error generated in the baseband modulation,

$\Phi_{RF\ mod}$ = the phase error generated in the RF modulator, and

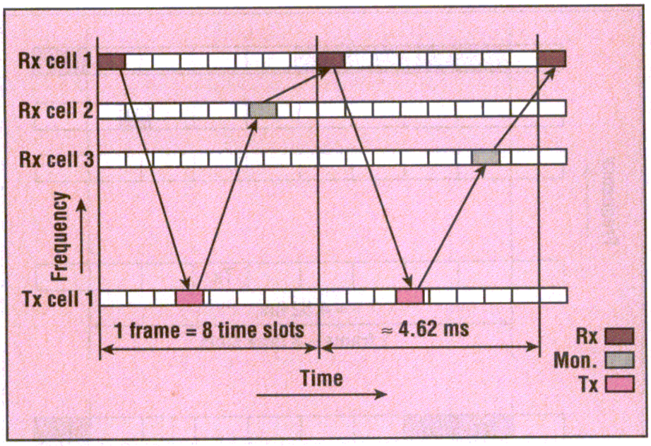
Φ_{PA} = the phase error which occurs in the power amplifier (PA) [saturation, amplitude-modulation-to-phase-modulation (AM-to-PM) conversion].

To enable some implementation margin for all of these contributors, the RMS phase error of the synthesizer should not exceed 2 deg. This value can be higher if the performance of the other contributors is low. The loop band-

Table 1: GSM spurious-level requirements (GSM 05.05 version 7.0.0, ref. 6)

Frequency offset (kHz)	Maximum spurious level according to GSM (dBc)
200	–30
400	–60
600 to < 1200	–60
1200 to < 1800	–60
1800 to < 3000	–63
3000 to < 6000	–65
≥ 6000	–71

width exhibits a simple relationship between phase error and switching time—as the loop bandwidth is increased, the switching time is decreased, but the phase error is increased. The limiting factor is the close-in noise-floor density of the synthesizer. The close-in noise is the residual phase modulation within the PLL bandwidth caused by different noise sources of the loop components. The modulating signal arises from the voltage noise that is present at the loop filter introducing AC deviation at the control input of the voltage-controlled oscillator (VCO). Thus, a VCO output signal phase modulated with a peak phase excursion Δϕ can be described as follows:



4. This represents the timing of traditional GSM without frequency hopping.

$$s_{VCO}(t) = A\cos(\omega_c t + \Delta\varphi \sin\omega_m t) \qquad (2)$$

$$s_{VCO}(t) = A[\cos\omega_c t \times \cos(\Delta\varphi \sin\omega_m t) - \sin\omega_c t \times \sin(\Delta\varphi \sin\omega_m t)] \qquad (3)$$

where:

ΔΦ can also be considered as the modulation index.

If ΔΦ is small, narrowband frequency-modulation (FM) theory applies, which simplifies the analysis considerably.

For ΔΦ = 2-deg. RMS or approximately 34.9 mrad, sin (ΔΦ) = 0.033489 (ΔΦ} and cos (Δϕ}) = 0.99939 (1. Thus, the approximation of eq. 4 is valid.)

$$s_{VCO} = A\left\{\cos\omega_c t - \frac{\Delta\varphi}{2}[\cos(\omega_c + \omega_m)t - \cos(\omega_c - \omega_m)]\right\} \qquad (4)$$

According to eq. 4, the output-noise spectrum can be regarded as the sum of a large number of offset frequencies on both sides of the carrier due to the PM caused by a large number of sinusoidal signals at low levels. The level of the noise sidebands on each side with respect to the carrier is:

$$L(\omega) = 20\log_{10}\left(\frac{\Delta\varphi}{2}\right) \qquad (5)$$

The noise spectrum is often uniformly distributed about the carrier and apart from the shaping effect of the loop filter. Looking at the requirement for GSM of 2-deg. RMS, it is possible to find the matching power-carrier spectrum.

To find the complete phase excursion, the sum of the energy of all the PM signals must result in an integration above the considered frequency range. If only the single-sideband (SSB) phase noise is used, then half of the RMS phase error (jitter) becomes:

$$\Phi_{PLL}/2 = \left(\int_{f_1}^{f_2} 2L(\omega)d\omega\right)^{0.5} \qquad (6)$$

where:

L(ω) = the SSB noise spectral power density,

f_1 and f_2 = the lower and upper boundaries, respectively, of the considered frequency range, and

Φ_{PLL} = the peak phase excursion of the synthesizer.

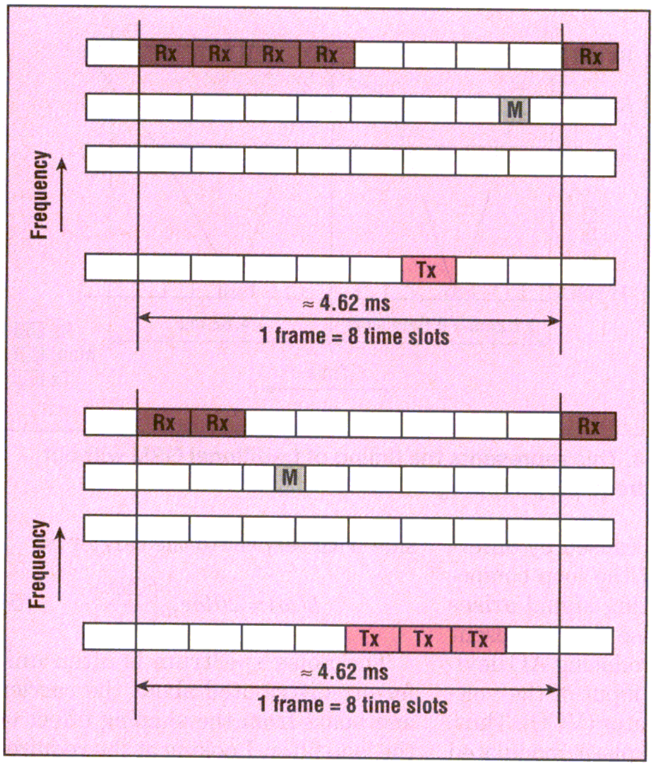
By a uniform distribution of the noise spectrum over a known bandwidth (BW), eq. 6 can be simplified to:

$$L\omega = (\Phi_{PLL/2})^2 / BW \qquad (7)$$

where:

$\Phi_{PLL\ RMS}$ = the RMS phase excursion of the synthesizer.

Expressing eq. 7 as a power ratio, the lefthand side can be interpreted as the phase-noise-to-carrier ratio, L (ω)



5. These two examples show the GPRS multislot allocation for multislot class 12, with RX = 4, TX = 4, and sum = 5.

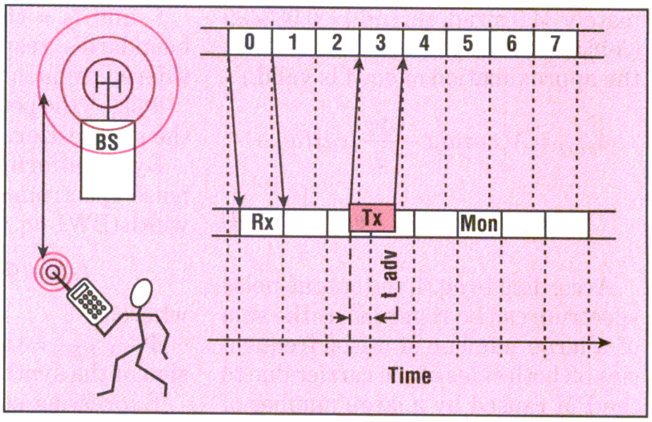
in dBc/Hz, with the formula now becoming:

$$L(\omega) = 20\log_{10}(\Phi_{PLL\ RMS}/2) - 10\log_{10}(BW)\ [dBc/Hz] \quad (8)$$

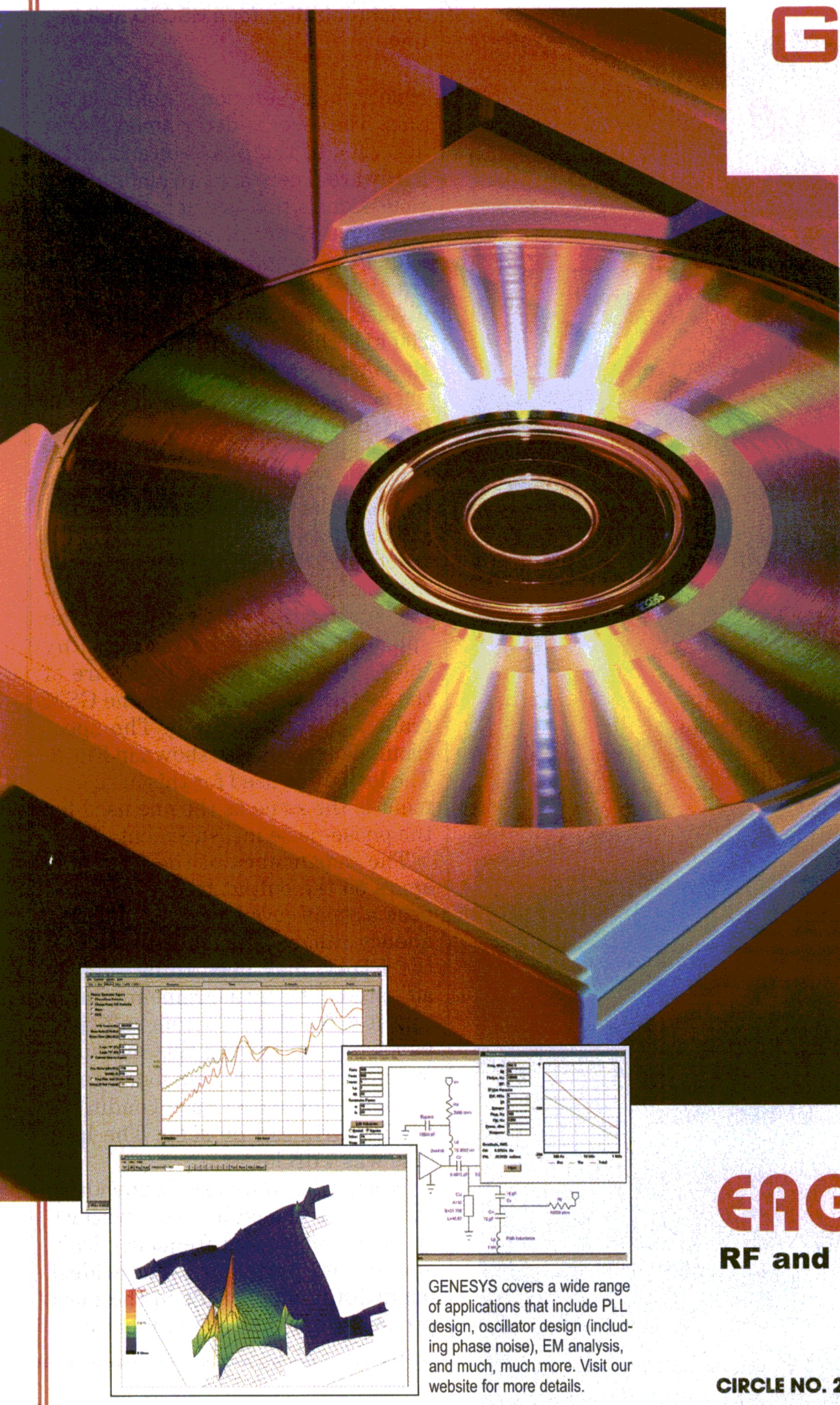
The bandwidth that is being considered in eq. 8 is the 3-dB bandwidth of the closed loop. In principle, by finding the necessary value for L(ω), the occupied bandwidth of the modulation scheme must be considered. GSM uses a symbol rate of 270 kb/s. The occupied bandwidth is reduced by pulse shaping (GMSK = 0.3) to approximately 200 kHz. But by using higher-order loops, the contribution of the residual phase-noise spectral density to the RMS phase error beyond the 3-dB cutoff frequency of the loop can be negligible due to the negative slope of the VCO noise skirt of more than 20 dB/decade.

For example, the previously mentioned 2-deg. RMS (35 mrad considered for a 30-kHz loop bandwidth requires a close-in noise-floor density of –80 dBc/Hz. The 30-kHz loop bandwidth is chosen to achieve the switching-speed requirements. The synthesizer IC and crystal oscillator used as the reference source determine the close-in noise-floor density. The design of the loop-transfer function influences the distribution of the noise. Thus, sometimes the integral of eq. 6 cannot be solved as easily as before. However, eq. 8 provides a good estimation of what is feasible with the selected synthesizer IC. Due to the close-in noise-floor density, either the phase error or the switching time can be optimized.

The model SA8026 fractional-N synthesizer from Philips Semiconductors provides a typical close-in noise-floor density of –85 dBc/Hz for the 900-MHz band. For a 30-kHz loop bandwidth, this results in an RMS phase error of approximately 19.5 mrad or 1.1 deg. This value is well



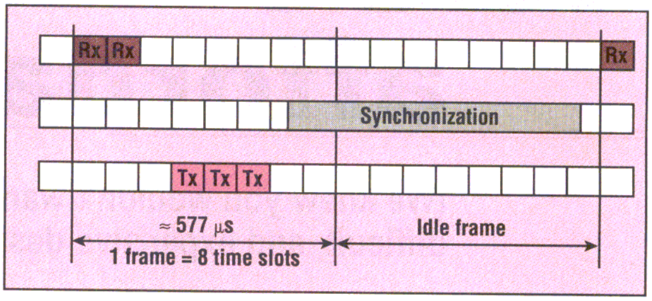
6. This is the required timing advance of the transmit burst for the mobile unit.



within the specification and leaves some implementation margin for other components. The estimated phase-error value for the GSM-1800 band of the SA8026 is 2-deg. RMS, coming from a typical close-in noise-floor density of –80 dBc/Hz for the 1800-MHz band.

Figure 1 shows the phase-noise skirt and the integrated residual PM for an application with the SA8026 at 1360 MHz. The 3-dB cutoff frequency of the loop is 30 kHz and the phase margin is 65 deg.

Inherent in the fractional-N principle is the generation of spurious signals. The level is determined by the accuracy of the phase-interpolation hardware. There are two kinds of spurious signals that are generated by a fractional-N synthesizer—the leakage of the comparison frequency and fractional spurious if the fractional divider is used. In order to obtain the 200-kHz channel raster for GSM with the SA8026, a 1-MHz comparison frequency and a fractional-N modulus of 5 are used. This results in the generated spurious at integer multiples of 200 kHz. Table 1 shows the requirements of the GSM standard.



7. This is the possible timing of synchronization for a HSCSD mobile unit.

The measurement shows that a fractional divider ratio generates more spurious signals than an integer synthesizer. Nevertheless, the spurious suppression provided by the phase interpolation hardware of the SA8026 is sufficient for the GSM transmitter application. The spectrum-analyzer plot is shown in Fig. 2. The loop filter used for this measurement is the same as the one used for the phase-noise measurement.

The dependency of the fractional spurs on the output frequency could pose a small problem. For wide frequency ranges, the optimal value of the FDAC may need to be slightly adjusted. The measurements imply that it is feasible to obtain sufficient performance. During this measurement, FDAC = 120 was found to be optimal. The worst-case conditions for 200 kHz can be seen. The best case was 7 dB lower.

When using wide-loop bandwidths, special care should be taken with respect to comparison frequency leakage and its harmonics. The widest bandwidths may result in the most problems. For these cases, it becomes

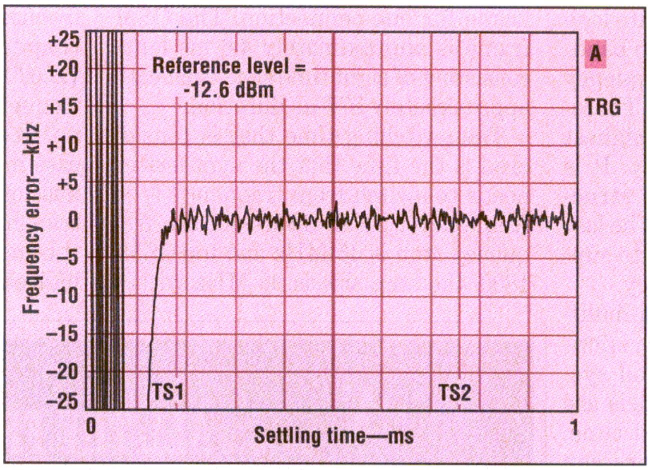
more difficult to find an adequate loop filter, because the desired loop bandwidth and the comparison frequency become closer to each other. Therefore, it is desirable to have the highest possible comparison frequency. It is recommended that the filter structure shown in Fig. 3 be used. The last pole is introduced specifically to suppress the comparison frequency.

GSM is a frequency-division-multiple-access (FDMA)/time-division-multiple-access (TDMA)-based system where the physical channels are orthogonal in frequency and time. Potentially, up to eight users can share one frequency (the RF channel). Thus, the receiver and transmitter are active approximately one-eighth of the time but never at the same time. Unfortunately, the receiver has to do more in the cellular-band GSM network. It has to monitor the signal strength of the neighboring cells to provide information for handover and cell re-selection. Thus, the receiver is more active. Usually, the time for measuring the signal strength of a neighboring cell is only a part of one time slot depending on the capabilities of the digital signal processor (DSP) and software used. To make a handover to a neighboring cell, it is necessary to synchronize the surrounding cells from time to time. During this synchronization, the frequency-correction channel (FCH) and the synchronization channel (SCH) of the neighboring broadcast-control channel (BCCH) are read. For this activity, the idle frame in connected mode, which occurs every 26th frame (120 ms), can be used.

The intention of HSCSD and GPRS for GSM is to deliver higher data rates. The specification for traditional GSM supports a maximum data rate of 14.4 kb/s. It is possible to change the coding and puncturing to increase the data rates, however, this comes with a penalty of lower robustness against the propagation conditions and, therefore, there is a decrease in system performance, especially in terms of capacity. As long as the modulation scheme remains unchanged, the best way to increase the data rates is to break with the convention of receiving and transmitting in only one time slot per frame and allocating several time slots per frame for one connection. The GSM frame is approximately 4.6 ms long, consisting of eight time slots each with approximately 577-μs duration.

The switching time that is considered is the time that the synthesizer needs to switch from frequency f_1 to frequency f_2. For GSM-900, the frequency step is 45 MHz and for GSM-1800, the step size is 95 MHz with a frequency accuracy of 90 and 180 Hz, respectively (GSM 05.05 version 7.0.0,[6]). Considering the monitoring frequencies, this frequency step range up to twice as much. This would be the case in the scenario where the transmission occurs at the low edge of the transmit band (i.e., 890 MHz) while the monitoring frequency is at the high edge of the receive band (i.e., 960

MHz) as a worst-case scenario for GSM-900. Fortunately, the required accuracy for signal-strength measurements is more relaxed. The time for settling on a frequency from power-down mode to active mode is also important for making terminals with long standby times but is not considered here.



8. These measurements show the frequency settling when switching from 1360 to 1290 MHz (with 16-Hz frequency error).

The previously mentioned frequency steps must be achieved in less than 850 µs. This requirement comes from the need to synchronize to one of the surrounding cells. To successfully synchronize and read the FCH and SCH in one attempt, a gap of nine time slots is necessary for unsynchronized neighboring base stations. Monitoring can be skipped in the pre-idle frame, so a gap of 12 time slots is available for this task. Reduced by the necessary nine time slots, only 1.5 time slots (850 µs on each side of the idle frame are left for switching the synthesizer.

For HSCSD and GPRS, the timings become different. Both achieve higher data rates by using more than one time slot for receiving and transmitting. Now, a lot of new, multislot classes for mobiles are specified which provide the allocation of a specific number of time slots for forward and reverse link. Every new class, using more than one time slot for either link decreases the available time for the synthesizer to switch frequency.

Most GSM terminals currently use a transceiver structure where they share the channel synthesizer between receiver and transmitter (half duplex). They can do this because receiving and transmitting is never performed at the same time. Figure 4 shows the timing of traditional GSM.

Currently, 29 multislot classes have been introduced for the new HSCSD and GPRS services (GSM 05.02 version 7.0.0, Annex B,[7]). If the sum of all time slots becomes eight or higher, a full-duplex transceiver architecture becomes necessary. Full-duplex operation appears necessary before the sum of time slots is allowed to reach eight because the time for switching the synthesizer is not zero. Owing to this, type 1 and type 2 can be distinguished between each other as follows: type 1 mobile units are not required to transmit and receive at the same time while type 2 mobile units must provide simultaneous transmission and reception. For the following, only type 1 will be considered, as type 2 classes would have a major impact on the transceiver architecture. This will increase cost and possibly limit the market potential of these mobiles.

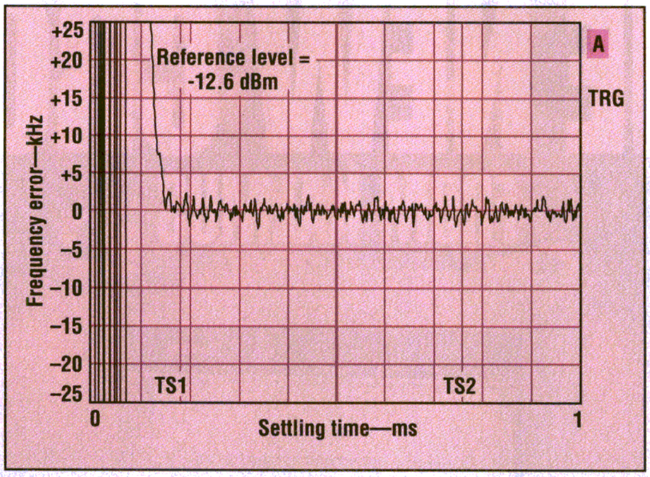
For these new services, fractional-N synthesizers are especially interesting due to their fast frequency-switching capabilities resulting from the higher comparison frequency. In the following paragraphs, the new demands on switching time will be derived. Table 2 shows the specification of the first 12 multislot classes. It is very likely that these classes will be implemented first and very soon.

The explanations used in Table 2 require some explanation (for more detail, please see GSM 05.02 version 7.0.0, Annex B,[7]). The terms Rx and Tx refer to the maximum number of receiver or transmit time slots that a mobile unit can use per frame. The mobile station (MS) must be able to support all integer values from 0 to Rx or Tx. The time slots need not be contiguous. For type 1 mobile units, the time slots should be allocated within the window of size Rx and Tx, and no transmit or receive time slot should occur between the receive or transmit time slots within a TDMA frame. The term "sum" refers to the total number of forward- and reverse-link time slots that can actually be used by the mobile unit per frame. The mobile unit must be able to support all combinations of

Table 2: First 12 multislot classes

Multislot class	Maximum number of slots Rx	Tx	Sum	Minimum number of slots T_{ta}	T_{tb}	T_{ra}	T_{rb}	Type
1	1	1	2	3	2	4	2	1
2	2	1	3	3	2	3	1	1
3	2	2	3	3	2	3	1	1
4	3	1	4	3	1	3	1	1
5	2	2	4	3	1	3	1	1
6	3	2	4	3	1	3	1	1
7	3	3	4	3	1	3	1	1
8	4	1	5	3	1	2	1	1
9	3	2	5	3	1	2	1	1
10	4	2	5	3	1	2	1	1
11	4	3	5	3	1	2	1	1
12	4	4	5	2	1	2	1	1

integer values of Rx and Tx time slots where 1≤ Rx + Tx ≤ Sum. The term T_{ta} refers to the time needed for the mobile unit to perform adjacent-cell signal-level measurements and to get ready to transmit. Parameter T_{tb} refers to the time needed for the mobile unit to prepare to transmit. This minimum requirement will only be used when adjacent-cell power measurements are not required by the service selected. Term T_{ra} is the time needed for the MS to perform adjacent-cell signal-level measurement and to get ready to receive. As with parameter T_{tb}, this minimum requirement will only be used when adjacent-cell power measurements are not required by the service selected. Term T_{rb} relates to the necessary time for the MS to get ready to receive.



9. These measurements show the frequency settling when switching from 1290 to 1360 MHz (with 19-Hz frequency error).

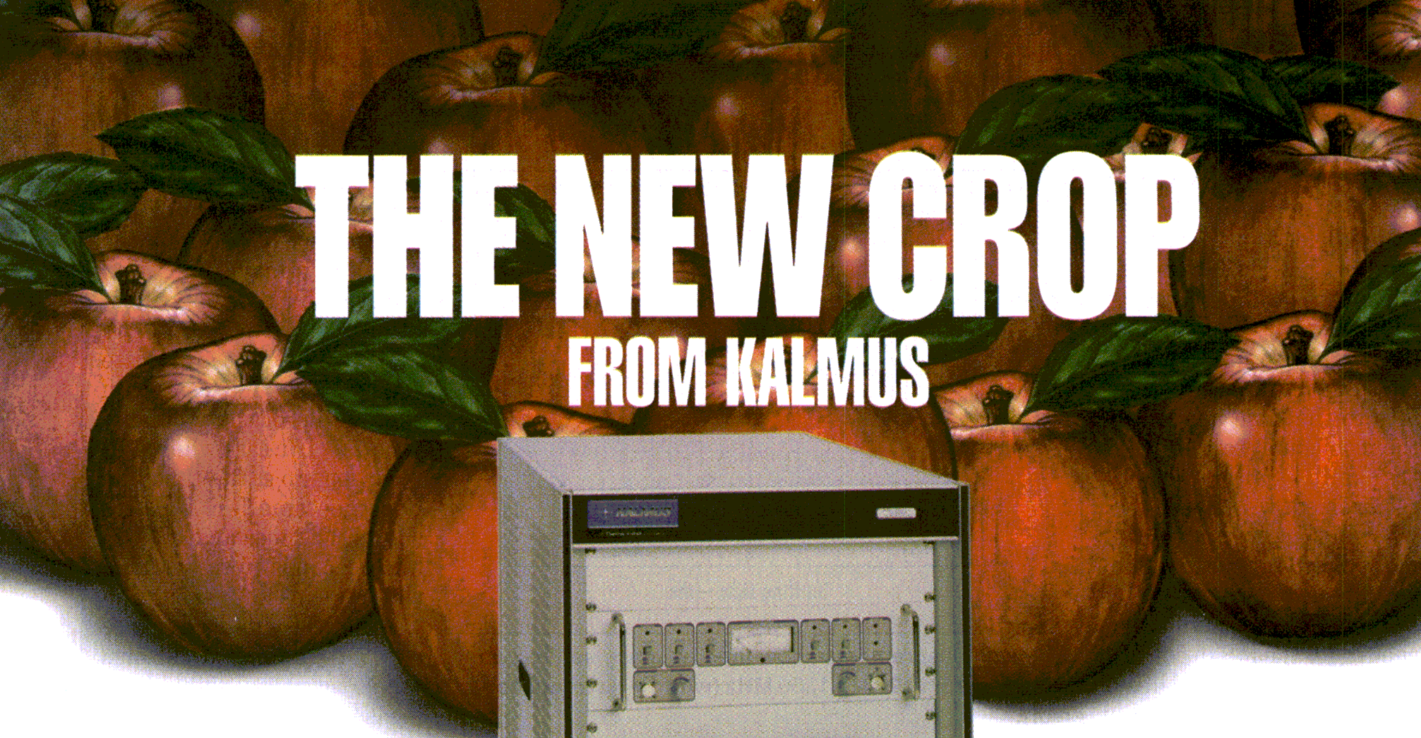
The data in Table 2 indicate the total time in terms of the time slots (each time slot represents 577 μs). For type 1 mobile units, it is the minimum number of time slots that are allowed between the end of the previous active time slot and the beginning of the next active time slot when a measurement is to be made in between. Note that for HSCSD, a symmetrical or forward-biased allocation with a minimum of one reverse-link time slot is necessary. This does not apply to GPRS. Figure 5 shows two different time-slot allocations for a GPRS mobile unit. The most stringent, class 12, is considered in this article.

To arrive at the available time for switching the synthesizer, two factors must be considered. It should be noted that, in practice, if the next active time slot is a transmit slot, the minimum time allowed may be reduced by the amount of timing advance. The timing advance is the time the mobile has to transmit earlier to the base station in order to be in the timing schedule of the base station. This value depends on the distance between a mobile unit and the base station. In GSM, this time is coded by 6 b and the time unit is 1 b (3.69 μs). Therefore, the maximum timing advance ($T_{advance}$) that the base station can request is 233 μs. This is related to the maximum distance to the base station of 35 km (Fig. 6). For this example, the time provided in Table 2 must be reduced by the timing advance.

The second factor that reduces the time for switching the synthesizer is the time needed to perform the adjacent-cell signal-level measurement. According to GSM 05.02, version 7.0.0[7], this only applies to T_{ta} and T_{ra}. Feasible times that depend on the capabilities of the signal-processing unit are between 150 and 300 μs. Furthermore, the flexibility of the timing-control unit for the positioning of the monitor burst has a major impact on the available time for switching the synthesizer. The best-case scenario is to locate the monitor burst exactly in the middle of the available time gap. In a case where this is not possible, the time gap becomes smaller. Table 3 shows the times available (in microseconds) for switching the synthesizer, assuming the highest timing advance and 300-μs time to perform the adjacent-cell signal-level measurement ($T_{monitor}$). This provides the shortest possible time gaps for the synthesizer, but leaves some margin for implementation difficulties owing to limited flexibility of the time-control unit. A further assumption is that the monitoring time slot is initially centered in the middle of the gap between Rx (Tx) and Tx slots by taking the timing advance into consideration. Table 3 is closely related to Table 2. The simple equations that follow were used to calculate the available times for switching the synthesizer as shown in Table 3, whereby the values

Table 3: Available time for switching the synthesizer depending on the multislot class

Multislot class	Maximum number of slots Rx	Tx	Sum	Maximum switching time (μs) T_{ta}	T_{tb}	T_{ra}	T_{rb}
1	1	1	2	599	921	1004	1154
2	2	1	3	599	921	716	577
3	2	2	3	599	921	716	577
4	3	1	4	599	344	716	577
5	2	2	4	599	344	716	577
6	3	2	4	599	344	716	577
7	3	3	4	599	344	716	577
8	4	1	5	599	344	427	577
9	3	2	5	599	344	427	577
10	4	2	5	599	344	427	577
11	4	3	5	599	344	427	577
12	4	4	5	310	344	427	577



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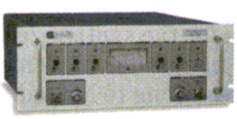

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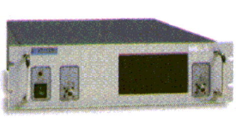

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of Table 2 must multiplied by 577 μs:

$t_{ta} = (T_{ta} - T_{advance} - T_{monitor})/2$
$t_{tb} = T_{tb} - T_{advance}$
$t_{ra} = T_{ra} - (tT_{monitor})/2$
$t_{rb} - trb = Trb$

where:

$T_{advance}$ = the timing advance of the MS transmit burst,

t_{ta} = the time needed for the mobile station to perform adjacent-cell signal-level measurements and prepare to transmit,

t_{tb} = the time needed for the MS to prepare to transmit,

t_{ra} = the time needed for the MS to perform adjacent-cell signal-level measurements and prepare to receive, and

t_{rb} = the time needed for the MS to prepare to receive.

Table 3 indicates that the synthesizer should switch from f_1 to f_2 within at most 310 μs. Unfortunately, there is a more stringent requirement for HSCSD as seen in Table 3. To make a handover to a neighboring cell possible, it is not only sufficient to perform adjacent-cell signal-level measurements. A periodic synchronization to the strongest neighboring cells must be performed. As was previously explained, nine time slots are needed for this task. Figure 7 shows this activity. Fortunately, adjacent-cell signal-level measurement (monitoring) is not necessary. This leaves a gap for changing the frequency of half a time slot which is 288 μs. In GPRS, a complete frame is kept free before synchronization to one of the neighboring cells. Thus, after including some implementation margin, a synthesizer capable of making the necessary frequency change in 200 μs, with the required accuracy, is well-suited for GSM HSCSD and GSM GPRS.

Figures 8 and 9 show SA8026 switching-time measurements using the same loop parameters as described in the phase-noise section.

The SA8026 fractional-N synthesizer meets the three key criteria for a GSM mobile telephone. The integrated residual phase error at 1300 MHz, which is in the middle of the GSM-900 and GSM-1800/1900 band, was measured as 1.1-deg. RMS. Spurious levels were 10 dB below the specification. A switching time of 180 μs was achieved making the realization of multislot GSM HSCSD and GPRS mobile phones feasible. Thus, the SA8026 provides approximately 100-μs margin for system implementation. ••

Acknowledgments

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DESIGN FEATURE

CAE Design

Synthesis + Simulation = Enhanced Design Process

The combination of circuit synthesis and simulation functions within a common CAE design tool can greatly improve the RF/microwave-design process.

Dale D. Henkes
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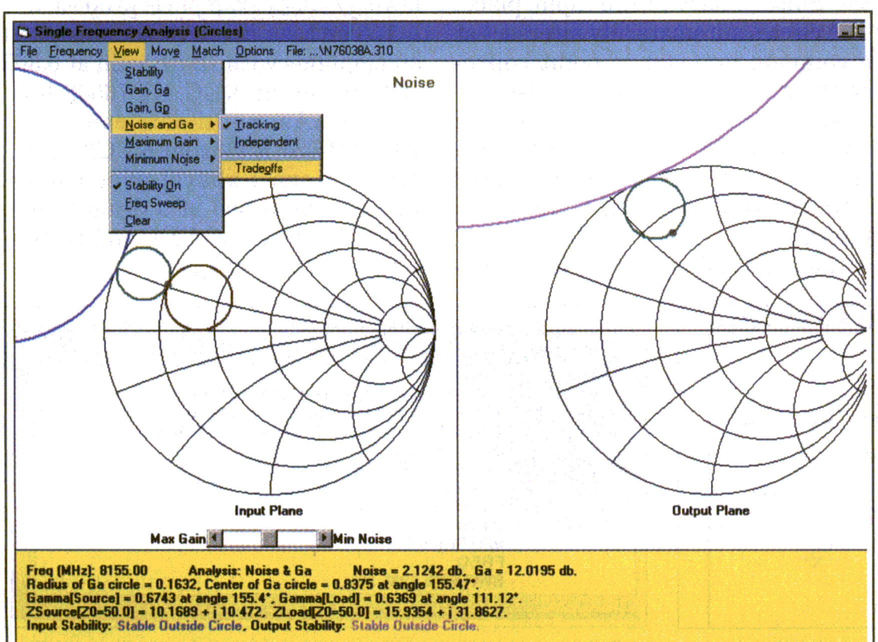
CIRCUITS can be created in several different ways with computer-aided-engineering (CAE) techniques. With a circuit-synthesis program, a designer starts by entering a list of specifications or design goals and pushing the "synthesize" button. Another approach might be to borrow a circuit topology from an existing design and then start a simulation program optimizing the circuit against a set of design goals. Perhaps the best approach, however, is to combine synthesis and simulation within the same CAE tool.

The synthesis approach to circuit design is more direct, but it may or may not provide the user enough flexibility in influencing the outcome. However, a well-designed synthesis program will attempt to provide the user with as much control over the final design as possible (or practical). This may include accepting a wide variety of input from the user, a choice of circuit topology, or both. After the design has been synthesized, it can then be analyzed in a circuit-simulation program to verify performance according to the engineer's requirements. Optimization or tuning can be used at this stage to tweak the design. Therefore, a complete set of design tools would include synthesis and simulation.



1. The MicroLINC CAE program combines synthesis and simulation, providing users with a great deal of analysis power through pull-down menus.

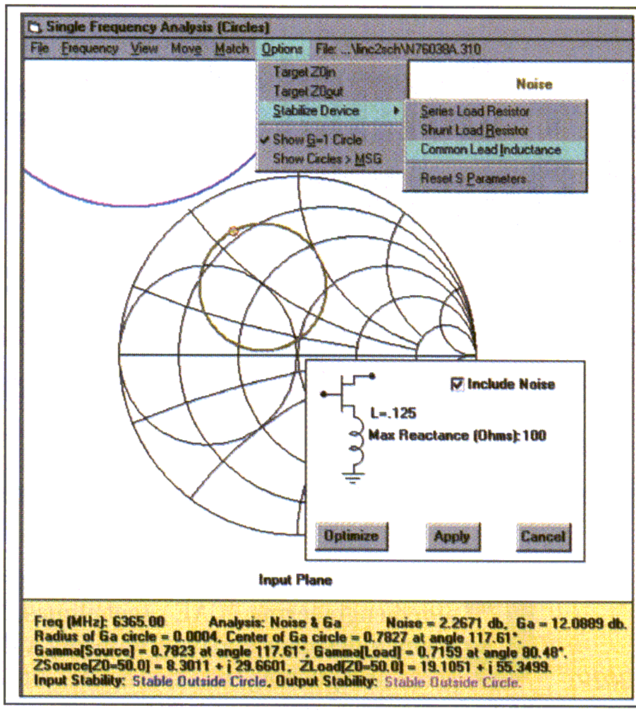
The design-by-simulation/optimization method is often a trial-and-error approach with no guarantee of success. An impedance-matching problem, for example, may not be solvable with the circuit topology presented to the optimizer. Worse than that is the fact that, because it cannot change the circuit topology (only the component values), the optimizer might get close to meeting an impossible goal by adjusting some circuit component's value to a very large or extremely small value that would not be practical or obtainable.

The MicroLINC™ program from Applied Computational Sciences (Escondido, CA) combines RF and microwave-circuit analysis (simulation) with a set of synthesis tools. One of the most comprehensive circuit-synthesis tools in the package is the "Circles Utility." Primarily a small-signal amplifier or low-noise-amplifier (LNA) design tool, this module is aimed at synthesizing input and output matching networks for the active device. The active device is usually a transistor [bipolar or field-effect-transistor (FET)] that is characterized by a set of S-parameters.

The philosophy behind this utility is to give the user as much or as little input into the synthesis processes as desired. In keeping with that philosophy, a substantial amount of analyses and data are available to assist the designer (Fig. 1). Thus, a designer experienced in the use of noise, gain, and stability circles can take advantage of the highly automated, yet interactive, nature of these tools as a guide to developing the best design that meets the requirements. On the other hand, a novice might simply input a gain specification and then select a default-matching network from the "Match" menu. The result is the creation of the entire circuit, seamlessly integrated into the simulator for immediate analysis and performance verification. All that remains to be done is to push the "Analyze Circuit" button for generating simulation results.

This is not to imply that a novice designer could not benefit from the circle utilities. Indeed, the interactive nature of the tool encourages experimentation. For example, a tool that proves as useful to the novice as it is to an experienced designer is the "Noise and Gain Trade-offs" tool shown in Fig. 1. When this is selected, gain and noise circles appear on the Smith Chart in the input plane. The circles automatically intersect at a common impedance point representing a typical compromise between maximum gain and minimum noise figure. A slider control below the Smith Chart points toward "Max Gain" on the left or "Min Noise" on the right.

Gain and noise-figure (NF) trade-offs can be viewed instantly by sliding the control toward Max Gain or Min Noise. As this is performed the gain and noise circles stay locked together, intersecting at the source reflection coefficient (Γ_S) as it moves along an optimum path between minimum noise and maximum gain. The gain and noise data are updated at the bottom of the screen so the user can determine when the appropriate trade-off has been made. As soon as a suitable trade-off between noise and gain is found, the program has all the data it needs to design the circuit. The next step is to select a set of matching networks from a list of various lumped and distributed topologies. Clicking on one of the items in the list automatically completes the circuit and generates the component values. It is possible to learn an effective design methodology simply by using this feature of MicroLINC.

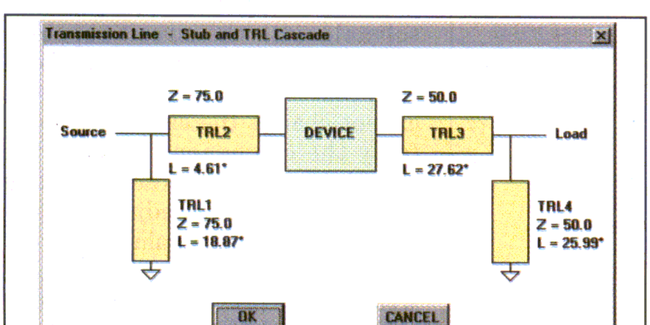


2. Stabilizing a high-frequency transistor for use in a microwave amplifier is a simple matter when using the "Stabilize Device" menu selection.

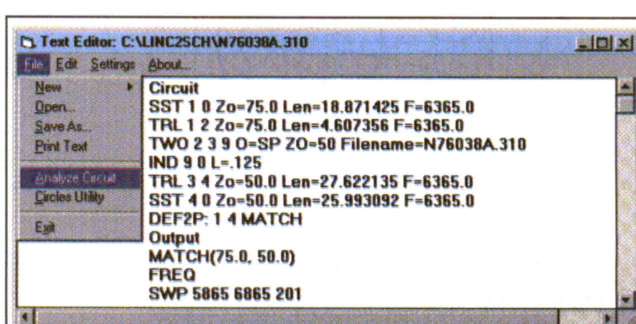
DESIGN EXAMPLE

To further illustrate the design process using CAE techniques, the following design example is proposed:

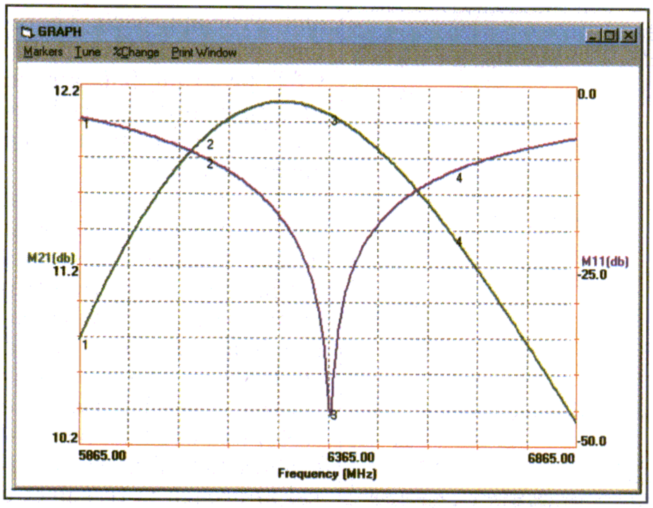
1. The task involves the design of an amplifier with 12-dB gain at 6.365 GHz using an NEC NE76038 low-noise GaAs metal-semiconductor FET (MESFET) from NEC/California Eastern Laboratories (Santa Clara, CA) biased at a drain-source voltage of V_{DS} = +3 VDC and a drain-source current of I_{DS} = 10 mA.



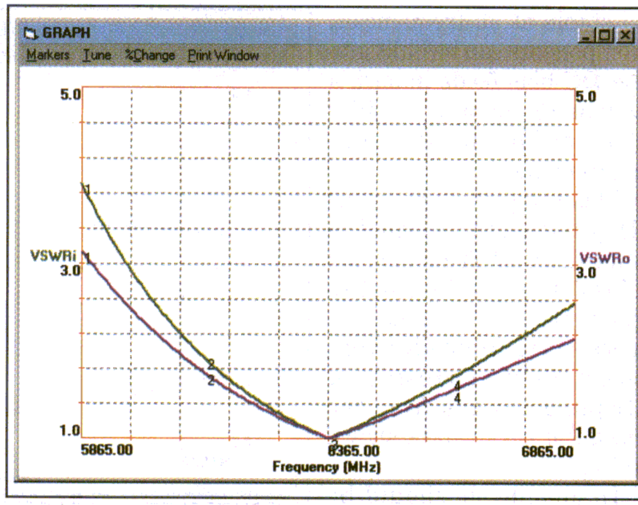
3. This circuit contains the matching input and output networks needed to meet the 75- and 50-Ω input and output conditions, respectively.



4. This circuit file represents the schematic diagram of Fig. 3. It is automatically generated and placed in MicroLINC's Text Editor for viewing and analysis.



5. The simulated performance of the example amplifier is shown here for gain (M_{21}) and return-loss (M_{11}) characteristics centered at the design frequency.



6. The plot above shows the quality of the input as well as output impedance-matching networks for the example amplifier.

2. The transistor must be stabilized within the operating band with both ports simultaneously matched [designed for maximum available gain (MAG) after stabilization].

3. The input port must be matched to an impedance of 75Ω while the output port is matched to 50Ω.

4. The amplifier's NF must then be determined when the amplifier has been matched for maximum gain.

5. The amplifier circuit should be synthesized using distributed (transmission-line) matching networks.

6. Simulation should be used to verify the gain and impedance-matching conditions.

Determine the amplifier's NF when matched for maximum gain.

With the MicroLINC Circles Utility, these six apparently complex steps take only a few minutes to accomplish. First, the NE76038 transistor's S-parameter file is opened and 6365 MHz is selected from the "Frequency" menu. Selecting "Maximum Gain...MAG" from the view menu reveals that it is unavailable. Attempting to match both ports to obtain the MAG fails because the device by itself is potentially unstable at this frequency. This is quickly verified by selecting "View Stability" and noting that the stability circles cut into the upper left part of the Smith Chart. Additionally, the stability factor reported is less than 1 (k = 0.799).

The Circles Utility provides several ways to stabilize a potentially unstable device. The method used here will be to place a small amount of inductance in the common (source) lead of the transistor. (Reference 1 points out some of the advantages of using this method). Selecting "Common Lead Inductance" from the "Stabilize Device" menu (Fig. 2) and clicking the "Optimize" button automatically inserts the minimum amount of inductance needed to stabilize the device at the design frequency. If "Include Noise" is checked, then the noise parameters of the device will be adjusted to include the effects of the inductor.

The next step is to change the input impedance from the 50-Ω default to 75Ω via the "Options... Target Z_{0in}" menu. Selecting "Maximum Gain... MAG" from the view menu now displays the optimum match points for maximum gain (~12.09 dB). The result is a single point (impedance match) in each of the input and output planes. This is referred to as a bilateral simultaneous conjugate match.[2] It is considered a bilateral match because the program solves the matching problem at both ports simultaneously, taking into account the fact that S_{12} is a nonzero value (the output match affects the input match and vice versa).

The selection "View...Noise and Ga" displays the noise circle that intersects the MAG point in the input plane. The NF is reported as ~2.27 dB at a gain of 12.09 dB as shown in Fig. 2. The program now has all the information it needs to complete the circuit. Selecting "Transmission Line...Stub and TRL Cascade" from the "Match" menu produces the circuit shown in Fig. 3. Then, the circuit file is automatically constructed and placed in the Text Editor (Fig. 4) for viewing and subsequent analysis.

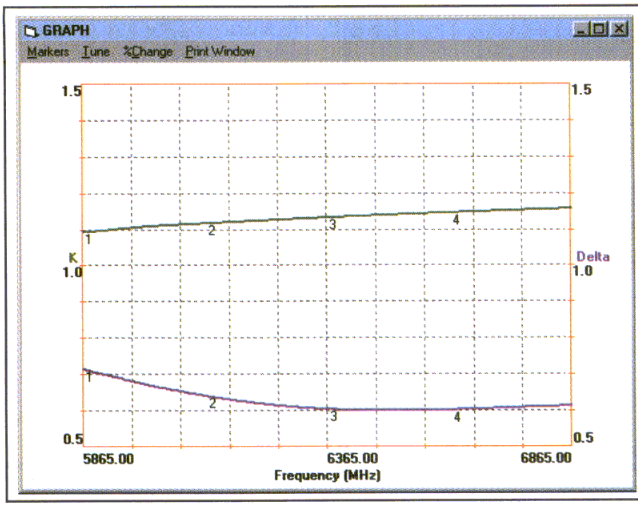
SIMPLE SIMULATION

"Analyze Circuit" starts the simulation, producing the results shown in Figs. 5 and 6. Figure 5 indicates that the gain specification has been met, while Fig. 6 shows the quality of the input and output match. The marker at 6365 MHz indicates that the input has been matched to 75Ω with a VSWR of 1.01:1 and the output is matched to 50Ω with approximately the same VSWR. An excellent match at both ports was expected (and obtained) because that is what was requested of the synthesizer when it was invoked to perform a MAG design.

Figure 7 shows that the additional goal of in-band transistor stabilization has been met. As indicated, the Rollett Stability factor (k) is greater than 1 while the absolute value of the determinant of the S-parameter matrix, |Δ|, is substantially less than 1 over the 1-GHz band around the operating frequency. This ensures that the transistor is unconditionally stable at the operating frequency. Of course, additional steps will need to be taken to ensure that the amplifier will be stable at all frequencies. Components can be built into the DC bias feeds in such a way as to enhance stability above and below the operating frequency.

This completes the initial RF portion of the design. The MicroLINC "Transmission Lines" tool can be used to generate the physical dimensions for printed-circuit-board (PCB) microstrip or stripline designs from the electrical parameters shown in Fig. 3.

In closing, it should be noted that simulation provides much more than just verification of the synthesized design. Simulation provides more performance analysis (and insight into circuit behavior) than could be known at the time of circuit synthesis. For example, the return loss (M_{11}) in Fig. 5 gives an indication of the narrowband nature of the input match. Additionally, Monte Carlo analysis (from the MicroLINC statistics module) can indicate the amplifier's sensitivity to component tolerances. However, design by simulation alone is a trial-and-error approach. Therefore, when selecting an RF CAE program, it is a good idea to consider a package that provides synthesis and analysis capabilities.



7. This plot illustrates the effectiveness of matching the transistor for high gain while maintaining good in-band operating stability.

In comparison, a design engineer can spend a great deal of time (and cost) on a combination of separate programs, such as impedance-matching tools, linear circuit simulators, and synthesis software, hoping that the tools mesh and can seamlessly share files. A more practical approach is to select a single tool with multiple functions, so that design files are not lost or outdated when an independent software tool is upgraded. ●●

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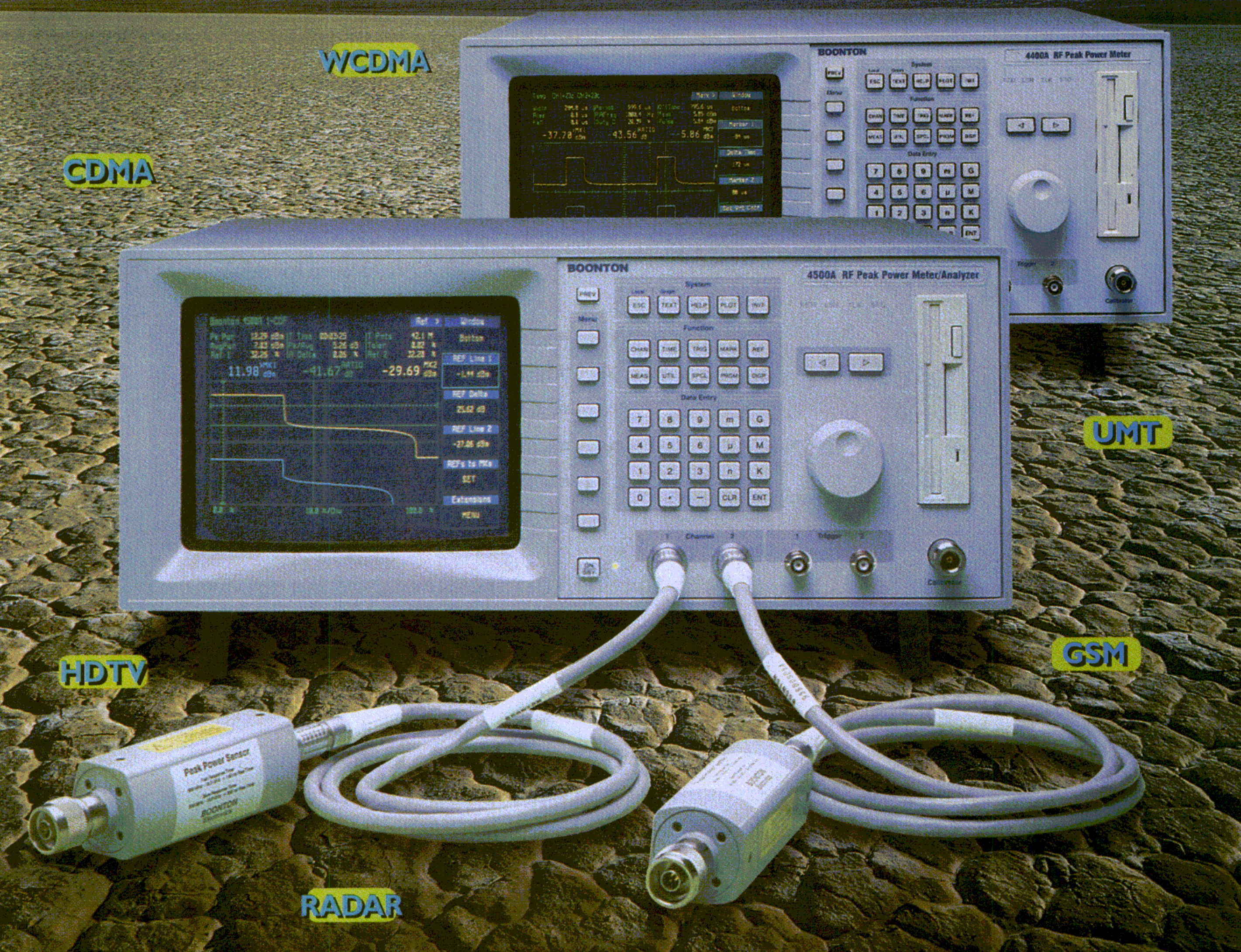

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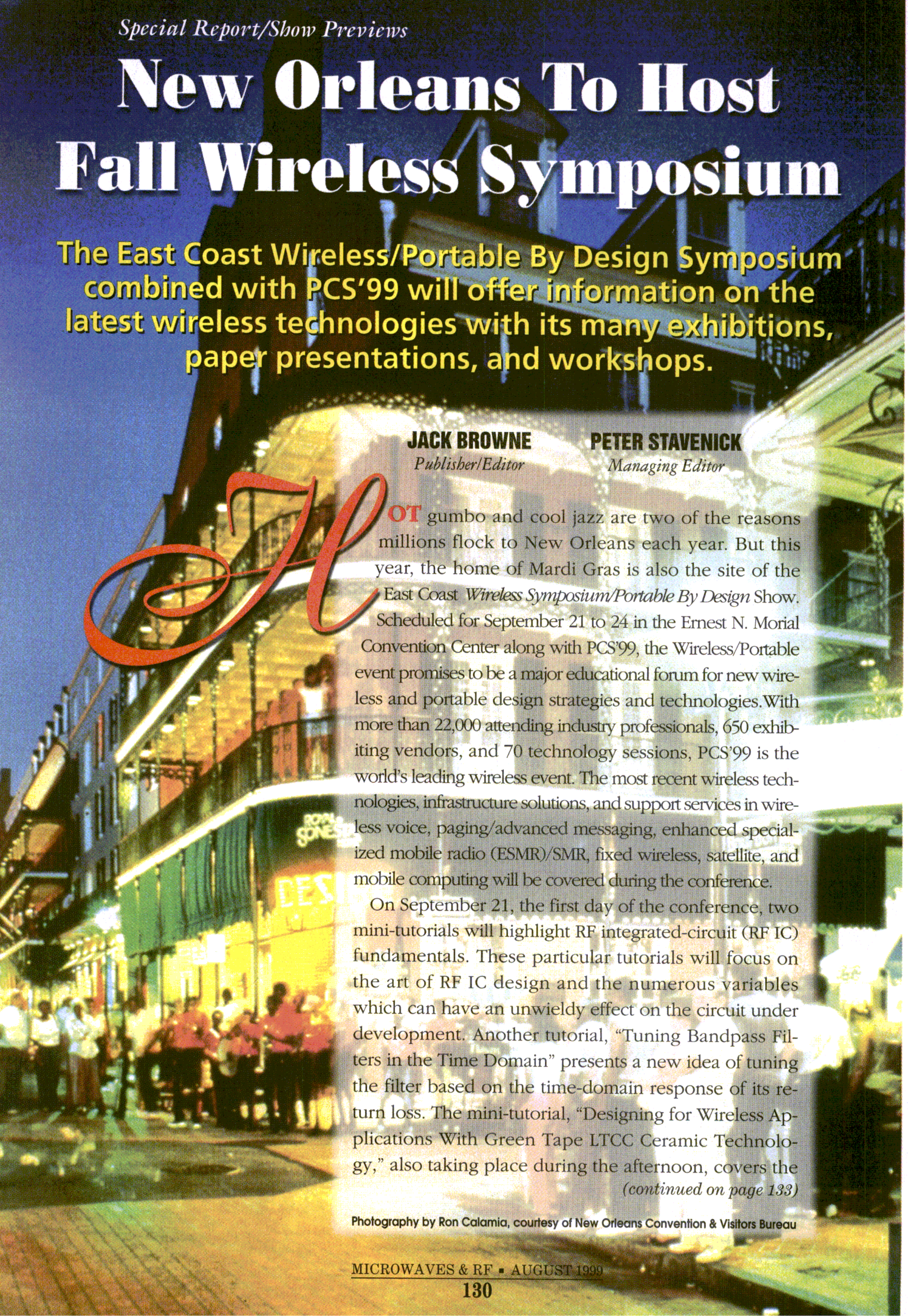

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Managing Editor

HOT gumbo and cool jazz are two of the reasons millions flock to New Orleans each year. But this year, the home of Mardi Gras is also the site of the East Coast *Wireless Symposium/Portable By Design* Show. Scheduled for September 21 to 24 in the Ernest N. Morial Convention Center along with PCS'99, the Wireless/Portable event promises to be a major educational forum for new wireless and portable design strategies and technologies. With more than 22,000 attending industry professionals, 650 exhibiting vendors, and 70 technology sessions, PCS'99 is the world's leading wireless event. The most recent wireless technologies, infrastructure solutions, and support services in wireless voice, paging/advanced messaging, enhanced specialized mobile radio (ESMR)/SMR, fixed wireless, satellite, and mobile computing will be covered during the conference.

On September 21, the first day of the conference, two mini-tutorials will highlight RF integrated-circuit (RF IC) fundamentals. These particular tutorials will focus on the art of RF IC design and the numerous variables which can have an unwieldy effect on the circuit under development. Another tutorial, "Tuning Bandpass Filters in the Time Domain" presents a new idea of tuning the filter based on the time-domain response of its return loss. The mini-tutorial, "Designing for Wireless Applications With Green Tape LTCC Ceramic Technology," also taking place during the afternoon, covers the

(continued on page 133)

Photography by Ron Calamia, courtesy of New Orleans Convention & Visitors Bureau

development of 943 Green Tape. On Thursday, the penultimate day of the Conference, the mini-tutorial, "3G Market Overview and Technology Basics of WCDMA and cdma2000" will take place.

In addition to the mini-tutorials, paper presentations of approximately one hour will be given. Each presentation is managed by a chairperson. Chair Dave Bursky, West Coast Executive Editor of *Electronic Design* magazine, will chair two presentations on the first day—"CPUs & DSPs For Portable Devices, Parts 1 and 2." Both presentations will examine some of the latest architectural developments in embedded central-processing units (CPUs), digital-signal-processor (DSP) engines, and merged controller/DSP architectures that suit the processors for low-power systems. During the same day, Don Brown, Director of the International Wireless Packaging Consortium will chair "Advanced Packaging Techniques" which will focus on packaging for wireless products.

Chair David Osika, High-Power Design Manager of Strategic Technologies at ANADIGICS, will chair the "High-Power Design" presentation the following day. This presentation will discuss the integration of GaAs and silicon (Si) technologies for power amplifiers (PAs). Highly linear amplifiers for wireless applications will also be covered. Tom Brinkoetter, Marketing Manager of Tektronix, will chair "Wireless Data & LAN Design" which will focus on the popular Blue-

WIRELESS AT WEMBLEY

Wireless technology with a European flavor can be found at this year's Microwaves + RF 99 Conference & Exhibition. Located in northwest London at the Wembley Conference Centre, Microwaves + RF 99 has traditionally offered a mix of commercial and military high-frequency technologies on its easy-to-navigate exhibit floor, along with a strong technical program consisting of full-day workshops and invited one-hour presentations. Technical discussions in years passed have taken on a more commercial tone, highlighting wireless issues of interest to European designers, including third-generation (3G) wireless systems, advanced Global System for Mobile Communications (GSM) formats, and line-of-sight millimeter-wave links at 38 and 42 GHz. For more information on the conference and/or exhibition, please contact the show's sponsor, Nexus Media Ltd., Nexus House, Swanley, Kent BR8 8HU, United Kingdom; (44) 13322-660070, FAX: (44) 1322-661257, e-mail: M+RF@nexusmedia.co.uk.

tooth system and on a 2.4-GHz radio solution for Bluetooth and wireless home networking. Darryl Schick, President of Linear Lightwave, Inc., will chair the "Test & Measurement" presentation and will provide information on measurement challenges for third-generation (3G) mobile systems, wireless code-division-multiple-access (WCDMA) ARIB signals, as well as measuring and troubleshooting jitter in wireless devices.

Furthermore, "Batteries & Power Management" chaired by Barry Huret, President of Huret Associates, will target lithium-ion (Li-ion) batteries, battery options, and systems design considerations, as well as cost-effective battery electronics for communications products. Rob McMorrow, Cellular, Cordless, & PCS Design Engineering Manager of Alpha Industries, will be chairing "Cellular/PCS Design" with a focus on raising the wireless quality standards, software-centric multimode handset solution, and a monolithic directional detector for handset wireless applications. Jeff Durec, IC Design Engineer, for Motorola SPS, will chair "Modulation Techniques." In this presentation, RF IC fundamentals, design techniques, and simplified filter tuning using time domain will be covered.

WORKSHOPS

The Fall Wireless Symposium/Portable by Design PCS'99 Exhibition also offers a series of full- and two-day workshops. On the first day, there will be a workshop that will target "Phase-Locked Loops and Frequency Synthesis for Wireless Design Engineers." This particular workshop will cover the use of PLL synthesizers and how they have increased in use over the last decade. Another full-day workshop that same day titled "Digital Modulation" looks at modulation methods that are presently used with the required filtering with an emphasis on the underlying principles of modulation and filtering. And the workshop "Fundamentals of CDMA Technology for PCS" will look carefully at CDMA wireless technology and how it is implemented in the TIA/EIA/IS-95 wireless communication standard.

On Wednesday, the second day of the conference, there will be a workshop on antenna properties, antenna-design considerations, and EF propagation. Titled "Antennas and Propagation for Wireless Communication," the workshop will begin with the concepts and definitions that are used in the antenna and propagation industry. Also, the workshop "3G Wideband CDMA Technology and Standards" will take place on the same day. This particular seminar will build upon the previous day's "Fundamentals of CDMA Technology for PCS" workshop. For those who are not familiar with CDMA fundamentals and IS-95, it is recommended that they attend Tuesday's workshop in preparation for Wednesday's 3G WCDMA session.

The last of the full-day workshops will be on Friday. The "Oscillators for Wireless" full-day workshop will explain a unified approach to the design of oscillators with inductive-capacitive (L-C), transmission-line, surface-acoustic-wave (SAW), and crystal resonators.

In addition to the full-day workshops, there are also workshops spanning two days. One of them, the "DSP Made Simple" workshop, Parts I and II, will provide a comprehensive introduction to DSP. The first part of this will be on Thursday and the second part of it will be held on Friday. Additional two-day workshops include "Wireless Made Simple"—a two-part workshop that is suitable for technical managers and marketing professionals who want to know about RF wireless systems at a block-diagram level while providing insights into different modulation techniques, system functions, and wireless markets. The third two-day workshop titled "RF Fundamentals," Parts 1 and II, will feature an introduction to passive and active RF circuit design with minimal mathematics. Real-life components, circuits, and design procedures will be discussed. The significance of impedance matching will be explained, and simple methods will be introduced to eliminate mismatch.

For more information on the Wireless Symposium/Portable by Design at PCS '99, visit the website at http://www.WirelessPortable.com or receive immediate fax-back show information at (800) 561-SHOW. ••

MICROWAVES IN MUNICH

Following the success of its event in Amsterdam last year, European Microwave Week is back again this year, this time it is scheduled from October 4-8, 1999 in the ICM International Congress Center in Munich, Germany. In what is actually a week-long collection of events, including a conference on GaAs monolithic microwave integrated circuits (MMICs), a conference on general wireless and microwave technologies, along with a large exhibition area (with more than 165 exhibitors from 15 countries already committed), European Microwave Week promises to be a major educational event for 1999. For more information on the conference or exhibition, contact either David Roberts, the Event Manager, at (44) 171-861-6385, e-mail: david.roberts@unmf. com or Nicola Jedrej, Event Coordinator, at (44) 171-861-6391, e-mail: nicola. jedrej@unmf.com. For information in the US, contact: KCS International, 94 Newport Rd., Leola, PA 17540-1821; (717) 656-4330, FAX: (717) 656-4643.

Sizing up the global VSAT landscape

Those interested in the future of very-small-aperture-terminal (VSAT) satellite-communications systems can learn the thoughts of a major player in the market. An application note from Hughes Electronics Corp. (El Segundo, CA), "The Global VSAT Landscape for the Millennium," reports on where the VSAT industry stands today and where it may be heading in the years to come.

Part of a presentation made by Jack Shaw, chairman and chief executive officer of Hughes Network Systems at the Global VSAT Summit (London, England, March 30, 1999), the note is also available on the "Speeches" section of the company's website. It details the more than 386,000 VSAT worldwide sites currently in use, a number expected to double in the next three years, and the number of opportunities created by demand for VSAT services, such as high-speed Internet access. In the US alone, Daimler Chrysler Corp. has approximately 5000 sites to interconnect dealers, factories, and suppliers through satellite.

Shaw points out the opportunities for VSAT growth in rural telephony and educational applications, such as remote classrooms transmitted via satellite. He details the state of VSAT markets in the US, Europe, Asia, The Pacific, Latin America, Africa, and in The Middle East, describing VSAT as a "workhorse" technology for global telecommunications. For a copy of the note, contact: **Hughes Electronics Corp., Corporate Communications, Building 001, M/S A123, P.O. Box 956, El Segundo, CA 90245-0956; (310) 364-6000, Internet: http://www.hughes.com.**

CIRCLE NO. 194

Simplify the design of a superheterodyne receiver

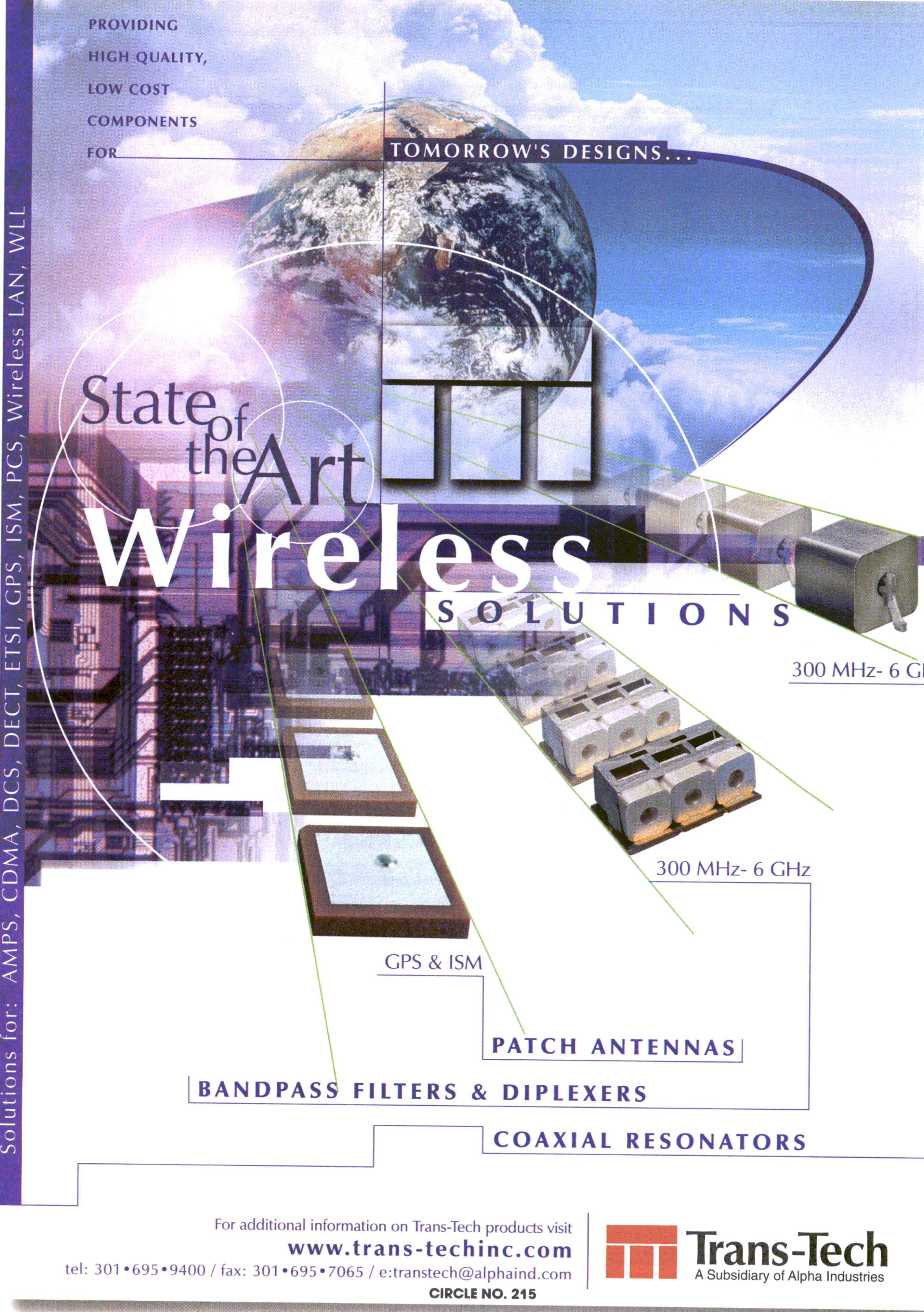
Superheterodyne receiver architectures dominate modern communications systems. The basic technique involves translation of high carrier frequencies to lower frequencies that can be converted to digital form for further processing. Frequency translation is usually performed by means of one or more mixers and local oscillators (LOs), subtracting and adding two signals in order to achieve a desired increase or decrease in final frequency. An application note from Analog Devices (Norwood, MA), "Designing a Superheterodyne Receiver Using an IF Sampling Diversity Chipset," describes how a few integrated circuits (ICs) can be used to simplify the design of a superheterodyne receiver.

Written by Analog Devices' Brad Brannon, the application note offers an introduction on superheterodyne receivers, then explores the concept of intermediate-frequency (IF) sampling to convert analog IF signals to the digital realm. The firm's model AD6600 IF data converter is presented as a solution. The integrated circuit (IC) consists of input attenuators (with 1-GHz bandwidth) 11-b analog-to-digital converter (ADC), additional 12-b ADC, peak detector, receive-signal-strength-indicator (RSSI) control, gain block, and a timing control. The input attenuator (which is controlled by the RSSI) controls two independent channels, such as diversity channels, with 30-dB total attenuation in 6-dB steps. Matching between the stages is better than 0.5 dB, while the phase match between the two attenuation channels is better than 0.2 deg. to 200 MHz.

The RSSI follows the input IF envelope one clock cycle before the envelope is digitized. During this period, the RSSI watches for signal peaks and sets the attenuation to the appropriate level for conversion of the IF signals to data. This prevents the data-conversion ADC from over-ranging on the following clock cycle.

The AD6600 is designed to work with another IC, the AD6620 digital preprocessor. The AD6620 provides a variety of functions, including quadrature demodulation and digital filtering. The two ICs together execute numerous IF sampling and processing operations, such as automatic gain control (AGC), digitizing, data-rate reduction, and channel filtering. The application note explains how these two ICs can be used in a basic superheterodyne receiver. The receiver block diagram (with the majority of gain to be found in the IF stages) is presented, along with an analysis on component choices [such as which types of surface-acoustic-wave (SAW) filters should be used] and signal-processing options. The sample design is applied to Global System for Mobile Communications (GSM) use, with a full evaluation of expected performance results under different operating conditions. For a copy of the application note, contact: **Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062; (781) 329-4700, Internet: http://www.analog.com.**

CIRCLE NO. 195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CIRCLE NO. 215
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Low-Cost CAE Suite Adds Power And Speed

The latest version of a PC-based CAE package combines electromagnetic and circuit co-simulation with additional speed and ease of use.

Todd Cutler
President
Eagleware Corp., 4772 Stone Dr., Tucker, GA 30084; (770) 939-0156, FAX: (770) 939-0157, e-mail: eagleware@eagleware.com, Internet: http://www.eagleware.com.

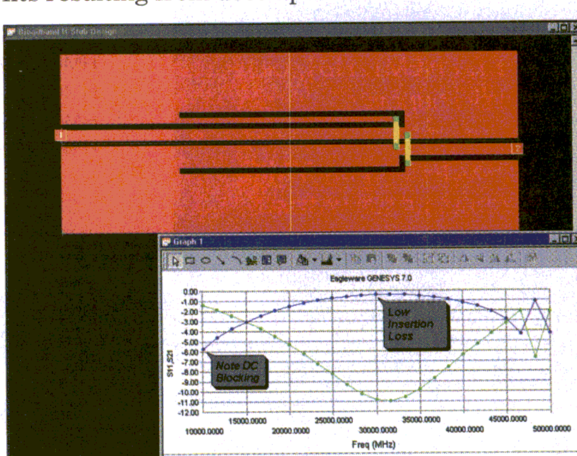
AFFORDABLE software has long been the trademark of Eagleware Corp. (Tucker, GA). The firm has just concluded an extensive development project culminating in the release of GENESYS Version 7. This high-speed and easy-to-use computer-aided-engineering (CAE) suite represents the firm's most significant release in more than six years, with new multilevel electromagnetic (EM)/circuit co-simulation capabilities, processing speed that is many times faster than earlier versions, a new multisimulator design environment, and a rich set of synthesis tools.

Extending the proven Method of Lines technique that was first commercialized in the company's =EMPOWER= EM simulation tool, =EMPOWER= ML is being introduced as part of GENESYS 7.0. Building on a reputation of speed, ease, and affordability, the simulator has been extended in three areas: multilevel EM simulation; multilevel, multimode decomposition; and EM-circuit co-simulation. For the first time, powerful features such as these are available in an EM simulator for less than $5000.

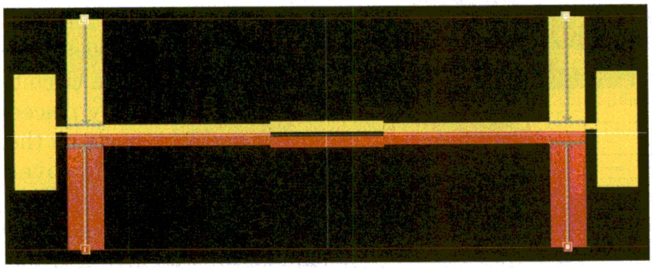
Based on technology developed at Eagleware,[1] =EMPOWER= ML can analyze signals traveling on an unlimited number of layers, using an arbitrary set of dielectric layers. Simulations assume a circuit design that is placed within a box with a cover. The simulator can calculate generalized S-parameters for arbitrary patterns of planar metal. Typical multilevel applications are designs that include air bridges. For example, Fig. 1 shows the simulation results of a structure similar to structures developed, built, and measured by the authors.[2] In their paper, the authors showed that it was possible to achieve an extremely broad bandwidth in combination with DC blocking.

Using a single-level EM simulator, it is not possible to characterize the air bridges that connect the center conductors of the coplanar waveguide, although these elements are essential to the broadband nature of the design. In =EMPOWER= ML, the main design is created on one layer, the air bridges on another, and solid vias are used to connect the two layers.

Multimode decomposition in =EMPOWER= ML makes it possible to break down large circuits into smaller segments which are connected by transmission-line sections. This sectioning enables accurate simulations in much less time. The principle benefits resulting from decomposition are:



1. This novel millimeter-wave coupler was designed with Version 7.0 of GENESYS.



2. This 3-dB broadside coupler features narrowly and widely spaced line sections as well as capacitive pads for the input and output ports.

• Real-time tuning of transmission-line sections inside a circuit is available. For example, the size of a meander line can be adjusted without re-running the simulation.

• Most circuits require far fewer frequency points for accurate analysis. Since quarter-wave resonant lines are broken down into much smaller lines that do not resonate, interpolation is possible. For example, =EMPOWER= ML can simulate a seventh-order interdigital filter with only five points, while 100 points are displayed in the output sweep.

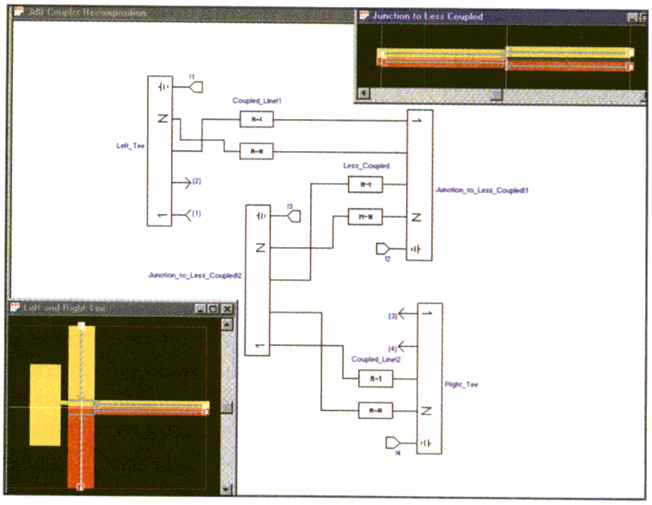
• Designs that are too large to run in a single pass can be analyzed in sections.

The multimode decomposition capability of GENESYS 7.0 was used to design a broadside-line 3-dB coupler (Fig. 2). Designed for 40-mil alumina with a 1.15-mil intermetal layer, the coupler was specified to operate from 1.5 to 2.2 GHz. Narrowly and widely spaced sections of offset-coupled lines were used to achieve the desired performance. Patches of metal were added to the ends of each side of the coupler to add capacitance for improved balance.

First, the transitions between each section of line were simulated using =EMPOWER= ML. Then, a schematic was created using two-mode coupled transmission lines to interconnect each of the transitions (Fig. 3). The propagation constants of each mode per line were set equal to the multimode (two in this example) propagation constants calculated in the transition analysis. Next, the company's =SuperStar= linear S-parameter simulator was used to simulate the performance of the complete coupler. This simulation recomposes the sections in mode space. The lengths of the interconnecting line segments were tuned in real time to obtain performance close to specification, and then the optimizer was used for final adjustment of the lines (Fig. 4).

The benefits of multimode decomposition in this example were the real-time tuning and the optimization to determine coupled line lengths. In addition, high accuracy of the simulation was possible. Many subsections were used to model the transitions and the impedance, but the problem remained manageable because the analysis was broken into parts.

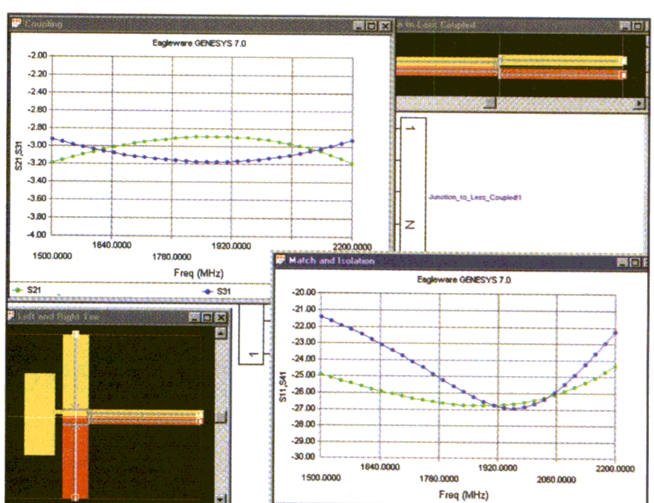
The GENESYS 7.0 program enables multilayer circuits with embedded lumped components to be verified without cumbersome data transfer. A typical application of this co-simulation is microwave circuits containing transistors, lumped capacitors, and distributed components such as Lange couplers and spiral inductors. In the past, engineers would have to split the design into multiple parts. EM simulation would be run on the distributed portions, data stored in intermediate files, the files transferred to a circuit simulator, then the data plus lumped elements analyzed using a circuit simulator. This process was cumbersome and it wasted time.



3. The recomposition of the broadside coupler sections includes the use of two-mode lines to connect the sections of the coupler.

Using GENESYS 7.0, EM and circuit verification are nearly transparent. After synthesis and schematic-level design, the circuit is laid out. EM ports are added to the layout and the simulation is run. In the background, GENESYS 7.0 automatically recognizes the lumped components, removes them, adds internal ports, and runs the EM simulation. Then, the multiport data are transparently included in a circuit theory simulation. Once the initial design is complete, the lumped components can be interactively tuned or automatically optimized at high speed.

A practical example[3] of the benefit of co-simulation can be seen in the design of a 900-MHz oscillator built on FR4 circuit-board material (Fig. 5). The oscillator has a high tolerance to FR4 material and −100-dBc/Hz single-sideband (SSB) phase-noise offset 10 kHz from the carrier. The circuit uses a microstrip line as a resonator. Shortening the resonator to less than quarter-wavelength and achieving resonance by loading with a lumped capacitor minimized the effects of the poorly controlled dielectric constant of the FR4 material. This capacitor was but one of the 10 lumped components in the oscillator.



4. These plots reveal the response of the broadside coupler after tuning and optimization. The upper graphs show the desired 3-dB coupling while the lower graph shows input match and isolation.

Various modules within GENESYS 7.0 were used in the design of the oscillator. The circuit was synthesized using GENESYS 7.0's =OSCILLATOR= module. S-parameters were simulated using =SuperStar=, and the layout was created using =LAYOUT= (Fig. 6). As is typical in RF design, components were placed with care to avoid undesired coupling and excessive size. However, the secondary couplings between transmission lines, lumped component pads, and interconnects were impractical to model with the circuit simulator. As a result, with the layout in place, EM-circuit co-simulation was used to analyze the entire circuit. The designer merely placed output and loop ports on the layout, designed the cover height and box size, and specified the grid size. When the simulation was invoked, the circuit was automatically partitioned, forming a 21-port metal section for =EMPOWER= analysis and another section of lumped components for =SuperStar= circuit analysis. Transparently to the designer, both sections were simulated. The combined simulation results showed that parasitic elements in the design caused the frequency to be 980 MHz instead of the design goal of 900 MHz. The engineer was then able to lower the loading capacitor to adjust for the parasitic elements. When built, the oscillation frequency was 887 MHz, well within the tolerances of the parts used in the design.

With the complexity of RF and microwave circuits continuing to grow, speed of simulation must also improve to keep an interactive design environment that emulates the test bench. Unfortunately, as the software itself grows in complexity, performance typically suffers, leading to sluggish behavior. However, even though GENESYS 7.0 includes many more features and greater capability, new simulation technology makes simulation faster than ever before. The company's software has long been known for nearly instantaneous tuning of small circuits. The new simulator dramatically improves the simulation and tuning performance of large circuits and of optimization.

Object-oriented techniques were used to improve the simulation and optimization speed by a factor ranging up to 10 or more. Based on diakoptic techniques,[4] a tree structure of caching stores and re-uses results without re-calculation. In addition, node elimination during the initial parsing of the schematic reduces the problem size. For example, for a nine-pole lowpass elliptic filter, the simulation was 12 times faster than in previous GENESYS versions. The improvement in speed for GENESYS 7.0 is even more apparent when simulating larger, more-complex circuits.

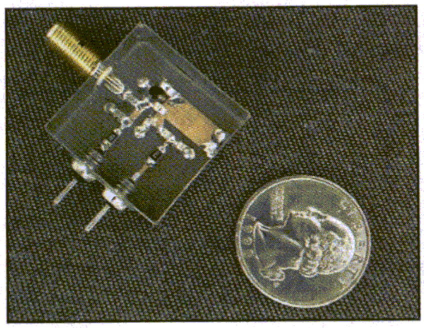
As engineers squeeze more and more information into a particular bandwidth, the design environment must develop to support more sophisticated design. While previous versions of the software coupled together various synthesis and simulation engines, the GENESYS 7.0 architecture was designed from the bottom up to support multiple simulators. Using object-oriented techniques, each element of the environment operates independently.

From tool bars to tips-of-the-day, GENESYS 7.0 includes graphical-user-interface (GUI) standards that follow the latest Microsoft standards. Built on Microsoft Foundation Classes, standard capabilities found in other Windows products are included in the release. Some examples include:

- Re-locatable toolbars to manage screen space.
- Right-mouse-button-controlled pop-up menus for quick local changes.
- Undo and redo to help experiment with different topologies and formats.
- Easy copy and paste to and from office-automation tools.
- Printing using standard printer drivers and configuration dialog boxes.
- Design file manager that is similar to that in e-mail programs.
- Built-in links to the web and e-mail.

By employing standard GUI conventions, GENESYS 7.0 is relatively easy to learn and use.

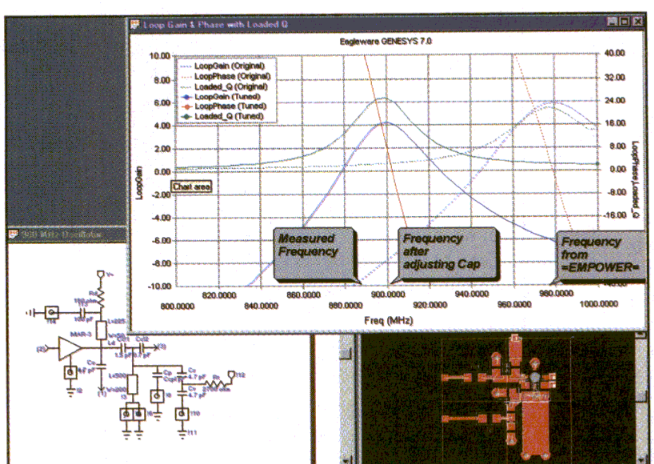
To facilitate new ways of analyzing data, a powerful post-processing engine is built into GENESYS 7.0. Data from many sources can be combined in limitless ways. Data collected from several sources, such as EM simulation, circuit simulation, and measurements, can be compared and operated on, or new parameters can be calculated from a single source of data. For example, Leeson's equation can be used to display phase noise for oscillators. In addition, relative gain, the difference between the maximum gain and the gain at any frequency, can be calculated and displayed. Conditional statements, such as IF-THEN and GOTO, support processing flow control.



5. Using EM and circuit co-simulation, this compact 900-MHz voltage-controlled oscillator (VCO) was developed.

Once the equations are entered and results displayed on graphs or tables, parameter values can be adjusted using the tuning keys. Data update on the graphs in real time as the keyboard is tapped and the data are updated. GENESYS 7.0 can be equipped with seven different synthesis modules that automatically create first-pass designs of oscillators, filters, matching networks, and equalization networks. Synthesis is used very early in the design process. An engineer enters the performance specifications for a circuit, and the synthesis engine produces a design. For example, =M/FILTER= is used to design distributed filters realized with microstrip-, stripline-, slabline-, or coaxial-manufacturing processes.

GENESYS 7.0 is available with up to seven different software modules. These include to M/FILTER=, =OSCILLATOR= ,=MATCH= (which automatically creates LC and distributed impedance-matching networks for single and multistage amplifiers with arbitrary terminations), =PLL= [which synthesizes and simulates phase-locked loops (PLLs)], =A/FILTER= (which synthesizes active filters with capacitors, resistors, and operational amplifiers), =EQUALIZE= (which designs group-delay equalizers, using the optimal number of all-pass networks to compensate for group-delay variations of target networks), and =T/LINE= (which computes transmission-line parameters from physical dimensions or synthesizes dimensions from a defined line impedance). Version 7 is available for personal computers (PCs) running with Windows 95, 98, and NT. P&A: stock; $9850 (complete GENESYS 7.0 suite) and $1000 and up (modules). **Eagleware Corp., 4772 Stone Dr., Tucker, GA 30084; (770) 939-0156, FAX: (770) 939-0157, e-mail: eagleware@eagleware.com, Internet: http://www.eagleware.com.**



6. GENESYS's multiple windows show the circuit schematic diagram for the 900-MHz VCO along with open-loop gain and phase and loaded quality factor (Q). The coupling capacitor was adjusted to 3.6 pF to achieve desired performance at 903 MHz. The measured frequency was 887 MHz, within expected variation due to component tolerances.

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CIRCLE NO. 51

CDMA/AMPS Chips Enable Dual-Band Transceivers

These four low-voltage ICs and a pair of power amplifiers meet most of the front-end needs for multiple-mode radio telephones.

JACK BROWNE
Publisher/Editor

INTEGRATED circuits (ICs) that are suitable for cellular-telephone handsets are available from a variety of manufacturers. But complete chip sets—providing all of the front-end radio functions—are usually assembled from several suppliers. The MAX23XX family of code-division-multiple-access (CDMA) ICs from Maxim Integrated Products (Sunnyvale, CA) enables designers to fill many of their cellular or personal-communications-services (PCS) handset front-end function needs from a single supplier. The chip set, which serves CDMA applications in cellular and PCS bands, as well as Advanced Mobile Phone Service (AMPS), includes a transmitter, RF and intermediate-frequency (IF) receiver ICs, and a baseband processor.

The four front-end ICs are the MAX2310 IF receive IC, the MAX-2320 RF receive IC, the MAX2360 transmit IC, and the MAX2384 baseband processor. The MAX2264 cellular band power amplifier (PA) and the MAX2294 PCS-band PA complete the lineup. Few additional components are needed to complete a triple-mode, dual-band cellular-radio front end.

The MAX2310 IF receiver IC operates from 40 to 300 MHz with a minimum variable-gain-amplifier (VGA) range of 105 dB (–49 to +56 dB). The input third-order-intermodulation (TOI) performance is –31 dBm at a gain setting of 35 dB and –6 dBm at –35-dB gain. The chip contains separate voltage-controlled oscillators (VCOs) for cellular and PCS bands, frequency-synthesizer circuitry (with a programmable charge pump capable of 150 to 425 μA), and a simple three-wire control bus. The MAX2310 features a phase noise of better than –115 dBc/Hz measured 120 kHz from the carrier. It runs on voltages of +2.7 to +5.5 VDC, drawing only 24-mA current in CDMA mode and less than 1-μA current in a shut-down (sleep) mode. The MAX-2310 is housed in a 28-lead quarter-sized outline package (QSOP).

The MAX2320 RF receiver IC downconverts incoming cellular and PCS signals to IFs usable by the MAX2310 (Fig. 1). The MAX2320 works across a cellular range of 800 to 1000 MHz and a PCS range of 1400 to 2000 MHz. In a low-gain state, it achieves 12-dB gain with 17-mA current consumption. In a high-gain state, the gain is 26 dB with 20-mA current consumption. The input third-order intercept point (IP3) of the MAX2320's onboard low-noise amplifier (LNA) can be adjusted from +5 to +12 dBm, depending on the dynamic-range needs of a particular application. The MAX2320 can work with external local oscillators (LOs) at a level of –10 dBm. The IC, which runs on voltages as low as +2.7 VDC, is supplied in a TSSOP-20 package.

The MAX2360 quadrature transmitter IC incorporates a quadrature modulator, variable-gain IF and RF amplifiers, image-reject upconversion mixer, as well as dual IF and RF frequency synthesizers (Fig. 2). It supports CDMA for the PCS band and CDMA and AMPS for the cellular band. The MAX2360 does not require additional band-switching hardware, since it includes two IF VCOs, two IF input and output ports, two RF LO input ports, and three PA driver ports. The transmitter IC has an IF range of 120 to 300 MHz, a cellular RF range of 800 to 1000 MHz, and a PCS range of 1400 to 1980 MHz. It operates on voltages from +2.7 to +5.5 VDC and features a power-control range of better than 90 dB. The MAX2360 achieves an adjacent-channel power ratio (ACPR) of –52 dBc at +10-dBm output power. The transmitter draws 130 mA at +10 dBm out in CDMA mode and 75-mA current at 0 dBm out in CDMA mode. In shut-down mode, the current draw is less than 1 μA.

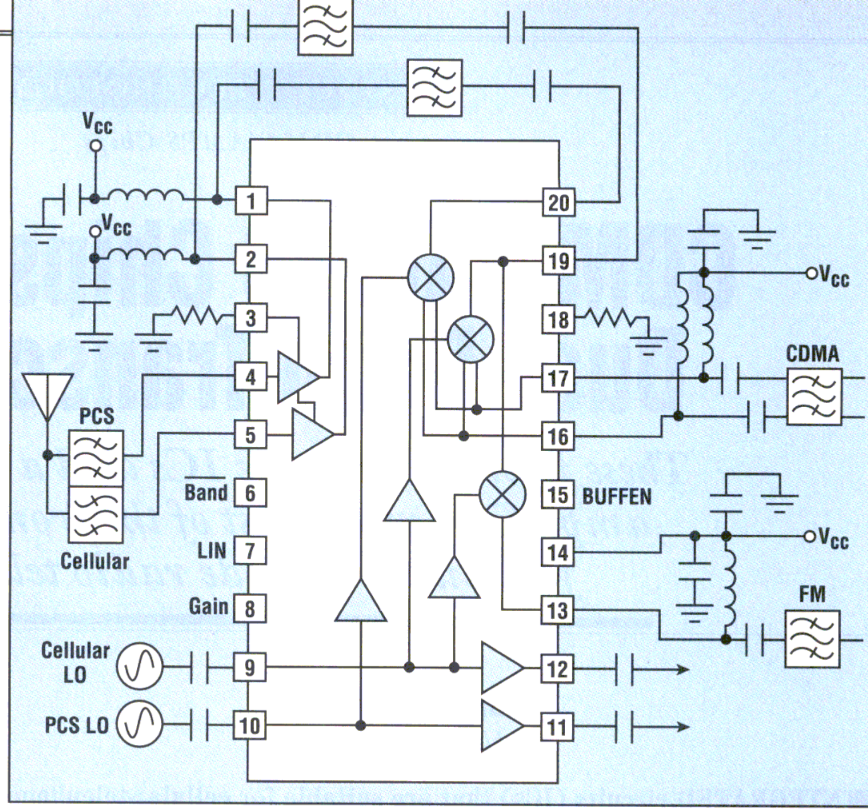
Since the receive-band noise is less than –140 dBm/Hz, low-cost three-pole filters can be used with the MAX2360. The IF VCO phase noise is less than –124-dBc/Hz offset 120 kHz from the carrier. Similar to the MAX2310, the MAX2360 transmit IC operates under three-wire (data, enable, clock) bus control. Single-band versions of the MAX2360 are available for PCS and cellular applications as models MAX2362 and MAX2364, respectively.

The MAX2380 is a baseband processor densely populated with signal-processing components. It features dual receive and transmit CDMA filters, dual receiver and transmit FM filters; 4-b CDMA and 8-b FM analog-to-digital converters (ADCs); 8-b CDMA/frequency-modulation (FM) digital-to-analog converters (DACs); and an 8-b, four-channel auxiliary ADC. The filtering achieves CDMA single-tone rejection of typically 63 dB at 900 kHz, with an FM single-tone rejection of typically 68 dB at 45 kHz. The MAX2380 exhibits less than 25-μs peak-to-peak group-delay deviation. It delivers peak-to-peak CDMA transmit output levels of 600 mV and an FM peak-to-peak output level of 555 mV. The MAX2380 operates on supplies from +2.7 to +3.6 VDC with multiple power-saving modes.

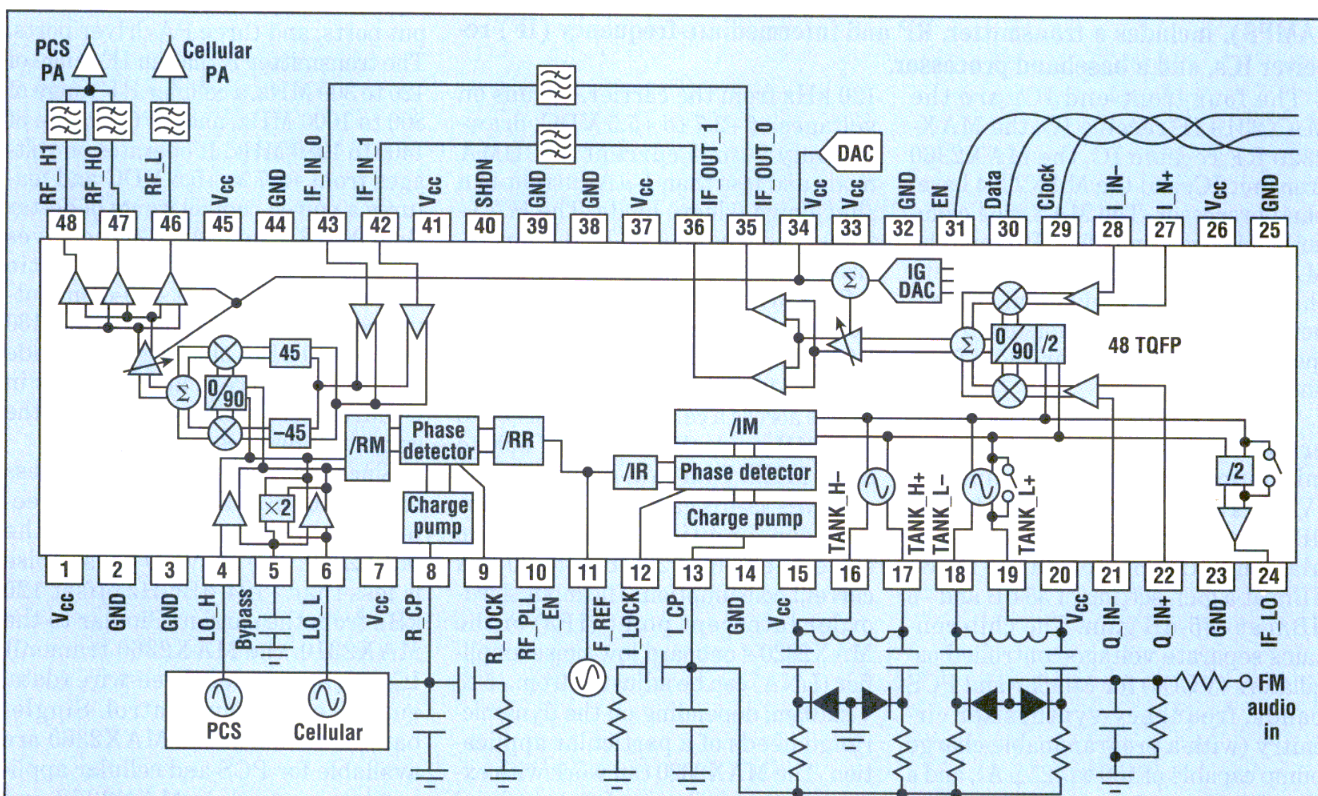
Finally, the MAX2264 PA is rated for typical output power of +28 dBm with 3-dB ACPR margin from 824 to 849 MHz. The amplifier achieves 25-dB typical power gain, and can operate on +2.7- to +5.0-VDC supplies.

Engineering samples and evaluation kits for the individual ICs are currently available. Also, a complete reference design will be available from Maxim later this year. **Maxim Integrated Products, 120 San Gabriel Dr., M/S 165, Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 732-8159, Internet: http://www.maxim-ic.com.**

CIRCLE NO. 52



1. The MAX2320 RF receiver IC downconverts cellular signals from 800 to 1000 MHz and PCS signals from 1400 to 2000 MHz to the IF range of the MAX2310.



2. The MAX2360 quadrature transmitter IC offers an IF range of 120 to 300 MHz, a cellular RF range of 800 to 1000 MHz, and a PCS range of 1400 to 1980 MHz.

Splitters/Combiners Bond High-Power Amplifiers

These compact stripline power-splitter/combiner networks support the design of flexible, modular power-amplifier architectures.

JACK BROWNE

Publisher/Editor

STRIPLINE power splitters and combiners can be considered the glue of high-power wireless amplifiers. Since many individual transistors and amplifier modules must be combined to attain cellular base-station power levels, splitters/combiners are essential to amplifier designers. The AdrenaLine® series of splitters/combiners from Anaren Microwave (East Syracuse, NY) consists of modular circuit-board components that not only combine and divide signal power, but include DC power distribution and decoupling capacitors for each power module in an amplifier.

The AdrenaLine splitters/combiners are currently available for cellular frequencies from 800 to 1000 MHz and for personal-communications-services (PCS) frequencies from 1800 to 2200 MHz (see table). The stripline power splitters/combiners feature a high length-to-width ratio for minimizing the length of interconnections between the splitters/combiners and active modules in an amplifier. With low insertion loss per unit, the stripline networks have been used to build high-power PCS amplifiers capable of 500-W peak-to-peak output power at 2 GHz (see *Microwaves & RF*, July 1999, p. 80).

The power splitters/combiners can be specified with any number of output ports from three to eight. The peak-to-peak amplitude unbalance ranges from ±0.25 dB for three-port units to ±0.6 dB for eight-port units. The input/output (I/O) return loss is 20.8 dB or better for all units. The minimum isolation between ports is 25 dB.

AdrenaLine power splitters/combiners are formed of bonded layers of RO3003® circuit-board material from Rogers Corp. (Chandler, AZ) and FR4. The FR4 top layer provides DC power distribution for connected amplifier modules as well as decoupling capacitors. Additional active functions (such as power detection and temperature sensing) can be included, depending upon a customer's requirements. The bonded circuit-board layers and integral power terminations are attached to a copper (Cu) base plate to facilitate cooling. Each splitter/combiner provides a termination power rating of 10 W average.

The power splitters/combiners can be supplied with SMA connectors or mounting tabs for use with solder straps. The networks include mounting holes for attachment to amplifier housings or subassemblies. They are suitable for single and multichannel high-power amplifiers. **Anaren Microwave, Inc., 6635 Kirkville Rd., East Syracuse, NY 13057; (315) 432-8909, FAX: (315) 432-8970, Internet: http://www.anaren.com.**

CIRCLE NO. 53

The AdrenaLine® splitters/combiners at a glance

Model	Frequency (MHz)	Output ports	Insertion loss (max., dB)*	Amplitude unbalance (dB)	Connector
4ASSA0304	800 to 1000	3	0.3	0.25	SMA
4ATTA0304	800 to 1000	3	0.3	0.25	Solder strap pads
4ASSA0306	1800 to 2200	3	0.4	0.30	SMA
4ATTA0306	1800 to 2200	3	0.4	0.30	Solder strap pads
4ATTA0404	800 to 1000	4	0.4	0.35	Solder strap pads
4ATTA0406	1800 to 2200	4	0.5	0.40	Solder strap pads
4ASSA0504	800 to 1000	5	0.5	0.45	SMA
4ATTA0504	800 to 1000	5	0.5	0.45	Solder strap pads
4ASSA0506	1800 to 2200	5	0.6	0.50	SMA
4ATTA0506	1800 to 2200	5	0.6	0.50	Solder strap pads
4ASSA0804	800 to 1000	8	0.6	0.50	SMA
4ASSA0806	1800 to 2200	8	0.7	0.60	SMA

* This is for narrowband specification (PCS, DCS, or WCDMA).

EM Simulator Is Free Of Charge

Even the tightest budget is no longer an excuse for those wishing to add powerful planar EM simulation capabilities to their PC.

JACK BROWNE
Publisher/Editor

ELECTROMAGNETIC (EM) simulators have become well-established recently as useful stand-alone analysis tools and as invaluable companion tools for linear and nonlinear circuit simulators. Three-dimensional (3D) EM simulators, which analyze the fields and current flowing through 3D structures, are still expensive. But the cost of planar EM simulators, which examine the fields around and the current through mainly planar structures, such as transmission lines, sell for less than $20,000. And now, for the price of a telephone call, a planar EM simulator can be obtained free of charge (excluding shipping). The software is called Sonnet Lite and the supplier is Sonnet Software (Liverpool, NY). Simply use one of the numbers at the end of this article to request a free copy.

The full version of Sonnet software, the Sonnet EM Suite, of course, is a well-established planar EM simulator used at thousands of sites around the world. It offers better simulation accuracy than standard linear circuit simulators, and is relatively easy to learn and use. The personal-computer (PC)-based suite of programs allows users to create a planar circuit or structure; modify the design; analyze the current flow and EM fields around the structure; plot simulated responses; and generate S-, Y-, and Z-parameters for use by other analysis programs, such as frequency-domain circuit simulators and time-domain SPICE simulators.

Certainly there must be a catch when a known supplier suddenly offers free software. In this case, the catch is some diminished features and capabilities in the free Sonnet Lite compared to the purchased full Sonnet suite of programs. Nonetheless, Sonnet Lite is a powerful analysis tool on its own, equivalent to some of the best planar EM-analysis tools of just a few years ago, and capable of performing useful analyses on a wide range of RF and microwave circuits.

Sonnet Lite is supplied on a compact-disc read-only memory (CD-ROM). It loads automatically in approximately five minutes, including time to copy files for Adobe Acrobat Version 3.0 (to read the files for software manuals and other literature). The CD-ROM includes a full bibliography of published work by Sonnet engineers and about Sonnet software, with an approximate 700-page biography of James C. Maxwell, written by Lewis Campbell and William Garnett. Published in 1882, it was digitally restored by Sonnet founder and president Jim Rautio in 1997.

Similar to its full-fledged counterpart, Sonnet Lite consists of a suite of software tools, including xgeom, em, emvu, and emgraph. Xgeom is the user-friendly graphical user interface (GUI) that guides operators through many functions and capabilities of the software suite. The em program is an EM-analysis engine that is based on a modified method of moments. It uses Maxwell's equations to perform 3D current analysis on mainly planar structures. The program can compute S-, Y-, or Z-parameters; transmission-line parameters; and SPICE equivalent lumped-element networks. Files that are created by em can be further processed by emvu, which supports visualization of current densities. The emvu program is useful for quick qualitative views of the EM interactions within a design. Finally, the emgraph program allows users to plot their response data from em (and other simulation tools) using standard engineering formats, such as Smith charts or Cartesian graphs.

What are the limitations of Sonnet Lite? First of all, it will not load or run on a computer that already contains the full version. Sonnet Lite is limited to two metallization layers in a circuit, and three dielectric layers (in contrast to an unlimited number of metallization and dielectric layers in the full version). The full version of Sonnet supports unlimited memory space for a design. The CD-ROM for Sonnet Lite includes a tutorial on the program, along with full operating manuals and a collection of application notes. For the price, who could ask for more? **Sonnet Software, Inc., 1020 Seventh North St., Suite 210, Liverpool, NY 13088; (315) 453-3096, FAX: (315) 451-1694, e-mail: info@sonnetusa.com, Internet: http://www.sonnetusa.com.**

CIRCLE NO. 54

Schottky Mixers Feature High Dynamic Range

These lumped-element mixers provide the distortion-free dynamic range for cellular and PCS wireless applications.

Byron Calderon

Engineering Product Manager

TRAK Microwave Corp., 4726 Eisenhower Blvd., Tampa, FL 33634; (813) 884-1411, FAX: (813) 886-2794, e-mail: sales@trak.com, Internet: http://www.trak.com.

MIXERS provide the frequency-translation function essential for wireless communications. High dynamic range is especially important for communications systems based on digital modulation, since limited range can result in signal distortion, lost data, and dropped calls. In response to the need for low-cost, high-dynamic-range mixers, TRAK Microwave Corp. (Tampa, FL) has developed a line of Schottky-diode mixers for use in cellular and personal-communications-services (PCS) bands with third-order intercept points (IP3s) up to +38 dBm.

The new mixers serve cellular and PCS designs. For cellular systems, the RF range is 820 to 850 MHz while the local-oscillator (LO) range is 735 to 765 MHz. For PCS use, the RF ranges are 1710 to 1785 MHz, 1850 to 1910 MHz, and 1820 to 1920 MHz and the LO ranges are 1210 to 1285 MHz and 1700 to 1800 MHz (see table). Depending on the model, the mixers provide intermediate frequencies (IFs) as low as 70 MHz and up to 1010 MHz. They are designed to work with LO power levels from +17 to +23 dBm, with conversion loss of typically 7 dB for most models.

In TRAK's high-dynamic-range mixers (HDMs), the LO drive and IF bandwidths have been optimized for maximum input IP3 performance. The typical input IP3 performance of the mixers ranges from +35 to +38 dBm.

For example, model MXR/6EE-02HD-1 is a cellular-band mixer with RF range of 820 to 850 MHz and LO range of 735 to 765 MHz. It operates with a fixed IF of 70 MHz and requires +17-dBm LO power to attain conversion loss of 8 dB. The mixer features minimum input IP3 of +35 dBm and typical input IP3 of +38 dBm. As with the other mixers in the line, the LO-to-IF isolation is typically 40 dB.

The HDMs feature tightly matched Schottky-diode quads and broadband RF balun transformers. Earlier designs (approximately 1994) achieved input IP3 performance of +31 dBm minimum with +17-dBm LO drive when mixing RF signals from 1805 to 1880 MHz and LO signals from 1665 to 1743 MHz to achieve a 140-MHz IF. By improving these designs, and optimizing the mixers for narrow IFs (as typically used in wireless communications designs), the input IP3 performance has been quite dramatically improved.

The new HDMs are housed in the company's standard -02 style low-cost surface-mount package (SMP), which measures 0.50 × 0.38 × 0.19 in. (1.27 × 0.9652 × 0.4826 cm). Models that have slightly reduced input IP3 performance can be supplied in smaller packages, while mixers with better input IP3 performance are available in more expensive hermetic housings.

The passive HDMs require no DC bias. They achieve their rated performance levels over an operating temperature range of –55 to +105°C. **TRAK Microwave Corp., 4726 Eisenhower Blvd., Tampa, FL 33634; (813) 884-1411, FAX: (813) 886-2794, e-mail: sales@trak.com, Internet: http://www.trak.com.**

CIRCLE NO. 57

The HDMs at a glance

Model number	RF range (MHz)	LO range (MHz)	IF range (MHz)	Input IP3 (dBm) [typ./min]	LO level (dBm)	Conversion loss (dB)
MXR/7FF-02N6	1710 to 1785	1210 to 1285	500	+38/+35	+23	8
MXR/7FF-02L2	1850 to 1910	840 to 895	1010	+36/+33	+19	7
MXR/7FF-02HD-1	1820 to 1920	1700 to 1800	140	+38/+35	+21	8
MXR/7EE-02HD-1	820 to 850	735 to 765	70	+38/+35	+21	8
MXR/6FF-02HD-1	1820 to 1920	1700 to 1800	140	+35/+33	+17	8
MXR/6EE-02HD-1	820 to 850	735 to 765	70	+37/+34	+17	8

Signal Generators Offer Enhanced Spectral Purity

These signal generators feature improved spectral purity, and some can change personality to suit a specific standard.

DON KELLER
Senior Editor

IMPROVEMENTS to a family of RF/microwave signal generators include eight new models with low phase noise and options for testing according to wireless standards. The ESG family of signal generators from Hewlett-Packard Co. (Santa Rosa, CA) has doubled from eight to 16 generators. The new line consists of four ESG-AP (analog) models and four ESG-DP (analog/digital) models (see table).

The eight new signal generators have much in common with their older siblings. They offer a choice of frequency coverage from 0.25 GHz to 1.0, 2.0, 3.0, or 4.0 GHz. All models have 0.01-Hz frequency resolution. Output levels can be set as low as –136 dBm, with available power levels of +13 dBm to 1 GHz, +10 dBm to 3 GHz, and +7 dBm to 4 GHz. Output levels can be set in 0.02-dB increments. Level accuracy is better than ±0.5 dB to 2 GHz without modulation and still better than ±0.6 dB with digital modulation. Harmonics are better than –30 dBc for carrier levels of +4 dBm or less. Spurious non-harmonic levels are better than –65 dBc for carrier frequencies to 1 GHz, better than –59 dBc for carriers from 1 to 2 GHz, and better than –53 dBc for carriers from 2 to 4 GHz.

The performance improvement shared by the new AP and DP models is increased spectral purity, which indicates how closely the output-frequency spectrum represents that of an ideal signal. A key measure of spectral purity is phase noise. The following single-sideband (SSB) phase-noise measurements for a 1-GHz carrier compare the spectral purity of the new models with that of their predecessors. At offsets to 100 Hz from the carrier, the phase noise is the same for all of the models, new and old. However, at 1 kHz from the carrier, the AP and DP models offer –110-dBc/Hz phase noise compared to approximately –98 dBc/Hz for the standard models. And at 10 kHz from the carrier, the AP and DP models provide better than –130-dBc/Hz phase noise compared to –110 dBc/Hz for the standard models. This improvement in phase noise is necessary for testing next-generation advanced phase-modulation-based cellular systems such as wideband code-division multiple access (WCDMA).

The analog/digital members of the ESG family—the old D models and new DP models—are available with "personality" options. Without any programming on the part of the user, these personalities enable the generator to produce signals that conform to specific telecommunication standards such as WCDMA, cdma2000, and enhanced data rates for global evolution (EDGE). These standard-specific options are often called "personalities" because they are implemented in the generator's firmware (depending on the modulation capabilities of a particular generator). The firmware options are themselves dependent on hardware options.

The newest ESG generators at a glance

Series	Model	Frequency range (MHz)	Power range (dBm)	Modulation formats
AP	E4423B	0.25 to 1000	–136 to +13	AM, FM, phase, pulse
AP	E4424B	0.25 to 2000	–136 to +10	AM, FM, phase, pulse
AP	E4425B	0.25 to 3000	–136 to +10	AM, FM, phase, pulse
AP	E4426B	0.25 to 4000	–136 to +7	AM, FM, phase, pulse
AD	E4434B	0.25 to 1000	–136 to +13	AM, FM, phase, pulse, I/Q, burst
AD	E4435B	0.25 to 2000	–136 to +10	AM, FM, phase, pulse, I/Q, burst
AD	E4436B	0.25 to 3000	–136 to +10	AM, FM, phase, pulse, I/Q, burst
AD	E4437B	0.25 to 4000	–136 to +7	AM, FM, phase, pulse, I/Q, burst

The previously mentioned WCDMA and cdma2000 personality options (referred to as Option 100 and Option 101, respectively) are dependent on Option UND, an arbitrary waveform generator that produces complex, digitally modulated waveforms. Option UND offers flexibility to test devices under varying signal conditions outside the boundaries of current and proposed air-interface standards. Option 100 generates multichannel, forward- and reverse-link partially coded signals according to the developing WCDMA international standards. Option 101 generates similar signals according to developing cdma2000 standards. The signals can be used for base-station, mobile, component, and subsystem tests.

The EDGE personality option (referred to as Option 202) is dependent on Option UN8, a real-time in-phase/quadrature (I/Q) baseband generator that builds digitally modulated signals by mixing and matching modulation types, symbol rates, and filters. Option 202 offers continuous or framed data for component and receiver testing. Individual time slots can be activated, and data can be assigned to each time slot's "encoded" data field independently. The data framing in each time slot matches that of a "normal" EDGE time slot. The user can edit the tail, steal-training sequence, and guard fields to keep pace with format changes or experiment with new formats. In addition, "custom" time slots enable the user to create other time slot types with downloaded data.

The improvements in spectral purity make these new signal generators ideal for applications that require a clean signal, such as local-oscillator (LO) substitution and next-generation system design. And the availability of standard-specific personalities makes testing easier and more foolproof, especially when performing production-line testing according to a wireless standard. The architecture of the AP and DP series is modular and expandable, and the programmable hardware of the DP series enables designers to completely modify existing standards or to create new formats. For license-key purchasers or owners of existing digital options, updated firmware can be downloaded from the HP ESG website to obtain future levels of measurement performance and personalities. **Hewlett-Packard Co., Test & Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052-8059; (800) 452-4844 ext. 6539, Internet: http://www.hp.com.**

CIRCLE NO. 59

Spectrum Analyzers Geared To Production Testing

A three-instrument family performs high-speed test and measurement in wireless, RF, and TV applications on the production line.

GENE HEFTMAN
Senior Editor

TESTING products rolling off a manufacturing line requires a different breed of test equipment than that found in an engineering lab. The production instrument must make measurements faster, be simpler to operate, have good data-collection capability, perform automated measurements, and be easily interfaced to a test bus that can handle high-speed data transfers. To meet these production-test requirements, Tektronix (Beaverton, OR) joined with Advantest of Japan to develop a three-instrument family of spectrum analyzers—the R3132/R3132N and the R3162 (see figure). Applications are in the rapidly expanding wireless, RF, and television (TV) manufacturing environments. Advantest designed and developed the instruments and Tektronix will market and support them in North America.

The spectrum analyzers are designed with two basic features in mind—testing speed or throughput and a user interface that is familiar to production-test operators. High-speed testing is made possible by the analyzers' wide resolution bandwidth filters and improved synthesized local oscillator (LO) that enables sweeping at 50 μs to support time-domain measurements such as burst-transmission rise and fall times (available as an option). The screen-update rate is 20 traces/s to provide test operators with a "live" feel when making manual adjustments on RF components while approaching real-time waveform measurement.

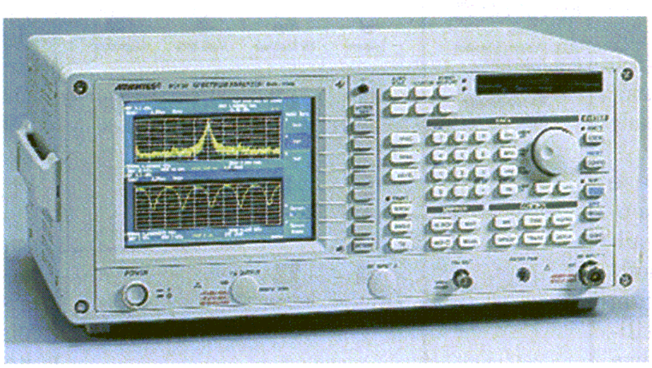
Many production tests used for communications products are automated, including adjacent-channel power (ACP), channel power, and occupied bandwidth. An ACP measurement, for example, can be made in one-sixth of a second. The front panel conforms to a three-button format of frequency, span, and level that is familiar to production operators in communications. A front-panel lockout protects the instruments against unauthorized programming changes, and the user interface uses a menu for easy access to key measurements.

Features that are optional in spectrum analyzers of this performance level are standard in the R3132/3132N and R3162 because they are necessary for fast testing and the data logging needed in production testing. They are a general-purpose interface bus (GPIB, or IEEE Std 488.2), an RS-232 port, parallel printer interfaces, a built-in 3.5-in. floppy-disk drive, and a high-definition color display with a video-graphics-array (VGA) output connector for sending the screen image to external displays.

The three analyzers each have a different operating frequency range. The R3132 spans 9 kHz to 3 GHz while the R3162 offers a range of 9 kHz to 8 GHz. The R3132N is a 75-Ω instrument intended for applications in cable TV (CATV), broadcast TV, and broadband local-area-network (LAN) applications, with a frequency range of 9.0 kHz to 2.2 GHz.

Total measurement accuracy level is ±1.5 dB while phase noise is specified at –100 dBc, at 10-kHz offset from the carrier, 1-GHz center frequency, for all models. P&A: R3132 and R3132N start at $12,750; R3162 starts at $17,950 (8 wks.). ARO. **Tektronix Measurement Business Division, P.O. Box 3960, Portland, OR 97208-3960; (800) 426-2200 (code 1158), FAX: (503) 222-1542, Internet: http://www.tek.com/ Measurement.**

CIRCLE NO. 60



The R3132 spectrum analyzer from Tektronix, Inc. shown here is one of three similar instruments optimized for high-throughput production testing in wireless, RF, and TV manufacturing environments.

Software Simplifies IR Communications

This software suite coordinates IR data communications between PCs and portable devices such as PDAs, digital cameras, and cell phones.

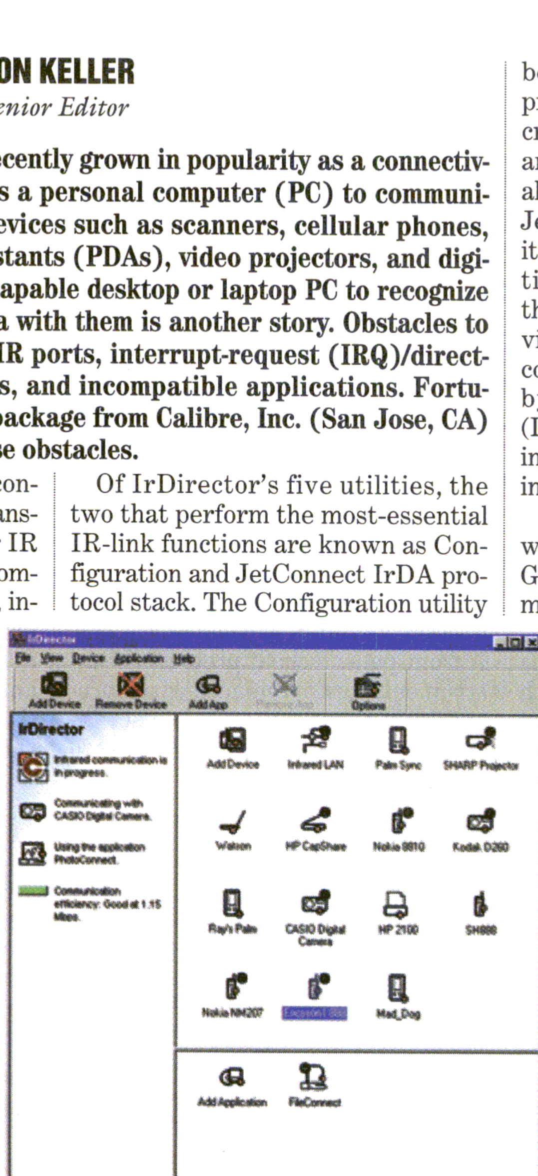
DON KELLER
Senior Editor

INFRARED (IR) links have recently grown in popularity as a connectivity method. An IR link allows a personal computer (PC) to communicate with other electronic devices such as scanners, cellular phones, pagers, personal digital assistants (PDAs), video projectors, and digital cameras. But getting an IR-capable desktop or laptop PC to recognize these devices and exchange data with them is another story. Obstacles to IR data links include disabled IR ports, interrupt-request (IRQ)/direct-memory-access (DMA) conflicts, and incompatible applications. Fortunately, the IrDirector software package from Calibre, Inc. (San Jose, CA) makes it easier to negotiate these obstacles.

IrDirector manages all of the connection, handshaking, and data-transfer functions that are required for IR communications. It configures a computer's IR port and solves driver, interrupt, and memory issues. It also allows a computer to sense the type of device it is linking to and automatically launches an application. For example, a PDA can be placed near a laptop computer for wireless transfer of e-mail from the computer to the PDA. In the presence of a digital camera, IrDirector can auto-launch an application that uploads images to the laptop computer.

IrDirector performs these feats through its utilities and optional applications that are available from Calibre and other software providers. The program offers a maximum of five utilities—four of them controlled by a graphical-user-interface (GUI) utility. Of the four GUI-controlled utilities, three are standard and one is optional.

Of IrDirector's five utilities, the two that perform the most-essential IR-link functions are known as Configuration and JetConnect IrDA protocol stack. The Configuration utility begins the installation procedure by presenting a user with a familiar Microsoft Windows-style "shield" shell and installation window. This utility also configures the PC's IR port. The JetConnect IrDA Protocol Stack utility contains a stack of IR-communication protocols—the core software that allows the PC and the linked device to communicate. These protocols conform to standards that are set up by the Infrared Data Association (IrDA). Upon installation, the utility inserts the IrDA-compliant protocols into the PC.



IrDirector's monitor and control GUI shows link status, available devices, and available applications.

The third utility that is included with IrDirector and controlled by the GUI is known as Place and Play Enumeration. This utility identifies IrDA-compliant devices and installs the required drivers. Based on the device identification obtained in the discovery phase of the IrDA protocol, it provides addresses to IrDirector's phone book. The phone book lists the supported devices, applications, and device drivers. It is available to the user through IrDirector's GUI. The Place and Play Enumeration utility also allows the user to launch applications automatically.

IrDirector's optional utility is known as SnoopIR. It audits connected devices to ensure that the appropriate protocol stack is in place. If it finds a device that uses non-IrDA protocols or a proprietary implementation of the IrDA protocols, it automatically switches to the required stack. This utility allows IrDirector to

RF Micro Devices Presents

Not so

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support a very wide selection of devices, including so-called "legacy" devices that were manufactured before the established IrDA standards.

IrDirector's GUI utility (see figure), known as Monitor and Control, shows the user a window that contains the status of the link, the devices that are currently available, and the available application programs. It also allows the user to set an application as the default for a particular device and launch it automatically. This feature is very convenient when using a single-function device such as a digital camera, or for activating applications that are frequently used with a device.

The manufacturers of IrDirector offer four Calibre Connect applications that can be used with IrDirector to perform device-specific tasks. FileConnect lets users transfer files of all types among portable appliances and PCs. PhotoConnect allows users to send and receive digital pictures between digital cameras, photo printers, scanners, and PCs. MobileConnect allows users to exchange electronic business cards, schedule information, and short messages between pagers and mobile handsets. And PrintConnect enables printing to an IR-capable printer.

For portable-device original-equipment manufacturers (OEMs) who would like to add IR capability to their hardware, Calibre manufactures a small, self-contained integrated-circuit (IC) transceiver that OEMs can build into their products. The CHX2000 employs two IR light-emitting diodes (LEDs)—one for transmission and one for reception. The entire package measures 9.8 × 4.0 × 4.84 mm. The transceiver is IrDA compatible and supports transmission rates to 4 Mb/s. It can be powered at voltages ranging from +2.7 to +5.25 VDC and draws only 2.5-mA current in the receive mode. In the transmit mode and depending on the distance of the link, its current requirement varies from 10 to 500 mA. **Calibre, Inc., 1762 Technology Dr., San Jose, CA 95110-1308; (408) 573-3890, FAX: (408) 573-3899, Internet: http://www.calibre-inc.com.**

CIRCLE NO. 61

Doublers Drive YIG Sources To 44 GHz

This series of low-phase-noise oscillators provides the spectral purity needed for high-capacity digital radios.

DON KELLER

Senior Editor

YTTRIUM-IRON-GARNET (YIG)-TUNED oscillators can be susceptible to microphonics and residual frequency modulation (FM) from shock and vibration. But a line of YIG-tuned oscillators from Micro Lambda, Inc. (Freemont, CA) achieves low phase noise with virtual immunity to microphonics and residual FM effects. By adding frequency doublers to these oscillators, the company has created an additional line of oscillators that covers frequencies to 44 GHz (see figure). The fundamental-frequency MLPW oscillators and the frequency-doubled MLPX oscillators are ideal for digital microwave radios using high-capacity modulation formats such as phase-shift keying (PSK), quadrature PSK (QPSK), and quadrature amplitude modulation (QAM). The MLPX line is also ideal for higher-frequency applications such as local multichannel distribution system (LMDS). In both product lines, the frequency range covered by each model is incorporated into its part number (see table). For example, model MLPX-2836 is a doubled YIG that operates from 28 to 36 GHz.

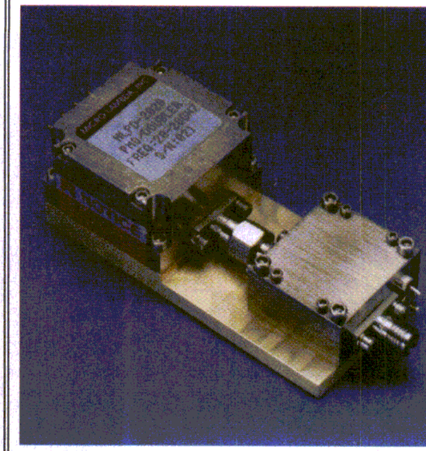
Most of the reduction in phase noise in these oscillators can be credited to the use of silicon (Si) bipolar transistors instead of gallium-arsenide field-effect transistors (GaAs FETs). Typical bipolar phase noise is approximately 8 to 12 dB lower than that of GaAs FET circuits. And although frequency doubling adds approximately 6 dB of phase noise, the MLPX models still enjoy 2 to 6 dB less phase noise than comparable fundamental GaAs FET oscillators.

The oscillators' extremely low susceptibility to microphonics and FM effects is due to the structure of the magnetic circuit and the materials used in it. A YIG-based oscillator is essentially a small YIG sphere placed in the air gap of a variable magnetic field. Any change in the gap size, which can be caused by vibration or temperature changes, can disrupt the stability of the magnetic field and create microphonics, phase hits, and FM effects. To overcome these effects, the MLPW and MLPX oscillators use proprietary magnetic materials in a magnetic structure that is miniaturized, ridged, and shock mounted. In addition, surface-mount components are used in the oscillators to minimize the effects of vibration and temperature changes.

The advantages of the design innovations employed in these oscillators are borne out in their specifications. In addition to low phase noise, the oscillators provide substantial output-power levels that remain relatively flat over their respective frequency ranges. As expected, specifications for phase noise, power output, and power flatness are best for oscillators operating at lower frequency ranges. Minimum spurious noise is –70 dBc for all models, and minimum third-harmonic distortion is –20 dBc for all

MLPW and MLPX YIG-based oscillators at a glance

Model	Frequency range (GHz)	Phase noise (dBc/Hz) 10-kHz offset	Phase noise (dBc/Hz) 100-kHz offset	Minimum power output (dBm)	Maximum power output variation (dB)
MLPW-0812	8 to 12	–98	–120	+13	±1.5
MLPW-1014	10 to 14	–85	–110	+13	±1.5
MLPW-1418	14 to 18	–85	–105	+13	±1.5
MLPW-1822	18 to 22	–80	–100	+10	±2.0
MLPX-1624	16 to 24	–92	–114	+10	±3.0
MLPX-2028	20 to 28	–79	–104	+8	±3.0
MLPX-2836	28 to 36	–79	–99	+8	±3.5
MLPX-3644	36 to 44	–74	–94	+8	±4.0



The MLPX models consist of a fundamental oscillator and a frequency doubler.

models. Minimum second-harmonic distortion is –12 dBc for all MLPW models and –20 dBc for all MLPX models. The tuning response (sensitivity) of the main coil is 14 MHz/mA for all MLPW models and 28 MHz/mA for all MLPX models. All of the models operate from a +12-VDC power supply at 100 mA, and all of them operate over a temperature range of –20 to +70°C. The MLPW models measure 1.25 × 1.25 × 0.75 in. (3.75 × 3.75 × 1.905 cm) while those with frequency doublers measure 2.84 × 1.25 × 1.0 in. (7.2136 × 3.75 × 2.54 cm).

The low-phase-noise characteristics of these oscillators makes them ideal for applications involving modern phase-based modulation formats, such as PSK and QPSK. And the integral frequency doubler used in the MLPX models is especially helpful to designers of high-frequency systems such as LMDS who might otherwise have to endure the rigors of matching a frequency doubler to a YIG oscillator. **Micro Lambda, Inc., 48041 Fremont Blvd., Fremont, CA 94538; (510) 770-9221, FAX: (510) 770-9213, Internet: http://www.micro-lambda.com.**

CIRCLE NO. 62

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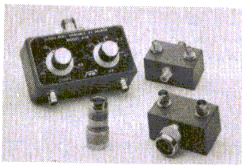

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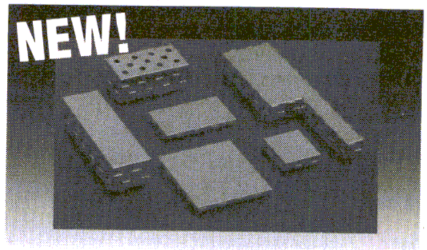

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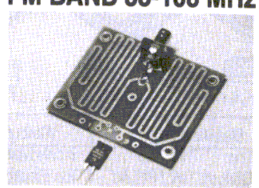

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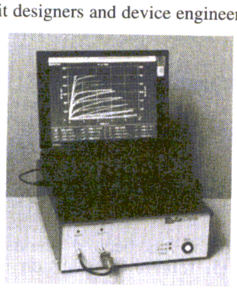

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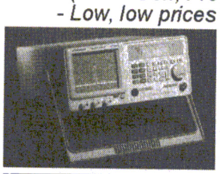

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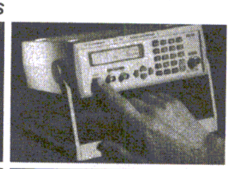

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Tuesday, Sept. 21, 12:30 p.m.

Electronic Design Continuing Education (EDCE) has instituted an ongoing educational program for design engineers and engineering managers. EDCE's 1999 Analog Workshop is the first in a series of events to help designers stay in tune with state-of-the-art and emerging technology approaches to problem solving.

This is your opportunity to meet, mix, and mingle with your peers and proven analog experts from your industry. Explore the inside track and hear why and how the experts make their design solution decisions. See for yourself how emerging technologies help deliver better products to market faster. Experience the excitement of learning from those who have found solutions to new and more complicated analog design technical problems. This is a not-to-be-missed workshop experience.

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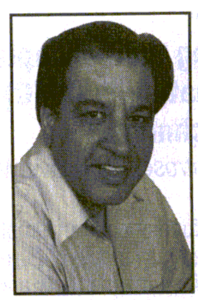

Ashok Bindra (left) will chair this important two-day Analog Workshop program. Ashok is *Electronic Design's* Analog, Power Supplies & DSP Editor, and has gained considerable experience organizing numerous technical conferences, workshops, panel discussions, and forums. His latest accomplisment was co-chairing the World Spring Design Conference in 1998.

Turn page for workshop information, schedules, and registration forms.

For workshop information, call Fred Sklenar at 201.393.6082

Analog Workshops at a glance

Tuesday, Sept. 21, 8:30 a.m. - 12:30 p.m.;
Room: Stevens Creek

1. Applying High-Speed Operational Amplifiers in Communication Systems

Instructor: Michael Steffes, Senior Strategic Engineer, Burr-Brown Corp.

Topics to be covered:

I. Relative merits of voltage-feedback and current-feedback type amplifiers: a.) Frequency response; b.) Noise and distortion; c.) External techniques to improve performance.

II. Amplifiers in wireless systems: a.) Receiver channel applications; b.) Transmit channel applications.

III. Amplifiers in wired systems: a.) DSL line interface options; b.) Cable modem requirements.

Tuesday, Sept. 21, 8:30 a.m. -12:30 p.m.; Room: Winchester

2. Designing Class D Amplifiers for Audio Systems

Instructor: Pat Begley, Senior Manager of Audio Programs, Harris Semiconductor

The workshop agenda includes an introduction and overview of amplifier techniques, switching amplifier approaches versus Class D, benefits of Class D in terms of efficiency, size and weight, future directions for audio, and demonstration of hi-fidelity Class D amplifier solutions.

Tuesday, Sept. 21, 1:30 p.m. - 5:00 p.m.;
Room: Stevens Creek

3. Understanding the Concepts of Electro-Magnetic Compatibility (EMC) and PCB Suppression Techniques

Instructor: Mark Montrose, Consultant, Montrose Compliance Services

Besides learning EMC fundamental and implementation techniques, this course will provide an overview of European EMC directives. It will discuss in a simplified manner how and why electro-magnetic interference (EMI) exists within a printed-circuit board (PCB) without the use of sophisticated math. It will disclose proper design and layout techniques to attain first-time compliance with International EMC requirements.

Tuesday, Sept. 21, 1:30 p.m. - 5:00 p.m.; Room: Winchester

4. Designing With High-Speed Data Converters

Instructor: Paul Hendriks, Senior Applications Engineer, High-Speed Data Converter Group, Analog Devices Inc.

Starting with an overview of analog-to-digital and digital-to-analog (ADC and DAC) architectures, this workshop will show how to drive high-speed high-resolution ADCs for direct IF sampling in a variety of applications, including digital receivers. Understanding DAC specifications also will be covered, as it simplifies the workings of direct digital synthesis. Optimizing DAC performance also will be discussed. Finally, this workshop will demonstrate the use of ADCs and DACs in high-speed communications systems.

Wednesday, Sept. 22, 8:30 a.m. - 12:30 p.m.;
Room: Stevens Creek

5. Performance Verification For High-Resolution Data Converters: Getting All The Bits You Paid For

Instructor: Jim Williams, Staff Scientist, Linear Technology

Instrumentation, waveform generation, data acquisition, feedback control systems and other applications are utilizing high-resolution ADCs and DACs. 16-,18-, and even 20-bit resolution measurements are becoming increasingly common. This lecture describes hardware-based methods for verifying high-resolution converter performance. In particular, settling time measurements of 16-bit DACs is covered. Additionally, techniques for testing ADC linearity beyond 20 bits are also presented.

Wednesday, Sept. 22, 8:30 a.m. - 12:30 p.m.;
Room: Winchester

6. Designing Switching Power Supplies

Instructor: Robert A. Mammano, Vice President of Advanced Technologies, Unitrode Corp.

This workshop will start with an introduction to switching techniques and topologies, and then go directly into practical topologies for off-line applications, DC/DC converters, and AC/DC converters. This discussion will also describe specialized topologies such as compound converter, resonant, and softswitching topologies. Additionally, it will focus on component considerations in the design of switch-mode power supplies, as well as magnetic fundamentals including inductor and transformer designs. Finally, the workshop will address myriad control issues and solutions, as it presents design examples to highlight the control methodology.

Wednesday, Sept. 22, 1:30 p.m. - 5:00 p.m.;
Room: Stevens Creek

7. Design Of AC/DC Motor Control Circuits

Instructor: Dal Y. Ohm, Principal Consultant, Drivetech Research

The pupose of this workshop is to provide basic concepts and technical skills necessary to design various types of AC and DC motor drives. Types of motors to be discussed will include brushed and brushless DC, stepper, reluctance, and induction motors, with special emphasis on low to medium power drives. Practical and useful procedures in selecting components and control methods, design rules, and performance versus cost tradeoffs will be discussed.

Wednesday, Sept. 22, 1:30 p.m. - 5:00 p.m.; Room: Winchester

8. Building the RF Front-End for a Software Radio

Instructor: Clive Winkler, Vice President, Engineering, Cubic Communications

There are powerful reasons for providing an analog RF downconverter prior to digitizing the signal for a software radio. Amongst them, dynamic range and the signal environment are a couple of the most important. We start with the need for dynamic range, phase noise and aperture jitter and derive the theoretical equations that relate them. Then we develop a clear perspective of the physical processes and requirements that need to be met for a modern software radio which is also able to cope with the high accuracy (amplitude and phase response) necessary for more advanced digital modualtions (high order m-ary PSK and QAM).

The newer evolving architecures for both the receive and transmit RF elements are considered along with ways of correcting for the amplitude and phase errors encountered in practical components.

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Advanced registration with payment must be postmarked or faxed by September 13, 1999. After September 13, please register on site.

STEP 1.

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Title ______________________

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STEP 2.

Workshop Selection(s):

Tues., Sept. 21

- ❑ 8:30 a.m. Workshop 1
- ❑ 8:30 a.m. Workshop 2
- ❑ 1:30 p.m. Workshop 3
- ❑ 1:30 p.m. Workshop 4

Wed., Sept. 22

- ❑ 8:30 a.m. Workshop 5
- ❑ 8:30 a.m. Workshop 6
- ❑ 1:30 p.m. Workshop 7
- ❑ 1:30 p.m. Workshop 8

❑ Yes, I will attend the Keynote Luncheon on Tuesday, September 21. (Complimentary for Workshop attendees.)

STEP 3.

Payment:

One Workshop Fee:
Advanced Registration: **$250**
On-site Registration: **$300**

Two Workshops Fee:
Advanced Registration: **$400**
On-site Registration: **$500**

Three Workshops Fee:
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Refund Policy:
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Please allow 6-8 weeks for refund to be processed.

Analog Workshop Schedule

TUESDAY, SEPTEMBER 21, 1999

	TIME	WORKSHOP DESCRIPTION	LOCATION
REGISTRATION	7:30 a.m. - 8:30 a.m.	Continental Breakfast	Outside Stevens Creek
WORKSHOP 1	8:30 a.m. - 10:15 a.m.	Applying High-Speed Amplifiers in Communication Systems	Stevens Creek
WORKSHOP 2	8:30 a.m. - 10:15 a.m.	Designing Class D Amplifiers for Audio Systems	Winchester
BREAK	10:15 a.m. - 10:30 a.m.	Refreshments	In rooms
WORKSHOP 1	10:30 a.m. - 12:30 p.m.	(Continued)	Stevens Creek
WORKSHOP 2	10:30 a.m. - 12:30 p.m.	(Continued)	Winchester
LUNCHEON	12:30 p.m. - 1:30 p.m.	Keynote Speaker, Bob Dobkin	
WORKSHOP 3	1:30 p.m. - 3:15 p.m.	Understanding concepts of EMC and Suppression Techniques	Stevens Creek
WORKSHOP 4	1:30 p.m. - 3:15 p.m.	Designing with High-Speed Data Converters	Winchester
BREAK	3:15 p.m. - 3:30 p.m.	Refreshments	In rooms
WORKSHOP 3	3:30 p.m. - 5:00 p.m.	(Continued)	Stevens Creek
WORKSHOP 4	3:30 p.m. - 5:00 p.m.	(Continued)	Winchester

WEDNESDAY, SEPTEMBER 22, 1999

	TIME	WORKSHOP DESCRIPTION	LOCATION
REGISTRATION	7:30 a.m. - 8:30 a.m.	Continental Breakfast	Outside Stevens Creek
WORKSHOP 5	8:30 a.m. - 10:15 a.m.	Performance Verification for High-Resolution Data Converters	Stevens Creek
WORKSHOP 6	8:30 a.m. - 10:15 a.m.	Designing Efficient Switching Power Stations	Winchester
BREAK	10:15 a.m. - 10:30 a.m.	Refreshments	In rooms
WORKSHOP 5	10:30 a.m. - 12:30 p.m.	(Continued)	Stevens Creek
WORKSHOP 6	10:30 a.m. - 12:30 p.m.	(Continued)	Winchester
LUNCH	12:30 p.m. - 1:30 p.m.		Mezzanine
WORKSHOP 7	1:30 p.m. - 3:15 p.m.	Design of AC/DC Motor Control Circuits	Stevens Creek
WORKSHOP 8	1:30 p.m. - 3:15 p.m.	Building the RF Front-End for a Software Radio	Winchester
BREAK	3:15 p.m. - 3:30 p.m.	Refreshments	In rooms
WORKSHOP 7	3:30 p.m. - 5:00 p.m.	(Continued)	Stevens Creek
WORKSHOP 8	3:30 p.m. - 5:00 p.m.	(Continued)	Winchester

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CIRCLE NO. 67

Radiation badge covers 1 to 40 GHz

Model 60A RF/microwave radiation monitor is designed to be worn as a badge by personnel who may be exposed to potentially hazardous levels of non-ionizing RF and microwave radiation. It monitors the frequency range of 1 to 18 GHz, with optional coverage to 40 GHz, and provides real-time power-density information (mW/cm^2) via its liquid-crystal display (LCD). The device has two measurement modes, instantaneous and six-minute averaging, and provides a user-adjustable alarm-level setting from 0.2 to 20 mW/cm^2. The LCD contains a bar graph that displays the current power-density level as a percentage of the alarm-level setting. The badge contains an audio alarm that activates in conjunction with the visual alarm when the alarm level is exceeded, and the frequency of the alarms increase with increasing exposure levels. The badge measures 3.7 × 2.75 × 1.1 in. (9.398 × 6.985 × 2.794 cm) and weighs 5 oz. Standard accessories include a carrying case and an earphone for high-noise environments. **General Microwave Corp., 5500 New Horizons Blvd., Amityville, NY 11701; (516) 226-8900, Internet: http://www.generalmicrowave.com.**

CIRCLE NO. 68

Surface-mount oscillators span 70 to 125 MHz

Models EC1700 and EC1800 plastic, surface-mount oscillators operate from 70 to 125 MHz and are designed for applications such as Gigabit Ethernet and Fiber Channel. The EC1700 is a +5-VDC device and the EC1800 is a +3.3-VDC version for low-voltage applications. The oscillators are available with a stability of ±25, ±50, or ±100 PPM, and a duty-cycle tolerance of ±10 or ±5 percent. They are also available in one of two operating-temperature ranges—0°C to +70°C, or –40°C to +85°C. The plastic package measures 10.2 × 13.2 × 6.7 mm, which is comparable to the plastic SG-615 package. **Ecliptek Corp., 3545 Cadillac Ave., Costa Mesa, CA 92626; (714) 433-1200, FAX: (714) 433-1234, e-mail: sales@eciptek.com, Internet: http://www.ecliptek.com.**

CIRCLE NO. 69

Quadrature coupler blends high-power transmitters

The model 12A2ND-3N quadrature coupler can be used for coherent or non-coherent combining of two high-power transmitters up to an average power level of 100 W from 890 to 960 MHz. The coupler exacts a loss of less than 0.2 dB and provides more than 25 dB of isolation. Its modular construction enables users to cascade them to form four-way and eight-way combiners, and its bi-directional design allows it to be used as a high-power divider. **Renaissance Electronics Corp., 1300 Mass Ave., Boxborough, MA 01719; (978) 263-4994, FAX: (978) 263-4944, e-mail: rec-info@rec-usa.com, Internet: http://www.rec-usa.com.**

CIRCLE NO. 70

High-power terminations handle 60 W

The RFP-60-50 TP/TPC/TPR series half-flanged 50-Ω terminations operate from DC to 6 GHz at power levels to 60 W. These terminations provide a VSWR of 1.1:1 from DC to 2 GHz, 1.2:1 from 2 to 4 GHz, and 1.25:1 from 4 to 6 GHz. Designed to meet or exceed applicable portions of MIL-E-5400 and MIL-R-55342, this series of terminations is constructed using a proprietary thick-film substrate with welded leads for soldering directly to a printed-circuit board (PCB). The leads measure 0.05 in. (0.127 cm) wide and at least 0.15 in. (0.381 cm) long. In the TP model, the leads are oriented from the left; in the TPC model, bottom; and in the TPR model, right. **RF Power Components, Inc., 125 Wilbur Pl., Bohemia, NY 11716-2482; (877) RFPCINC, (516) 563-5050, FAX: (516) 563-4747, Internet: http://www.rf-power.com.**

CIRCLE NO. 71

ADC converts at 1 GSamples/s

The MAX104 is an 8-b, monolithic, bipolar, analog-to-digital converter (ADC) with a digitizing rate of 1 GSamples/s. It achieves a signal-to-noise ratio after distortion (SINAD) of 47 dB and a spurious-free dynamic range (SFDR) of 52 dB at 500 MHz. It maintains these levels within 1 dB to 1 GHz. The ADC's fully differential input track/hold (T/H) typically achieves integral nonlinearity (INL) and differential nonlinearity (DNL) of less than ±0.25 least-significant bit (LSB), a full-power bandwidth of 2.2 GHz, and less than 0.5 ps aperture jitter. **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (800) 998-8800, Internet: http://www.maxim-ic.com.**

CIRCLE NO. 72

Frequency synthesizer generates 13.2 GHz

Model NXPLOS-1001-01 frequency synthesizer uses a reference frequency of 100 MHz to generate an output frequency of 13.2 GHz. At a reference power of +13 dBm ±3 dB, the synthesizer maintains output power at +12 to +15 dBm ±1 dB at temperatures from –20 to +65°C. It suppresses harmonics to better than –20 dBc and spurious emanations to better than –60 dBc. Phase noise is –95 dBc/Hz at 1-kHz offset, –110 dBc/Hz at 10-kHz offset, and –115 dBc/Hz at 100-kHz offset. **Nexyn Corp., 678 Bend Dr., Sunnyvale, CA 94087; (408) 732-0793, FAX: (408) 730-0378, Internet: http://www.nexyn.com.**

CIRCLE NO. 73

RF amps feature small package

The models UPC2747TB, UPC-2748TB, and UPC2749TB are +3-VDC RF amplifiers housed in packages measuring just 2 × 1.25 × 0.9 mm. The UPC2747TB amplifier delivers 12-dB gain with a noise figure of 3.3 dB at 900 MHz. It features low current (5 mA) and low power (15 mW) consumption to help conserve battery power in portable receivers. The UPC2748TB amplifier has a gain of 19 dB and a noise figure of 2.8 dB at 900 MHz. It also features low current (6 mA) and low power (18 mW) consumption. The UPC2749TB features wideband (900-to-1900-MHz) operation, delivering 16 dB of gain with a noise figure of 4 dB at 1900 MHz. Like its brethren, it has low current and power consumption for portable applications. **California Eastern Laboratories, 4590 Patrick Henry Dr., P.O. Box 54964, Santa Clara, CA 95054-1817; (408) 988-3500, FAX: (408) 988-0279, Internet: http://www.cel.com.**

CIRCLE NO. 74

Direct I/Q modulator operates to 2.5 GHz

Model AD8346 direct quadrature modulator performs direct RF in-phase/quadrature (I/Q) modulation from 800 to 2500 MHz. It is intended for use in digital transmitters covering the major cellular and industrial-scientific-medical (ISM) bands. For transmitter designers, the modulator eliminates the need for a separate intermediate-frequency (IF) stage, thereby saving design time, cost, and board area. It operates over a temperature range of –40 to +85°C, and a power-supply voltage range of +2.7 to +5.5 VDC. **Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062; (781) 329-4700, FAX: (781) 326-8703, Internet: http://www.analog.com.**

CIRCLE NO. 75

Power amps support C-band applications

Models ITT6401FM, ITT8401FM, and ITT8402FM GaAs field-effect-transistor (FET) power amplifiers (PAs) operate at C-band frequencies, and are suited for very small-aperture terminal (VSAT) and industrial-scientific-medical (ISM) applications. The ITT6401FM operates from 4.5 to 7.1 GHz and has typical linear output power of +33 dBm at 1-dB compression. It has linear gain of 18 dB and a power-added efficiency (PAE) of 40 percent. The ITT8401FM operates from 6.0 to 9.0 GHz and has typical linear output power of +35 dBm at 1-dB compression. Its linear gain is 20 dB and its PAE is 25 percent. The ITT8402FM operates from 6.0 to 7.6 GHz and has typical linear output power of +36.5 dBm at 1-dB compression. Its linear gain is 20 dB and its PAE is 25 percent. All three of the devices are supplied in flange-mount ceramic packages. **GaAsTEK, 5310 Valley Park Dr., Roanoke, VA 24019; (540) 563-8665, FAX: (540) 563-8616, Internet: http://www.gaastek.com.**

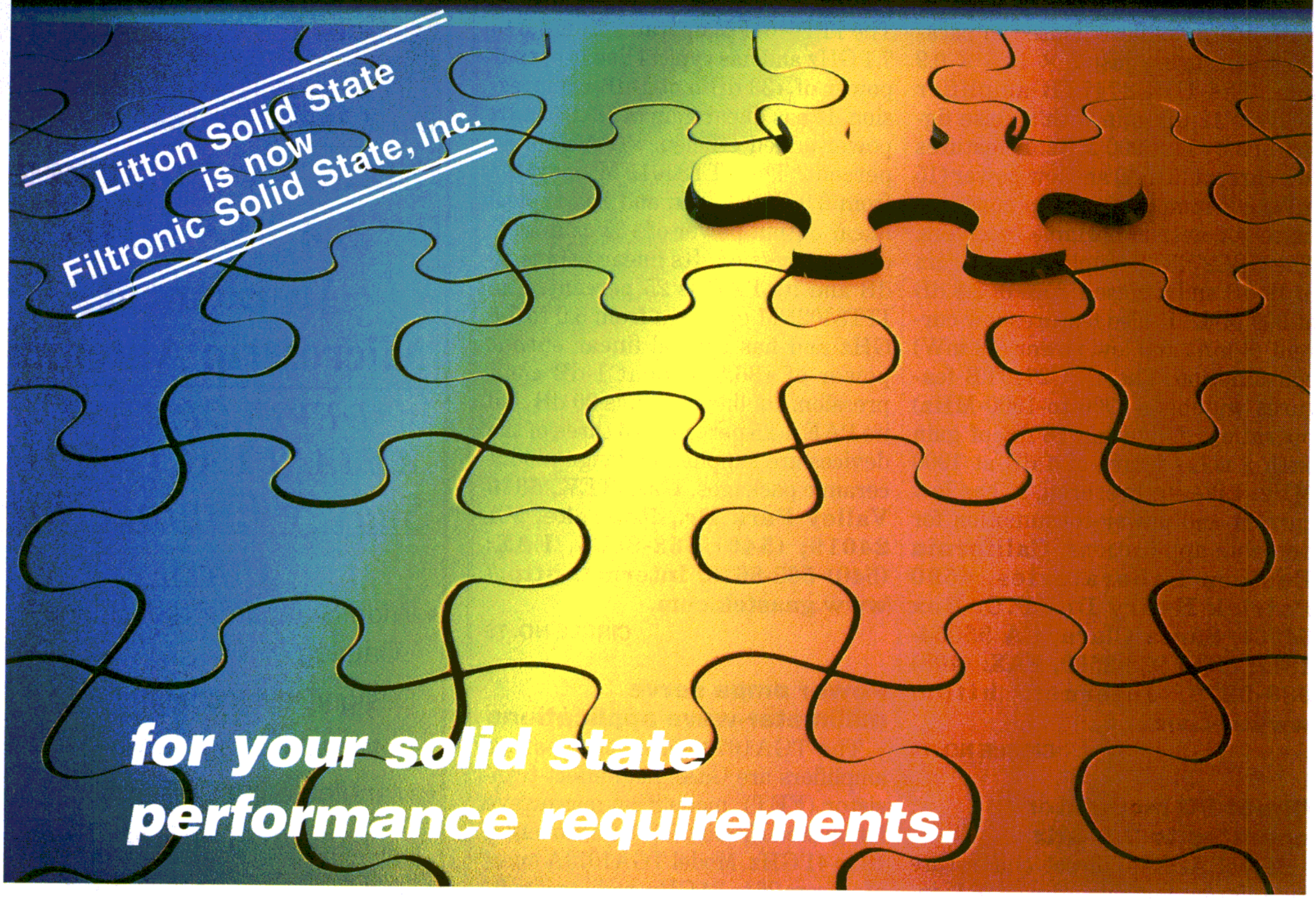
CIRCLE NO. 76

Power amps serve millimeter-wave applications

The TGA1073-series three-stage amplifiers are GaAs field-effect-transistor (FET), monolithic microwave integrated circuits (MMICs) covering 19 to 41 GHz. Model TGA1073A operates from 26 to 34 GHz, making it suitable for both terrestrial digital radio and Ka-band satellite-communication (satcom) applications. It provides 300-mW output power and 19-dB small-signal gain. Model TGA1073B operates from 27 to 32 GHz with output power of 700 mW and small-signal gain of 25 dB. It is suitable for those terrestrial and satcom applications requiring higher power than that available from the TGA1073A. The TGA1073C amplifier addresses a higher frequency range (37 to 41 GHz), and is particularly appropriate for both point-to-point and point-to-multipoint wireless data systems at 38 GHz. It delivers 400-mW output power while offering 16-dB small-signal gain. **TriQuint Semiconductor, 13510 North Central Expressway, Dallas, TX 75243; (972) 994-8575, FAX: (972) 994-8504, Internet: http://www.triquint.com.**

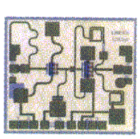
CIRCLE NO. 77

We have *All* the pieces



PHEMT MMICs

Filtronic now has a full offering of low noise and medium power MMICs for your mmW Short Haul Radio, Ka Band SATCOM, and LMDS applications. These MMICs are offered in die or package form. Consult the factory for options.



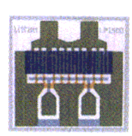
Applications:

- **LMDS/LMCS**
- **18, 23, 26, and 38GHz Short Haul Radio**
- **Ka Band Satellite/Hi-Rel**
- **VSAT**

PHEMT FETs

Filtronic has completed the puzzle with a full offering of FETs including low noise, general gain block, high linearity and power (5W) devices. Low cost PHEMTs can now be purchased in die or package form to meet your high performance requirements.

Applications:

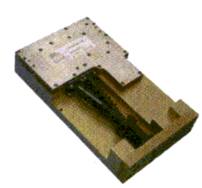


- PNC/PCS
- LMDS/LMCS
- MMDS
- SATCOM
- mmW Short Haul Radio
- Ka Band Satellite/Hi-Rel
- VSAT

TRANSCEIVERS

At the other end of the spectrum, Litton offers the complete solution in microwave and millimeter wave transceivers for Short and Medium Haul Radios. PHEMT MMIC technology offers the best performance at an affordable price.

Applications:



- PNC/PCS
- LMDS/LMCS
- MMDS
- SATCOM
- mmW Short Haul Radio
- Ka Band Satellite/Hi-Rel
- VSAT

Visit our website, http://www.FiltronicSolidState.com

FILTRONIC SOLID STATE

3251 Olcott St., Santa Clara, CA 95054-3095 / Phone (408) 988-1845 / FAX (408) 970-9950

Amplifier offers extreme bandwidth

The model VTL5400 RF/microwave amplifier operates over an extremely wide frequency range of 10 to 2500 MHz. It has gain of 38 dB, power output of 3 W at 1-dB compression, and a noise figure of 6 dB across its entire bandwidth. The amplifier offers harmonic performance of –30 dBc at its rated power, and a third-order intercept point (IP3) of +48 dBm. The VLT5400 operates from a +12-VDC power supply, but will operate down to +7 VDC with reduced performance. It can be applied to portable, multiband communications systems or as a high-level driver for high-speed analog or digital signals. **Vectawave Technologies Ltd., 2 Winston Close, Ryde, Isle of Wight PO33 3QF, United Kingdom; +44 (0) 1983 616804, FAX: +44 (0) 1983 812963, e-mail: sales@vectawave.co.uk, Internet: http://www.vectawave.com.**

CIRCLE NO. 78

Crystal supports portable application

The model VFC232 ultra-miniature ceramic crystal measures only 6 × 3.5 × 1 mm and is targeted for applications in PCMCIA cards, portable electronics, personal communications services (PCS), and wireless communications. The crystal can be supplied for frequencies from 11 to 150 MHz with stability of ±50 PPM. Its frequency tolerance is ±10 PPM at 25°C, and it ages at a rate of +5 PPM per year. The crystal is designed for operating temperatures from –10 to +60°C. **ValpeyFisher Corp., 75 South St., Hopkinton, MA 01748; (508) 435-6831, FAX: (508) 497-6377, Internet: http://www.valpeyfisher.com.**

CIRCLE NO. 79

GaAs FET power amps cover 6 to 18 GHz

The AMP/180-series GaAs field-effect-transistor (FET) power amplifiers (PAs) cover the 6-to-18-GHz frequency range with minimum gain of 40 dB and a maximum gain flatness of ±2.5 dB. The amplifiers have maximum noise figure of 8 dB and maximum VSWR of 2:1. Model AMP/180-3640 has power output of 4 W, minimum output power of +36 dBm at 1-dB compression, and typically draws 7.6 A from a +12-VDC power supply. Model AMP/180-3840 offers a power output of 8 W, minimum output power of +38 dBm at 1-dB compression, and typically draws 12 A from a +12-VDC power supply. **CTT, Inc., 3005 Democracy Way, Santa Clara, CA 95054; (408) 988-8521, FAX: (408) 986-9097, Internet: http://www.cttinc.com.**

CIRCLE NO. 80

Amp serves noninvasive physiologic EPRI

The model 1000W1000A is a high-power RF amplifier for use in noninvasive, physiologic, electron paramagnetic-resonance imaging (EPRI). The amplifier offers class-A operation and 1000-W minimum power over a frequency range of 80 to 1000 MHz. It can achieve any pulse width and duty cycle to 100 percent. Other W-series amplifiers are available for testing smaller or larger objects. **Amplifier Research, 160 School House Rd., Souderton, PA 18964-2400; (800) 933-8181, (215) 723-8181, FAX: (215) 723-5688, e-mail: info@ar-amps.com, Internet: http://www.ar-amps.com.**

CIRCLE NO. 81

Drop-in isolators provide low insertion loss

Models 0380IED and 0270IAD drop-in isolators exhibit insertion loss of 0.5 dB and VSWR of 1.25:1 over their respective bandwidths. Model 0380IED operates from 3.4 to 4.2 GHz and provides 20-dB isolation. It handles operating temperatures from –20 to +85°C, and can be stored at temperatures between –50 and +125°C. Its package size is 0.75 × 0.75 × 0.25 in. (1.905 × 1.905 × 0.635 cm). Model 0270IAD operates from 2.5 to 2.9 GHz and provides 22-dB isolation. It operates from –20 to +85°C, and can be stored between –50 and +115°C. **Nova Microwave, 380 Tennant Ave., Morgan Hill, CA 95037; (408) 778-2746, FAX: (408) 779-5967, e-mail: novamic@ msn.com, Internet: http://www.novamicro.com.**

CIRCLE NO. 82

Power dividers channel Ku-band

The A8338-series power dividers operate from 10.7 to 14.5 GHz, thereby covering the uplink and downlink frequencies of Ku-band communication satellites. The series consists of three dividers—a two-way, a four-way, and an eight-way version. All three versions have VSWR of 1.25:1, amplitude balance of 0.2 dB, and phase balance of 3 deg. per split. The dividers provide isolation typically greater than 20 dB and can handle a maximum of 30-W input power. They can also be used as signal combiners. They are designed for operating temperatures from –55 to +100°C and relative humidity to 95 percent. Each of the three models has stainless-steel SMA connectors and is housed in an aluminum (Al)-alloy package. The two-way is 1 × 1 in. (2.54 × 2.54 cm) and the eight-way is 4 × 3 in. (10.16 × 7.62 cm). All three are 0.5 in. (1.27 cm) thick. **Atlantic Microwave Ltd., 40A Springwood Dr., Braintree, Essex CM7 2YN, United Kingdom; 01376 550220, FAX: 01376 552145, e-mail: sales@atlanticmicrowave.co.uk, Internet: http://www.atlanticmicrowave.com.**

CIRCLE NO. 83

Software aids wireless site planning

The Site Planner software package is a computer-aided RF planning tool for all phases of in-building or campus-wide wireless site design. It handles all wireless standards and all modulation frameworks, including digital cellular, personal-communications-services (PCS), wireless private-branch-exchange (PBX), and wireless local-area-network (WLAN) systems. The software aids in relocating antennas and distributed/leaky feedline systems, analyzing the impact of directional antennas, determining channel sets, determining noise figures, and performing link-budget calculations. It presents all measured and predicted data, as well as optimized coverage models, equipment lists, and bill-of-material pricing tables in an open-spreadsheet format. The program works on any personal computer (PC) running Windows 95, Windows 98, or Windows NT. **Wireless Valley Communications, Inc., 104 Hubbard St., P.O. Box 10727, Blacksburg, VA 24062; (540) 552-8300, FAX: (540) 552-8324, Internet: http://www.wvcomm.com.**

CIRCLE NO. 84

Software models packaging costs

The EPCostModel software is a cost-modeling tool specifically tailored to the electronics-packaging community. The program helps manufacturing engineers and operations managers consider packaging-cost complexities such as different manufacturing facilities, varying delivery rates, labor inflation, learning curves, reworks, equipment and floor-space requirements, and building- and land-investment costs. It allows the user to alter operation sequences and add or delete inspection steps to determine their effects on manufacturing costs, and it ranks significant cost drivers to help identify potential savings. The program works on any personal computer (PC) running Windows 95, Windows 98, or Windows NT. **Relative Metrics, Inc., 5908 Westslope Dr., Austin, TX 78731; (512) 458-5560, FAX: (512) 458-5560, e-mail: info@relmet.com, Internet: http://www.relmet.com.**

CIRCLE NO. 85

Diplexers serve mobile communications

The LTF3216D-F series diplexers are ceramic-chip, dual-band frequency separators for mobile-communication systems such as Advanced Mobile Phone Service (AMPS), personal communications services (PCS), Global System for Mobile Communication (GSM), distributed communications systems (DCS), personal digital cellular (PDC), and Personal HandyPhone System (PHS). The diplexers, available in a carrier-frequency range of 800 to 2000 MHz, separate frequency bands downstream of the antenna for optimal flexibility in dual-band RF cellular design. They have insertion loss of less than 0.5 dB and average minimum attenuation of 20 dB in either the high or low band. The chips measure 3.2 × 1.6 × 1.0 mm. **Toko America, Inc., 1250 Feehanville Dr., Mt. Prospect, IL 60056; (847) 297-0070, FAX: (847) 699-1194, e-mail: info@tokoam.com, Internet: http://www.tokoam.com.**

CIRCLE NO. 86

Indoor antennas link wireless systems

The I-800M3G-series indoor antennas operates across the 0.8-to-3.0-GHz frequency range and can be used in single or multiband wireless-communication systems such as Advanced Mobile Phone Service (AMPS), Global System for Mobile Communications (GSM), personal communications services (PCS), etc. The antennas can handle multiple systems simultaneously, and their broad instantaneous bandwidth prevents them from becoming detuned by mounting structures or other interfering objects. Models are available with circular or linear polarization, as well as with omnidirectional or unidirectional pattern coverage. **Wang Electro-Opto Corp., 1335 Capital Circle, Marietta, GA 30067; (770) 955-9311, FAX: (770) 984-9045, Internet: http://www.weo.com.**

CIRCLE NO. 87

Low-IMD diplexers screen PCS and DCS signals

Models W1805D and 1856D miniature diplexers boast very low intermodulation distortion (IMD). Two standard +40-dBm signals yield IMD of less than –130 dBm. The diplexers present less than 1.2-dB insertion loss, return loss of better than –16 dB, and can handle more than 50-W input power. Model W1805D covers the personal-communications-services (PCS) band and provides receive/transmit isolation of more than 90 dB. The model W1805D measures 2 × 2 × 9 in. (5.08 × 5.08 × 22.86 cm). Model W1856 covers the Global System for Mobile Communications (GSM) band and provides receive/transmit (Rx/Tx) isolation of more than 95 dB. It measures 2 × 2 × 10 in. (5.08 × 5.08 × 25.4 cm). **Wireless Technologies Corp., 4000 Haile Lane, Springdale, AR 72762; (501) 750-1046, FAX: (501) 750-4657, Internet: http://www.diplexers.com.**

CIRCLE NO. 88

Inductors offer 11 inductance values

Available in 11 inductance values from 1 to 47 μH, the LPT3305 series of power-wafer inductors is designed for handheld electronic devices, type 1 personal-computer (PC) cards, disk drives, and other low-profile power applications. With saturation current ratings ranging up to 6 A, root-mean-square (RMS) current ratings can reach 1.6 A. The series is in a ceramic case that measures 1.8 mm in height with a 0.35 × 0.40-in. (8.9 × 10.2-mm) footprint. P&A: $0.50 to $0.93 (10,000 qty.); stock. **Coilcraft, 1102 Silver Lake Rd., Cary, IL 60013; (847) 639-6400, FAX: (847) 639-1469, e-mail: info@coilcraft.com., Internet: http://www.coilcraft.com.**

CIRCLE NO. 89

DROs span 12 to 16 GHz

A line of local-multichannel-distribution-system (LMDS) phase-locked dielectric resonator oscillators (DROs) offers 100-to-200-MHz external reference, a frequency range of 12 to 16 GHz, and a power output of +13 dBm. The DROs also span the –10 to +65°C range with –20-dBc harmonics. They also provide +12 VDC at 160-mA current. **Nexyn Corp., 678 Bend Dr., Sunnyvale, CA 94087; (408) 732-0793, FAX: (408) 730-0378, Internet: http://www.nexyn.com.**

CIRCLE NO. 90

Tuner covers fundamental and harmonic bands

The model CCMT-5010-2H programmable combo tuner covers a fundamental frequency band from 10 to 50 GHz and a harmonic band from 20 to 60 GHz. Proprietary software enables both parts of the tuner to be calibrated independently, measuring $N_1 + N_2$ points instead of $N_1 \times N_2$, thereby accelerating the process to between one and three minutes per frequency. In load-pull measurements, T_{f0} and T_{2f0} can be tuned independently and optimized for measuring power, efficiency, etc. **Focus Microwaves, Inc., 970 Montee de Liesse, Suite 308, Quebec, Canada H4T-1W7; (514) 335-6227, FAX: (514) 335-6287, e-mail: focusmw@compuserve.com, Internet: http://www.focus-microwaves.com.**

CIRCLE NO. 91

Data generator reaches 1.1 Gb/s

The model DG2040 is a high-speed, dual-channel, 1.1 Gb/s data generator that is suitable for serial signal simulation. This logic source supplies high-speed data or clock stimulus for designing, characterizing, as well as verifying high-speed semiconductors and digital logic circuits. It offers an edge-control feature that modulates all or specific pattern edges, simulating the jitter and wander that is likely to occur in real operating conditions. At the system level, edge control can be used to evaluate the amount of margin in the circuit under test. The generator tests precise timing margins to 500 MHz and jitter to ±100 ps. It features a 256-kb pattern memory and an easy-to-use graphical user interface (GUI). The DG2040 includes DG-Link, a PC-based software translator that simplifies ASCII-format vector imported from other instruments or logic-simulation software. **Tektronix Measurement Group, P.O. Box 3960, Portland OR 97208-3960; (800) 426-2200, FAX: (503) 222-1542, Internet: http://www.tek.com.**

CIRCLE NO. 92

Modules supplement engineering software

Octave and Rainflow are two new add-on modules for the DADiSP digital-signal-processing (DSP) engineering spreadsheet. The DADiSP/Octave module performs octave and 1/3-octave analysis, which is widely used in military and commercial applications to measure and analyze the frequency spectra of sonar, audio, vibration, seismic, and other signals. It contains a variety of octave algorithms, including octave filter-bank implementation, 1/3-octave filter-bank implementation, A and C filter weighting and design, and extended octave ranges. The DADiSP/Rainflow module performs rainflow and cycle-counting analysis, which is widely used in the automotive and aerospace industries to perform fatigue analysis. It contains a number of cycle-counting procedures, including level crossing, peak, simple range, and rainflow. **DSP Development Corp., One Kendall Square, Cambridge, MA 02139; (617) 577-1133, FAX: (617) 577-8211, e-mail: dspdev@world.std.com, Internet: http://www.dadisp.com.**

CIRCLE NO. 93

Dual four-stage filter targets 0.5 to 18 GHz

The model M1851 yttrium-iron-garnet (YIG) dual four-stage bandpass filter covers 0.5 to 18 GHz with typical insertion loss of 3.5 dB. The 3-dB bandwidth varies from 25 to 35 MHz, and each channel offers a rejection bandwidth of ±70 MHz at –90 dBc. The filter can be integrated with an analog driver (0 to 10 VDC) or a 12-b digital driver to tune it from 8 to 12 GHz. Its tuning sensitivity is typically 18 MHz/mA. The filter's operating temperature ranges from –55°C to +85°C, and it measures 1.7 × 1.7 × 1.7 in. (4.38 × 4.38 × 4.38 cm). **OMNIYIG, Inc., 3350 Scott Blvd., Bldg. #66, Santa Clara, CA 95054-3125; (408) 988-0843, FAX: (408) 727-1373, e-mail: omniyig@ix.net com.com, Internet: http://www.omniyig.com.**

CIRCLE NO. 94

Bandpass filter screens LMDS

The model CEC-1676 28.265-GHz bandpass filter is designed to be used in systems serving the local-multi-channel-distribution-system (LMDS) band. The filter passes frequencies from 28.160 to 28.370 GHz and provides 50-dB rejection at ±1.350 GHz from the passband. It features an insertion loss of less than 1.5 dB (1 dB typical), and offers a return loss that is greater than 20 dB. The filter can handle power levels to 25 W (peak), and comes with CPR28 EIA flange connectors. Optional notches can be added in order to enhance band-edge rejection. **Communications & Energy Corp., 7935 Taft Park Dr., East Syracuse, NY 13057; (800) 882-1587, (315) 452-0760, FAX: (315) 452-0732.**

CIRCLE NO. 95

Film resistors

A line of foil and film resistors is described in a 12-page catalog. More than 35 power and precision resistors and networks are featured that use advanced metal-foil, metal-film, and thick-film elements. The products include low-ohm foil resistors for current sensing and shunt applications, as well as high-power foil and film resistors with dissipation ratings to 2000 W. **Riedon, Inc.;** *(626) 284-9901, FAX: (626) 284-1704, Internet: http://www.riedon.com.*

CIRCLE NO. 96

Crystal oscillators

A 20-page catalog describes oven-controlled crystal oscillators (OCXOs), temperature-controlled crystal oscillators (TCXOs), and voltage-controlled crystal oscillators (VCXOs). Specifications include frequency range, output, and warm-up time. Outline drawings are provided. **MTI-Milliren Technologies, Inc.;** *(978) 465-6064, FAX: (978) 465-6637, Internet: http://www.mti-milliren.com.*

CIRCLE NO. 97

SDH networks

An application note describes ITU-T recommendations and their practical applications in piesiochronous-digital-hierarchy (PDH)/synchronous-digital-hierarchy (SDH) networks. SDH equipment functional blocks, jitter and wander requirements, performance limits, and protection techniques are featured. The application note suits engineers and technicians working for network operators and network equipment manufacturers. **Wandel & Goltermann GmbH & Co.;** *+49 7121 86-1616, +49 7121 86-1333, e-mail: info@wago.de, Internet: http://www.wg.com.*

CIRCLE NO. 98

High-power amplifiers

A four-page brochure features a series of microprocessor-controlled high-power amplifiers. The amplifiers cover the frequency range of 500 kHz to 2.5 GHz in discrete bands and are available in 10-, 100-, 500-, 1000-, and 10,000-W power-output levels. Specifications include RF input, input overdrive, spurious output, efficiency, and AC input. Application information is provided. **Communication Power Corp.;** *(516) 434-7306, FAX: (516) 434-7026, e-mail: commpower@erols.com, Internet: http://www.cpcamps.com.*

CIRCLE NO. 99

Surface-mount devices

Crystals, quartz-crystal oscillators, temperature-compensated crystal oscillators (TCXOs) with high-performance complementary metal-oxide semiconductor (HCMOS) and sine-wave outputs, monolithic crystal filters, helical filters, and surface-acoustic-wave (SAW) filters are outlined in an eight-page short-form catalog. Voltage-controlled oscillators (VCOs) and chip inductors are highlighted. Frequency-range information and mechanical specifications are provided. **Frequency Products Ltd.;** *01460 57166, 07000 QUARTZ, FAX: 01460 57777, 07000 4 QUARTZ, e-mail: sales@frequencyproducts.com.*

CIRCLE NO. 100

Broadband noise

A 50-page catalog covers noise-figure measurement devices, noise generators, and components. A tutorial on noise basics is offered. Specifications and application notes are included. **Noise Com, Inc.;** *(201) 261-8797, FAX: (201) 261-8339, e-mail: info@noisecom.com, Internet: http://www.noisecom.com.*

CIRCLE NO. 101

Amplifiers/analyzers

Amplifiers, analyzers, calibration equipment, component testers, data-acquisition (DAQ) equipment, and electronic counters are listed in a 16-page catalog. Meters, oscilloscopes, power supplies, plotters, printers, RF/microwave equipment, and signal generators are provided. **Pacific Test Equipment Corp.;** *(408) 441-7341, FAX: (408) 441-8049, Internet: http://www.pacifictest.com.*

CIRCLE NO. 102

Magnetic shielding

A brochure focuses on magnetic shielding. Information on lab kits, magnetic pickup probe, and what one needs to know for building a prototype shield is offered. Shape of the shield, flux density, saturation, attenuation, and RF shielding are also presented. **Magnetic Shield Corp.;** *(630) 766-7800, FAX: (630) 766-2813, e-mail: admin@magnetic-shield.com, Internet: http://www.magnetic-shield.com.*

CIRCLE NO. 103

Millimeter-wave mixer

Millimeter-wave mixer products are presented in a 64-page catalog. Double-sideband and sampling mixers, as well as low-noise-amplifier (LNA)/image-rejection downconverter and block-converter assemblies are detailed. Data sheets provide electrical characteristics, typical data, outline drawings, and a question-and-answer section. A product index is also included. **MITEQ, Inc.;** *(516) 436-7400, FAX: (516) 436-7430.*

CIRCLE NO. 104

RF solutions

A short-form catalog offers products intended to provide solutions for RF, automotive, and satellite communications. The catalog includes applications and product information for cellular, corded, and cordless phones, wireless communications, broadcast media, automotive, wireless and industrial control, aerospace, and application-specific integrated circuits (ASICs). **TEMIC Semiconductors;** *(908) 630-9200, FAX: (908) 630-9202, Internet: http://www.temic-semi.de.*

CIRCLE NO. 105

Test instruments

A 52-page catalog covers analyzers, coaxial connectors, electromagnetic-interference (EMI) diagnostics, frequency counters, and generators. Lightwave instruments, oscilloscopes, and data-acquisition (DAQ) equipment are also specified. Descriptions are provided. **Tucker Electronics;** *(800) 527-4642, (214) 348-8800, FAX: (214) 348-0367, Internet: http://www.tucker.com.*

CIRCLE NO. 106

Plugs and jacks

Connectors, series adapters, and cable assemblies are highlighted in a 12-page short-form catalog. Specifications are provided. **Tru-Connector Corp.;** *(800) 262-9878, (508) 532-0775, FAX: (508) 531-6993.*

CIRCLE NO. 107

Coaxial connectors

A 12-page, short-form catalog contains information on cable-type connectors, bulkhead connectors, printed-circuit-board (PCB) connectors, surface-mount connectors, and adapters/blind-mate connectors. Application notes and cable-assembly data are included. Complete specifications are provided. **Sabritec;** *(949) 250-1244, FAX: (949) 250-1009, e-mail: sdahdul@sabritec.com, Internet: http://www.sabritec.com.*

CIRCLE NO. 108

Inductors/transformers

A 20-page bulletin describes a line of surface-mount-technology (SMT) inductors and transformers. Fixed and variable surface-mount inductors, coils, and transformers are listed. Application information, features, specifications, outline drawings, application notes, as well as an application guide are included. **Sprague-Goodman Electronics, Inc.;** *(516) 334-8700, FAX: (516) 334-8771, e-mail: info@spraguegoodman.com.*

CIRCLE NO. 109

Telecommunications cables

A 50-page catalog features central-office cables, specialized configurations to increase cable density, flexibility, or corrosion resistance. Fiber-optic cables in a variety of sizes and styles are also covered. Construction details, electrical characteristics, and features are included along with application recommendations and ordering information. **Montrose/CDT;** *(800) 346-6626, (508) 791-3161, FAX: (508) 793-9862, e-mail: sales@montrose-cdt.com, Internet: http://www.montrose-cdt.com.*

CIRCLE NO. 110

Frequency control

Crystals and resonators, clock oscillators, temperature-compensated crystal oscillators (TCXOs), voltage-controlled crystal oscillators (VCXOs), oven-controlled crystal oscillators (OCXOs), and filters are covered in a 122-page catalog. Specifications include frequency range, frequency stability, operating temperature range, and supply voltage. A subject index is provided along with a section on accessories. **Golledge Electronics Ltd.;** *+44 1460 256100, FAX: +44 1460 256101, e-mail: sales@golledge.co.uk, Internet: http://www.golledge.co.uk.*

CIRCLE NO. 111

Millimeter-wave amplifiers

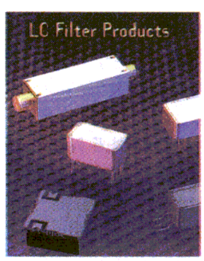
Low-noise amplifiers (LNAs), general-purpose amplifiers, power amplifiers (PAs), and active multipliers are listed in a six-page brochure. Specifications include output frequency, output power, input frequency, and DC current. Outline drawings and features are presented. **Spacek Labs, Inc.;** *(805) 564-4404, FAX: (805) 966-3249, e-mail: spacek@silcom.com.*

CIRCLE NO. 112

LC filters

A brochure specifies a line of inductive-capacitive (LC) filters. The LC filters are available for commercial and military applications. The brochure offers a fax-back order form to indicate one's specifications. **Piezo Technology, Inc.;** *(407) 298-2000, FAX: (407) 293-2979, e-mail: sales@piezotech.com, Internet: http://www.piezotech.com.*

CIRCLE NO. 113



Frequency control

Information on a line of quartz frequency-control products for the original-equipment-manufacturers (OEM) electronics market is included in a 32-page catalog. The catalog contains application information, specifications, definitions, and information on the company's crystal units, monolithic crystal filters, and crystal oscillators. **Tekmark, Inc.;** *(770) 346-9102, FAX: (770) 346-9106, Internet: http://www.tekmarkusa.com.*

CIRCLE NO. 114

Adapters and connectors

Adapters, attenuators, bias tees, circulators, coaxial-cable assemblies, and coaxial connectors are covered in a 138-page catalog. Coaxial switches, DC blocks, detectors, directional couplers, patch cords, phase trimmers, and terminations are also specified. A connector identifier and coaxial-cable assembly selection list are included along with outline drawings. **Pasternack Enterprises;** *(949) 261-1920, FAX: (949) 261-7451, e-mail: sales@pasternack.com, Internet: http://www.pasternack.com.*

CIRCLE NO. 115

Signal generators

A company's news publication highlights the latest product innovations. Microwave signal generators SMR and a family of electromagnetic-interference (EMI) test receivers are presented. Middle class spectrum analyzers, Digital European Cordless Telecommunications (DECT) protocol test systems, and case studies concerning measurement and radiocommunication applications are included. **Rohde & Schwarz GmbH & Co. KG;** *+4989/4129-1765, FAX: +4989/4129-3208, Internet: http://www.rsd.de.*

CIRCLE NO. 116

Chip resistors

A 44-page catalog overviews thick-film chip resistors, low-ohm thick-film chip resistors, high-ohm thick-film chips, thin-film chip resistors, fusible chip resistors, and chip-resistor arrays. Precision resistor arrays, chip-resistor networks, trimmable chip resistors, chip attenuators, and chip thermistors are specified. Carbon film resistors, metal-film resistors, metal-oxide film resistors, and fusing resistors are also covered. **Kamaya Electric Co. Ltd.;** *(219) 489-1533, FAX: (219) 489-2261, Internet: http://www.kamaya.com.*

CIRCLE NO. 117

Thin-film resistors

A short-form catalog highlights thick-film flat-chip resistors, thin-film MELF resistors, thin-film flat chip resistors, thin-film leaded resistors, and laboratory samples. Specifications include tolerance percentage, resistance range, and metric size. **Beyschlag;** *+49-481-95-0, FAX: +49-481-95-209.*

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CIRCLE NO. 284

Cable assemblies

A four-page brochure highlights low-loss cable assemblies, test-cable assemblies, custom cable assemblies, and semirigid products. Descriptions are included along with information on cable types and armoring options. **Reynolds Industries Ltd.;** *(44) 1635 31137, FAX: (44) 1635 30920.*

CIRCLE NO. 119

Sensor discretes

Part number and product-series characteristics for emitter and sensor discretes, optoelectronic slotted assemblies, hybrid assemblies, as well as hall-effect dicretes and assemblies are covered in a brochure. Discrete infrared light-emitting diodes (LEDs), optical sensors, hall-effect sensors, and hybrid packaging of encoder arrays and integrated circuits (ICs) are also featured. **Optek Technology, Inc.;** *(972) 323-2200, FAX: (972) 323-2396, e-mail: optek1@optekinc.com, Internet: http://www.optekinc.com.*

CIRCLE NO. 120

MBE growth

A brochure covers optoelectronic devices, bioelectronics, electron-beam lithography, molecular-beam-epitaxial (MBE) growth, millimeter-wave device prototyping, as well as millimeter-wave testing and modeling. Features are provided, along with information on the company's capabilities. **Kelvin Nanotechnology;** *+44 (0) 141 330 4869, FAX: +44 (0) 141 330 3726, e-mail: s.hicks@elec.gla.ac.uk, Internet: http://www.elec.gla.ac.uk/knt/.*

CIRCLE NO. 121

Couplers/attenuators

A 12-page short-form catalog overviews microwave devices, including couplers, attenuators, filters, transistors/adapters, and subsystems. Rigid, space-approved, flexible/twistable, as well as hybrid and seamless flexible, waveguide assemblies are also featured. **Credowan Ltd.;** *+44 (0) 1243 670711, FAX: +44 (0) 1243 672907, e-mail: sales@credowan.co.uk.*

CIRCLE NO. 122

Mixers and VCOs

An 88-page catalog covers mixers, voltage-controlled oscillators (VCOs), circulators and isolators, power splitters, and directional couplers. Quadrature and junction hybrids, in-phase/quadrature (I/Q) circuits, variable phase shifters, variable and fixed attenuators, lowpass and highpass filters, matching transformers, and stripline components are specified. **TRAK Microwave Corp.;** *(813) 884-1411, FAX: (813) 884-2941, e-mail: sales@trak.com, Internet: http://www.trak.com.*

CIRCLE NO. 123

Resistors/terminations

High-frequency resistors, terminations, attenuators, and cable assemblies are described in a six-page brochure. Specifications include voltage, size, and frequency range. **Florida RF Labs;** *(800) 544-5594, FAX: (561) 283-5286, e-mail: rflabs@rflabs.com, Internet: http://www.rflabs.com.*

CIRCLE NO. 124

RF rotary joints

A 384-page guidebook examines RF rotary joint designs. Single-channel-coaxial, single-channel-waveguide, single-channel hollow-shaft, dual-channel-coaxial, dual-channel-waveguide, dual-waveguide-coaxial, three-channel, four-channel, and multichannel designs are presented. Line drawings are provided for most of the designs. Information on the company's capabilities is also included. **Kevlin Corp.;** *(978) 657-3900, FAX: (978) 658-5170.*

CIRCLE NO. 125

Signal recovery

Preamplifiers, lock-in amplifiers, digital delay generators, voltmeters, and fiber-optic light sources are detailed in a 68-page catalog. Application information is included. **EG&G Signal Recovery;** *+44 (0)118 977 3003, FAX: +44 (0)118 977 3493, e-mail: info_sigrecovery@egginc.com.*

CIRCLE NO. 126

Microwave capacitors

A selection of microwave capacitor products is available in a catalog. Directional couplers, thin-film inductors, multi/single-layer capacitors, and maxi single-layer capacitors are presented. **AVX Corp.;** *(843) 946-0414, FAX: (843) 448-1943, Internet: http://www.avxcorp.com.*

CIRCLE NO. 127

Signal generators

A 30-page short-form catalog provides information on signal generators, safety testers, oscilloscopes, jitter meters, and DC power supplies. Specifications are provided, along with descriptions and options. **KIKUSUI Electronics Corp.;** *(800) 835-2352, e-mail: info@ifrinternational.com, Internet: http://www.ifrinternational.com.*

CIRCLE NO. 128

Free-running oscillators

A series of free-running and phase-locked oscillators is featured in a 40-page catalog. Coaxial resonator; voltage-controlled; cavity-tuned, crystal, single-, and dual-loop designs are offered. Complete specifications are included. **MITEQ, Inc.;** *(516) 436-7400, FAX: (516) 436-9219, Internet: http://www.miteq.com.*

CIRCLE NO. 129

Microwave components

Microwave components and subassemblies are examined in a 138-page catalog. Specifications and descriptions on more than 100 products are contained within the catalog. Attenuators, couplers, dividers, phase shifters, switches, and resistors are presented. A section of application notes is included. **KDI/triangle Corp.;** *(973) 887-8100 ext. 500, FAX: (973) 884-0445, Internet: http://www.kditriangle.com.*

CIRCLE NO. 130

Optical instruments

Apertures, high-power-laser apertures, bandpass filters, circular polarizers, circular variable filters, and a fiber-optics kit are listed in a 270-page catalog. Infrared (IR) bandpass filters, laser bandpass filters, and silicon (Si) detectors are also specified. **Edmund Scientific Co.;** *(609) 573-6250, FAX: (609) 573-6295, e-mail: industrialsales@edsci.com, Internet: http://www.edsci.com.*

CIRCLE NO. 131

Oscilloscopes and meters

A 200-page catalog focuses on new and reconditioned instruments, including oscilloscopes, meters, frequency counters, function generators, signal generators, power supplies, spectrum analyzers, and logic analyzers. Reconditioned digital meters and waveform synthesizers are also described. An index is provided. **Tucker Electronics;** *(800) 527-4642, (214) 348-8800, FAX: (214) 348-0367, Internet: http://www.tucker.com.*

CIRCLE NO. 132

Power meters

Modern and traditional applications of power meters are introduced in a 16-page brochure. High-speed, dynamic-range, and sensor electrically erasable programmable read-only memories (EEPROMs) that resolve problems associated with traditional power meters are discussed. **Anritsu Co., Microwave Measurement Div.;** *(408) 778-2000, FAX: (408) 778-0239, Internet: http://www.global.anritsu.com.*

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Analog Devices	www.analog.com/DDS	57
Anaren Microwave, Inc.	www.anaren.com	135,165
Anritsu Co.	www.anritsu.com	24, 26
Ansoft Corp.	www.ansoft.com, e-mail: info@ansoft.com	71,73,75,179
Applied Wave Research	www.mwoffice.com	175
Arden Technologies	www.ardentech.com	168
ARRA, Inc.	www.arra.com	Inside Back Cover
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Aviel Electronics	www.avielelectronics.com, e-mail: avielconn@aol.com	169
Avnet Electronics	www.avnet.com	23
Avtech Electrosystems Ltd.	www.avtechpulse.com, e-mail: info@avtechpulse.com	18
AVX Corp.	www.avxcorp.com	66
B		
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Bird Electronics	www.bird-electronics.com, e-mail: sales@bird-electronic.com	80
Bomar Crystal Co.	www.bomarcrystal.com	169
Boonton Electronics Corp.	www.boonton.com, e-mail: boonton@boonton.com	78
Bree Engineering	www.breeeng.com	34
C		
Cal Crystal Lab, Inc.	www.calcrystal.com	168
California Eastern Lab	www.cel.com	4
Cascade Microtech	www.cascademicrotech.com, e-mail: sales@cmicro.com	90
Champion Technologies	www.champtech.com, e-mail: sales@champtech.com	6
Communications Techniques	www.cti-inc.com, e-mail: sales@cti-inc.com	149
CST of America, Inc.	www.cst.de	104
CTS Reeves Frequency Products	www.ctscorp.com	46
CTT	www.cttinc.com, e-mail: sales@cttinc.com	133
D		
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Digi-key		10
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Dupont	www.dupont.com/mcm	55
E		
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EDTN Network	www.edtn.com	65
Electronic Design		171,172-173
EM Research, Inc.	www.emresearch.com	168
EMC Technology, Inc.	www.emct.com, e-mail: sales@emct.com	79,81,83
The Engineers Club	www.engineers.com, e-mail:sales@engineers.com	79
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F		
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G		
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GaAsTek	www.gaastek.com	35,37,39
Giga-tronics, Inc.	www.gigatronics.com	76
H		
Herotek, Inc.	www.herotek.com, e-mail: info@herotek.com	101
Hewlett-Packard Co.	www.hp.com	Inside Front Cover,32a-b*,33,48a-b*,49,185
Hittite Microwave	www.hittite.com, e-mail:hittite@hittite.com	142
I		
IMAPS	www.imaps@imaps.org, e-mail: imaps@imaps.org	64
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Interad Ltd.	e-mail: interad@pop.erols.com	18
J		
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Leader-Tech		170
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M		
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Microwave Db, Inc.	www.microwavedb.com	58
Microwave Filter Co., Inc.	www.microwavefilter.com, e-mail: mfcsales@microwavefilter.com	100
Microwave Power Devices Tech	www.mpd.com, e-mail: sales@mpd.com	45
MITEQ, Inc.	www.miteq.com	1,11,125
Mitsubishi Electronics America	www.mitsubishichips.com	40-41*
MTI-Milliren Technologies	www.mti-milliren.com	81
N		
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National Semiconductor	www.national.com	30
Nexyn Corp.	www.nexyn.com	93
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O		
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P		
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PTEK		128
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Q		
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Remec, Inc.	www.remec.com,e-mail:marketing@remec.com	42-43,121
Renaissance Electronics	www.rec-usa.com, e-mail:rec-info@rec-usa.com	133
RF Micro Devices	www.rfmd.com, e-mail:info@rfmd.com	161
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Rohde & Schwarz Gmbh & Co.	www.rsd.de	63
S		
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Sawtek, Inc.	www.sawtek.com, e-mail: sales@sawtek.com	47
Seavey Engineering	www.seaveyantenna.com, e-mail: info@seaveyantenna.com	177
Sonnet Software, Inc.	www.sonnetusa.com, e-mail:info@sonnetusa.com	114,181
Sonoma Scientific, Inc.	www.sonomascientific.com, e-mail: isolators@sonomascientific.com	163
Sprague-Goodman Electronics	www.spraguegoodman.com, e-mail: info@spraguegoodman.com	109
Stanford Microdevices	www.stanfordmicro.com, e-mail:sales@stanfordmicro.com	14-15,126,189
Stanford Telecom	www.stanfordtelecom.com	167
Stellex Microwave Systems	www.stellexms.com, e-mail: sales@stellexms.com	22
SV Microwave	www.svmicro.com, e-mail:sales@svmicr.com	138
Synergy Microwave	www.synergymwave.com, e-mail:sales@synergymwave.com	117,131,153
T		
Taiyo Yuden	www.t-yuden.com, e-mail: tyusa@t-yuden.com	3
Tecdia, Inc.	www.tecdia.com	169
Techtrol Cyclonectics, Inc.	www.tci-ant.com, e-mail:techtrol@paonline.com	163
Telecom Analysis Systems	www.taskit.com, e-mail:sales@taskit.com	16
Temex Electronics, Inc.	www.temex-az.com, e-mail:sales@temex-az.com	52
TRAK Microwave Corp.	www.trak.com, e-mail: sales@trak.com	155
Trans-tech	www.trans-techinc.com, e-mail:transtech@alphaind.com	140
TTE, Inc.	www.tte.com, e-mail:sls@tte.com	13
U		
Universal Microwave Components	www.members.aol.com/umcc111, e-mail:umcc111@aol.com	169
V		
Vari-l Co., Inc.	www.vari-l.com	190
Vectron Labs, Inc.		19
Voltronics International Corp.	www.voltronicscorp.com, e-mail: info@voltronicscorp.com	194a-b
V-Tech Communications Ltd.	www.vtech-cms.com, www.vtechoem.com	50
W		
Watkins Johnson Co.	www.wj.com	20
Wavecon	www.waveconsoft.com	168
Weinschel Corp.	www.weinschel.com	68
Wide Band Engineering	www.wbecoinc.com, e-mail: wideband@wbecoinc.com	170
X		
Xemod, Inc.	www.xemod.com, e-mail: info@xemod.com	103
Z		
Zeland Software, Inc.	www.zeland.com, e-mail:zeland@zeland.com	132
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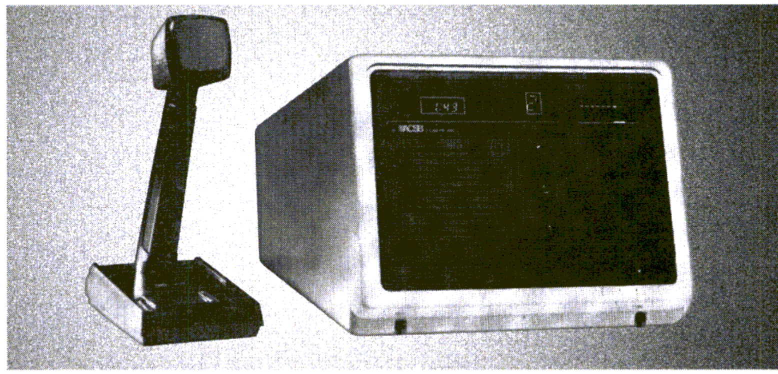

A Special Report in August 1983 detailed the use of single-sideband (SSB) technologies to conserve valuable land-mobile communications spectrum. Using amplitude companded sideband (ACSB), the 150-to-174-MHz Pioneer 1000 radios from Sideband Technology occupied about one-fifth the bandwidth of conventional FM radios.

Microwaves & RF September Editorial Preview

Issue Theme: Dual-Use Technology

News

Many commercial applications owe much to the military. For example, spread-spectrum techniques are behind the emerging wireless local-area-network (WLAN) market.

But can commercial applications continue to leverage military research? And how well are military system designers adapting to the use of commercial-off-the-shelf (COTS) electronics? Are high-frequency manufacturers still interested in military business? For an insightful update on the military side of high-frequency electronics, don't miss this Special Report.

Design Features

The lead article in September will explore an extremely low-cost microwave design approach—using an electromagnetic (EM) simulation. Other articles highlight a self-calibration technique for improving the reliability of frequency synthesizers based on embedded microprocessors and show how to design a 40-W push-pull amplifier for personal-communications-services (PCS) code-division-multiple-access (CDMA) base-station applications. In addition, an author from China will reveal a design approach for a high-Q Gunn oscillator with good stability at 36.8 GHz.

Product Technology

Power measurements are critical to many systems, including code-division-multiple-access (CDMA) communications networks. To aid in these measurements, a major integrated-circuit (IC) manufacturer has developed a logarithmic amplifier IC capable of making true-root-mean-square (RMS) power measurements over a wide instantaneous dynamic range. Additional Product Technology stories will evaluate a free sample kit of shielding materials and a high-power transistor that is based on silicon carbide (SiC).

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