A PENTON PUBLICATION JANUARY 2000

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FOR DESIGNERS AT HIGHER FREQUENCIES

Microwaves & RF

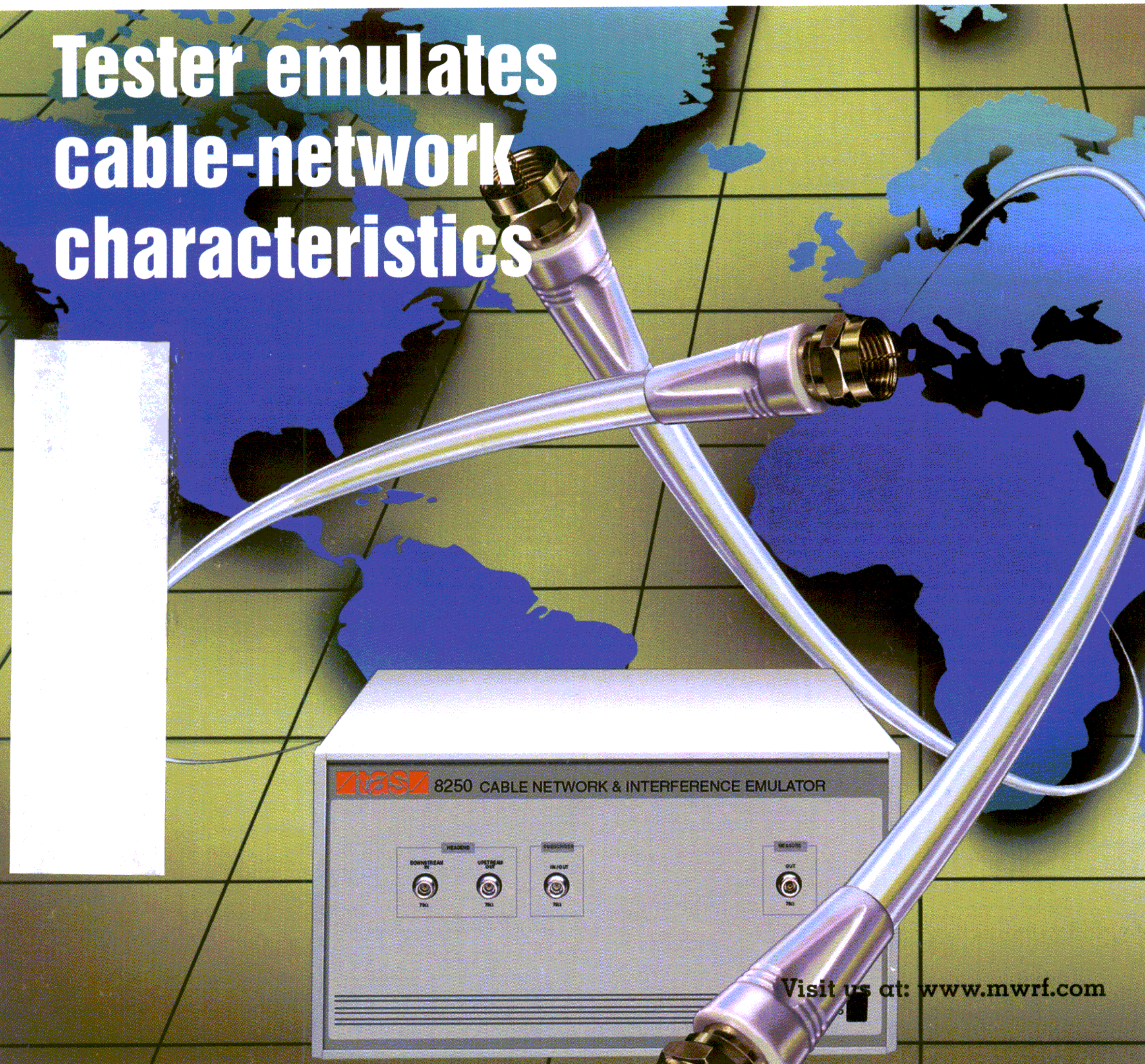
Test & Measurement Issue

NEWS
Instruments check wireless handsets

DESIGN FEATURE
Gauge harmonics with a spectrum analyzer

PRODUCT TECHNOLOGY
Radio IC captures Bluetooth signals

Tester emulates cable-network characteristics



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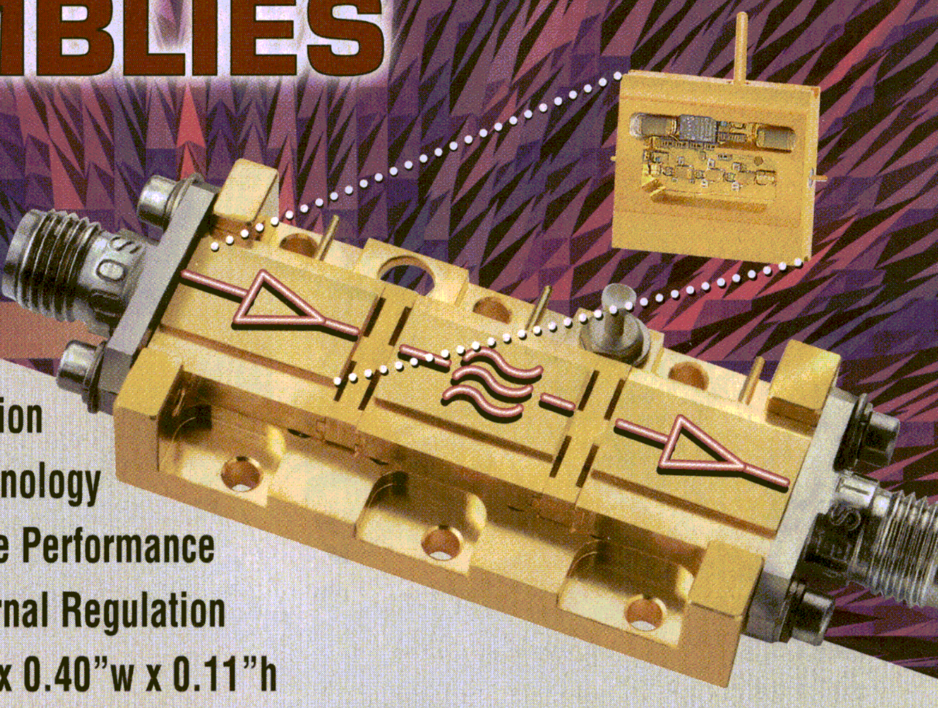
TO 60 GHz



FEATURES

- ✦ Ease of Design Optimization
- ✦ Proven JS Amplifier Technology
- ✦ Superior Noise and Phase Performance
- ✦ All Modules Contain Internal Regulation
- ✦ Module Sizes are 0.45"l x 0.40"w x 0.11"h
- ✦ Compact Assembly Sizes Fit Most System Applications

OPTIONS

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- Integrated filtering to reduce noise bandwidth and I.M. distortion
- Ultra-low noise and medium power module pairings for high dynamic range
- PIN attenuators to enhance system flexibility
- Front-end RF limiters to protect against high level inputs
- A single-broadband input can be divided into multiple sub-bands

For additional information, please contact Rosalie DeSousa at (516) 439-9458 or send e-mail to rdesousa@miteq.com.

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- ✔ Medium Power Amplifiers
- ✔ High-Gain Amplifiers
- ✔ Low-Noise Amplifiers
- ✔ Frequency Multipliers
- ✔ High-Pass Filters
- ✔ Band-Pass Filters
- ✔ PIN Attenuators
- ✔ Power Dividers
- ✔ Input Limiters
- ✔ IF Amplifiers
- ✔ Couplers

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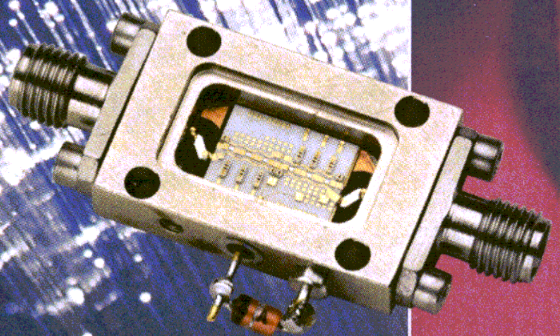
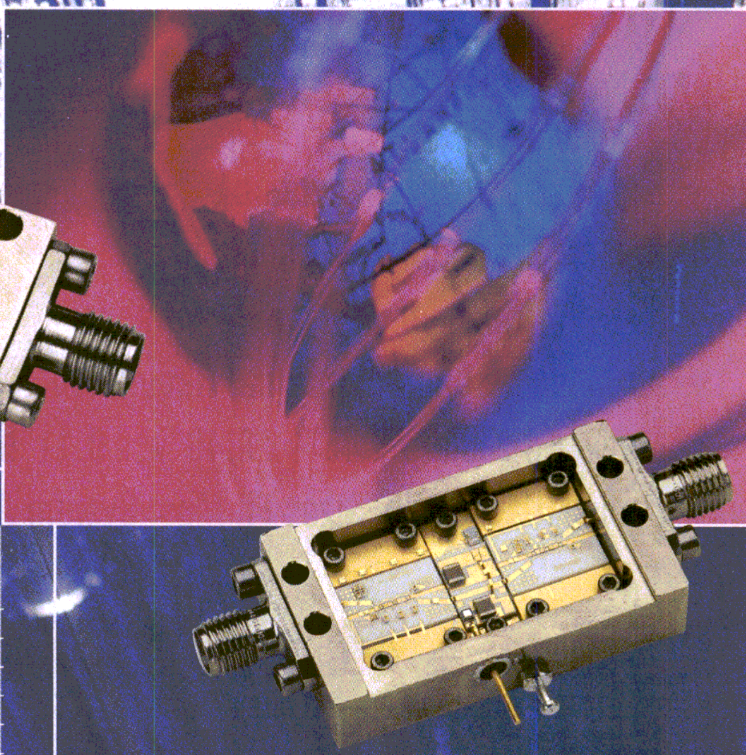
CIRCLE NO. 208

AMPLIFIERS

10 MHz to 18 GHz Ultra-Broadband for Fiberoptic and Telecommunications





MODEL NUMBER	FREQ. RANGE GHZ	GAIN dB MIN	NOISE FIG. dB MAX	GAIN FLATNESS +/-dB	1dB COMP. PT. dB MIN	3RD ORDER ICP TYP.	VSWR IN/OUT MAX	DC CURRENT MA
JCA008-201	.01-8.0	25	*5	2.0	0	10	2.0:1	175
JCA008-202	.01-8.0	24	*5	2.0	5	15	2.0:1	200
JCA008-203	.01-8.0	22	*5	2.0	10	20	2.0:1	225
JCA008-301	.01-8.0	35	*5	2.5	0	10	2.0:1	300
JCA008-302	.01-8.0	34	*5	2.5	5	15	2.0:1	325
JCA008-303	.01-8.0	32	*5	2.5	10	20	2.0:1	350
JCA0010-201	.01-10.0	24	*5	2.0	0	10	2.0:1	175
JCA0010-202	.01-10.0	22	*5	2.0	5	15	2.0:1	200
JCA0010-203	.01-10.0	20	*5	2.0	10	20	2.0:1	225
JCA0010-301	.01-10.0	34	*5	2.5	0	10	2.0:1	300
JCA0010-302	.01-10.0	32	*5	2.5	5	15	2.0:1	325
JCA0010-303	.01-10.0	30	*5	2.5	10	20	2.0:1	350
JCA0012-201	.01-12.0	23	*5	2.0	0	10	2.0:1	175
JCA0012-202	.01-12.0	21	*5	2.0	5	15	2.0:1	200
JCA0012-203	.01-12.0	20	*5	2.0	10	20	2.0:1	225
JCA0012-301	.01-12.0	33	*5	2.5	0	10	2.0:1	300
JCA0012-302	.01-12.0	31	*5	2.5	5	15	2.0:1	325
JCA0012-303	.01-12.0	30	*5	2.5	10	20	2.0:1	350
JCA0118-201	.1-18.0	22	**5	2.5	3	13	2.0:1	200
JCA0118-202	.1-18.0	20	**5	2.5	5	15	2.0:1	250
JCA0118-203	.1-18.0	20	**5	2.5	7	17	2.0:1	300
JCA0118-301	.1-18.0	31	**5	2.5	3	13	2.0:1	250
JCA0118-302	.1-18.0	29	**5	2.5	5	15	2.0:1	300
JCA0118-303	.1-18.0	29	**5	2.5	7	17	2.0:1	350

* Noise Figure is specified above 300 Mhz
** Noise Figure is specified above 500 Mhz

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JANUARY 2000 VOL. 39, NO. 1

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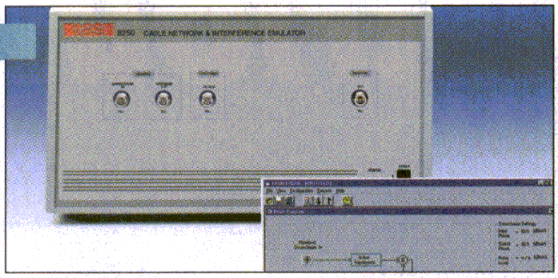
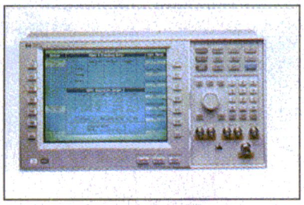


DEPARTMENTS

NEWS



DESIGN FEATURES

PRODUCT TECHNOLOGY

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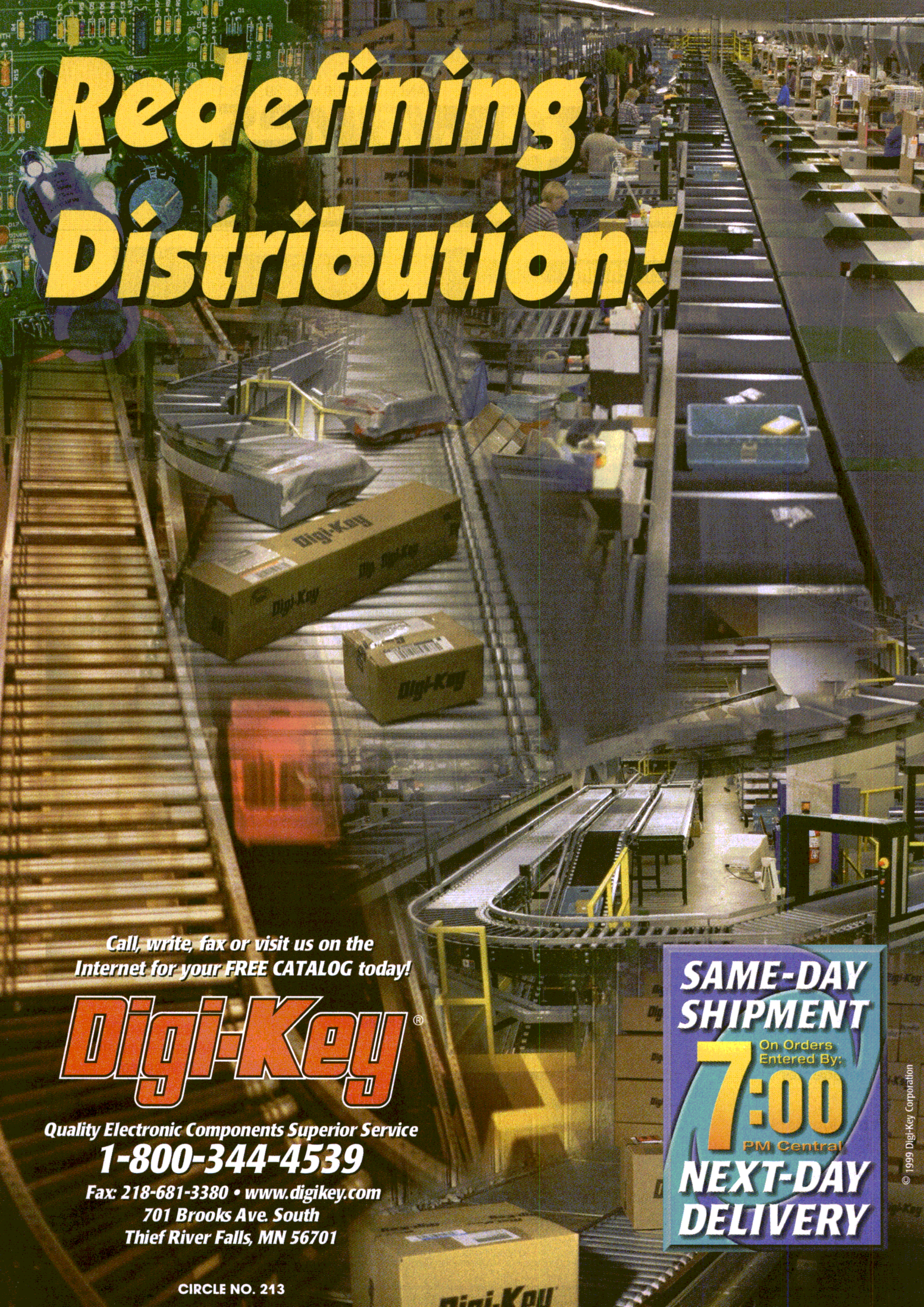
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CIRCLE NO. 213

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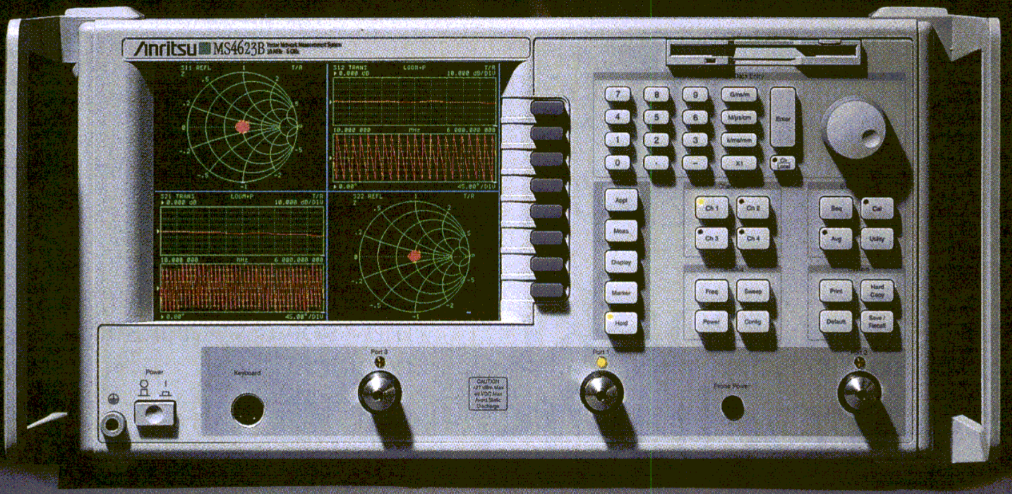
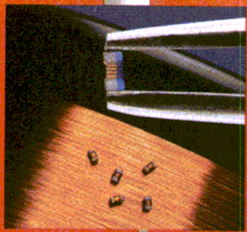


Introducing the first 0402 wirewound inductors



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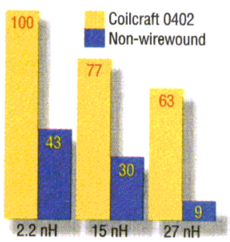

These new wirewound 0402 chip coils have Q factors that are comparable to our 0603 chips. And far higher than competitive parts.

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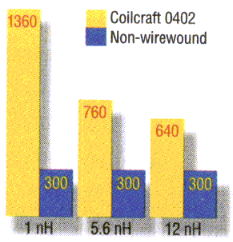

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CIRCLE NO. 217

DECLINING TECHNOLOGY

To the editor:

I was astonished by the concern expressed by Jack Browne in regard to the decline of vacuum-tube technology in his November 1999 editorial (p. 17). That editorial reveals how truly out of touch Jack Browne is with today's world of microwave systems. The reason for the decline in vacuum-tube technology is that solid-state devices can, in most cases, provide the same system-level capability as tubes, but with the real advantages of lower voltages, higher reliability, lower life-cycle cost, increased personnel safety, etc. For example, older radars with megawatt (peak-power) transmitters employed very-low duty-factor waveforms, producing average-power outputs of only a few kilowatts.

The same average-power levels can be achieved with solid-state systems that use higher duty-factor waveforms with more sophisticated signal processing. These systems can be implemented by using power-combined solid-state amplifiers in the lower microwave frequency regions or with solid-state active phased arrays at higher frequencies.

Also, the drop in the cost of signal processing permits the use of more cooperative and distributed system architectures, further reducing the need for high-power transmitters. Inroads are also being made by solid-state technology into ultra-high-frequency (UHF) broadcasting and other areas. The encroachment into application areas previously dominated by vacuum tubes is inexorable. Although vacuum tubes have had their day, they, similar to the steam engine, should be allowed to pass into the history books. Mr. Browne should stop fretting about the need for megawatt transistors and instead should learn more about the real requirements of today's systems.

J. Lee Blanton
Radiophysics Corp.
Temecula, CA

PHRASE INDEX

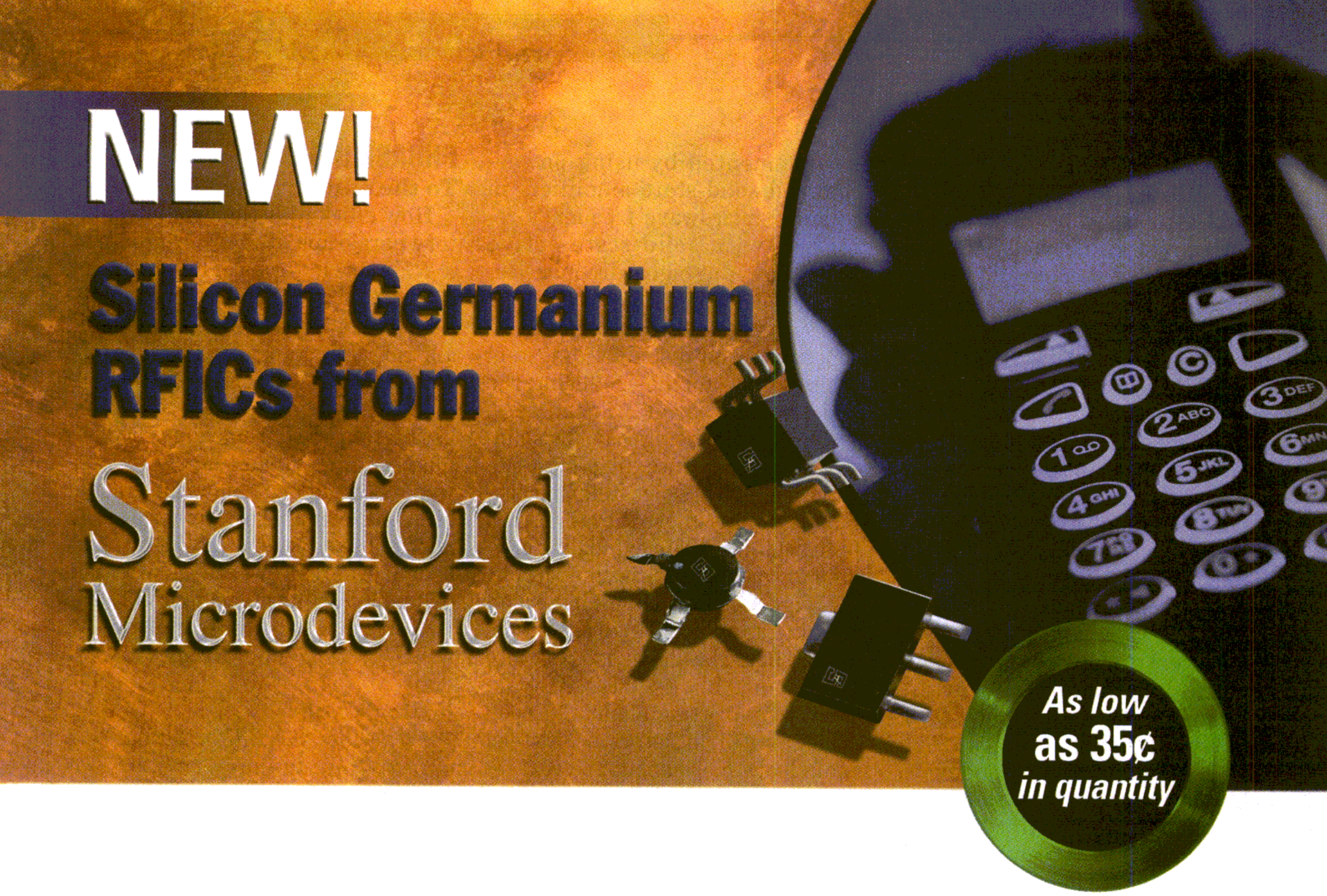
To the editor:

How efficient is the bold introductory paragraph of every *Microwaves & RF* story in terms of telling a very busy reader what the article contains? Wouldn't a phrase index (i.e., a listing of certain specifications, devices, components, and more that appear in the article) be better? This listing could be a tremendous boon to busy engineers and more articles would be read. All unique ideas could be listed, even those peripheral to the main subject if they could be of interest to readers. Fewer ideas would be missed by workers and your authors.

Keats Pullen Jr.
Kingsville, MD

Editor's Note:

Please see the Editor's Note that appeared in January 1999's Feedback (p. 13). Last year, we responded to a similar type of letter. Our response to the letter above echoes that of a year ago.



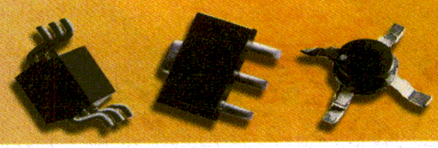
Silicon Germanium (SiGe), Stanford Microdevices' latest RF semiconductor process, offers benefits not attainable by conventional silicon-bipolar technologies: lower noise figures, lower power consumption, high output power at high efficiency, and high integration level.

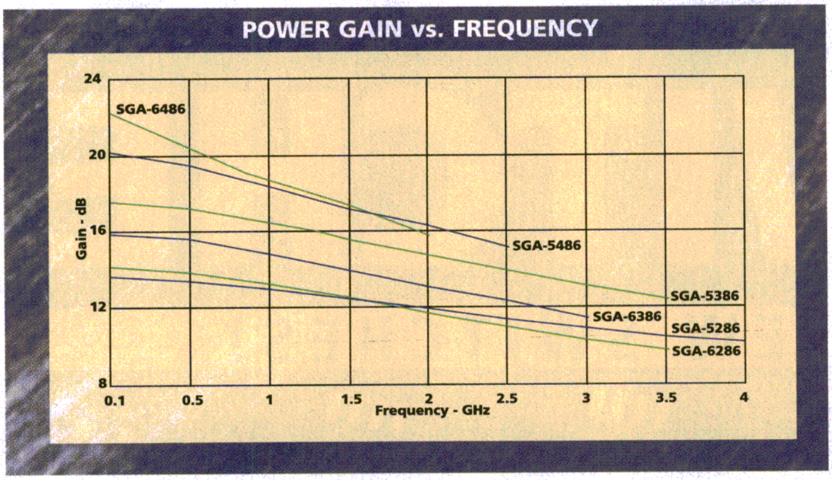
As part of a series of Stanford Microdevices' initiatives to apply silicon germanium technology to a broad spectrum of communications applications, we are now offering the wireless market devices built using a patented silicon germanium manufacturing process. As these devices enter the marketplace, consumers 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.

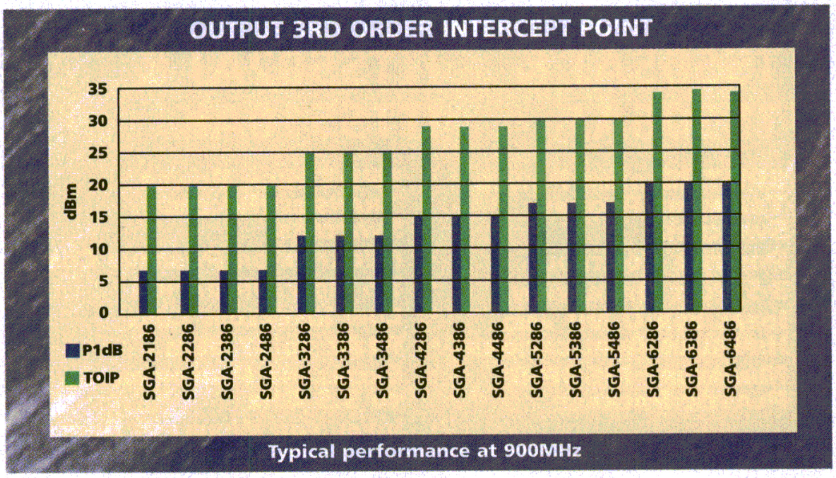
PRODUCT SELECTION GUIDE
General Purpose Amplifiers

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







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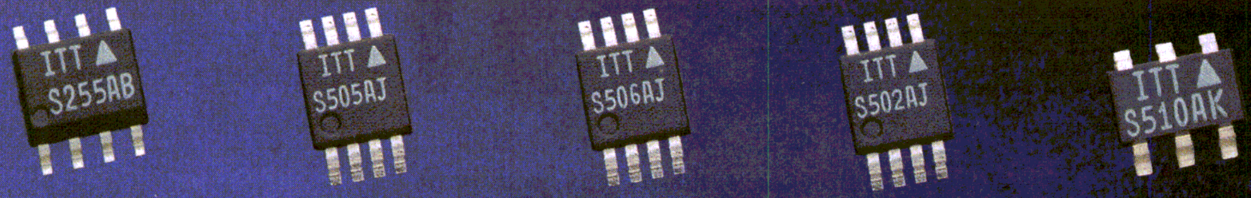
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TESTING THE WIRELESS WORLD BEYOND US

New years always bring with them the promise of a fresh start, of a blank slate, of a time when we can begin again. It is only fitting then that in the world of high-frequency design, this first issue of a new year, of a new century, should have to do with test and measurement. For in any field of electrical design, the ability to test supports the beginning and the end of a design cycle. It provides the characterization so essential during the early stages of product development, and the final data that ensure us that some wild design really does work.

It is also fitting that this industry's largest test and measurement company—formerly part of Hewlett-Packard Co.—would enter the new century with a new name: Agilent Technologies. Spun off from the parent company last November, this new entity will likely live up to its name, with a newfound agility and command of technology that befit its smaller size. Ironically, it is the "computer" side of the company—the part that remains as Hewlett-Packard Co.—that now identifies itself with the humble beginnings of Dave Packard and Bill Hewlett (in television commercials showing new President and CEO, Carly Fiorina, in front of the garage where the company started.

The folks at Agilent (and just about any other high-frequency test and measurement company) point to the importance of wireless markets for their future growth (see "Mobile-Phone Test Sets Take Aim at A Moving Target" on p. 29). The expansion of cellular services has seemingly only just begun, with service providers racing to upgrade their systems for wider bandwidths and wireless data, and handset manufacturers trying to cram as many features as possible into a continuously shrinking footprint (or is it handprint?). With each successive generation of base station and handset, test-equipment manufacturers must provide more functions and more capability. It is no wonder that so many test-equipment suppliers have adopted modular architectures with heavy dependence on software to implement new features.

For test-equipment suppliers, cellular markets are just one slice of a future wireless pie, with the twin shadows of Bluetooth and HomeRF looming large on the horizon. Given the industry support of these unlicensed 2.4-GHz applications, the potential exists for Bluetooth product manufacturers to be testing millions of units per month.

For Bluetooth and other future wireless markets to take off, testing must be quick and inexpensive. The end result is that test-equipment manufacturers must make instruments that are powerful, but extremely easy to learn and use. The equipment must be strongly based in software, with the ability to upgrade functions and capabilities over the Internet, but it must also be easy to program.

Test equipment is the beginning and end of design engineering. And test-equipment manufacturers have traditionally stayed close to their customers to learn of future requirements. At the pace of modern development cycles, it is almost mandatory for test-equipment suppliers to be part of each customer's design projects.

Jack Browne

Publisher/Editor

Microwaves & RF

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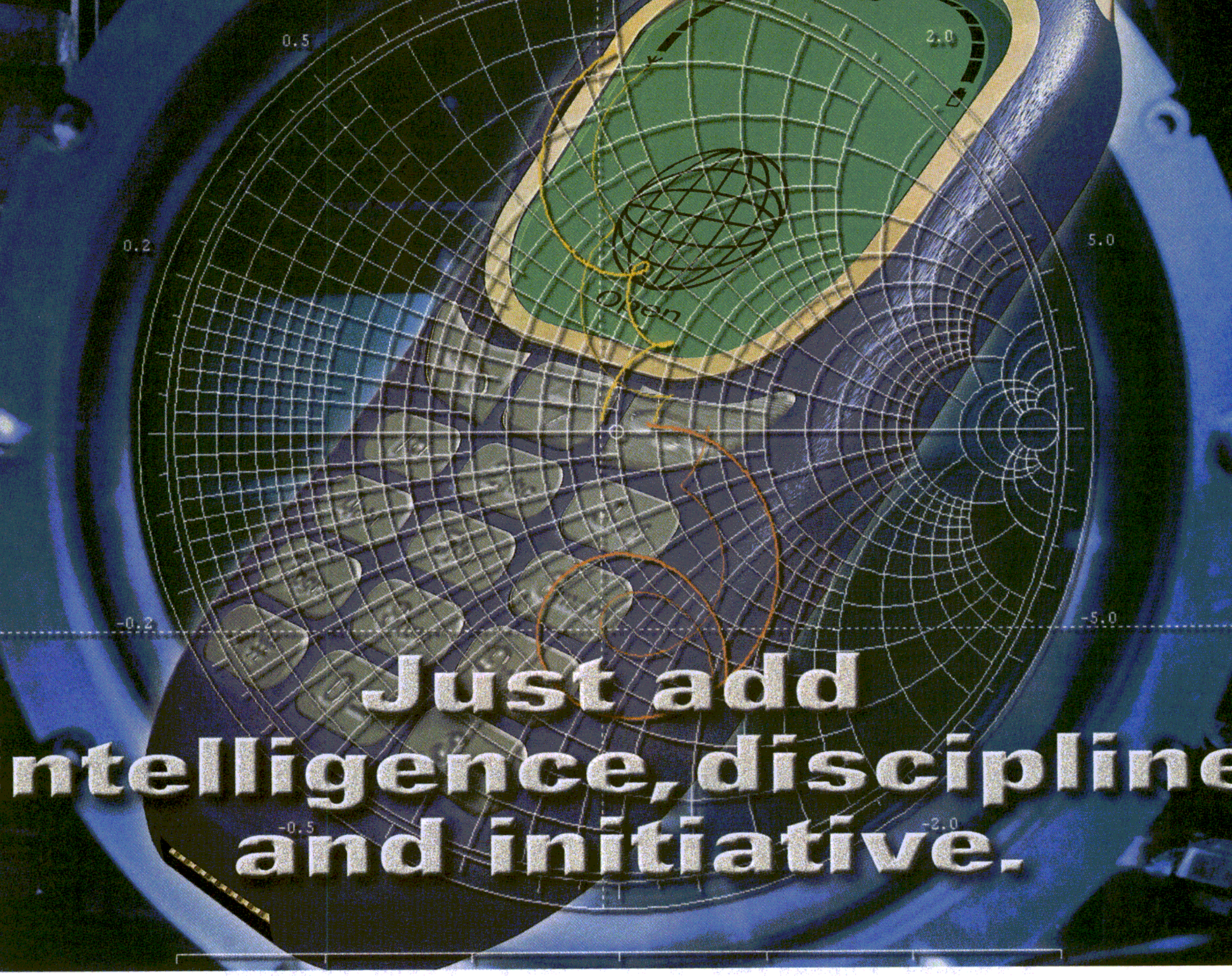
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IP Technology Solution Breaks The Spectrum Barrier

GENEVA, SWITZERLAND—ArrayComm, Inc., a leader in spectrally efficient solutions for the wireless telecom industry, recently announced at Telecom99 the introduction of its i-BURST™ technology, a breakthrough broadband wireless Internet-protocol (IP) application of its patented and commercially proven IntelliCell® adaptive smart-antenna (spatial-processing) technology.

Operating on as little as 5 MHz of unpaired spectrum, i-BURST will outperform today's cellular data solutions by over 400 times and tomorrow's third-generation (3G) solutions by more than 40 times. A typical deployment will deliver in excess of 40-Mb/s data throughput per cell and provide connection to the Internet, anytime, anywhere, at user data rates in excess of 1 Mb/s.

"The implications of i-BURST technology extend far beyond our company and beyond the Internet and telecom industries as well," says Martin Cooper, chairman and CEO of ArrayCom. "With few exceptions, the power of the Internet today is constrained by time and space—bound to the desktop by cords, cables, and telephone lines, its access limited to work, home, or the occasional kiosk. Despite this, it has become a dominant influence in society. By untethering the Internet and making access to it ubiquitous, at affordable and scalable rates, i-BURST releases the full potential of networked information technology into the living, breathing spaces of our lives."

Revenue From Bandwidth Services To Cross $90 Billion By 2003

NORWALK, CT—According to a Business Communications Co., Inc. study, *RG-242 Bandwidth Supply and Demand in Access Networks*, the US is experiencing the highest growth of data transmission in the world. With an average annual growth rate (AAGR) of 30 percent, the bandwidth demand for data services in the US will grow from 2.01 million tera bits per second in 1999 to 5.7 million tera bits per second in 2003 (see table). This demand will be met in the access segment by incumbent service providers including IXCs and ILECs, as well as CLECs, wireless service providers, cable-television (CATV) companies, and satellite-phone service operators. It will be met using twisted copper (Cu), optical fiber, coaxial cable, wireless, and satellite connections supported by XDSL, asynchronous transfer mode (ATM), Synchronous Optical Network (SONET), synchronous digital hierarchy (SDH)/ADM, VPN, dense wavelength-division multiplexer (DWDM), wireless broadband, Internet, and other technologies.

Growth of broadband services, 1999 to 2003

	1999	2003	AAGR (percentage) 1999 to 2003
Volume of data (millions of tera bits per second)	2.01	5.70	29.8
Revenue (millions of dollars)	5660	90,044	99.7

Most demand for broadband services will fall within the broadband ranges of 2 to 10 Mb/s, 10 to 55 Mb/s, 55 Mb/s and above, while originating from medium to small businesses, large businesses, small-office/home-office (SOHO), and private-home customers. While demand will vary considerably within each range, most 55 Mb/s and above services will come from large businesses. Overall revenues for service providers amounted to $5.66 billion by the end of 1999. Growing at an AAGR of 87 percent, the overall revenue stream for service providers to customers for all service types will rise to $90.04 billion by the end of 2003.

The growth in demand for broadband applications will generate a healthy market for hardware to support the deployment of appropriate services. Prominent among them will be customer premises equipment, integrated-access devices, cable modems, wireless base stations, and digital-subscriber-line (DSL) modems.

The study covers the major services and technologies that are used in the broadband services industry. It presents an overview of technologies, such as SONET and VPN, as well as the role of the Internet in the growth of broadband services. Also covered is the demand for data services as opposed to voice and the relevance of broadband bandwidth in the deployment of data services. A focused analysis on the application markets is detailed.

World's First 6-in. InGaP HBT Wafer Fab Is Introduced

WARREN, NJ—ANADIGICS has successfully demonstrated the fabrication of the first indium-gallium-phosphide heterojunction-bipolar transistor (InGaP HBT) on 6-in. (15.24-cm) wafers. The achievement marks the addition of InGaP HBT capability in ANADIGICS' recently announced 6-in. (15.24-cm) manufacturing facility, which already offers gallium-arsenide (GaAs) metal-semiconductor-field-effect-transistor (MESFET) and pseudomorphic-high-electron-electron-mobility-transistor (PHEMT) wafer production.

"The development of six-inch InGaP HBT wafers marks a major milestone in ANADIGICS' HBT development program as well as an outstanding achievement for the semiconductor industry," says Jim Gilbert, vice president of technology development at ANADIGICS.

HBT devices have provided millions of high-performance power-amplifier (PA) circuits for cellular and personal-communications-services (PCS) handsets. InGaP HBTs offer outstanding power efficiency and high linearity for PAs, enabling longer battery life and better signal characteristics in wireless devices. In addition, InGaP HBTs also provide high-performance characteristics for use in high-data-rate fiber-optic devices.

Locator Technology To Aid Cell-Phone 911 Callers

WASHINGTON, DC—Federal regulators are taking the next steps toward ensuring that cellular-phone users who dial 911 automatically provide emergency dispatchers with a key piece of information—their location. The action, which was taken in mid-September by the Federal Communications Commission (FCC), sets the technology standards for cellular companies to follow as they make 911 caller location available in their phones. Regulators hope that cellular companies will begin providing phones with locator technology within two years. The commission voted five to zero to set the rules.

"This decision will save lives without question," says FCC chairman Bill Kennard. In situations such as auto accidents, when a few hours can mean the difference between life and death, knowing the location increases the chances that emergency personnel will get to the scene on time, Kennard says.

Currently, when a person places a 911 call from a regular wire-line phone from home or work, for example, the location of the caller will pop up on a screen read by emergency dispatchers. Regulators want to see similar information provided for cellular 911 calls. In 1996, the FCC adopted rules requiring wireless carriers to set up systems by October 1, 2001, that could locate a cellular caller within 410 ft. New innovations have cropped up since then, so cellular companies now have some choices in reaching this goal, Kennard says. The FCC is trying to lay out the rules that carriers must follow, but are staying neutral on which technology to select, says Kennard.

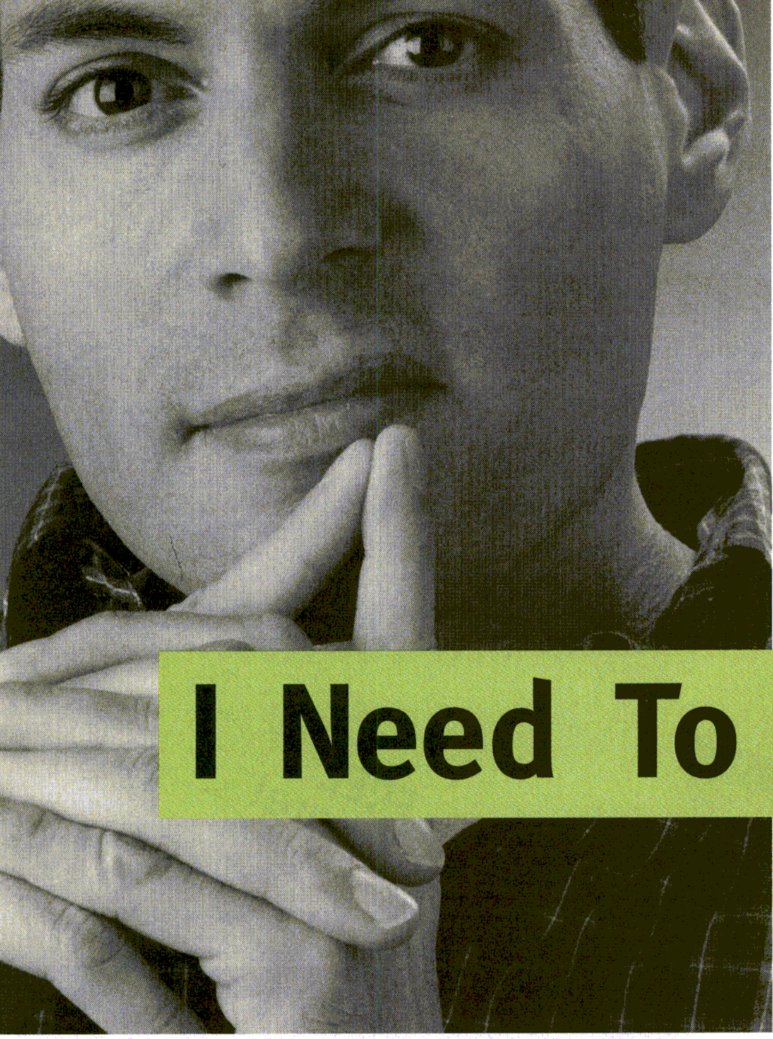
Bluetooth Sales To Exceed $2 Billion By 2005

OYSTER BAY, NY—The most obvious need for wireless connectivity is found in the clutter of wires snaking their way from device to device at the rear of the typical work station. Bluetooth technology is about to change all of that by replacing cables joining user devices with a short-range radio link that is universally compatible.

Bluetooth will enable a wireless connection between virtually any electronic device over a distance of up to 10 m. Broadcasting at the 2.4-GHz industrial-scientific-medical (ISM) band, Bluetooth microtransceivers take advantage of the recently formalized IEEE 802.11 specification for wireless local-area networks (WLANs). Future Bluetooth iterations will extend the initial range to 30 m. An early version was scheduled for 1999 and requires no licensing or royalty fees. The connectivity air interface will be very successful early in its tenure, with Bluetooth module shipments exceeding 400 million units by 2005.

Bluetooth revenue generated could exceed $2 billion annually after 2004. The rapid decline in Bluetooth module cost, at $30 initially and declining to $5 within a few years, will be one of the keys to growth. The market for Bluetooth technology is described in a report from Allied Business Intelligence, Inc. (ABI), "Wireless Data Communications 2005: From WANs to Bluetooth."

User devices can include virtually any digital communications or control device found in the home, factory, or workplace. Examples include notebook, desktop, and handheld computers, as well as personal digital assistants (PDAs).



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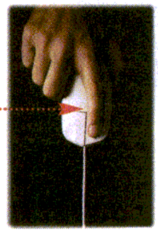

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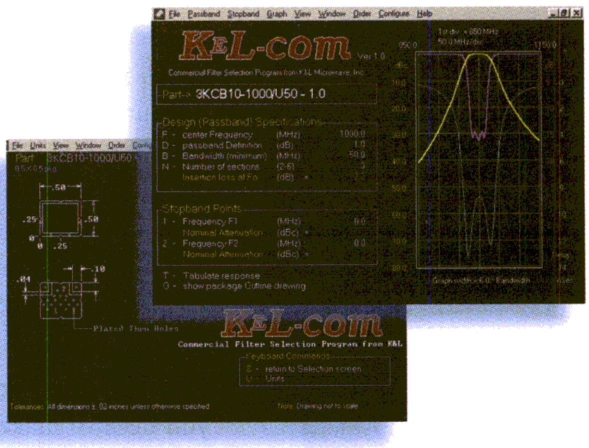

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Mayo Clinic To Test Emergency-Communications Unit

ROCHESTER, MN—The Mayo Clinic, the Minnesota Department of Transportation, and the Veridian Corp. of Buffalo, NY have allied to test Veridian's technology Mayday Plus, which combines cellular-phone and Global Positioning System (GPS) communications in three boxes that are bolted under an automobile's backseat.

When an accident occurs, the device automatically contacts the local 911 center and hospital's emergency room. The device relays data on the vehicle's speed at impact; whether airbags were deployed; whether the impact was from the rear, side, or front; and if the car rolled over. The emergency personnel can call people in the car through a cell phone linked to the system. A built-in GPS system automatically provides the car's location to rescue teams.

It is potentially an advance over emergency-communication devices such as General Motors' OnStar. That system, available in some GM models, uses GPS and cellular technology to contact a GM communications center where someone can provide assistance or relay emergency information to emergency authorities. The Mayday Plus is said to deliver more detailed information directly to local authorities.

The Mayo Clinic, the State Patrol, and Veridian have been developing the system for two-and-a-half years, and they are ready to test it. They have installed the boxes in 120 cars for a test period in the Rochester, MN area that will last until May or June. The Department of Transportation wants to see whether the system works at all, if it works during winter conditions, and whether it reduces accident response time.

Companies Collaborate On Wireless Communications Chip Technology

FISHKILL, NY and GREENSBORO, NC—IBM and RF Micro Devices, Inc. recently announced an agreement to jointly develop RF integrated circuits (RF ICs) based on IBM's silicon-germanium (SiGe) process technology.

The two companies intend to design highly integrated RF ICs for next-generation cell phones. This collaborative relationship is expected to dramatically reduce the number of chips in wireless handsets over time, shortening time to market for manufacturers, and resulting in smaller phones that use less power and offer longer battery life.

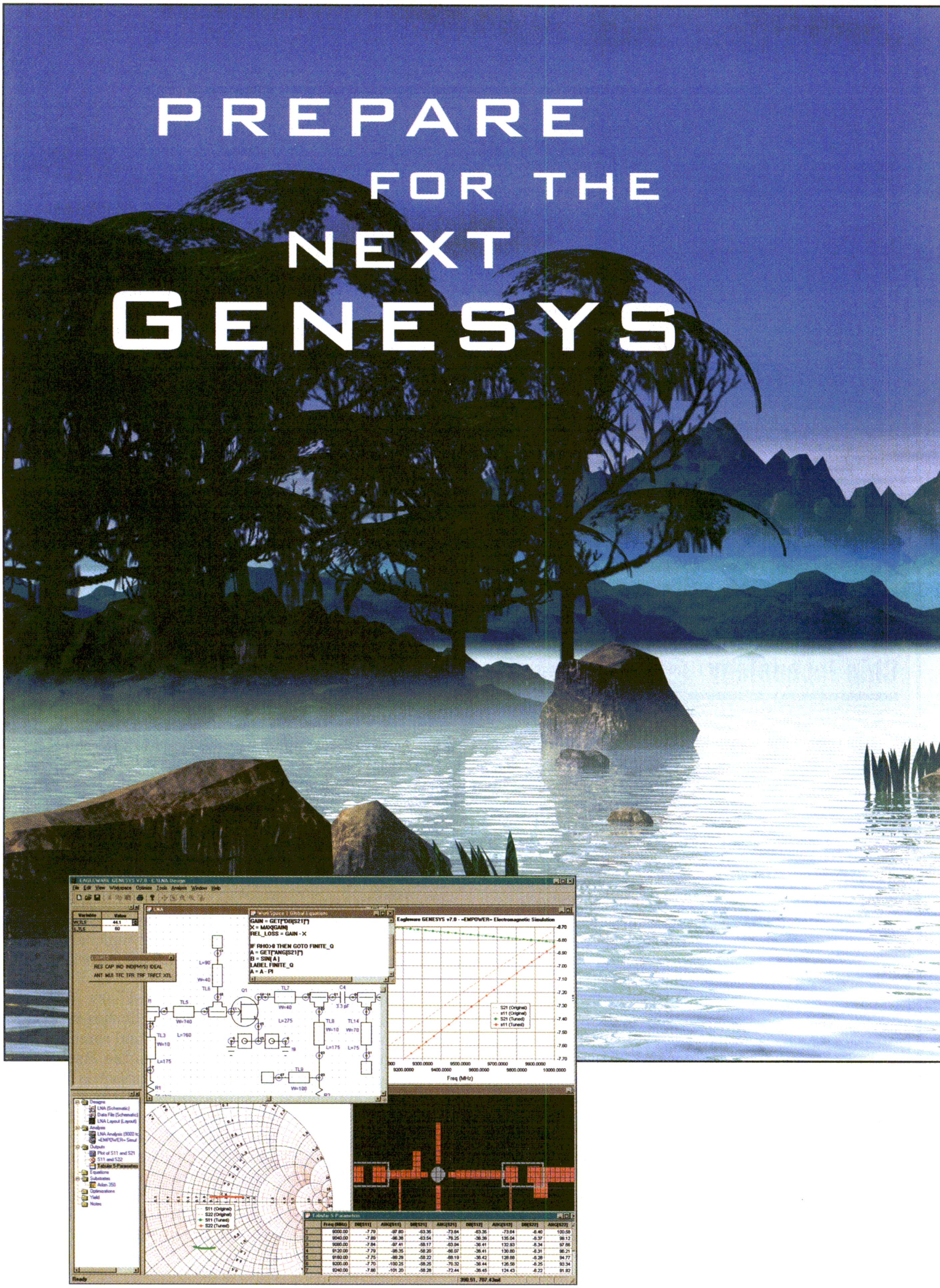
"Today's fast-paced wireless communications industry demands high performance, integrated solutions that help customers bring their product to market faster," says Michael Concannon, vice president of wireless communications at IBM Microelectronics. "The combination of IBM's proven SiGe process technology and RFMD's advanced RF IC design skills are expected to result in a new class of semiconductors for the next generation of mobile communications products."

Global Network To Be Developed For The WHO

MELBOURNE, FL—The World Health Organization (WHO) has selected a consortium led by Harris Corp. to install and operate a new global telecommunications backbone network to more effectively manage its worldwide health initiatives. The WHO Global Private Network (GPN) became operational in late 1999, proiding videoconferencing, voice, and data communications through satellite and terrestrial links between WHO's headquarters in Geneva, Switzerland and six regional offices around the world. Joining Harris in the consortium are Ericsson, Tele Danmark, and N.E.T.

Harris, through its Maritime Communications Services (MCS) subsidiary, was awarded the contract from WHO following an extensive competitive selection process. As a prime contractor, Harris is responsible for the design, installation, and commissioning of the network, and will manage the network's operations from the Harris MCS Network Management Center in Melbourne, FL. Swedish-based Ericsson is furnishing engineering support and network equipment at all site locations, and the physical hub of the network will be located at Tele Danmark facilities in Denmark, including the multipoint videoconference unit. The N.E.T. Promina 800 series multiservice access platform is at the heart of the network, and will ensure efficient allocation of network bandwidth between the various videoconferencing, voice, and data applications.

"We are very pleased to be part of the partnership agreement that will make this very dynamic network possible. WHO can benefit from the economies of single-platform delivery of multiple services," says Jean-Pierre Breton, responsible for Networking Integration Solutions at Ericsson Switzerland.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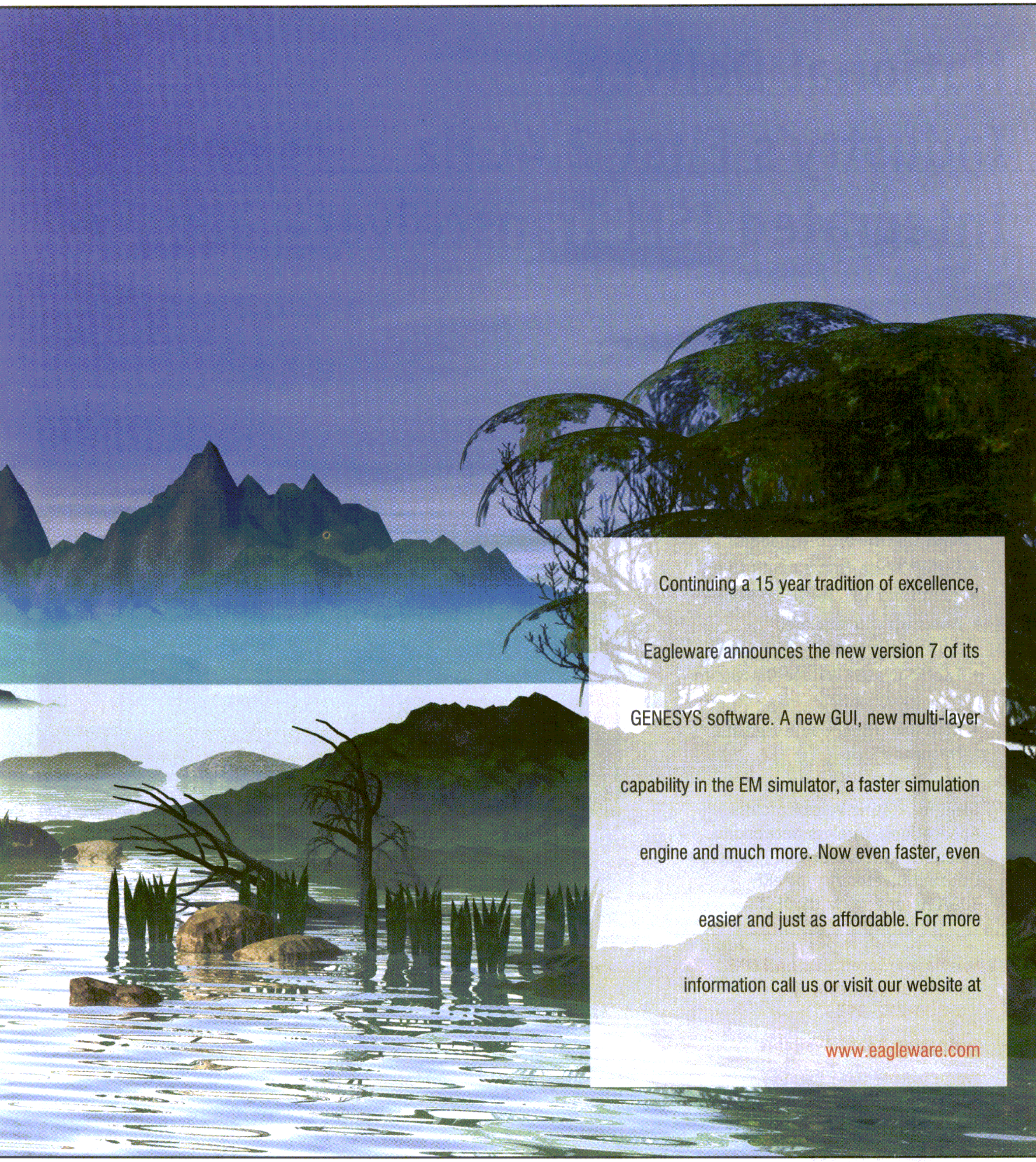
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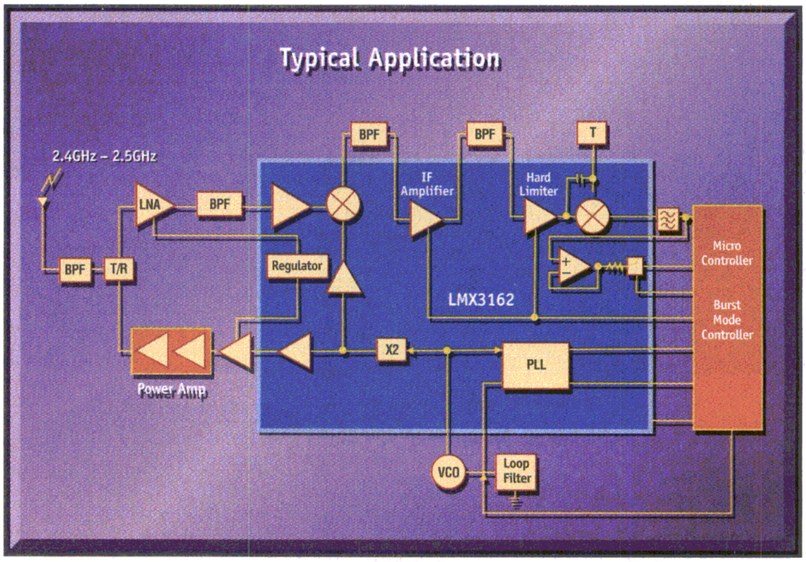

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The increasing complexity of wireless communications handsets adds new burdens for those faced with production-line measurements.

Mobile-Phone Testsets Take Aim At A Moving Target

BARRY MANZ
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FOR the less adventurous, the task of evaluating the performance of wireless telephones on the production line inspires a longing for a simpler time. Little more than a decade ago, handset testing was confined to "running the AMPS commands" [in reference to the command set for the Advanced Mobile Phone Service (AMPS) architecture], measuring the receive performance and output power of the transceiver, and ensuring the power supply, keyboard, and display worked satisfactorily. Of course, some of these actions are still core measurement tasks today, but they are now complemented by tests at multiple frequencies, with multiple access methods and additional features. Very soon, they will include Bluetooth specifications as well.

Faced with this daunting array of measurements, instrument manufacturers are striving to increase repeatability and speed, while increasing measurement performance and making test fixtures more robust and repeatable. Advancements in processing technology have already reduced test time to seconds, making the time required to connect and disconnect the device under test (DUT) a greater contributor to overall test time. The overall goal is to more accurately characterize the telephone under test in less time, and with the ability to be modified easily to accept new responsibilities.

"We work closely with our customers from an engineering perspective to optimize the production environment," says Earl Thompson, inbound strategy manager for wireless market solutions at Agilent Technologies. "We look at the core measurements, at what stage of production the measurements are performed, whether certain tests need to be performed in production rather than on a sample basis outside the production line. We also try to find new ways to handle call processing as well as calibration."

A thumbnail sketch of the handset market paints a clear picture of why phone manufacturers are concerned about every second that can be carved from production test. In 1999, more than 100 million handsets will have been produced, principally by Nokia, Motorola, Ericsson, and Toshiba, along with a growing list of Asian manufacturers entering those markets there. In this environment, even a few seconds shaved from the test process produces meaningful improvements when multiplied by millions of units per year.

While handset production has leveled off, it will no doubt head up again, as third-generation (3G) systems are deployed later in 2000 and early 2001. Unlike their forebears, these phones will have at least some of the advanced capabilities that the IMT-2000 blueprint originally described, including Internet access, wireless data capability, and Bluetooth connectivity.

SHORT-ORDER T&M

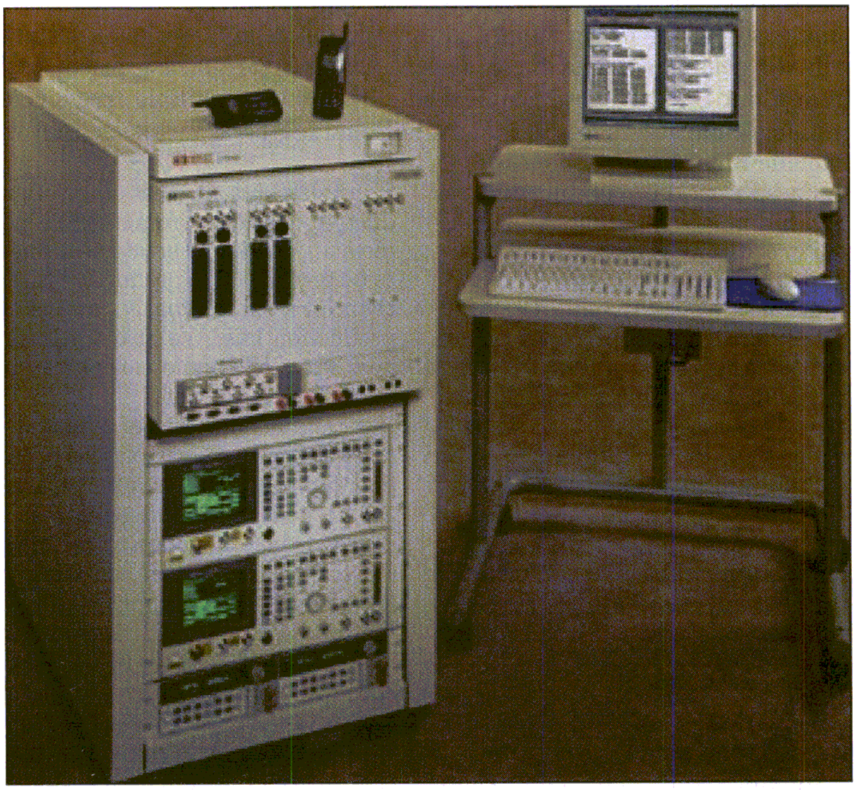
For instrument companies, the next wave of wireless applications will bring immense opportunities, and technical challenges commensurate with the level of sophistication that these products will have. Alleged 2.5G telephones that incorporate wireless data and Internet access have recently appeared, and their capabilities are a hint of what wireless communications products will soon be able to accomplish.

The 2.5G environment offers test equipment manufacturers the opportunity to transition from second generation (2G) to 3G in steps, without making one huge leap. The term 2.5G has been coined to describe the enhancement of existing 2G infrastructure with wideband data services and increased network capacity. One of the key 2.5G enhancements is the general-packet-radio-system (GPRS) overlay network, which builds on traditional circuit-switched Global System for Mobile Communications (GSM) voice network, while adding a packet-switched component for data communications. The result is data rates as high as 160 kb/s in place of the existing 9.6-kb/s capability of the worldwide GSM infrastructure. Test equipment manufacturers have already accommodated this interim enhancement within existing instruments.

In addition to EDGE, CDMA2000, GSM, and the other acronyms that must be accommodated by mobile-phone test systems, Bluetooth has now arrived—the open specification for wireless local-area networks (WLANs) [or personal-area networks, as they are now called]. {Bluetooth, which is designed to unite all types of wireless-enabled devices, was named after King Harald Bluetooth, a 10th-century Danish king who is credited with uniting Denmark and Norway.} The mission of Bluetooth is to allow capable devices to communicate with each other over very short distances—a broader adaptation of what the Infrared Data Association (IrDA) infrared techniques were supposed to achieve. Communication is through Gaussian-filtered 2 frequency-shift keying (FSK) in the 2.4-GHz unlicensed industrial-scientific-medical (ISM) band with data rates as high as 721 kb/s. Bluetooth employs a frequency-hopping, spread-spectrum (FHSS) access method, which makes it well-suited for the interference-laden slice of spectrum in which it operates.

Bluetooth supports the connection of household appliances, personal digital assistants (PDAs), computers, and entertainment systems without wires. Notebook computers that communicate with wireless phones, which communicate with home-management systems (the Bluetooth-enabled refrigerator that alerts its owner by telephone to buy more milk) is not so far fetched as it might appear.

Bluetooth was designed from scratch to be robust yet inexpensive to build—two necessities that are required to ensure its inclusion in the greatest array of consumer products. However, Bluetooth is by no means



1. The TS-5550 measurement system performs all pertinent RF measurements, call initiation, and protocol handling on a cellular or PCS handset. (Photograph courtesy of Agilent Technologies, Santa Rosa, CA.)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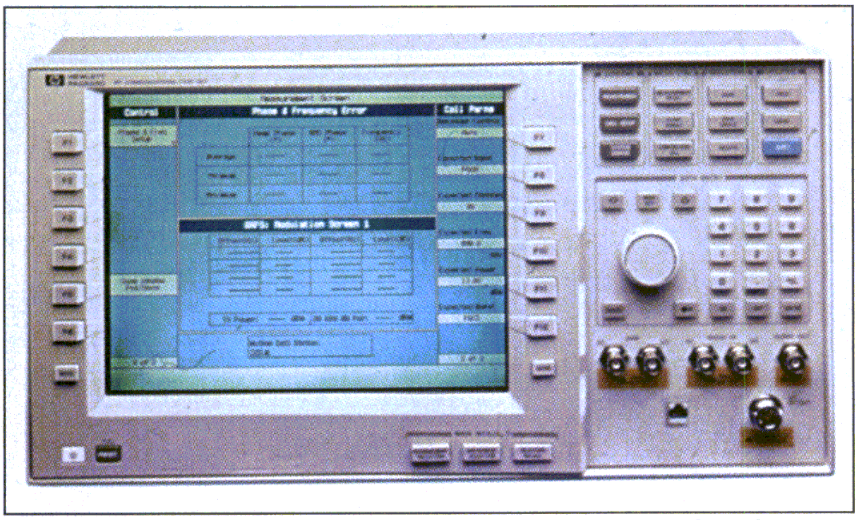

2. The CMU200 is a universal platform for the production testing of present and future mobile-telephone standards. (Photograph courtesy of Rohde & Schwarz, Munich, Germany.)

simple, and requires the very same level of measurement sophistication as its higher-powered wireless counterparts.

Transmitter test parameters include peak and average power, power density, power control, output spectrum, modulation characteristics, carrier-frequency tolerance, carrier-frequency drift, and burst profile. Receiver test parameters include single and multislot sensitivity, carrier-to-interference (C/I), blocking performance, intermodulation (IM), and maximum input level. The complete transceiver must meet regulations for spurious emissions as well.

While all of these tests may not necessarily be performed on every wireless-enabled product, and some are redundant with the standard battery of tests performed on wireless phones, some new tests remain. As a result, the wireless phone test system of the very future must incorporate the facilities to make them.

"There will be an effort in R&D to test everything," says Stephen Wood at Tektronix. "However, in the production environment, I expect production managers will look at Bluetooth as a component part," Wood continues. "You don't need to do a lot of specific testing on Bluetooth at this point. We will use the Bluetooth capability in our instruments to communicate with the phone, and test the link itself at the same time we are communicating with the phone. We are looking at having that capability next summer."

INCREASING INTEGRATION

The key to effective management of production testing is the integration of test functions within a common platform that can be increased or decreased in complexity without a massive investment in additional test equipment. The most elaborate example of this approach comes from Agilent Technologies (http://www.agilent.com).

The TS-5550 cellular-phone functional test platform is the company's most comprehensive system for testing mobile phones (Fig. 1). It is essentially a universal test platform that can be configured with hardware and software to address testing at any stage of the production process.

The TS-5550 performs all pertinent RF measurements, call initiation, and protocol handling, through incorporation of various instruments, depending on the access method of phones under test. The system automatically characterizes the RF path (cabling and fixturing) between the phone and testset.

To perform audio tests, the TS-5550 employs a C-size VXI module called the E1432A, which is a 16-channel digital signal processor (DSP) that includes transducer signal conditioning and alias protection to perform Fast Fourier transforms (FFTs) and aliasing on the input signal. Frequency response, compressor/expander response, distortion, and other measurements are specified in test specifications such as IS-98 and GSM11.10. An internal function generator delivers sine wave, noise, or arbitrary-waveform test stimuli. All of the frequencies are measured at once in the same time required to perform traditional single-tone tests. The E1432A is a shared resource in the system, and can simultaneously test four handsets.

The TS-5550 also provides battery emulation to characterize the performance of the phone, as it would be when using a battery. It performs peak current measurements required to characterize pulsed current demands, as well as powering the phone. The system power supply closely simulates actual operating conditions of digital phones, which transmit in short bursts. The supply digitizes current pulses to evaluate transmit, standby, and off-current waveforms every 15.6 μs.

Battery-charging capability can be evaluated with the optional 6612B power supply, which maintains a constant supply voltage and a programmable level of current down to the microampere region. Low-frequency measurements are handled with a digital multimeter (DMM), frequency counter, and an audio signal source. The test platform has two RS-232 serial ports for each phone under test that allow the test system to communicate with the phone in order to change power level, channel, internally route audio signals, access registers, or send power-level calibration information to the phone.

The hardware comprising the TS-5550 is orchestrated by development and test execution software that runs under Windows NT 4.0. Each test stand includes a controller and software that controls two sets of hardware to simultaneously test two phones. The test executive allows tests to be organized and places in a routine, configures the test stand, lets the user profile execution speed, and perform debugging. Integration in a factory-automation system is accommodated, as are bar-code read-innovation #3

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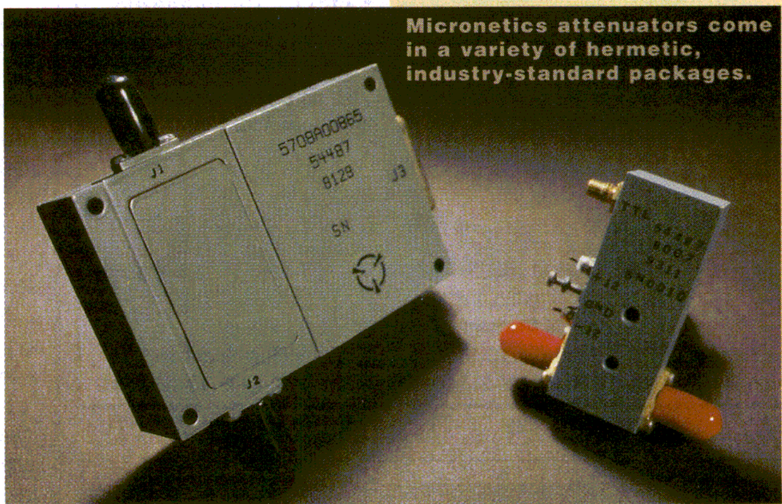

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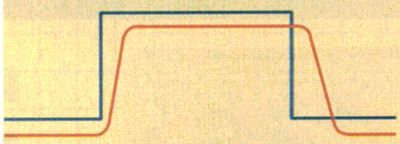

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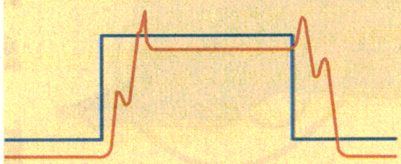

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ers and printers. The test software is hierarchical and allows re-use over diverse test configurations. Functional blocks of tests are included that can be linked to form a test plan, with the addition of sequencing and application-specific tests. Once a test plan has been verified, debug tools and a speed profiler can be used to optimize it.

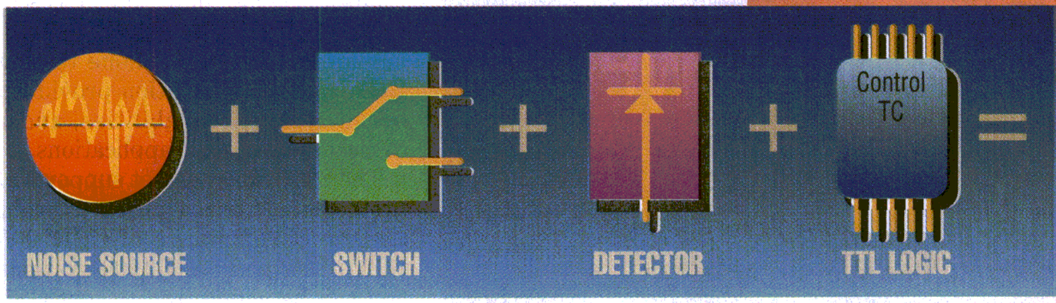
The entry-level sibling to the TS-5550 is the model TS-5530. The TS-5530 is suited for manufacturing facilities that are just beginning to test wireless phones, and is delivered as a fully assembled, racked, and cabled solution that needs to be only configured for its particular assignment. It incorporates the same test software, RF testsets, phone and serial-communications assistant of the TS-5550, and is best suited for semi-automated test environments.

Fixturing a comprehensive test system such as the TS-5550 would be a long, tedious process if it were not for the company's TS-50 test fixtures. Agilent claims that the entire process of fixturing can be completed in a few days versus a few weeks or longer without it. The TS-50 fixtures contain all of the fixturing necessary to configure a complete system, less only the phone's system, battery, and antenna connections. The fixtures are designed to be used with the TS-5500 series systems as well as those from other manufacturers.

Tektronix (http://www.tek.com) has taken a different approach create its latest "universal" radio-communication tester, the CMU200 (Fig. 2). The CMU200 is one of the fruits of the strategic alliance formed in 1993 between Tektronix (Beaverton, OR) and Rohde & Schwarz (Munich, Germany). The CMU200 is a multiprotocol test set that accommodates current wireless phone test requirements as well as those of the future with minimal investment in time and new hardware.

For example, the CMU200 can be configured to serve GSM test environments now, and CDMA2000, WCDMA, and Bluetooth environments as their requirements become clearer. The company's goal is to create a dynamic test environment that can adapt to new requirements, in innovation #4

a new concept in built-in test — the MicroCal Noise Module



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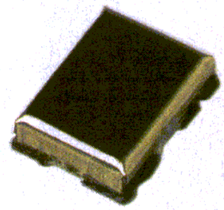
What makes the MicroCal Module different from anything else in the marketplace is the fact that it combines a noise source, switch, detector and TTL-control logic into a single component. Because the MicroCal Module packs so much into such a little space, you can use it virtually anywhere – in amplifiers, antennas, cable connectors and filters. You can even mount it in difficult-to-reach places, such as communications towers.

And that's not all. We're constantly finding new applications for the MicroCal Module, like remote monitoring of antennas and base stations. To learn more, call 603-883-2900 x302, or visit our web site at www.micronetics.com.



The MicroCal Module comes in a variety of sizes and package styles – all the way down to 1/4" square.

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test equipment
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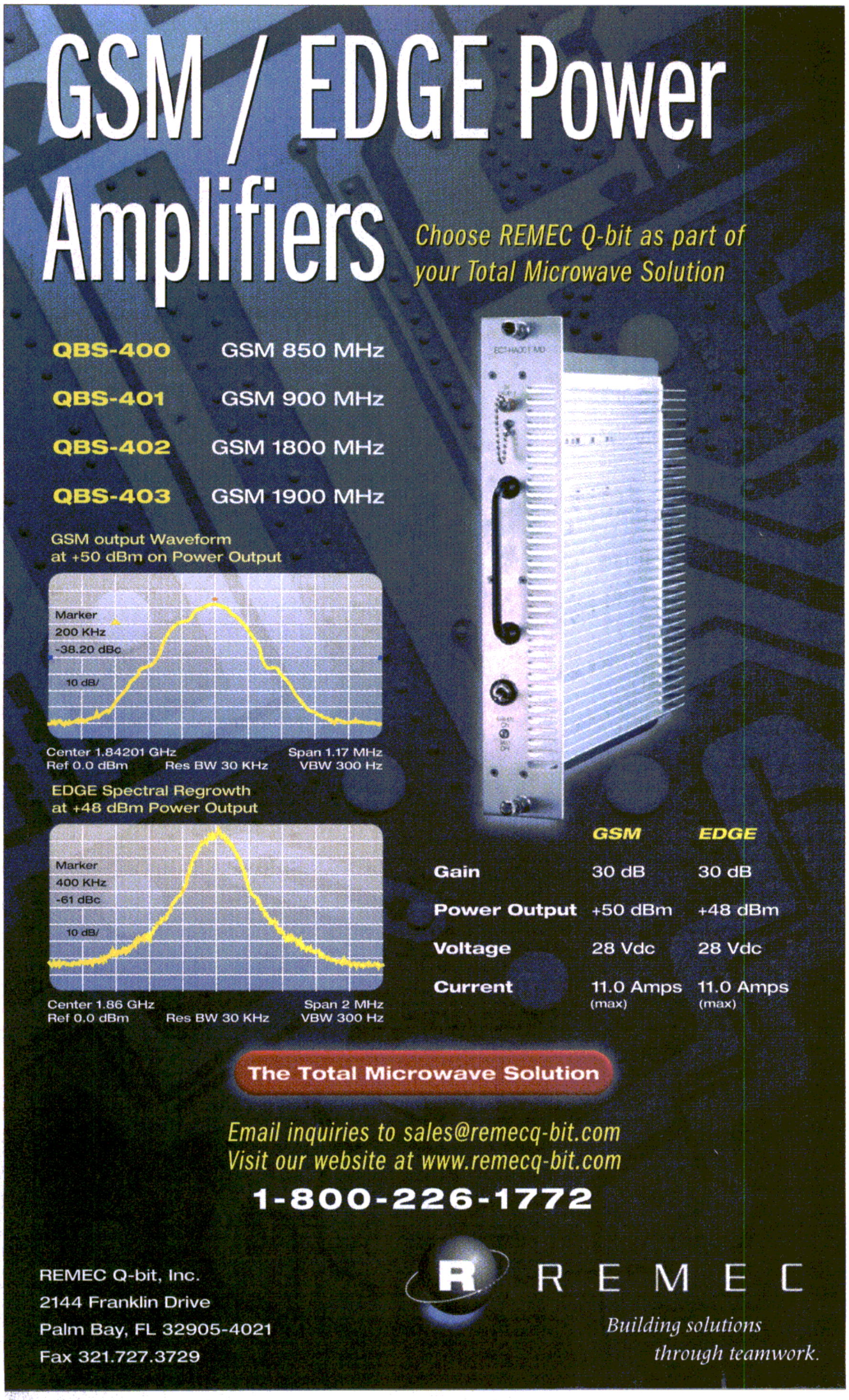
CIRCLE NO. 361

effect becoming a universal test solution. To add a protocol, internal hardware or software is installed without additional external components. The instrument performs all signaling and RF functions of a base station as it interacts with the mobile phone.

To accommodate test requirements for phones that serve two or more access methods, the CMU200 employs parallel test processing and DSP, allowing several receiver and transmitter measurements to be performed simultaneously. All of the instruments processors are socketed, in order to provide an upgrade path for the system. The instrument detects and corrects changes in temperature, output power, and frequency while tests are conducted, and Tektronix claims a three-fold improvement in accuracy over earlier products as a result. In its current configuration, the CMU200 accommodates GSM-900, GSM-1800, and GSM-1900, and will be enhanced with IS-95, IS-98, IS-136, AMPS, Bluetooth, UMTS, and WCDMA in 2000.



ANOTHER APPROACH

IFR Americas (http://www.ifrinternational.com), best known for its radio-servicing equipment, has several instruments that can be employed for mobile-phone testing. Each single-box solution provides a broad array of capabilities, and is dedicated to specific applications.

The 2967 radio testset supports all protocols that are required to evaluate the performance of GSM-900, GSM-1800, and GSM-1900 systems, and can be configured to test GSM handsets when equipped with the PhoneTest software suite. PhoneTest runs under Windows 95/98 or NT 4.0, and includes a phone driver, PhoneTest Repair, PhoneTest-Manager, and PhoneTest Exchange software. In addition to GSM, the 2967 supports AMPS, TACS, NMT, and MPT 1327 trunking. It performs a full complement of transmitter tests, including power, peak and root-mean-square (RMS) phase error, frequency and timing error, and it shows power and phase profiles against GSM masks. Receiver testing covers all classes of bit-error rate (BER), RBER, and frame error rate (FER), as well as automatic sensitivity measurement. RS-232 and IEEE-488 interfaces are standard.

The IFR-1900 CSA is a personal-communications-services (PCS) testset designed for mobile- and base-station testing of TIA/EIA-136 conformance testing. It covers 400-, 800-, and 1900-MHz PCS bands, and supports AMPS- and narrowband AMPS (NAMPS)-compliance testing as well. The IFR-1900 can be incorporated in a larger test system through RS-232 or IEEE-488 interfaces. The IFR-1900 CSA measures adjacent power and power levels as low as –40 dBm, while performing dual-mode analog/digital authentication and protocol-compliance tests for dual-mode mobile phones. It incorporates VSELP and ACELP vocoder technology and can be configured with protocol-compliance test software.

The Wavetek 4400M production test system from Wavetek Wandel Goltermann (http://www.wwgsolutions.com) is a GSM-only testset that covers all three GSM variants. It was designed exclusively for testing mobile phones, and will add other access methods such as code-division multiple access (CDMA) in the future.

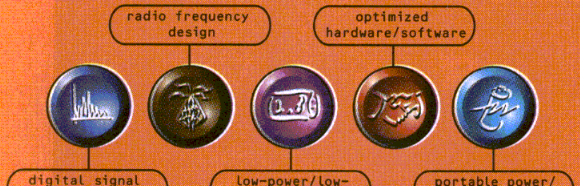
The 4400M employs a software platform called RAPID!, which uses the BASIC programming language to enable custom test routines to be created and stored on an external diskette drive or its internal hard disk. The 4400M supports cross-band channel assignment, which is necessary for testing dual-mode phones, and reduces test time. An IEEE-488 interface is included for remote control and data distribution, as are two PCMCIA slots for modem or LAN connection, along with serial and parallel interfaces.

SINGLE-BOX SOLUTION

The MT8802B radio-communication analyzer from Anritsu Co. (http://www.anritsu.com) is a comprehensive, single-box solution that essentially incorporates eight discrete measurement functions within a single enclosure. It can evaluate the performance of AMPS, NAMPS, GSM/DCS-1800, PCS-1900, TIA/EIA-136A, IS-95, and Personal HandyPhone System (PHS) phones. It supports Service Options 1, 2, and 9 for IS-95, as well as call processing and sensitivity testing using the loopback method for GSM, DCS-1800, DCS-1900, and TIA/EIA136A. The call-processing function, transmission reception-measurement functions, analog-measurement function, and thermocouple power meter are standard in the base instrument. A microwave spectrum analyzer can be added as well.

To speed testing in production, the MT8802A uses high-speed adjacent-channel power and occupied bandwidth measurement functions based on the company's proprietary measurement algorithm and DSP. Transmission frequency, modulation accuracy, output power, rise and fall characteristics of the burst wave, as well as adjacent-channel power can be measured.

For mobile-phone manufacturers, the commitment by instrument manufacturers to participate in the development process is surely welcome. Also, the continuing stream of advancements in semiconductor technology is increasing measurement speed, while fixturing issues are being addressed with pre-configured solutions. The result is a dynamic environment that can reduce the time between production of next-generation products and the systems designed to test them. ••

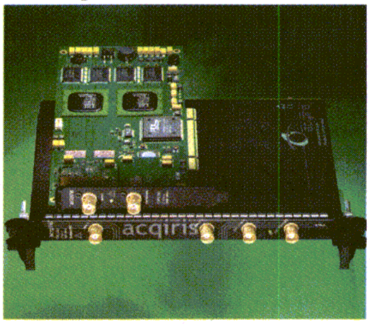


Mobile phones mean freedom to communicate wherever and whenever we choose. Philips Semiconductors is ready today with the competences and solutions you need to take that freedom to the next generation. Baseband (embedded DSPs), RF design and low-voltage/low-power technologies are at the core of our expertise. And our competence in hardware/software optimization, power management, mixed-signal ICs, speech recognition, LCD driver technology, packaging and MCMs, - along with the industry's broadest range of discretes - adds up to a capability that has made us a world


create the next generation
in communications

DAQ cards hit 2-GSamples/s rates

High-speed data-acquisition (DAQ)-card models DP210 and DC240 are capable of sampling rates to 2 GSamples/s. The cards feature 500-MHz analog input bandwidths and long acquisition memories. The digitizers provide oscilloscope-like performance, but fit the popular PCI and CompactPCI 6U form factors. The single-channel model DP210 and dual-channel model DC240 can handle input-voltage ranges of 50 mV to +5 VDC full scale. Internal calibration supports 1-percent voltage accuracy. Precise timing is ensured with a clock system capable of ±2-PPM accuracy and a trigger-time interpolator with 5-ps timing resolution. A sequential trigger mode that rearms the cards with less than 500 ns of dead time simplifies the capture of high-repetition-rate signals, burst signals, and pulsed signals. The digitizers incorporate a proprietary cooling technique that allows components to operate at safe and stable temperatures. The method extends component life while minimizing temperature-based errors. The cards work with off-the-shelf software packages, such as LabWindows from National Instruments (Austin, TX). **Acquiris USA, P.O. Box 2203, 234 Cromwell Hill Rd., Monroe, NY 10950-1430; (914) 782-6544, FAX: (914) 782-4745, e-mail: info@acquiris.com, Internet: http://www.acquiris.com.**



CIRCLE NO. 58 or visit www.mwrf.com

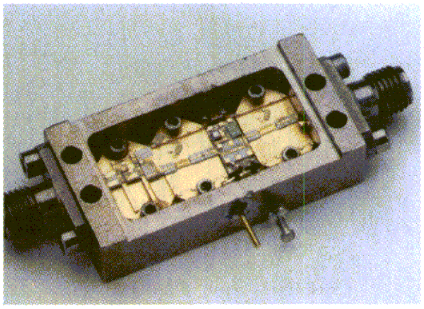
Antenna adjusts to frequency of interest

The HD-1 directional handheld dipole antenna is designed to improve the directionality and accuracy of pinpointing an RF leak from a cable-television (CATV) plant. Its retractable elements can be adjusted to the appropriate length to match the frequency of interest. The dynamic range is approximately 10 to 20 dB with a strong leak or in an outdoor environment or 5 to 10 dB in an indoor environment. The HD-1 antenna is designed for use with the company's CCI series of leakage meters, such as the CLI-1450, for example, which tunes to video carriers ranging from 115 to 140 MHz. **Wavetek Wandel Goltermann, Cable Networks Div., 5808 Churchman Bypass, Indianapolis, IN 46203; (317) 788-9351, FAX: (317) 614-8313, Internet: http://www.wwgsolutions.com.**

CIRCLE NO. 59 or visit www.mwrf.com

Broadband amplifier boosts 1 to 8 GHz

Model JCA08-B01 is a broadband solid-state amplifier based on gallium-arsenide (GaAs) field-effect-transistor (FET) technology. It achieves 25-dB gain from 1 to 8 GHz with a gain flatness of ±1.5 dB across the full frequency range. It delivers +20-dBm output power at 1-dB compression with a typical noise figure of 3 dB. The unit, which includes removable SMA connectors for combined drop-in microstrip applications and ease of testing, features an input/output (I/O) VSWR of 2.0:1. The basic amplifier offers the option of easy modification to meet the custom requirements. **JCA Technology, Inc., 4000 Via Pescador, Camarillo, CA 93012; (805) 445-9888, FAX: (805) 987-6990, e-mail: jca@jcatech.com, Internet: http://www.jcatech.com.**



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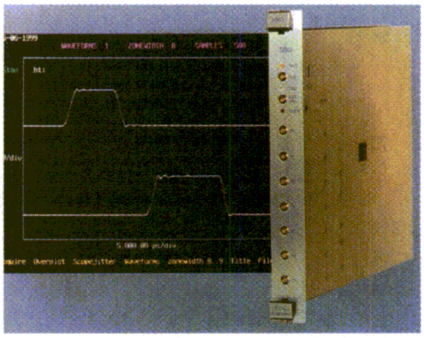
Delay generator fits C-size VXI module

The V951 digital delay generator is a single-width, C-size VXI module that accepts a single trigger input signal and generates six separately programmable delay output signals. The six delay channels can be combined in sequences to form three delay-and-width outputs. The V951, which has 40-ps delay resolution, features a 32-b dynamic range. Each delay is programmable from 0 to 167.8 ms; all six channels can be updated coherently. The delay generator achieves repetition rates to 2.5 MHz. The root-mean-square (RMS) jitter is less than 50 ps + 1×10^{-9} × the programmed delay. **Highland Technology, 320 Judah St., San Francisco, CA 94122; (415) 753-5814, FAX: (415) 753-3301, Internet: http://www.highlandtechnology.com.**



CIRCLE NO. 61 or visit www.mwrf.com

China Telecom Door To Open

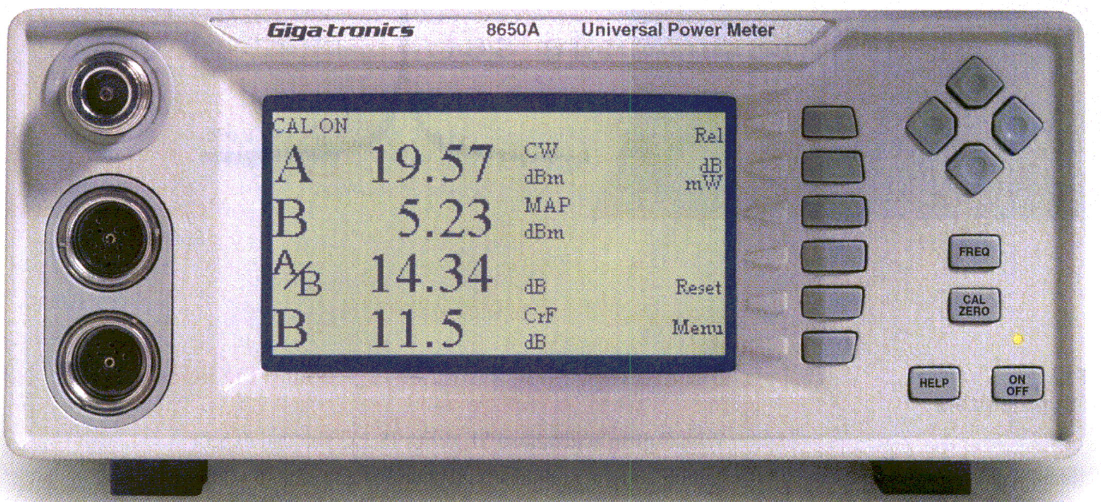
China took a giant economic-step forward in November when it signed an agreement with the US to join the World Trade Organization (WTO). Although other nations of the 135-member WTO must also complete agreements with China, the pact is seen as a breakthrough to make it a full partner in the world trading system. The rewards for US banking, insurance, and telephone companies could be substantial since the agreement will lift barriers that previously blocked foreign expansion in China.

Control of its telecommunications industry by foreign companies has long been a sticking point for the Chinese government in its dealing with these companies because of national security considerations. Telecom companies, in turn, were fearful of making huge capital outlays that could backfire if China did not allow them parity in the companies formed by the investments. Under the WTO agreement, foreign firms will be permitted to take a 50-percent ownership in these companies beginning two years after China enters the organization. This is a marked change from only a year ago when the government changed its rules on Chinese-foreign financial models to make it more difficult for outsiders to control their investments. That decision cast a pall on international telecommunication investments that had already been made or were in the works.

The stakes are very high in the China telecom market because the need for modern wired and wireless communications is so urgent if the country is to become a 21st century industrial society. Under communism (which is still the form of government), China is largely an agrarian culture with the vast majority of its citizens living in rural areas. The telecom infrastructure is old and needs rebuilding while the wireless portion is in its infancy. Meanwhile, the possibilities of providing communications equipment and services to more than a billion people without encumbrances has foreign investors licking their chops.

American wireless-equipment manufacturers such as Motorola see tremendous potential in China if they have control over the mobile-phone systems and other telecom areas in which they invest. The company could expand its existing commitment in the country—it already manufactures cell phones, pagers, and semiconductors in China—and invest in new ventures under a liberalized ownership policy.

Another major opportunity for US companies lies in the fledgling Chinese Internet business, now taking the world by storm. According to AT&T, US companies are now precluded from investing in Chinese Internet providers. ••



The Giga-tronics 8650A Series Universal Power Meter Delivers Fast, Accurate Power Measurements for Development and Production Environments.

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CIRCLE NO. 286

Contracts

Berkeley Varitronics Systems—Was awarded a contract by Texas Instruments to provide 2.4-GHz microcell test tools comprised of Lizard 1-W transmitters and Mongoose receivers.

Harris Corp.—Has been awarded a $55 million contract from MariTEL to help establish a wireless national marine-communications network that will, for the first time, enable boaters throughout the US to easily place phone calls, send/receive faxes, and even check e-mails—all from a next-generation marine radio.

ADC Telecommunications, Inc.—Canada's Image Wireless Communications has chosen ADC's CellSpan MMDS broadband wireless system as its platform for delivering two-way data services throughout Image's area of coverage in Saskatchewan, Canada. The contract agreement covers an initial product deployment valued at $1.4 million with the opportunity for future contract extensions as determined by deployment requirements.

Nitres—Has been awarded a $1.4 million contract for development of ultraviolet (UV) solar-blind focal-plane arrays by the Defense Advanced Research Projects Agency (DARPA). The funds will support the development of solar-blind UV photodetectors and focal-plane arrays, which are very sensitive to UV light and reject visible emission from the sun.

Fresh Starts

M2 Global Technology Ltd.—Has purchased the microwave-component and metal-fabrication operations from Harris Corp., Microwave Communications Division (MCD). The purchase includes the microwave-assembly operation and the metal-fabrication and finishing production unit that is collocated in the company's facilities in University Park, TX.

Noise Com, Inc.—Announced the execution of a definitive agreement to merge Boonton Electronics Corp. into a wholly owned subsidiary of Noise Com.

STMicroelectronics and Dot Wireless—Have announced a partnership to develop code-division-multiple-access (CDMA) technology and integrated baseband chips based on this technology for third-generation (3G) cellular phones.

Andrew Corp.—Has acquired Chesapeake Microwave Technologies, Inc., a privately owned company that designs and develops RF and microwave amplifiers and assemblies.

Fox Paine & Co. LLC—Has agreed to buy Watkins-Johnson Co., a manufacturer of wireless communications equipment, for $41.125 per share cash, or approximately $280 million. Watkins-Johnson says that it expects the transaction with FP-WJ Acquisition Corp., a new company formed by investment funds managed by Fox Paine, to be completed in early 2000.

LCC International, Inc.—Has completed the previously announced sale of its Products Division to Ericsson.

Lucent Technologies and Qualcomm—Announced an alliance to commercialize a wireless technology that dramatically increases the capacity and data capabilities of Lucent's network equipment based on code-division multiple access (CDMA). Under terms of the co-development agreement, Qualcomm CDMA Technologies will provide the core chip and software to be incorporated into Lucent's CDMA base-station equipment.

IMAPS—Presented its new website (http://www.imaps.org) at IMAPS '99, the 32nd International Microelectronics Symposium, which took place from October 26 to 28 at the Chicago Hilton and Towers in Chicago, IL.

Cell Loc, Inc.—Agreed to purchase Intelligent Databases International Ltd. of Calgary, Alberta, Canada for 455,555 company shares. In the acquisition, Cell-Loc will assume full ownership of IDI including its Position Collection and Distribution System technology which is an object-oriented Java-based software platform. This will allow the Cellocate Service Bureau to offer Internet-based wireless-location services to the end user.

American Technical Ceramics (ATC)—Announced a commercial-off-the-shelf (COTS) quality program to support the US government's COTS initiative. ATC's solutions offer a cost-effective approach to qualify standard capacitor products for enhanced reliability applications. The flexible COTS program provides customers with a choice of several different screening packages.

Agilent Technologies EEsof Division and IBM—Announced a cooperative effort to speed the development of integrated circuits (ICs) used in communication products, such as mobile phones. The two companies have collaborated on a design kit to enable HP's ADS software to work with IBM's silicon-germanium (SiGe) technology. The kit will enable designers to quickly produce high-performance communications chips.

Larsen Antenna Technologies—Has been acquired by RADIALL, an international producer of specialty RF connectors and cable assemblies.

Spectrian Corp.—Announced that its semiconductor division will begin to operate as an autonomous business unit known as UltraRF. The new business unit, wholly owned by Spectrian, will operate under a management team that will work independently from Spectrian's power-amplifier (PA) division.

Communication Solutions, Inc.—Announced the formation of CommEX, LLC as a wholly owned subsidiary. The company focus is the design and manufacture of high-frequency (HF), very-high-frequency (VHF), and ultra-high-frequency (UHF) high-performance surveillance receivers, special-purpose spectrum survey tools, and related products.

SV Microwave—Formed a new company, SV Microwave Commercial Products Group. The new company specializes in passive RF components for the high-volume commercial wireless and broadband markets. The company designs, develops, and manufactures high-performance mixers, power dividers, modulators, demodulators, directional couplers, hybrids, phase shifters, attenuators, and matching transformers.

Electronic Industries Alliance (EIA)—Lee Abernathy to director of management information systems; formerly served as a consultant with HCI Technologies and BEC.

Alpha Industries, Inc.—Bruce Nonnemaker to vice president of operations; formerly director of operations for Alpha Microwave. Also, David Aldrich to president and chief operating officer; formerly executive vice president and general manager of Alpha's Wireless Semiconductor operations.


NONNEMAKER


WARREN

ANADIGICS—John E. Warren III to vice president of human resources; formerly vice president of human resources for AlphaNet Solutions. Also, Thomas C. Shields to chief financial officer; formerly vice president of finance and controller at Fisher Scientific Co.

IPC—Raul Catangui to director of public policy; formerly state legislative and regulatory analyst for the American Insurance Association.

Scientific Atlanta—Peter Cresse to vice president of marketing for Satellite Television Networks; formerly sales director for the PowerVu Plus™, PowerVu IP™, and PowerVu@ networks in Europe.

Metawave Communications Corp.—Andy Merrill to vice president of customer operations; formerly field engineering manager for Motorola's Western Region.

CTS Corp.—Susan M. Opeka to director-financial controller for the wireless components business; formerly division vice president of finance for North American operations with Outboard Marine Corp.

Ohmite Manufacturing Co.—Al Kirwan to national distributor manager; formerly worked for Ohmite's Commercial Products Group (CPG). Also, Hank Werner to national sales manager of Ohmite's Victoreen Components Group; formerly held several positions in the electronics industry.

G.T. Microwave—Leonard Kahn to international sales and marketing manager; formerly worked with and represented more than 100 microwave firms in the foreign marketplace.

TESSCO Technologies, Inc.—David Young to controller; formerly assistant controller for Integrated Health Services.

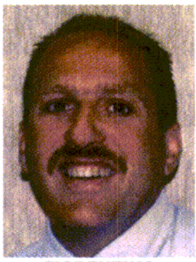
AML Communications, Inc.—Dan Faigenblat to director of sales; formerly division manager for TRW Semiconductors.

Micro Networks Corp.—Bertho Simons to director of European sales; formerly director of European sales at Coto Technology Heerlen in The Netherlands.

Rodale Electronics Corp.—Paul Ablequist to vice president of sales and marketing; formerly vice president of marketing for the EMS Division of Ultra Electronics, plc.

TriPoint Global Communications, Inc.—Daryl Dickson to director of sales engineering for RSI; formerly principal engineer with STM Wireless. Also, Thomas J. Scanio to chief technical officer; formerly vice president of product development for TriPoint's RSI Controls operation.


SCANIO


FIORENTINO

Narda Microwave—Joseph Fiorentino to sales engineer; formerly sales/applications engineer at LogiMetrics, Inc.

JDS Uniphase Corp.—Harry L. Deffebach to president of the Transmission Group; formerly vice president and general manager at Harris Corp.

EDUCATIONAL MEETINGS

Short Courses

Telecom Trends: Markets & Technologies
January 27-28, 2000 (Portofino Hotel and Yacht Club, Redondo Beach, CA)
Technology Futures, Inc.
13740 Research Blvd., Suite C-1
Austin, TX 78750-1859
Kirsten Palumbo (800) TEK-FUTR, FAX: (512) 258-0087
e-mail: seminars@tfi.com

Introduction to Delta-Sigma Data Converters and Delta-Sigma Converters for Communications
January 31-February 5 (Monterey, CA)
Mead Microelectronics, Inc.
7100 NW Grandview Dr.
Corvallis, OR 97330
(541) 758-0828, FAX: (541) 752-1405
e-mail: valence@mead.ch
Internet: http://www.mead.netgate.net

Infrared Imaging Systems and Applications
February 9-11, 2000 (Los Angeles, CA)
UCLA Extension, Department of Engineering, Short Courses
10995 Le Conte Ave., Suite 542
Los Angeles, CA 90024
(310) 824-3344, FAX: (310) 206-2815
e-mail: mhenness@unex.ucla.edu
Internet: http://www.ucla.edu/shortcourses

Fiber Optic Communication Systems
February 14-16, 2000 (Madison, WI)
Department of Engineering Professional Development
University of Wisconsin-Madison
432 North Lake St.
Madison, WI 53706
(800) 462-0876, FAX: (608) 263-3160
e-mail: Custserv@epd.engr.wisc.edu
Internet: http://epd.engr.wisc.edu.

Introductory RF and Microwaves
March 20-21 (Holiday Inn Select, Niagara Falls, NY)
R.A. Wood Associates
1001 Broad St., Suite 450
Utica, NY 13501
(315) 735-4217, FAX: (315) 735-4328
e-mail: rawood@rawood.com

Meetings

Portable Design 2000 Conference & Exhibition
January 24-27, 2000 (San Diego Coronado Island Marriott, San Diego, CA)
PennWell Corp.
98 Spit Brook Rd.
Nashua, NH 03062
(603) 891-9267, FAX: (603) 891-9490
e-mail: nualak@penwell.com
Internet: http://www.portable-design.com

Commercialization of Military and Space Electronics Workshop
January 30-February 2, 2000 (LA Airport Marriott Hotel, Los Angeles, CA)
Components Technology Institute, Inc.
904 Bob Wallace Ave., Suite 117
Huntsville, AL 35801
(256) 536-1304, FAX: (256) 53339-8477
e-mail: dale@cti-us.com

IEEE International Solid-State Circuits Conference (ISSCC '00)
February 7-9 (San Francisco Marriott, San Francisco, CA)
Courtesy Associates
2000 L St. NW
Washington, DC 20036
Diane Suiters
(202) 331-3000, FAX: (202) 331-0111
e-mail: isscc@courtesyassoc.com

Wireless Symposium/Portable by Design
February 22-24, 2000 (San Jose Convention Center, San Jose, CA)
Penton Media
611 Route 46 West
Hasbrouck Heights, NJ 07604
(888) 947-3734, FAX: (201) 393-6297
Internet: http://www.WirelessPortable.com

Fourth Annual Army Research Laboratories (ARL) Federated Laboratory Symposium (Fed Lab 2000)
March 21-23 (The Inn and Conference Center, University of Maryland University College, College Park, MD)
TMC Design Corp.
P.O. Box 2218
Suffolk, VA 23432
Jean Thomas
(757) 357-4011, FAX: (757) 357-5108

2000 IEEE Emerging Technologies Symposium on Broadband, Wireless Internet Access
April 10-11 (Dallas, TX)
Dallas Section of the IEEE
Dr. Gallon Brehm, Technical Co-Chair
TriQuint Semiconductor
(972) 994-8571, FAX: (972) 994-8502
e-mail: gbrehm@tqtx.com

IEEE International Conference on Phased Array Systems and Technology
May 20-26 (Dana Point, CA)
Dr. Michael Thorburn
The Aerospace Corp.
P.O. Box 92957, M1/111
Los Angeles, CA 90009-2957
(310) 336-2197, FAX: (310) 336-6225
e-mail: m.a.thorburn@ieee.org
Internet: http://www.ieeeaps.org/ISPAST00

Call for Papers

International Microelectronics And Packaging Society (IMAPS) Symposium 2000
September 18-22 (Hynes Convention Center, Boston, MA)
International Microelectronics And Packaging Society
1850 Centennial Park Dr.,
Reston, VA 20191-1517
(703) 758-1060, FAX: (703) 758-1066
e-mail: IMAPS@imaps.org
Abstract deadline: February 4, 2000

Asia-Pacific Microwave Conference (APMC) 2000
December 3-6, 2000 (The Wentworth Hotel, Sydney, Australia)
IEEE MTT Society
Dr. Trevor Bird
+61 2 9290 3366, FAX: +61 2 9290 2444
e-mail: apmc@icms.com.au
Internet: http://www.icms.com.au/apmc
Paper submission deadline: April 1, 2000

Test set measures RF parameters accurately

A homemade instrument for measuring the noise figure and gain of any microwave two-port network goes beyond classical analog testers by using microprocessor technology to make measurements faster and more accurately. Developed by Alessandra Di Paola and Mario Sannino of the Dipartmento di Ingegneria Elettrica, University of Palermo (Palermo, Italy), they claim that their instrument offers a capability not matched by commercial test equipment. That is, it can measure mismatched transistors, whereas commercial testers can handle only input- and output-matched (50-Ω devices. An original measurement methodology measures both noise figure (F) and available gain (G_a) simultaneously through noise-figure measurement only. The instrument itself is a tunable personal-computer (PC)-controlled receiver with double-down conversion to simplify image-frequency rejection. It is driven by software graphical-user interface (GUI) that simulates the instrument's front panel. See "A Novel Noise Figure and Gain Test Set for Microwave Devices," *IEEE Transactions on Instrumentation and Measurement*, Vol. 48, No. 5, October 1999, p. 921.

HBT MMIC amplifier sets figure-of-merit record

A 44-GHz monolithic-microwave-integrated-circuit (MMIC) amplifier based on Indium-phosphide (InP) heterojunction-bipolar-transistor (HBT) technology is thought to have the best figure-of-merit of any amplifier of its type ever designed. A good figure-of-merit is defined by a high third-order intercept point (IP3) and low DC power consumption (P_{dc}). The device was developed by Kevin W. Kobayashi, Liam T. Tran *et al.* at the Electronics and Technology Division, TRW, Inc. (Redondo Beach, CA) and John C. Cowles of Analog Devices, (Beaverton, OR). The authors measured the linearity figure-of-merit or LFOM (IP3/P_{dc}) at 21:1 and 42.4:1 using conventional and special HBT collector-epitaxy designs. Previously, the best HBT-based MMIC amplifiers posted LFOMs of 11.6:1. These new high-linearity HBTs are well suited for millimeter-wave receivers and low-voltage wireless applications. See "A 44-GHz-High IP3 InP HBT MMIC Amplifier for Low DC Power Millimeter-Wave Receiver Applications," *IEEE Journal of Solid-State Circuits*, Vol. 34, No. 9, September 1999, p. 1188.

Analysis tool models microstrip-antenna structures

The finite-difference-time-domain (FDTD) method is a time-domain full-wave analysis tool that has been used extensively to solve two- and three-dimension scattering problems. Authors J. Xia, S.H. Tan, and K. Arichandran of the School of Electrical and Electronic Engineering at Nanyang Technological University (Singapore) used the method to model various type of microstrip antennas. In particular, FDTD was applied in a microstrip antenna designed with a substrate-superstrate method intended to increase the antenna's gain (such antennas are noted for narrow bandwidth and low gain). A microstrip antenna was fabricated and both simulated with FDTD software tools and measured electrically with a network analyzer. The simulated results came out in close agreement with the measured ones. Moreover, the antenna has a maximum gain of 10.4 dBi and wide bandwidth, which makes it applicable to mobile-satellite communications, Global Positioning Systems (GPS), remote sensing, and other microwave systems. See "Analysis of One Wide-Band and High-Gain Patch Microstrip Antenna Using the FDTD Method," *International Journal of RF and Microwave Computer-Aided Engineering*, Vol. 9, No. 6, November 1999, p. 468.

Can the DOCSIS specification handle Internet over cable TV?

High expectations are being pinned on the Data Over Cable Systems Interface Specification (DOCSIS) 1.0 protocol to deliver Internet Protocol (IP) traffic over cable television (CATV) at significantly higher rates than either analog modems or integrated-services-digital-network (ISDN) links. The question is whether DOCSIS 1.0 can do the job given its limited Quality Of Service (QOS) features and modem population of up to 500 nodes. Some answers come from P. Tzerefos, V. Sdralia, C. Smythe, and S. Cvetkovic of the Department of Computer Science, University of Sheffield (Sheffield, England). After extensive analysis, a number of problem areas were revealed. For example, the number of data streams that can be supported is lower than the theoretical maximum due to collisions and protocol overheads. The final conclusion on DOCSIS 1.0 is that it can be best used only in dedicated channels. See "Delivery Of Low Bit Rate Isochronous Streams Over The DOCSIS 1.0 Cable Television Protocol," *IEEE Transactions on Broadcasting*, Vol. 45, No. 2, June 1999, p. 206.

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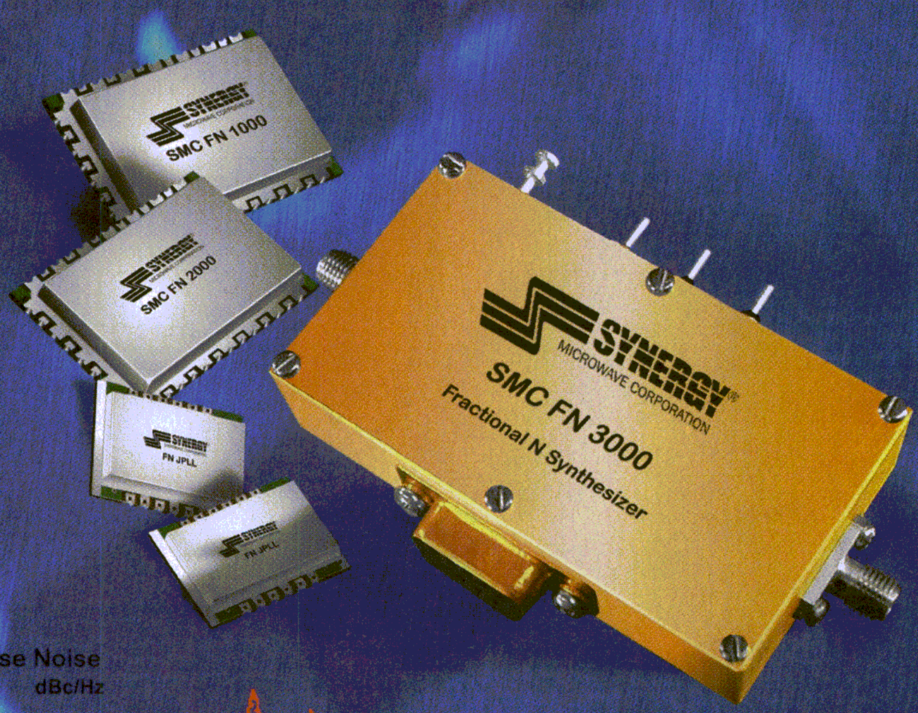

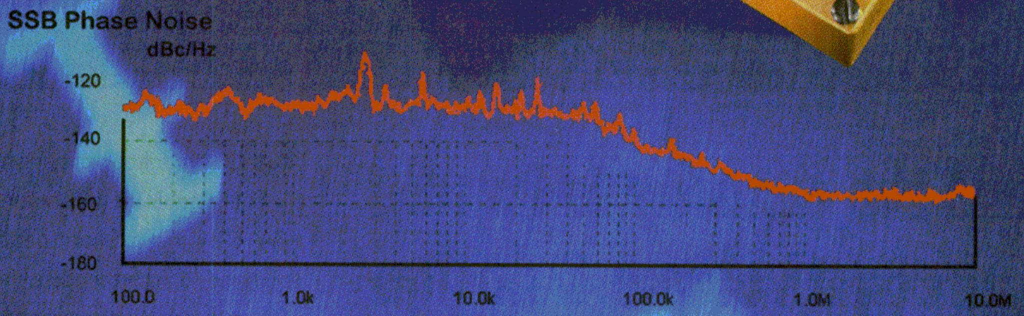

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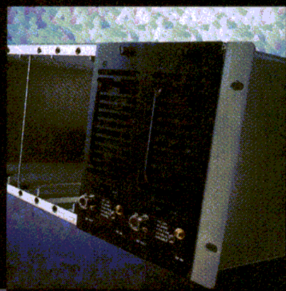

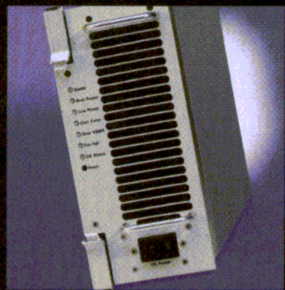

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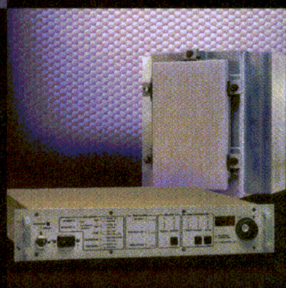

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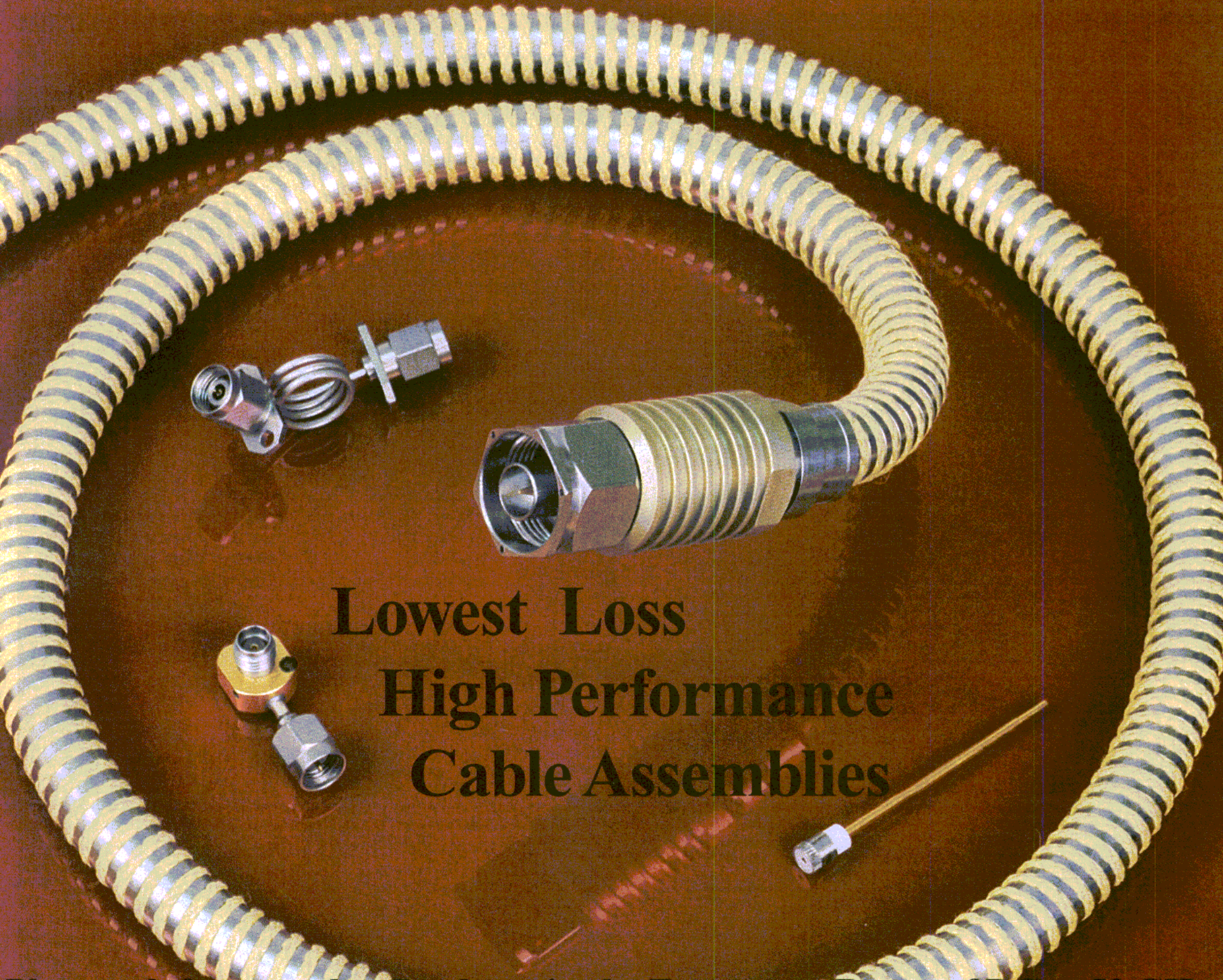

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Measure Harmonics With A Spectrum Analyzer

These measurement algorithms can be applied to the analysis of harmonic signals at audio and microwave frequencies.

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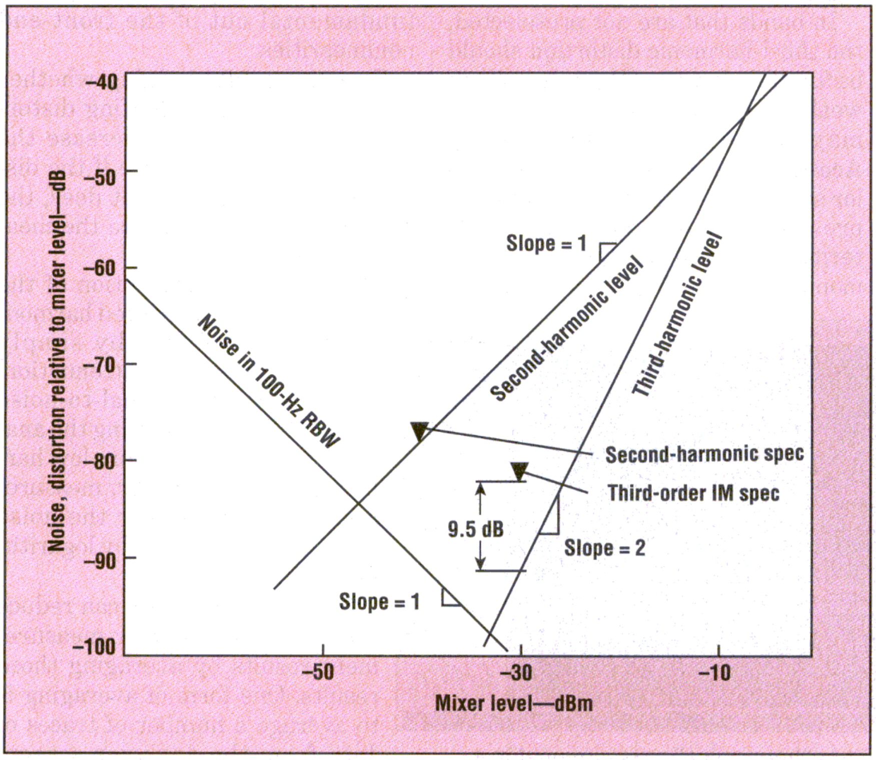
RADIO engineering involves making measurements of the harmonics of RF signals, and sometimes the determination of the total harmonic distortion (THD) of audio signals. The RF signals may be modulated or continuous-wave (CW) signals. They may be produced by drifting voltage-controlled oscillators (VCOs) or solidly phase-locked oscillators or synthesizers. Modern spectrum analyzers can make these measurements with the techniques described later in the article. This article discusses how to tell if the harmonics are generated in the analysis equipment or the device under test (DUT), optimum measurement techniques for different kinds of signals, and the uses of log averaging, voltage units, and root-mean-square (RMS) computations.

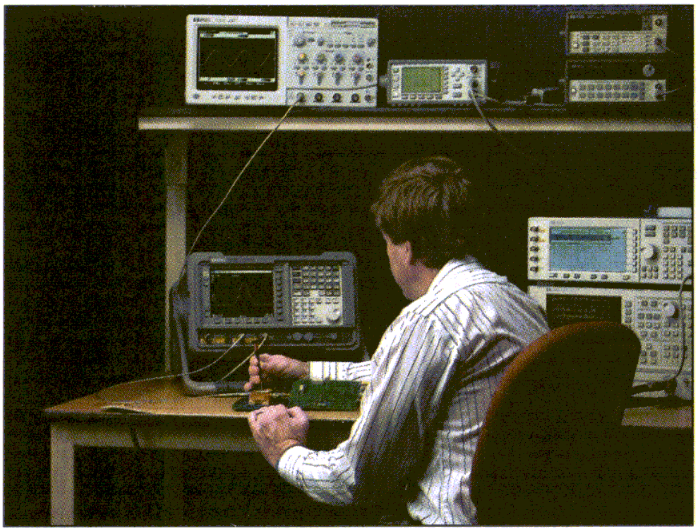


1. Spectrum-analyzer distortion limits can be predicted by drawing 1:1 and 2:1 slopes from the specification points for second and third harmonic levels, respectively.

In this discussion, assume that all signals are periodic. That is, they are repetitive in their voltage-versus-time characteristics. Fourier analysis makes it possible to represent any repetitive signal as the summation of a number of sine waves. The lowest-frequency sine wave, the one that is intentionally produced, is known as the fundamental signal. The sine waves are called the harmonic signals. A spectrum analyzer can be used to measure the amplitudes of the fundamental signal and its harmonic signals.

Harmonics are often undesirable. In radio transmitters, they can interfere with other users of the RF spectrum. In local oscillators (LOs) for heterodyne receivers, for example, they can create spurious signals. Therefore, normally they should be monitored and minimized.

When signals are measured with a spectrum analyzer, the analyzer's circuits contribute some distortion of their own. To make accurate measurements, a user needs to know whether this measured distortion is



2. The ESA family of spectrum analyzers from Agilent Technologies (Santa Rosa, CA) uses the count-and-average-in-zero-span algorithm, which is optimal for locked and modulated sources.

part of the signal of interest or if it is contributed by the analyzer.

The analyzer generates distortion due to weak nonlinear behavior (since it is not ideal). Therefore, it is possible to represent a spectrum analyzer's signal-processing behavior with a Taylor series, showing the relationship between the output (O) and input (I) voltages:

$$V_o = k_1V_i + k_2V_i^2 + k_3V_i^3 \ldots \qquad (1)$$

where:
V_o = the output voltage,
V_i = the input voltage, and
k_1, k_2, and k_3 = constants.

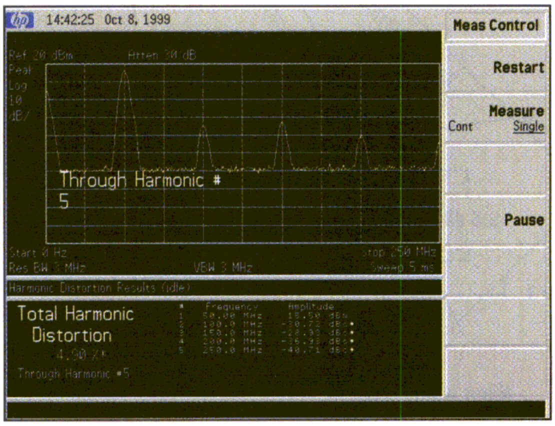
With this relationship, it is straightforward to show that a doubling in input voltage (6 dB) provides a quadrupling in the V^2_I term, and, thus, a quadrupling in second-harmonic response to a sine wave. Similarly, the third- harmonic distortion increases by the cube law with input level. There are two ways to tell if the analyzer is contributing to the measured distortions—by specification or experiment.

To judge the analyzer's contribution from its harmonic distortion specifications, convert those specifications provided in dBc relative to a specified signal at the analyzer's input mixer to dBc for the chosen input level using knowledge of the order of the distortion. A graphical example of this process is shown in Fig. 1. Note that only second- and third-order distortions are specified for spectrum analyzers. Higher-order distortions are usually negligible.

Note that third-order harmonic distortion, the parameter of interest, is different from third-order intermodulation distortion (IMD3), the parameter specified.

In bands that are not preselected, the third-harmonic distortion should be 9.5 dB below the IM products for a weak nonlinearity. This relationship may be derived by substituting Acos(xt) + Bcos(yt) for V_i in the Taylor series (eq. 1) that was mentioned previously, and comparing the IM terms, such as cos[(x-2y)t] to the harmonic terms, such as cos(3xt). If the gain of the front end changes between the fundamental signal and the third-harmonic signal, it changes the relationship between IM and observed analyzer-generated harmonic levels by the same amount. If the third harmonic is in a preselected band, it is much lower than the IM products specified, though, because the preselection filter keeps the fundamental out of the front-end nonlinearities.

Experimentally judging whether the analyzer is contributing distortion is easier. Simply increase the input attenuation and see if the distortion level changes. If it does, the analyzer is contributing to the measured distortion.



3. A built-in "harmonics" measurement in a spectrum analyzer shows a table of individual harmonic levels in dBc and a computed total-harmonic-distortion (THD) result.

Although the contribution of the analyzer to the measured harmonics can be reduced by simply increasing the input attenuation, this reduces the signal-to-noise ratio (SNR), thus limiting the analyzer's ability to measure low harmonic levels. However, measurements of signals near the noise floor can be improved by logarithmic averaging.

Spectrum analyzers can reduce the variations in their measurement results by averaging those results. One form of averaging is to average a number of traces of data from the analyzer screen. Another form is the video filter. When performing these averaging actions, it is important to be aware

of the amplitude scale on which the averaging occurs. When video filtering or trace averaging occurs on a signal represented on a logarithmic scale, the result is the average of the logarithm of the signal. Alternatively, the averaging could take place on a linear (voltage) scale. Some analyzers are capable of averaging on a power (RMS voltage) scale. Fast Fourier transform (FFT)-based analyzers typically average only on this scale.

THE LOGARITHMIC SCALE IS BEST FOR MEASURING LOW HARMONIC LEVELS BECAUSE IT REPORTS A SIGNAL LEVEL THAT IS LEAST AFFECTED BY THE NOISE FLOOR.

It is well-known that the measured level of pure noise differs for these three scales, with the log scale underreporting noise by 2.51 dB. Not surprisingly, the logarithmic scale is best for measuring low harmonic levels because it reports a signal level that is least affected by the noise floor. Thus, the log scale should be used to measure harmonic levels, with a reduction in the video bandwidth or an increase in averaging as required. (More information on this topic is available in application note 1303 from Agilent Technologies, *Spectrum Analyzer Measurements and Noise*, available at the company's website at http://www.agilent.com.)

The ideal repetitive signal discussed previously does not exist in nature. The two important deviations from the ideal are drift and modulation. A drifting signal from an unlocked VCO can create measurement challenges. The drift can be so large that, to measure a harmonic, it is necessary to sweep through the frequency range where it can be and use a peak detector to measure its level. With this high variability in frequency, averaging can cause errors and should not be used. Furthermore, peak detection is particularly good at detecting noise, so the measurement range of the analyzer suffers when measurements are made with this sweep-and-peak-detect technique. Nonetheless, this type of algorithm is very robust and is used in some spectrum analyzers, such as the 8560 E-series from Agilent Technologies (Santa Rosa, CA), equipped with the company's 85672A spurious response measurements utility.

Modulated signals are also a measurement challenge. When the signal is modulated, its spectral width increases and, thus, a wide-enough resolution bandwidth (RBW) must be used to respond to all of the energy in the signal. Using a wide bandwidth increases the noise floor and, therefore, reduces the available dynamic range. The spectral width of signals with frequency modulation (FM), pulse modulation (PM), and common digital modulation formats increases in proportion to the harmonic number, so an increase in the RBW with harmonic number is recommended.

Modulated signals are nearly always phase locked. Therefore, one possible algorithm is to carefully measure the frequency of the fundamental using a frequency counter, then look for all of the harmonic signals at their expected frequencies using the spectrum analyzer's zero-span analysis capability. Zero-span analysis, a mode where the analyzer is not sweeping, is optimal because it averages all the data of a sweep, not only the peak amplitudes. The ESA family of spectrum analyzers from Agilent Technologies (Fig. 2) uses this count-and-average-in-zero span algorithm, with scaling resolution bandwidths. Though less robust than the sweep-and-peak-detect algorithm, it is very fast at achieving low-variance results and works well with modulated sources. A typical display is shown in Fig. 3.

The sum of the amplitudes of all the harmonics is a figure of merit that is often used in the audio industry. It is called total harmonic distortion (THD). It is based on a power summation, not a voltage summation. The definition of THD is:

$$THD = 100\% \times \left(\sum_{n=2}^{n_{max}} E_n^2 \right)^{0.5} / E_f \quad (2)$$

where:

E_n = the voltage of the nth harmonic,

E_f = the voltage of the fundamental, and

n_{max} = the highest harmonic number to be considered. (In many cases, this is limited to 10. In other cases, it is the highest harmonic that does not exceed 20 kHz, the top of the audio range.)

The three scales where averaging can occur—voltage, log, or power—were discussed previously. Note how THD measurements relate to these scales. The data are best acquired and averaged on a log scale. The computation of THD is a root-sum-of-squares (RSS) computation, which is related to RMS or power computations. But the result is computed from voltages, and the percentage is a voltage percentage.

In summary, RF and audio harmonics and THD can be measured with a spectrum analyzer using the techniques described. In some spectrum analyzers, these measurement algorithms are automated to speed the measurements. ••

References

1. *Spectrum Analysis Basics*, Agilent Technologies Application Note 150, available at http://www.tm.agilent.com/tm/Notes/English/5952-0292.html.

2. *Spectrum Analyzer Measurements and Noise*, Agilent Technologies Application Note 1303, http://www.tm.agilent.com/tm/Notes/English/5966-4008E.html.

3. Robert A. Witte, "Distortion Measurements Using a Spectrum Analyzer," *RF Design*, September 1992, pp. 75-84.

Design A Logamp RF Pulse Detector

Monolithic logarithmic amplifiers offer the sensitivity, dynamic range, and speed needed to detect RF bursts.

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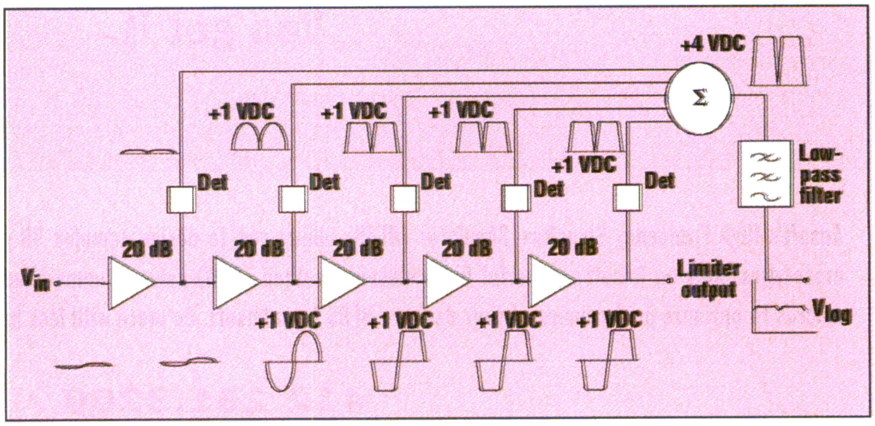
Analog Devices, Inc., 804 Woburn St., MS-124, Wilmington, MA 01887; (781) 937-1239, FAX: (781) 937-1024, e-mail: eamon.nash@analog.com

LOGARITHMIC amplifiers (commonly known as logamps) are useful for burst detection and measurement due to their ability to detect signals that vary over a very large dynamic range. Monolithic logamps are capable of detecting RF bursts as short as 20 ns at frequencies to 3.5 GHz, and they can detect amplitude variations as large as 120 dB.[1] Logamp burst detectors are commonly used in applications such as radar and the demodulation of amplitude-shift-keying (ASK) signals. This article describes the issues that designers must consider when applying logamps to these tasks, and discusses techniques and pitfalls associated with measuring a logamp's pulse response time.

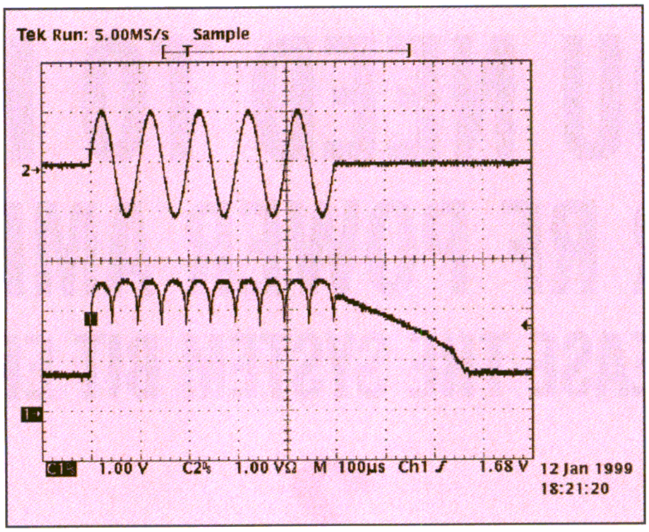
To understand how a logamp detects RF bursts, it is first necessary to understand the basics of logamp operation. Figure 1 shows a simplified block diagram of a typical logamp. The core of the device is a cascaded chain of linear amplifiers, each with a gain typically between 10 and 20 dB. For simplicity, this example shows a chain of five amplifier stages, each with a gain of 20 dB, or 10X. A small continuous sine wave is fed into the first amplifier in the chain and progresses through the chain. At some stage, it becomes so big that it begins to clip. In this example, the clipping (or limiting) level has been set at +1-VDC peak, and it occurs at the output of the third stage. The clipped signal continues through the signal chain, maintaining its +1-VDC peak ampli-



1. Logamps use successive detection to calculate the log of the envelope of a signal. The full-wave rectified outputs from the detectors are summed and must be filtered before the output. The corner frequency of the lowpass filter determines the response time of the logamp to change at the input.

tude as it goes.

The signal at the output of each amplifier is fed into a full-wave rectifier or detector, and the outputs of these rectifiers are summed together. The summed output is then applied to a lowpass filter, which removes the ripple of the summed, full-wave-rectified signal. (Some logamps have built-in lowpass output filters, whereas others require external filters.) The summed current increases linearly for an exponential increase in input signal, so the output signal is proportional to the log of the envelope of the input signal. When the input signal is continuous (not pulsed), the logamp responds by putting out a steady-state DC voltage. (A more-detailed explanation of the operation of the logamp is contained in reference 2.)



2. Applying a signal to a logamp whose input frequency is equal to or lower than the video bandwidth will result in excessive ripple at the output. This ripple can be easily eliminated with additional external lowpass filtering. The linear tail on the output signal is caused by the non-ideal (exponential) decay on the input signal.

Now consider what happens if the input signal is not continuous, but pulses on and off instead. The logamp's response time—the time it takes the output to change in response to a change at its input—is dominated by the RC time constant of the lowpass output filter. The bandwidth of this filter is commonly referred to as the video bandwidth. Setting the video bandwidth very high obviously will produce residual output ripple for low-frequency input signals. Figure 2, for example, shows the response of an AD8313 monolithic logamp to a 10-kHz input burst. The AD8313 can work at frequencies to 2.5 GHz and achieves a 65-dB dynamic range. Since the on-chip video bandwidth of the AD8313 is set to approximately 13 MHz, there is excessive output ripple in response to this low-frequency input. This scenario demonstrates the fact that the corner frequency of the lowpass output filter determines the logamp's minimum input frequency. Logamp designers customarily set the minimum input frequency to a value somewhere between five and 10 times the video bandwidth. However, the logamp can be used to detect lower-frequency inputs without any penalty as long as sufficient external lowpass filtering is used. (In some cases, this can be as trivial as adding a load capacitor to the log output.[3]

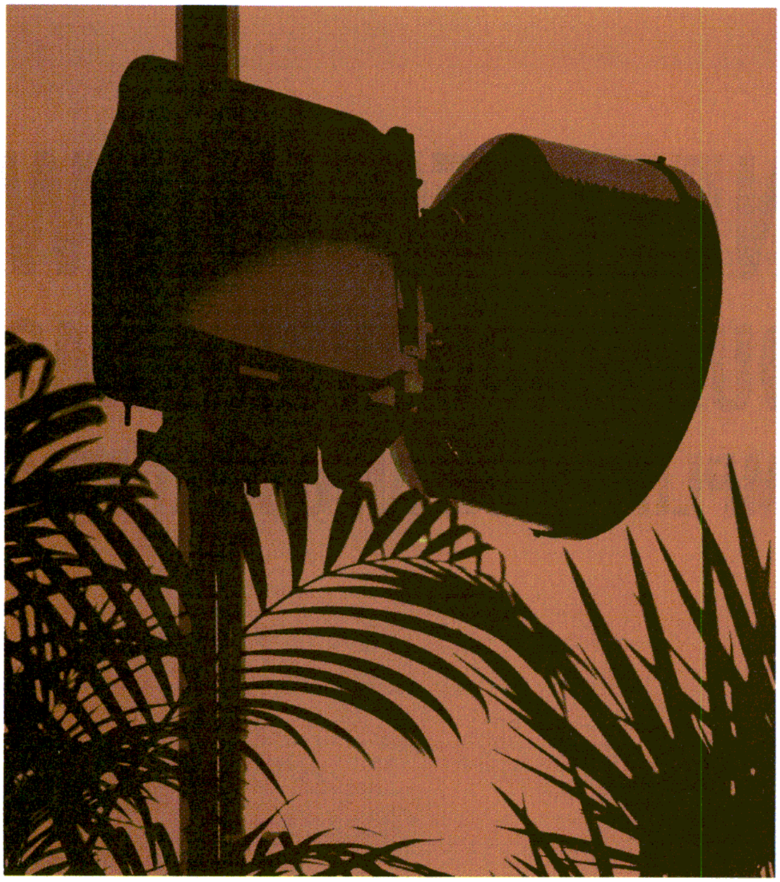
The logamp's video bandwidth should not be confused with its input-signal bandwidth. The input signal bandwidth of a monolithic logamp typically ranges from 50 MHz to approximately 2.5 GHz, whereas the video bandwidth of the output filter typically ranges from 1 to 30 MHz. The table lists the maximum input frequencies and video bandwidths for a number of Analog Devices' logarithmic amplifiers. Note that the AD640 and AD641 do not have any on-chip, lowpass filter, and require external filtering. The advantage of this arrangement is that the corner frequency can be set at an arbitrarily high frequency. This can yield rise times as low as 6 ns.

When selecting a logamp for its response time, the designer must consider its primary application. Figure 3 shows a logamp used in a circuit to detect a simple ASK signal. In this example, the presence or absence of an RF burst conveys the 1s and 0s of digital information. It can also be used for radar applications where the arrival time of the burst is the critical parameter to be measured.

Although the signal detected by the logamp can vary over a large dynamic range, the logamp's output amplitude is of no interest. What matters is that it detects the presence or absence of the burst. Indeed, in the

Logamps with high video bandwidths respond quickly to bursts

Device	Maximun input bandwidth	Video bandwidth	Rise time 10 to 90 percent	Dynamic range	Log conformance	Limiter output
AD640	120 MHz	N/A (see text)	6 ns	50 dB	±1.0 dB	Yes
AD641	250 MHz	N/A (see text)	6 ns	44 dB	±2.0 dB	Yes
AD8306	500 MHz	3.5 MHz	67 ns	95 dB	±0.4 dB	Yes
AD8307	500 MHz	5.0 MHz	500 ns	92 dB	±1.0 dB	No
AD8309	500 MHz	3.5 MHz	67 ns	100 dB	±1.0 dB	Yes
AD8310	440 MHz	25 MHz	15 ns	95 dB	±1.0 dB	No
AD8313	2500 MHz	13 MHz	45 ns	65 dB	±1.0 dB	No



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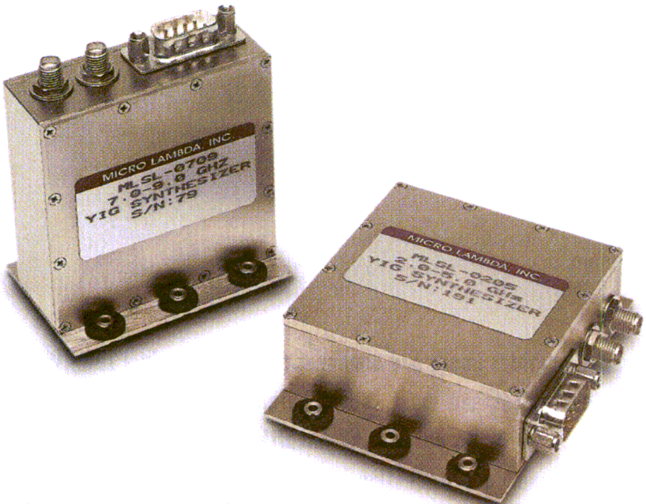

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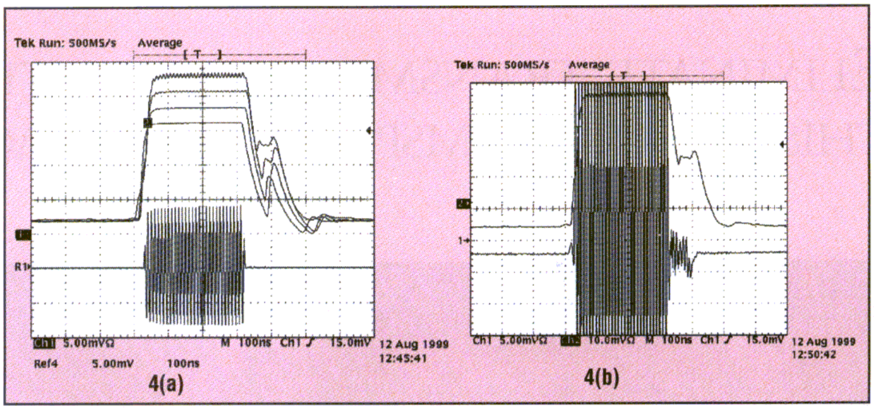
48041 Fremont Blvd. Fremont, CA 94538 (510)770-9221 mcrolambda@aol.com www.micro-lambda.com application shown, the logamp's output is fed to a comparator. The comparator's threshold is set to a voltage that corresponds to a logamp input level that is slightly above the bottom of its dynamic range. In applications such as this, it is standard practice to specify the response time as a 10-to-90-percent rise time—that is, the time it takes the signal to go from 10 to 90 percent of its final value. While this standard does not indicate how long it takes before the logamp provides a precise reading of the input amplitude, it does give a good indication of how narrow a pulse the logamp can detect.

In applications where measurement of the size of the input signal is critical, it is more appropriate to define the response time as the time between the onset of the burst and the point where the logamp's output reaches a certain portion of its final value (0.5 dB of final value is commonly used).

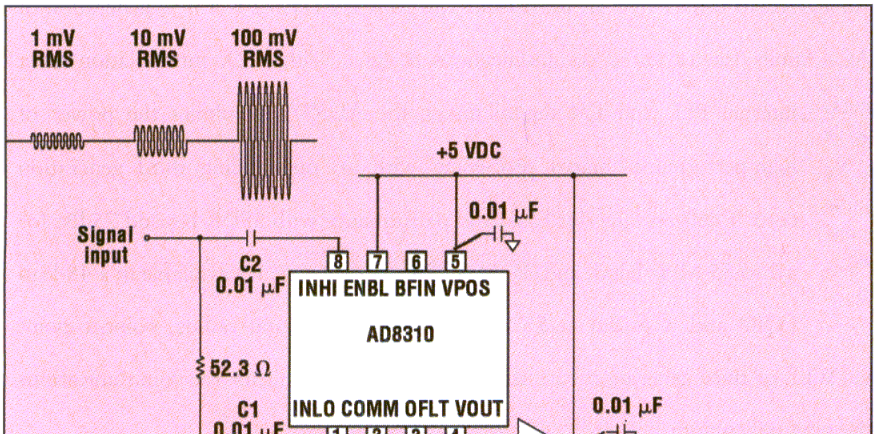
Figures 4a and b show the results of pulse-response measurements on the AD8314, which is optimized for detection and control of transmitted time-division-multiple-access (TDMA) bursts in mobile handsets. The logamp operates from 100 MHz to 2.5 GHz and has a dynamic range of 45 dB. Figure 4a shows the output responses for input levels of +10, 0, –10, and –20 dBm (the +10-dBm input signal is shown). It is immediately apparent that there is a problem with the falling edge of the logamp's output signal. The falling edge on this plot has a long tail that is very slow to settle, compared with the rising edges. However, on closer examination, it can be concluded that the logamp is doing exactly what it should be doing—detecting signals that vary over a very large dynamic range. Looking closely at the decay of the input signal in Figure 4a, it can be seen that it does not immediately and completely turn off at the end of the 300-ns burst. This signal decays to a level that is barely visible to the eye on a linear scale such as that of an oscilloscope. However, in the log domain, the signal remains relatively large after the end of the burst. Of course, the logamp detects this relatively large signal.



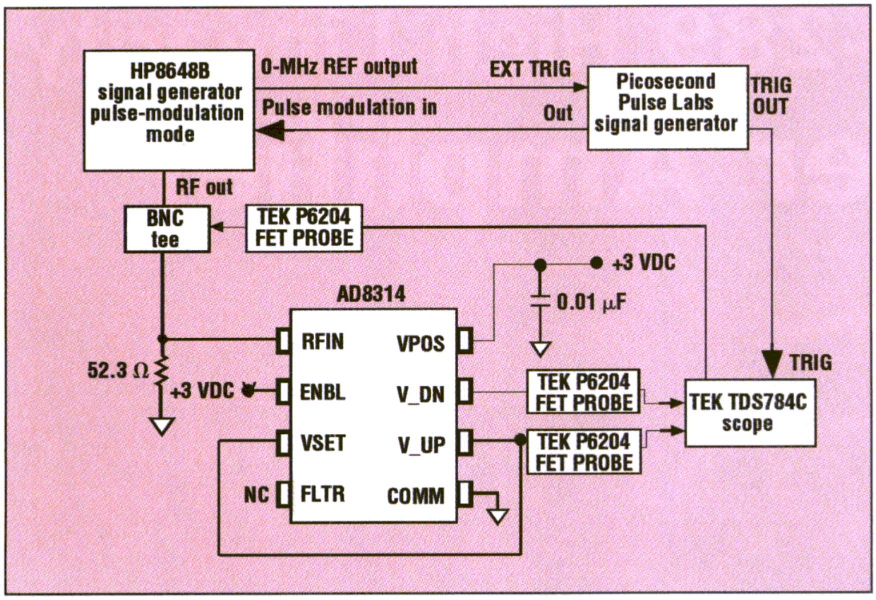
4. Excessive fall time is a characteristic of many logamp response-time measurements. On closer examination, however, the input burst, which at first glance seems to have a clean decay (a), actually decays quite slowly from a logarithmic perspective (b). The logamp faithfully measures this signal, which is still relatively large from a logarithmic perspective.

Figure 4b shows the +10-dBm input signal magnified to a larger scale. Here, it is clear that the burst persists at a lower level for an additional 100 ns and takes some additional time after that to settle. The result of this 100-ns burst extension is clearly visible at the output of the logamp. Note that this problem is not visible at the onset of the burst. When rising, the input signal quickly ramps from zero to a value that is close to its final value. The settling portion of the rise time entails moving through a voltage range that, in decibel terms, is quite small. For example, log(20) – log(10) > log (100) – log(90).

Clearly, precise control of the turn-off of the burst is critical for measuring the fall time of the logamp's output—more critical than for linear amplifiers. Figure 5 shows a circuit



3. In a simple amplitude-shift-keying (ASK) system, the logamp converts bursts that can vary over a large dynamic range into pulses that vary in amplitude over a very narrow range. A comparator is used to provide a constant amplitude output for all input levels.



5. To measure the response time of fast rise-time logamps, a pulse generator with picosecond resolution is required to precisely control the turn-on and turn-off of the burst. FET probes are used throughout to avoid adding excessive load capacitance, which can affect the quality of rising and falling edges.

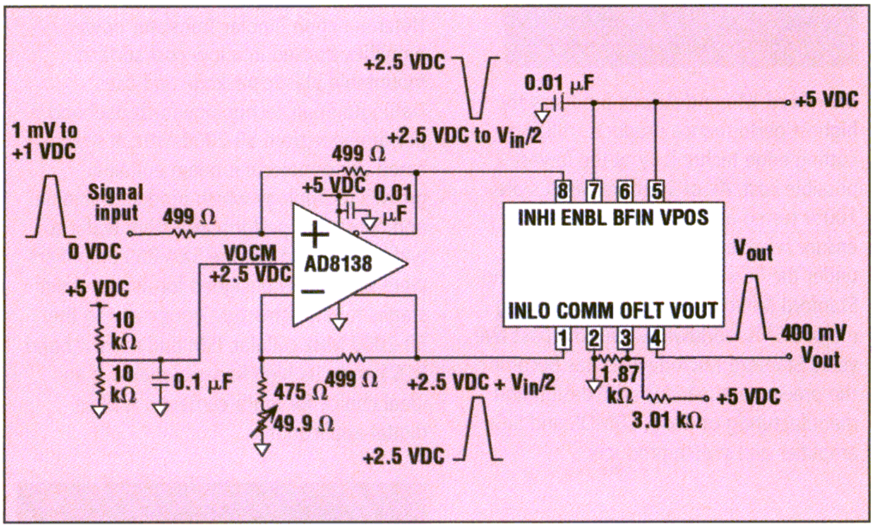
for accurately measuring logamp rise and fall times. A pulse generator is used to turn the RF source on and off. To receive a sharp falling-edge response from the logamp, it is necessary to adjust the pulse width of the pulse generator in 100-ps increments. This allows the RF-generator control to be tweaked until the turn-off pulse disables the burst just as it makes a zero crossing. The ability of the RF generator to react to the burst-enable signal is also critical. Generally, this characteristic of the generator is unknown, and determining it requires some experimentation.

Throughout these signal measurements, field-effect-transistor (FET) probes are used because they contribute very little load capacitance. This is especially true for the measurement of the logamp's output, because even small amounts of load capacitance can form a lowpass filter with the logamp's output impedance and slow down the output edges.

Up to now, the discussion has focused on detecting RF bursts (also called RF pulses)—AC signals that turn on, stay on for a short period of time, and then turn off. Logamps can also detect baseband pulses, but they are not optimized for this function. A baseband pulse is defined as a signal that changes from one DC level (usually, but not always, 0 VDC) to another level for a short period, and then it returns to the original value. A good example might be the signal from a photodiode. In general, DC coupling of this pulse is required. Since most logamps are internally DC-coupled, this is fundamentally feasible. However, there is a practical constraint when using single-supply logamps with differential inputs. The input signal must be positioned a few volts above the ground potential for proper biasing of the first stage. Furthermore, the source is usually a single-ended, ground-referenced signal, so it will also be necessary to provide a single-ended-to-differential conversion in order to correctly drive the logamp's differential inputs.

Figure 6 shows how a signal can be level shifted and converted to a differential form using the AD8138 differential amplifier. The AD8138's differential outputs then drive the AD8310 logamp, which has an input impedance of approximately 1 k Ω. The four 499-Ω resistors set the differential amplifier's gain to unity. An output common-mode (or bias) voltage of +2.5 VDC is achieved by applying +2.5 VDC (from a supply-referenced resistive divider) to the AD8138's VOCM pin.

In this application, it is necessary to trim the circuit's offset voltage. Remember that an offset of only a few millivolts can dramatically reduce dynamic range in the log domain. Under normal (AC-coupled) operation, the AD8310 compensates for its internal offset voltages. (This is another reason why AC coupling is normally recommended.) When the inputs



6. Logamps can detect DC-coupled baseband pulses, but some signal conditioning is necessary. The pulse must be converted to a differential signal with a bias level that is around mid-supply. Baseband pulses from 1 mV to 1 V can be detected. The pulse width can be as narrow as 40 ns.

are DC coupled, this offset-compensation circuitry must be disabled. This is performed by applying a nominal voltage of approximately +1.9 VDC to the AD8310's OFLT pin. Note that this does not trim the logamp's offset voltage—it merely holds it at a fixed level and prevents the logamp's offset-compensation circuitry from misinterpreting DC-input signals as offsets.

The AD8138's trim, therefore, compensates for both devices' offsets. The trim occurs by grounding the circuit's input and slightly varying the gain resistor on the AD8138's inverting input (a 50-Ω potentiometer is used in this example) until the voltage at the AD8310's output reaches a minimum. After trimming, the lower end of the dynamic range is limited by the broadband noise at the output of the AD8138, which is approximately 425 µV peak-to-peak. Figure 7 shows how this circuit responds to a series of 100-µs pulses having amplitudes of 1 mV, 10 mV, 100 mV, and +1 VDC. The circuit can detect pulses as narrow as 40 ns. The excessive noise on the output signal before and after the pulse is due to signal-generator noise. ••

THROUGHOUT THESE SIGNAL MEASUREMENTS, FIELD-EFFECT-TRANSISTOR (FET) PROBES ARE USED BECAUSE THEY CONTRIBUTE VERY LITTLE LOAD CAPACITANCE. THIS IS ESPECIALLY TRUE FOR THE MEASUREMENT OF THE LOGAMP'S OUTPUT, BECAUSE EVEN SMALL AMOUNTS OF LOAD CAPACITANCE CAN FORM A LOWPASS FILTER.

References

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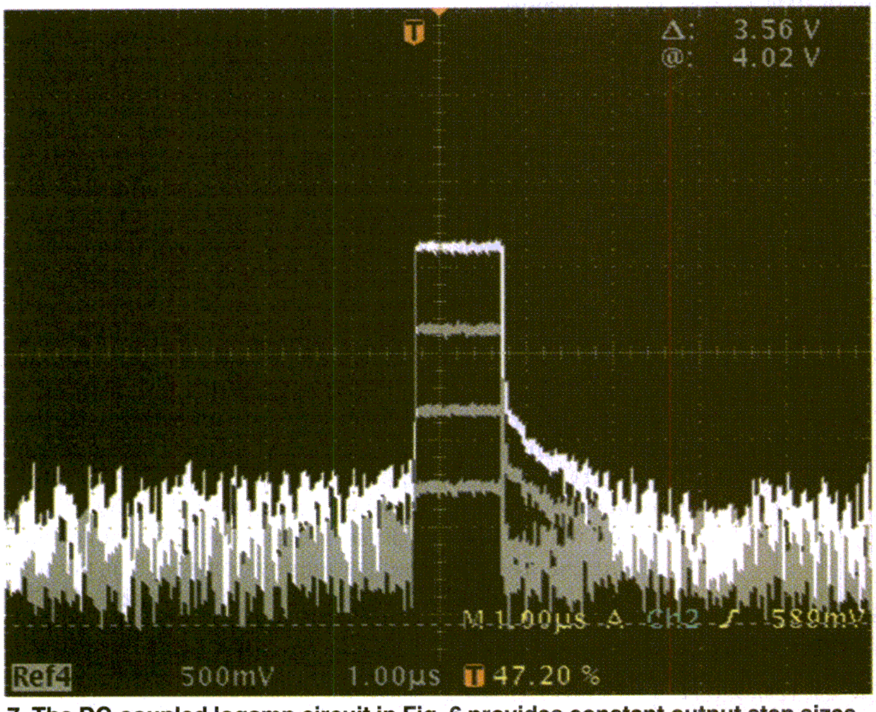

7. The DC-coupled logamp circuit in Fig. 6 provides constant output step sizes for constant ratio changes at the input. The output signals represent the response to 100-µs input pulses of amplitude 1 , 10, and 100 mV, and +1 VDC.

NIST Unveils Status Of PIM Testing

A series of NIST-monitored tests of signal-distortion measurements on passive components provides necessary measurement assurance to manufacturers.

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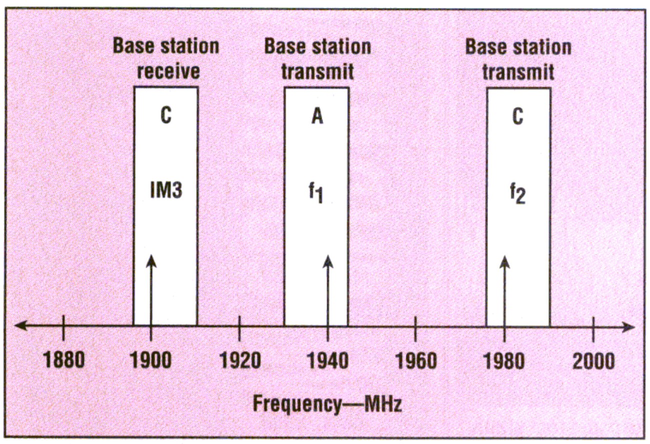
PASSIVE intermodulation (PIM) is a form of signal distortion that occurs whenever signals at two or more frequencies conduct simultaneously in a passive device, such as a cable or connector, which contains some nonlinear response. Requested by US industry and members of the International Electrotechnical Commission, the National Institute of Standards and Technology (NIST) initiated a comparison of measurements of PIM for the US wireless industry. The goal was to determine the level of agreement in measurements of PIM made by US manufacturers and suppliers of passive components for wireless-communication base stations. This study reveals not only the difficulties that industry is experiencing in making PIM measurements, but also provides US companies with a tool to improve their measurement capabilities as they deal with PIM-related trade barriers.

Since August 1998, 10 US companies have participated in the PIM comparison. The participants measured four round-robin test samples and contributed 19 data sets for four different commercial communications bands. No company is singled out, and each can determine how well its measurements compare with the group averages for each of the four test samples in each of the four communication bands. While the majority of participants report PIM levels within one standard deviation of the mean value, some companies report quite significant discrepancies.



1. Potential third-order modulation in broadband PCS results from collocation of two or more transceivers at a single site.

In PIM, the nonlinear behavior produces spurious signals, where the frequencies are linear combinations of the frequencies of the original signals. The lower odd-ordered intermodulation (IM) products [e.g., f (IM3) = $2f_1 - f_2$] are usually the most difficult in the wireless industry since they have the highest potential of falling within the receive band, or uplink, of a base station, creating RF interference (RFI) in the receiver.[1] Although frequency allocations are specifically designed to guard against this problem, collocation of two or more base-station transceivers at a single site substantially increases the risk of PIM interference,[2] as illustrated in Fig. 1.

Base stations built for mobile communications systems such as personal communication services (PCS-1900), Advanced Mobile Phone System (AMPS), Global System for Mobile Communications (GSM), and Digital Communications System (DCS-1800), use DIN (Deutsche Industrinorm) 7-16 and type-N coaxial connectors to handle the high transmit-power requirements. At high power (more than 1 W), nonlinearities in coaxial connectors become apparent and measurable.[3] The many possible causes of IM in coaxial connectors and cables include poor mechanical contact, dissimilar metals in direct contact, ferrous content in the conductors, debris within the connector, poor surface finish, corrosion, vibration, and temperature variations. The sources of PIM have been studied quite extensively at various laboratories.[4-15]

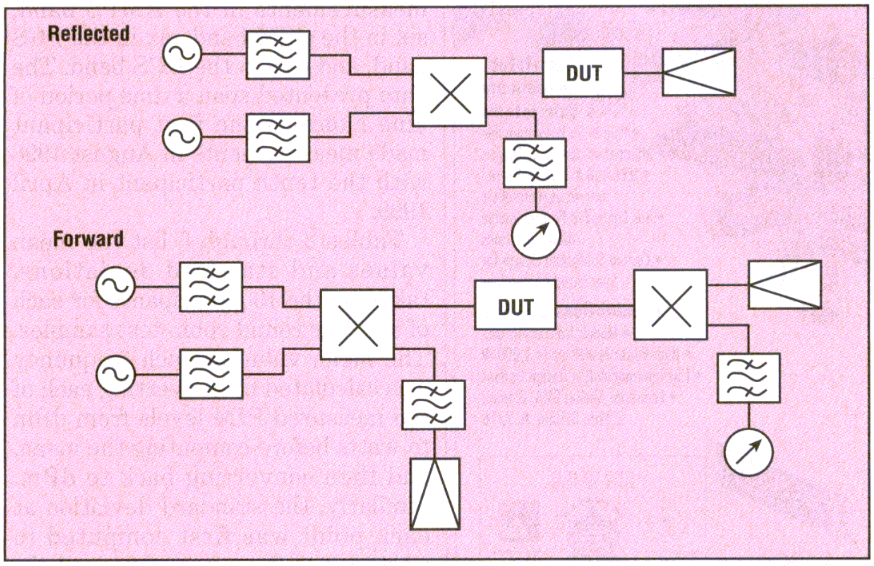
Table 1: Receive and transmit frequencies for four communication bands

Communication band	Base-station receive frequencies (uplink)	Base-station transmit frequencies (downlink)
AMPS	824 to 849 MHz	869 to 894 MHz
PCS-1900	1850 to 1910 MHz	1930 to 1990 MHz
GSM	890 to 915 MHz	935 to 960 MHz
DCS-1800	1710 to 1785 MHz	1805 to 1880 MHz

TEST METHOD

To conduct the comparison, NIST obtained two sets of test samples. One was used as a control test sample, and the other was circulated among the participating companies. The test samples were labeled with different colors to distinguish them: red, white, yellow, and blue. Each test sample had two ports with male and female DIN 7-16 connectors and varying passive nonlinearities. The red, white, and yellow test samples were simply male-to-female adapters with diodes inserted through the outer conductor wall to generate nonlinearities of varying degrees. The blue test sample, which also had a diode inserted in one connector, was a cable assembly whose purpose was to create noticeable frequency-dependent behavior.

Following the International Electrotechnical Commission's guidelines,[16] the power levels for the third-order IM products of each test sample were measured with two continuous-wave (CW) signal sources, each measuring +43 dBm (20 W) at the test ports. Each test sample was measured within the base-station receive (uplink) band of any or all of the four communications bands listed in Table 1, when the two +43-dBm signals were tuned to fall within the corresponding base-station transmit (downlink) band. The minimum



2. Two configurations for measuring passive IM products are reflected and forward. The DUTs can be connectors or a cable assembly.

required data from each participant was a single third-order IM power in one communication band.

Participating companies were asked to measure either or both forward and reflected IM products (Fig. 2). To measure reflected IM, participants were instructed to connect the male connector of the test sample to the active test port of their system and the female connector to a low PIM load. To measure forward intermodulation, they were instructed to connect the male connector of the test sample to the active test port of their system with the female connector being connected to their own cable that was, in turn, connected to the receiving port of their system. Participants who had the ability to make swept-frequency measurements were encouraged to make additional measurements at specified frequencies. Those who had systems that could measure IM products in more than one communication band and those who had multiple systems were encouraged to measure the devices in as many different bands as possible.

The role of NIST in this comparison was to act as a pilot laboratory. Without knowing absolute PIM values, its tasks were to organize the comparison, measure the stability throughout the study, keep a data base of the measurements, and report the results.[17] Its first responsibility was to procure a passive IM analyzer and two sets of test samples, one of which was kept in-house for measuring the long-term stability of the system, and the other was circulated among the participants. After each company measured the set of four test samples, they were returned to NIST along with their data, and test samples were re-measured to ensure that they were still in working order before sending them to the next company. To date, 10 companies have contributed 19 data sets over the past nine months. Each participant's measurements are compared against the group, keeping all companies' identities confidential.

AMPS

Of the 10 participants, five made measurements in the AMPS band, six in the GSM band, six in the PCS band, and two in the DCS band. The data presented span a time period of nine months—the first participant made measurements in August 1998 with the tenth participant in April 1999.

Tables 2 through 5 list the mean values and standard deviations, taken by the 10 participants for each of the four round-robin test samples. The mean value at each frequency was calculated by converting each of the measured PIM levels from dBm to watts before computing the mean, and then converting back to dBm. Similarly, the standard deviation at each point was first computed in watts and then converted to decibels. The following are the results

obtained in each of the four communications bands.

Five IM3 frequencies (844, 845, 846, 847, and 848 MHz) were specified for measurements spanning the AMPS band. Measurements at these frequencies could be obtained in two ways: holding source one at 869 MHz and sweeping source two downward from 894 to 890 MHz in steps of 1 MHz, or holding source two at 894 MHz and sweeping source one upward from 869 to 871 MHz in steps of 0.5 MHz. All five participants who made measurements in the AMPS band made swept-frequency measurements in both directions. One participant made reflected measurements, one made forward measurements, and three made forward and reflected measurements. Tables 2 and 3 list the mean values and standard deviations for each test sample at the five measured frequencies.

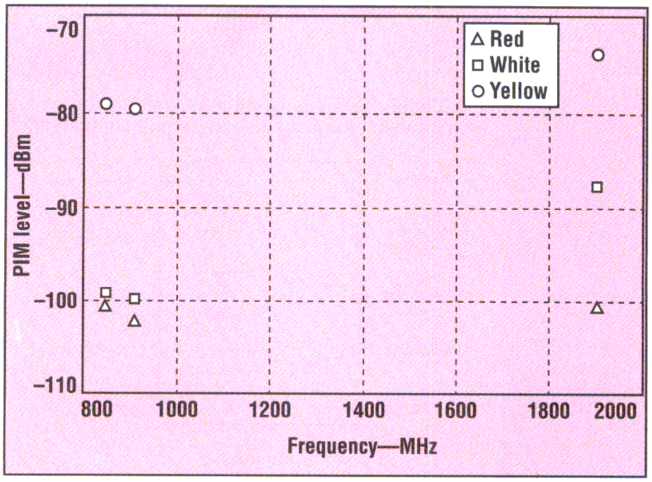
From the data compiled in all bands, including AMPS, it appears there is no significant difference between reflected and forward measurements for the electrically short test samples (red, white, and yellow). However, there were noticeable differences for the electrically long (blue) test sample, so the two measurements were separated when calculating the mean values and standard deviations. Also, the white test sample was less stable than the other test samples in all bands, yet its PIM values were very close to the red test sample. The mean values measured throughout the AMPS band for the red test sample varied between −100.3 and −101.4 dBm, with standard deviations ranging from 1.5 to 1.9 dB; the mean values of the white test sample varied between −98.8 and −99.5 dBm, with standard deviations from 2.8 to 4.8 dB; the mean values of the yellow test sample varied between −79.4 and −79.7 dBm, with standard deviations from 1.3 to 1.9 dB; the mean values of the blue test sample, measured in the reflected configuration, varied between −93.6 and −95.1 dBm, with standard deviations from 3.3 to 4.6 dB; and the mean values of the blue test sample, measured in the forward configuration, varied between −87.9 and −88.3 dBm, with standard deviations ranging from 1.4 to 2.1 dB.

Five IM3 frequencies (890, 895, 900, 905, and 910 MHz) were specified for measurements spanning the GSM band. Measurements at these frequencies could be obtained in two ways: holding source one at 925 MHz and sweeping source two downward from 960 to 940 MHz in steps of 5 MHz, or holding source two at 960 MHz and sweeping source one upward from 925 to 935 MHz in steps of 2.5 MHz. Of the six participants who made measurements in the GSM band, two made swept-frequency measurements. The other four made measurements at 910 MHz (source one at 935 MHz and source two at 960 MHz). Three participants made reflected measurements, one made forward measurements, and two made forward and reflected measurements.

Similar to the AMPS band comparison, the GSM measurements showed no difference between reflected and forward measurements for the electrically short test samples (red, white, and yellow) but did so for the electrically long (blue) test sample. And once again, the white test sample was less repeatable than the others. Since only two participants made swept-frequency measurements in the GSM band, statistical calculations were performed only for 910 MHz where all of the participants made measurements. One participant's measurements were more than 30 dB lower

Table 2: Mean values and standard deviations in the AMPS band (red, white, yellow)

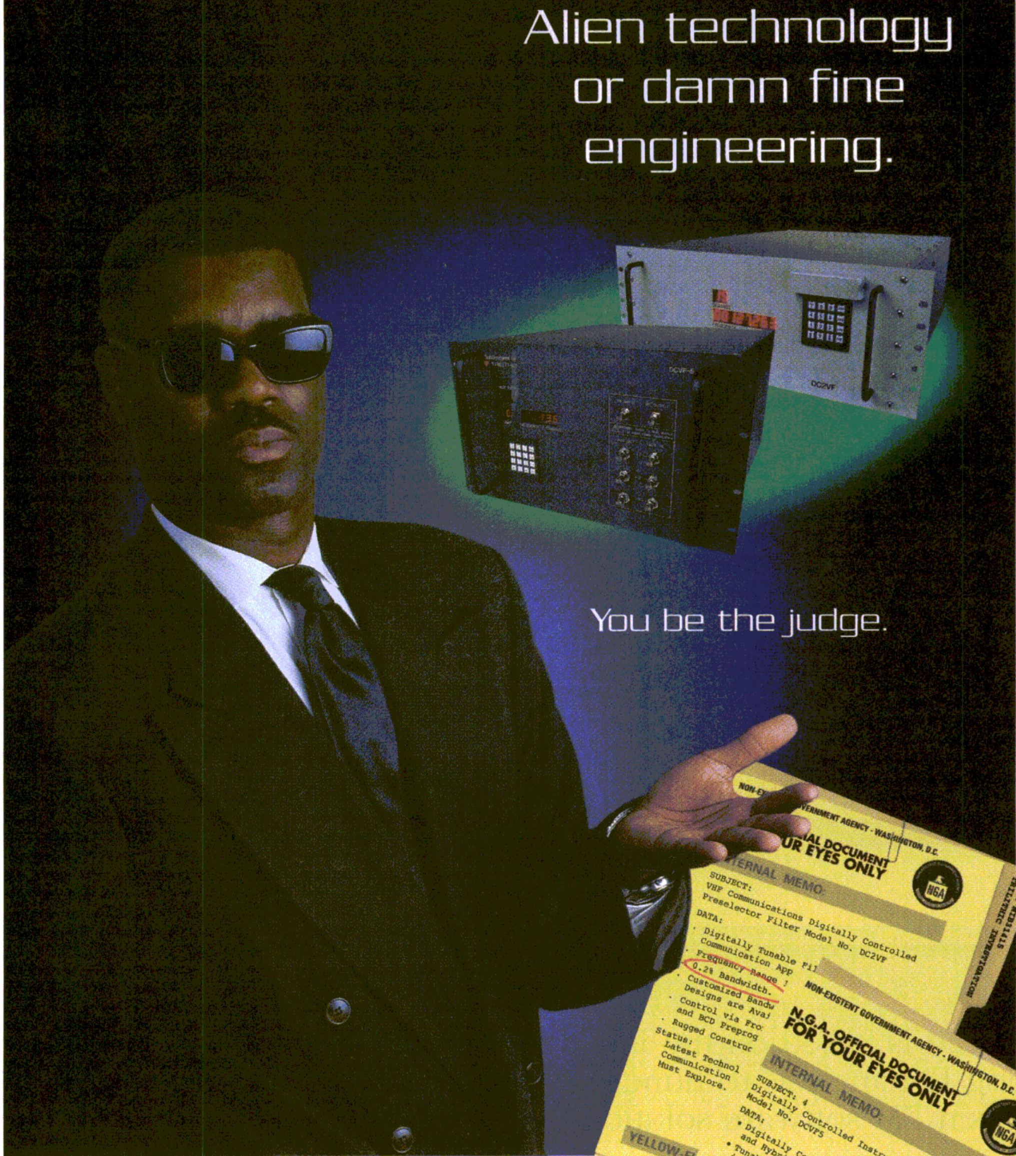
IM3 Frequency (MHz)	Red test sample		White test sample		Yellow test sample	
	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)
844	−100.6	1.9	−98.8	2.8	−79.4	1.9
845	−101.4	1.7	−99.5	3.0	−79.7	1.5
846	−100.8	1.5	−99.5	2.8	−79.4	1.5
847	−100.4	1.6	−98.9	4.8	−79.7	1.3
848	−100.3	1.7	−99.2	3.0	−79.4	1.6

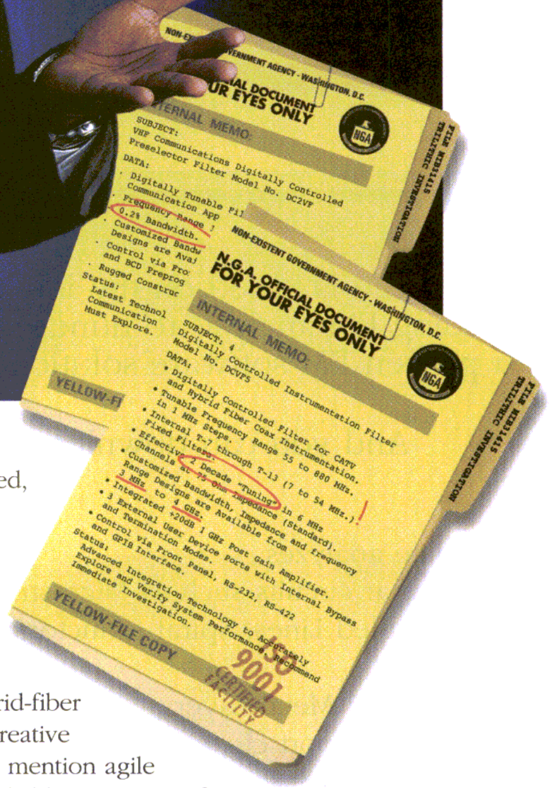


3. The frequency dependence of the red, white, and yellow samples shows that white has the greatest deviation between low (900-MHz) and high (1900-MHz) frequency.

Table 3: Mean values and standard deviations in the AMPS band (blue)

IM3 Frequency (MHz)	Blue reflected		Blue forward	
	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)
844	−95.1	4.6	−88.2	2.1
845	−94.5	4.4	−88.3	2.1
846	−94.2	3.8	−88.1	1.8
847	−93.7	4.1	−88.0	1.4
848	−93.6	3.3	−87.9	1.6





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than the others for all four test samples, so their data were not included in the computations of mean values and standard deviations. Of the remaining five participants, the mean value measured at 910 MHz in the GSM band for the red test sample was –102.3 dBm, with a standard deviation of 2.3 dB; the mean of the white test sample was –99.9 dBm, with a standard deviation of 3.6 dB; the mean of the yellow test sample was –80.1 dBm, with a standard deviation of 0.7 dB; the mean of the blue test sample, measured in the reflected configuration was –93.2 dBm, with a standard deviation of 1.1 dB; and the mean of the blue test sample, measured in the forward configuration, was –88.3 dBm, with a standard deviation of 2.6 dB.

Five IM3 frequencies (1870, 1880, 1890, 1900, and 1910 MHz) were specified for measurements spanning the PCS band. Measurements at these frequencies could be obtained in two ways: holding source one at 1930 MHz and sweeping source two downward from 1990 to 1950 MHz in steps of 10 MHz, or holding source two at 1990 MHz and sweeping source one upward from 1930 to 1950 MHz in steps of 5 MHz. Of the six participants who made measurements in the PCS band, five made swept-frequency measurements in both directions, and one made swept frequency measurements in one direction (source one held constant). One participant made reflected measurements, one made forward measurements, and four made forward and reflected measurements. Tables 4 and 5 list the mean values and standard deviations for each of the test samples at the five measured frequencies.

Overall, measurements in the PCS band showed significantly larger variations than those seen in either the AMPS or GSM bands, which is

Table 4: Mean values and standard deviations in the PCS band (red, white, yellow)

IM3	Red test sample		White test sample		Yellow test sample	
Frequency (MHz)	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)
1870	–100.4	3.3	–90.5	7.5	–74.4	3.9
1880	–98.9	7.4	–89.9	7.6	–74.3	3.9
1890	–99.2	6.0	–89.4	8.0	–74.3	3.8
1900	–98.9	5.5	–89.0	8.0	–74.1	4.8
1910	–100.6	2.3	–87.9	8.0	–73.7	3.5

consistent with the results of the European round-robin.[18] Similar to the AMPS and GSM comparisons, the PCS measurements showed no difference between reflected and forward measurements for the electrically short test samples (red, white, and yellow) but did for the electrically long (blue) test sample. Frequency-dependent behavior was observed in the blue test sample when reflected measurements were made, which is predicted by models developed by Deats and Hartman[19] and Jargon *et al.*[17]

This is not to say that the blue test sample is not frequency dependent at lower frequencies, but rather the frequency range of the PCS band is much wider than the AMPS and GSM bands. Thus, the frequency-dependent behavior is more apparent in PCS when swept frequency and reflected measurements are performed. Once again, the white test sample was found to be less stable than the others. The mean values measured throughout the PCS band for the red test sample varied between –98.9 and –100.6 dBm, with standard deviations ranging from 2.3 to 7.4 dB; the mean values of the white test sample varied between –87.9 and –90.5 dBm, with standard deviations from 7.5 to 8.0 dB; the mean values of the yellow test sample varied between –73.7 and –74.4 dBm, with standard deviations from 3.5 to 4.8 dB; the mean values of the blue test sample, measured in the reflected configuration showed a downward trend in PIM from –83.5 dBm at 1870 MHz to –95.1 dBm at 1910 MHz, with standard deviations from 2.5 to 3.7 dB; and the mean values of the blue test sample measured in the forward configuration varied between –84.3 and –85.7 dBm, with standard deviations from 2.5 to 3.2 dB.

DCS

Five IM3 frequencies (1730, 1740, 1750, 1760, and 1770 MHz) were specified for measurements spanning the DCS band. Measurements at these frequencies could be obtained in two ways: holding source one at 1805 MHz and sweeping source two downward from 1880 to 1840 MHz in steps of 10 MHz, or holding source two at 1880 MHz and sweeping source one upward from 1805 to 1825 MHz in steps of 5 MHz. Two participants made measurements in the DCS band. One participant performed forward and reflected measurements, and one effected reflected measurements.

Since only two participants made measurements in the DCS band, no statistical computations were performed. However, similar to the PCS band, frequency-dependent behavior was observed in the blue test sample when reflected measurements were made. And once again, this was attributed to the wide bandwidth of the DCS band.

For the first four months of the

comparison (August to November 1998), stability-check measurements were performed on an AMPS system, and then for the remainder of the comparison (November 1998 to April 1999), measurements were made on a PCS system. If the system showed large variations in the round-robin test samples, the in-house test samples could be used to determine whether the problem was due to the test samples varying or whether something was wrong with the system. Fortunately, this did not happen. The systems and the test samples remained stable throughout the comparison. Table 6 lists the standard deviations of the measurements made at NIST of the round-robin test samples. All of the test samples remained stable within standard deviations of 2.9 dB or less for up to five months on a single system.

Table 5: Mean values and standard deviations in the PCS band (blue)

IM3	Blue reflected		Blue forward	
Frequency (MHz)	Mean (dBm)	Standard deviation (dB)	Mean (dBm)	Standard deviation (dB)
1870	−83.5	2.5	−84.8	3.1
1880	−84.2	2.7	−85.7	3.0
1890	−86.1	2.9	−84.5	2.5
1900	−89.6	3.1	−84.4	3.2
1910	−96.1	3.7	−84.3	2.7

SUMMING UP

Of the 19 data sets received, most companies' measurements fell within two standard deviations of the measured means of each band. In the AMPS band, three of the five participants' measurements fell consistently outside one standard deviation (typically less than 3 dB), although all the measurements fell within three standard deviations. In the GSM band, only two of the six participants' measurements fell consistently outside one standard deviation (typically less than 3 dB), and all were within two standard deviations except for one which was as much as 50 dB from the mean. In the PCS band, not one of the six participants measured consistently outside one standard deviation (between 2 and 8 dB), except for measurements of the yellow test sample where two participants measured outside three standard deviations from the mean.

Several conclusions can be drawn with regard to PIM measurements. First, it appears that there is no significant difference between reflected and forward measurements for electrically short test samples (red, white, and yellow). However, there were noticeable differences for the electrically long (blue) test sample. Second, IM in passive devices is not always frequency independent. This contradicts the findings of the European round-robin performed in 1995.[18] Figure 3 plots PIM versus frequency for the red, white, and yellow test samples. The white and yellow test samples show deviations up to 10 dB between lower frequencies (AMPS and GSM) and higher frequencies (PCS and DCS). Frequency-dependent behavior was observed over a frequency range of 40 MHz in the blue test sample when reflected measurements were made. Measurements in the PCS band showed significantly larger variations than those seen in either the AMPS or GSM bands, due to the higher operating frequencies. This behavior agrees with the findings of the European round-robin. Finally, measurements made by the system on round-robin test samples remained stable within a standard deviation of 2.9 dB over a five-month period.

Table 6: Standard deviations of the NIST measurements

Test sample	AMPS standard deviation (dB)	PCS standard deviation (dB)
Red	2.8	1.3
White	2.9	1.6
Yellow	0.5	2.9
Blue	0.6	2.7

This comparison of passive IM measurements has addressed, in a timely manner, a direct need expressed to NIST by US base-station equipment manufacturers. This comparison allowed each participant to assess its capabilities in an impartial way, while allowing NIST to evaluate the urgency of any PIM measurement problems that may exist within the industry. ●●

Acknowledgments

The authors thank Werner Wild of Spinner GmbH; Charlie Spellman of RFS Cablewave Systems; and Rick Hartman, Brad Deats, and James Brunner of Summitek Instruments. This work is a contribution of this US Government and is not subject to US copyright.

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Extend DDS Bandwidth Above The Nyquist Limit

Extended DDS Bandwidth, Part 1

Several methods can be used to isolate and amplify DDS frequency components above the Nyquist limit.

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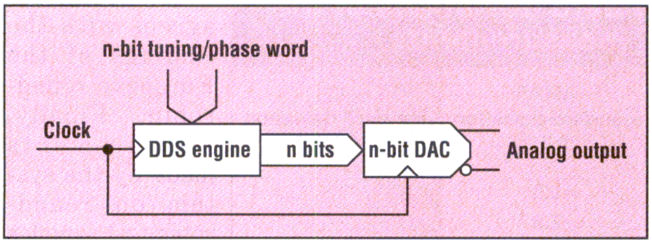
COMPLETE Direct Digital Synthesizer (C-DDS) products generate a constructed or sampled sine waveform whose frequency is dependent on input programming and an input reference clock. As such, the system's output spectrum is governed by the Nyquist Sampling Theorem. This article is the first of a two-part series that presents techniques for isolating and amplifying the frequency components of a C-DDS device above the Nyquist limit. Three types of filters will be described. Two of them, LC and surface-acoustic-wave (SAW) filters, have drawbacks that outweigh their advantages. The third type, the tunable tracking filter, holds the most promise in preserving the advantages of using C-DDS systems. Its operation and advantages over other types of filters will be presented in the second article of the series.

A general block diagram of C-DDS architecture is shown in Fig. 1. This block diagram shows that C-DDS devices use a DDS engine to generate n-bit binary data that is used by an n-bit clocked digital-to-analog converter (DAC) to generate analog-output waveforms. The spectral output of the DACs used in these C-DDS products can be described as that of a pulse-amplitude modulator. As such, the frequency spectrum they generate can be described mathematically as:

$$I(fo) = \sum_{k} (\omega(fo) * \delta(fo) - kf(c)) \times \left(\frac{\frac{\sin \pi f(o)}{fc}}{\frac{\pi f(o)}{f(c)}} \right) \quad (1)$$

where:
f(0) = the system output frequency,
f(c) = the system clock frequency,
and
ωf(0) = the binary input data.

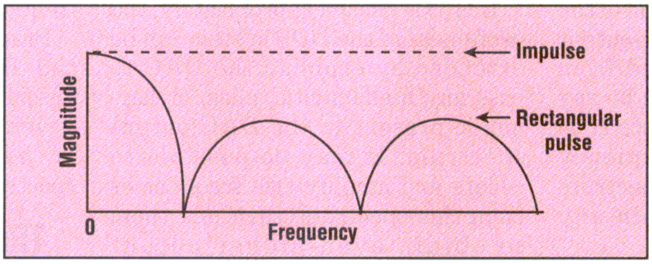
To fully understand the dynamics of the DAC and DDS output spectrum, Eq. 1 can be broken into a product of two parts. The first part (the summing expression) describes the mixing action between the input clock and the binary data input to the DAC from the DDS engine (recall that convolution in the frequency domain is multiplication in the time domain). The second part describes the



1. The general architecture of a C-DDS comprises a DDS engine and a digital-to-analog converter (DAC).

step-like nature of the DAC output waveform. This step-like waveform can be viewed as a series of rectangular pulses of varying amplitudes, and as such, can be mathematically described in the frequency domain as having a sin(x)/x shape.

Both parts are multiplied in the frequency domain or convolved in the time domain, producing the sin(x)/x shape seen in the DAC output spectrum. If, for example, it were possible to use an impulse function for the second part of Eq. 1, the DAC output spectrum would take on a flat response (Fig. 2).



2. These output waveforms from a C-DDS in the frequency domain show that the output takes the form of a sin (x)/x shape. If an impulse function is applied to the system, the output has a constant magnitude.

The summing expression of Eq. 1 describes the mixing action that takes place in the DAC's of C-DDS devices. Discounting the non-ideal functionality of the DDS and DAC (i.e., DDS to DAC truncation or quantization errors, DAC harmonics, clock jitter, etc.), the mixing that takes place in the DAC produces frequency products according to Eq. 2:

(n)f(clock) – f(output) = Negative image or alias

(n)f(clock) + f(output) = Positive image or alias

where:

(n) = the integer multiple of the clock rate,

f(clock) = frequency of the clock, and

f(output) = the programmed frequency of the part.

The second part of Eq. 1 describes the time-based convolution of the rectangular DAC pulses with the mixed products of the DDS and DAC. This convolution is responsible for the sin(x)/x shape of the DAC output spectrum. Due to the mixing action, it is possible to obtain more than just the fundamental or programmed frequency from these parts. If Eq. 1 is modified as in Eq. 3:

$$I(fo) = \sum_{k} (\omega(fo) * \delta(fo) - kf(c)) \left(\frac{\dfrac{\sin \pi f(o)}{fc}}{\dfrac{\pi f(o)}{f(c)}} \right) (H(f)) \qquad (3)$$

The overall transfer function of the DAC is modified, and higher-output frequencies can be obtained from these parts. H(f) in Eq. 3 can be any desired transfer function. Since H (f) is multiplied in the frequency domain, the DAC output spectrum may be reshaped to obtain any desired output frequency.

If H(f) is chosen appropriately, the usefulness of the DDS system can be extended by enabling the DAC to pass any fundamental, alias, or harmonic present in the DAC output spectrum. It may be possible to isolate and amplify two frequencies from this spectrum, then mix them to obtain even-higher output frequencies.

Practical circuits for implementing the H(f) function of Eq. 3 are described in the following sections. Several methods can be used to filter or reshape the DAC output spectrum.

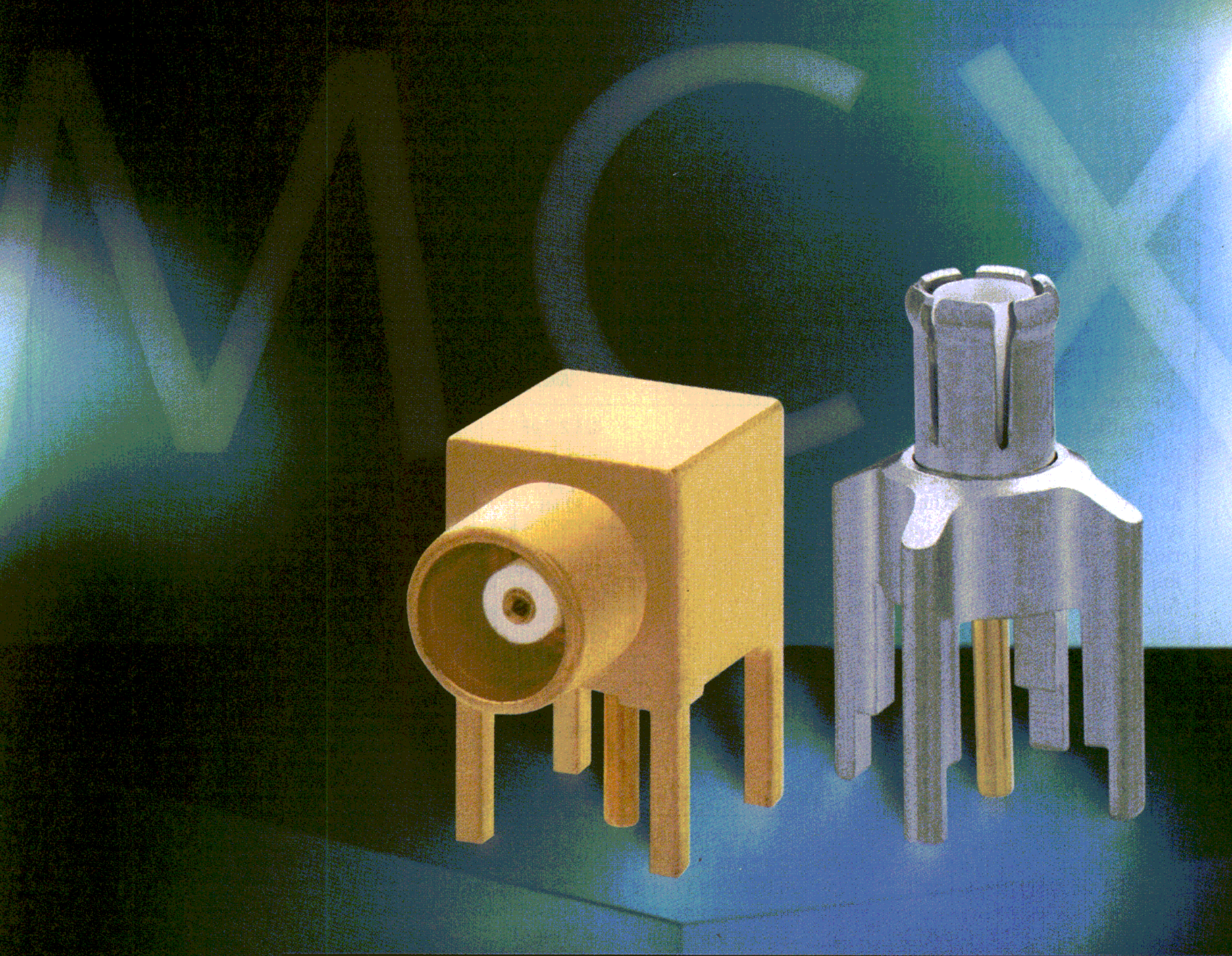
TRADITIONAL LC FILTERS

The most straightforward approach is to use fixed frequency filters (lowpass, bandpass) to isolate desired output frequencies. These are usually inductive-capacitive (LC) or surface-acoustic-wave (SAW) filters, and since the transfer functions of these filters are complex, design is best performed with MathCAD or some other software package.

THE MOST STRAIGHTFORWARD APPROACH IS TO USE FIXED FREQUENCY FILTERS (LOWPASS, BANDPASS) TO ISOLATE DESIRED OUTPUT FREQUENCIES.

Lowpass filters are used routinely on evaluation boards for C-DDS devices in order to eliminate mixed- and alias-products in the DAC output spectrum above Nyquist. These filters are designed to have breakpoints at or just below Nyquist for the top clock rate of each respective part, with rolloffs of 140 dB per decade. This modification of the DAC output spectrum effectively eliminates all of the major spectral components from the DAC output, leaving only the fundamental, its harmonics, in-band spurious components, as well as aliased harmonic products of the DAC.

Example circuit designs of lowpass filters are given in Fig. 3a and b. The filter in Figure 3a is designed for use with the top clock frequency of the AD9851, an Analog Devices C-DDS device that clocks at 180 MHz. It is a seventh-order filter with a –3-dB breakpoint at 70 MHz. The filter in Figure 3b is a seventh-order differ-



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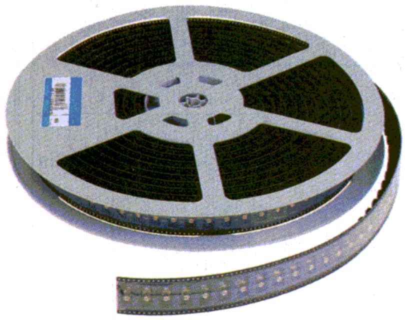

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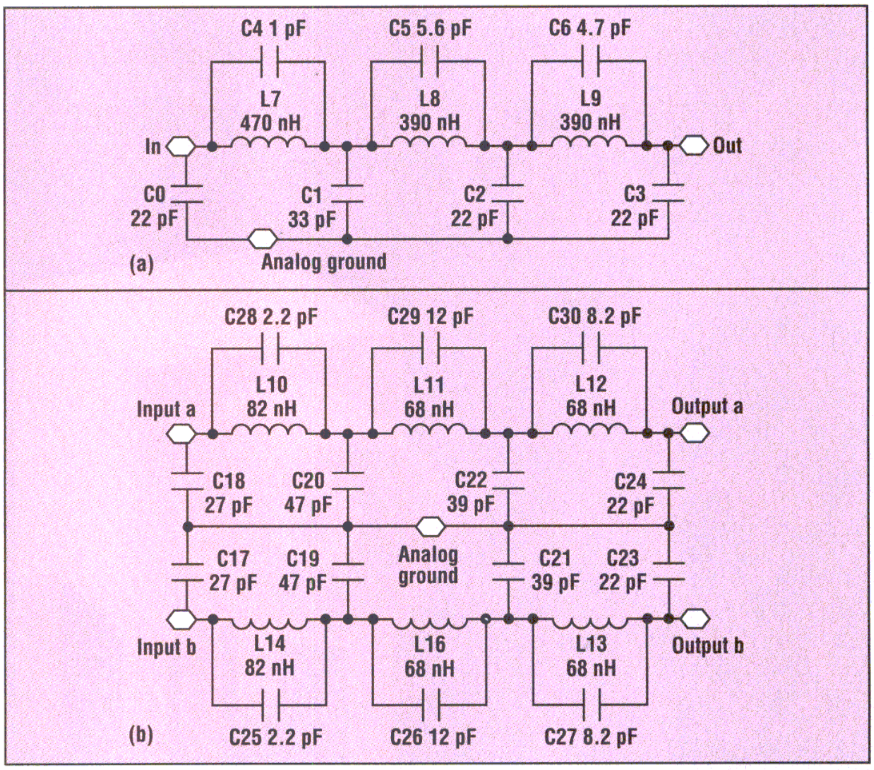
ential lowpass filter, designed for use with the AD9852 and AD9854 (300-MHz C-DDS devices), has a –3-db breakpoint at 125 MHz.

The limitations of this approach are obvious. First, the useful bandwidth of the DDS system is limited to frequencies below Nyquist with no useable frequencies possible beyond the breakpoint of these filters. Also, depending on the fundamental or programmed frequency of these parts, DAC and DDS anomalies such as DAC harmonics and their images, and low-level quantization-error spurious components are passed if they fall within the passband of the given filter. Clearly, this approach limits the useful bandwidth of the DDS system, requiring upconverter stages such as mixers and phase-locked loops (PLLs) to obtain higher than Nyquist output frequencies. This adds to the cost and complexity of frequency-generation systems using DDS products and limits their usefulness.

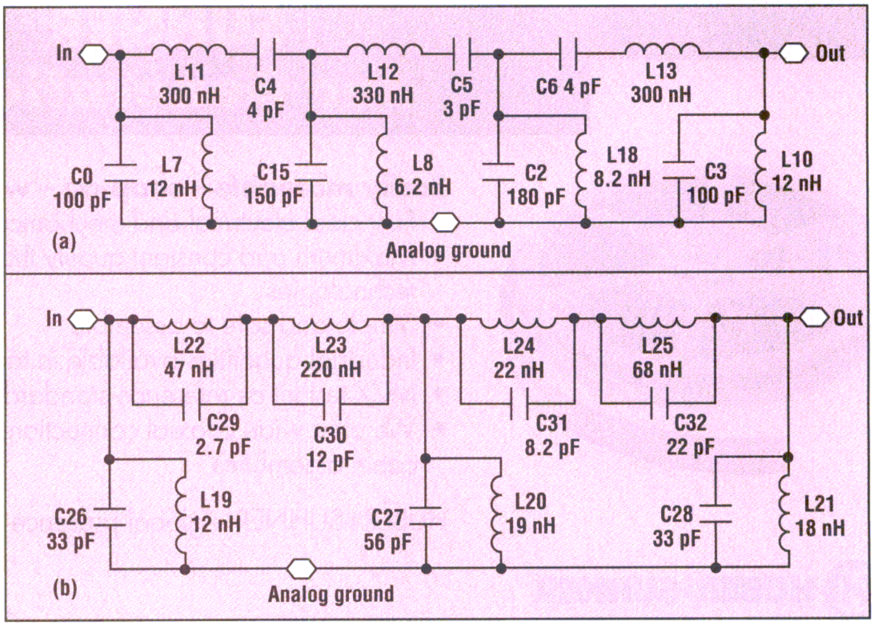
To obtain frequencies above Nyquist directly from the DDS system, it is necessary to use a filter that possesses a transfer function, (H(f)), that allows the frequencies of interest to be passed and all others rejected. The most intuitive method for doing this is to use bandpass filters that possess a passband in the frequency region of interest. Example circuit designs are seen in Figs. 4a and b.

The filter in Fig. 4a is a fifth-order bandpass filter with a passband of 130 to 160 MHz. This filter is designed for use with the AD9851 to pass negative image frequencies and attenuate all others by 100 dB. The filter of figure 4b is also a fifth-order filter, possessing a passband from 170 to 280 MHz. This filter is ideal for use with the AD9852 and AD9854 to pass negative image frequencies and attenuate all others by 70 dB.

Problems with this approach include the following: relatively low amplitude images (with respect to the fundamental) that the filter must pass perfectly with little passband attenuation, a higher spurious content (due to DDS word truncation, jitter, and other anomalies of the



3. This lowpass LC filter (a) is used to isolate output frequencies of the Analog Devices AD9851, a C-DDS device that can operate at a clock rate of up to 180 MHz. The filter is seventh order with a –3-dB break point at 70 MHz. A second lowpass filter (b) is designed for the Analog Devices AD9852/54 C-DDS, higher-speed versions of the AD9851. The –3-dB breakpoint is at 125 MHz.



4. Bandpass filters pass frequencies of interest and reject all others in C-DDS systems. The fifth-order type (a) has a passband that ranges from 130 to 160 MHz. Another fifth-order type (b) has a passband from 170 to 280 MHz. Both versions are used to obtain frequencies that are above the Nyquist limit. The lower passband filter can be used with the AD9851 and the higher with the AD9854/54.

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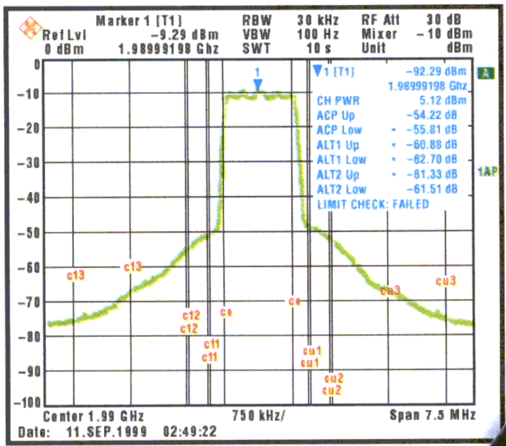

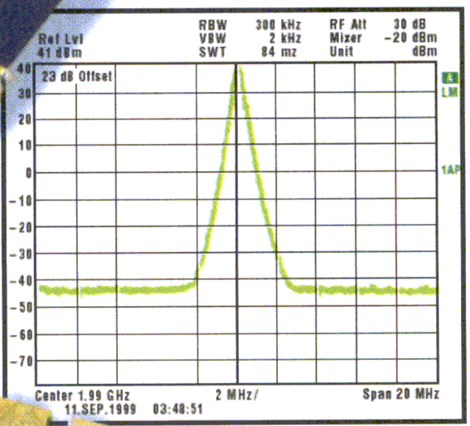

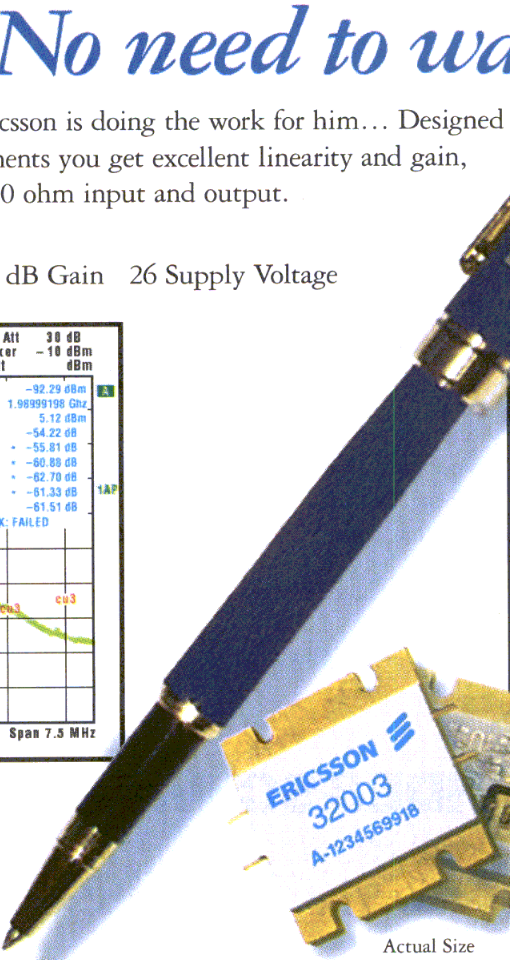

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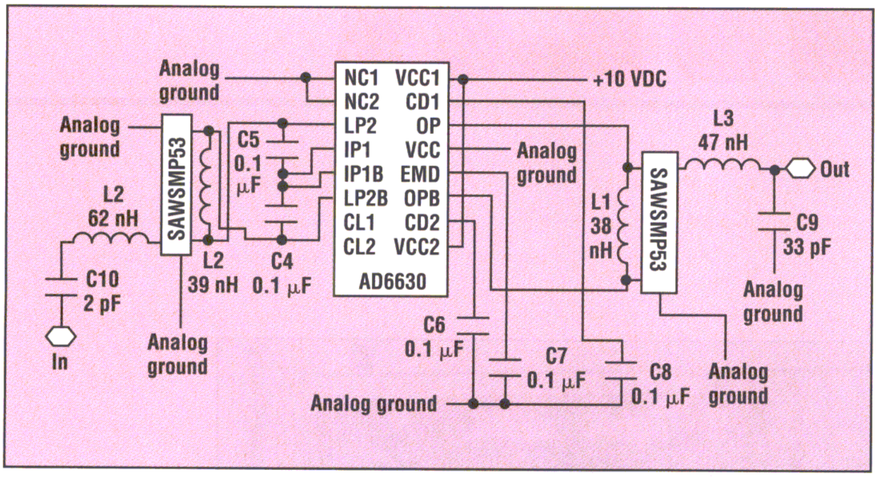


5. To get a filter with a narrow passband having gain only in the passband, SAW filters are used. This one is based on the Analog Devices AD6630 intermediate-frequency (IF) amplifier and has a 500-kHz bandwidth centered at 170 MHz. Two SAW filters are required in order to bandlimit the IF input and to bandlimit the IF output.

DDS system) in this frequency band, and a high-amplitude fundamental that must be suppressed by the filter. Also, in a practical sense, it is difficult to construct these filters because component tolerances become critical, and careful layout is crucial to avoid unwanted parasitic inductance and capacitance.

To combat these problems, components that can be varied must be built into the filter design. Two approaches to making these filters realizable are possible. The most obvious is to make certain filter components adjustable to compensate for any unwanted circuit parasitics or component tolerance mismatches that are present in the actual circuit. This is difficult, however, since it is impossible to know which component is out of tolerance and by how much it is off.

A better design approach is to include some type of passband gain or stopband attenuation adjustment. This is accomplished only by the use of some sort of gain block, either pre- or post-filter. While this will compensate for any gain lost in the passband of the filter and serve to amplify any signal presented to the filter, frequencies in the passband and reject bands of the filter will be amplified equally, causing the filter to have a less-effective reject band and not as pure an output spectrum. What is preferable is to have a very narrow filter passband, and second, to have gain only in the passband.

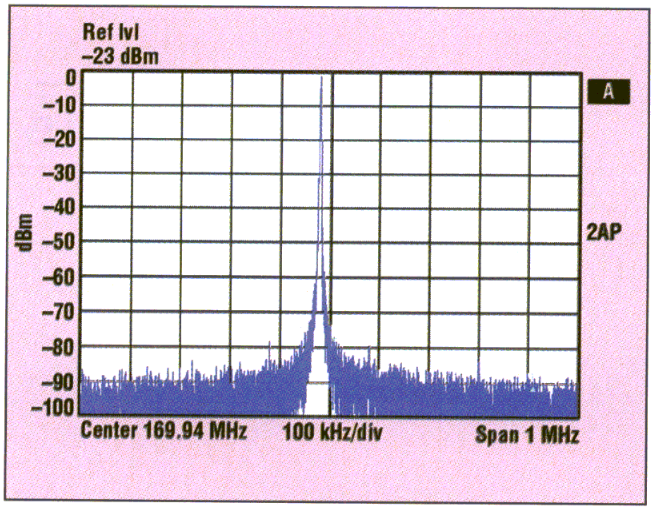
SAW FILTERS

A SAW filter approach meets the first requirement (a narrow passband). Figure 5 displays a SAW filter/intermediate-frequency (IF) amplifier implementation, which is designed for use with the AD9851. The SAW filter possesses a 500-kHz bandwidth centered at 170 MHz and an IF amplifier (the Analog Devices AD8839) that possesses a broadband gain (up to 250 MHz) of 24 dB. The design uses two SAW filters, one to band limit the input signal presented to the IF amplifier and a second filter to band limit the IF amplifier output.

Spectral plots of the output of this filter/amplifier combination are shown in Fig. 6. The filter is shown to amplify the 170-MHz alias and bandlimit the signal to 500 kHz. Depending on the clock rate, the output signal possesses a 60-to-80-db spurious-free dynamic range (SFDR).

Advantages to this approach include excellent ground and supply isolation from the DDS device, extremely narrow passbands, and signal gain in the passband. The primary disadvantage to this approach is that SAW filters have a very narrow passband and are dependent on a crystal lattice to produce this passband, and as such, cannot be adjusted. Systems using this solution lose the big advantage in using DDS products, the almost instantaneous frequency-hopping capability afforded by DDS.

To preserve the frequency-hopping characteristics and frequency-adjustment resolution of the DDS system, a filter that can track the output this system is needed. PLL's are typically used with sub-Nyquist output frequency DDS products to meet this need, but since the DDS system can change frequency rapidly, (on the order of 10 nanoseconds) and have a frequency resolution in the microhertz range, PLLs fall short. PLLs are also limited to the frequencies at which they are designed to lock. What is needed is a filter that can preserve the advantages of the DDS system and not be limited to frequencies below Nyquist. ••



6. The spectral plots of the SAW filter/IF amplifier combination in Fig. 5 shows the 170-MHz center-frequency alias signal being amplified and bandlimited to 500 kHz.

Acknowledgments
Special thanks to Rick Cushing, Applications Engineer, Analog Devices, Inc., for the SAW filter design and data presented in this article. Special thanks to Ken Gentile, Systems Engineer, Analog Devices, Inc., for the fixed, LC filter designs used and presented in this article.

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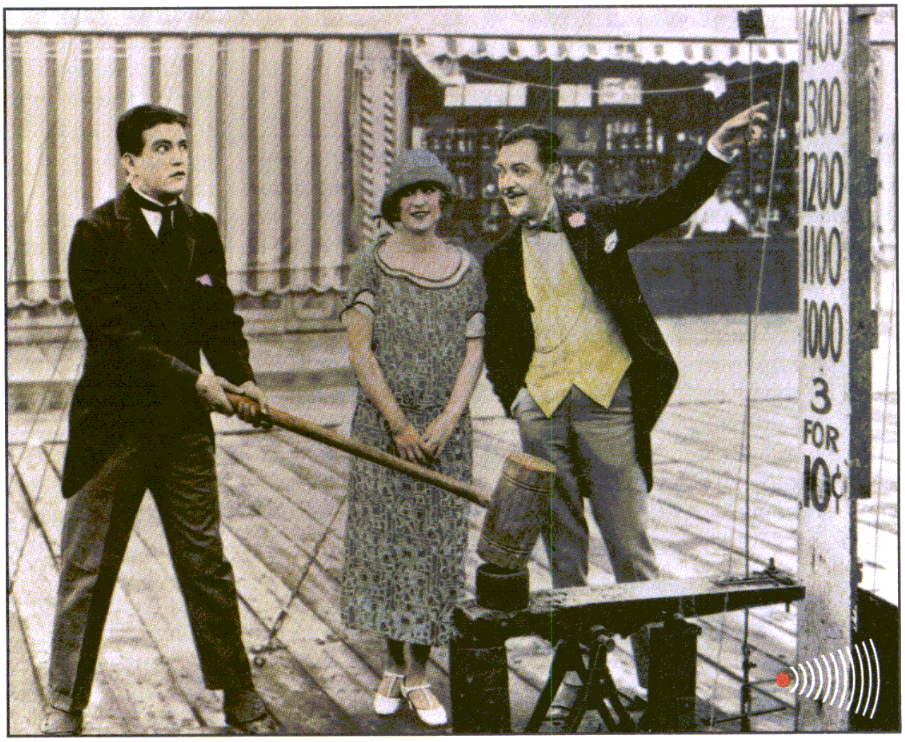

AMPLIFIERS

Develop A Trimless Voltage-Controlled Oscillator

Trimless VCOs, Part 2

Modeling and designing a trimless VCO requires a full understanding of the non-ideal nature of oscillator components and architectures.

Chris O'Connor
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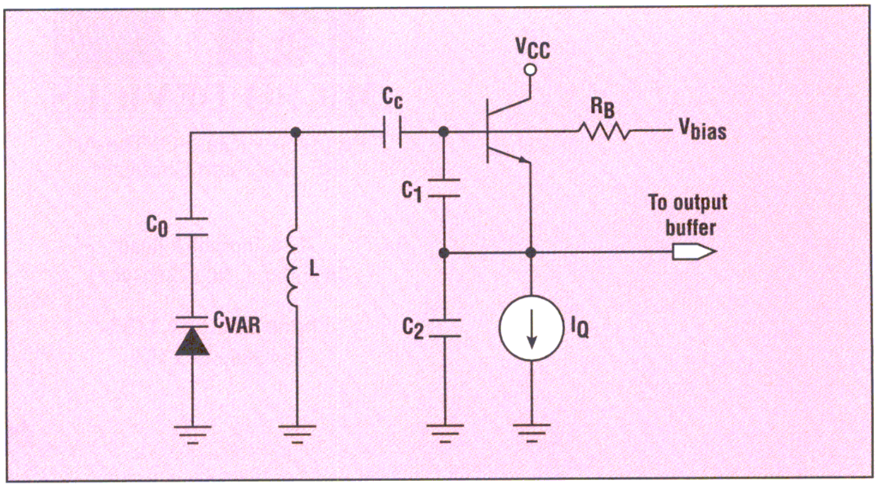
TRIMLESS voltage-controlled oscillators (VCOs) offer a practical alternative to conventional discrete VCO approaches that rely on tuning adjustments during production. The Colpitts style oscillator topology offers a proven circuit architecture for use in a trimless VCO design. A basic set of fundamental design equations can be derived for first-order oscillator design and selection of component values. Unfortunately, real-world components used to implement the trimless VCO are non-ideal and alter the governing equations. The conclusion of this two-part article on trimless VCOs covers how actual circuit implementation departs from the ideal, offering an improved method for modeling, designing, and implementing trimless VCOs.

In Part 1 (see *Microwaves & RF*, July 1999, p. 68), the Colpitts configuration (Fig. 7) was presented as the basis for a trimless VCO. The classic oscillator topology was described with a generalized set of equations to predict the fundamental oscillator behavior for the first-order design of the oscillator (i.e., component selection). The variation (error) in actual oscillation frequency was described in terms of the part-to-part errors of the frequency-setting components. The total frequency error was computed by skewing the value of each component by its worst-case tolerance. The equations proved useful in developing a table of calculations to predict the required tuning range, start-up conditions, phase noise, and



7. This VCO is based on an ideal Colpitts configuration (with a parallel-mode tank circuit).

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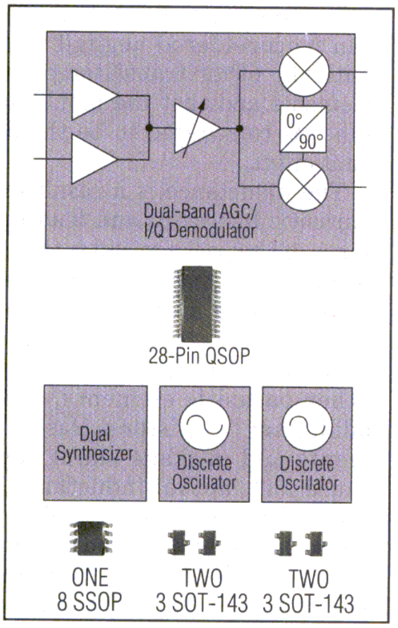

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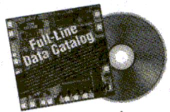

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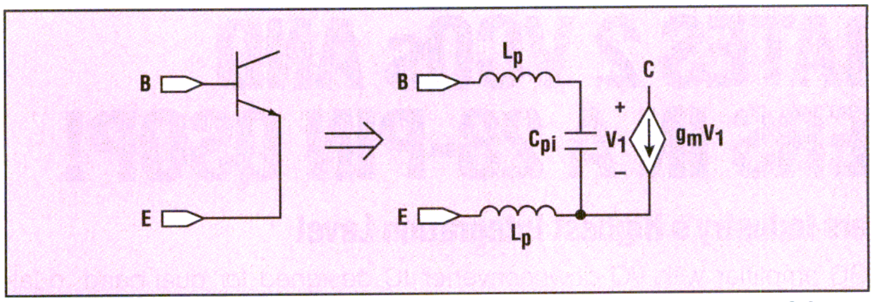


8. This revised small-signal packaged transistor model forms the core of the new trimless VCO design.

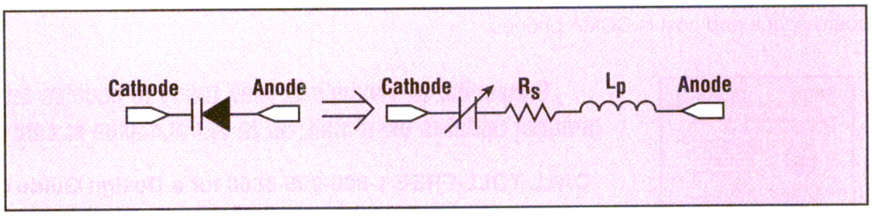
oscillation amplitude. Finally, a first-order, step-wise design process was introduced as a simple approach to select the initial component values for the Colpitts configuration with parallel-mode tank.

Although the basic theory applied in Part 1 is useful for first-order design, accurate selection of component values in a real-world oscillator requires consideration of important circuit details. The aim of this article is to present a possible approach to more accurately model the real-world equivalent of the Colpitts oscillator topology and to apply it to the trimless VCO concept. The primary objective is still to provide a simple design process that permits accurate selection of the initial component values close enough so that minimal fine tuning of the values in the actual circuit is needed to achieve oscillator operating requirements. This article will cover the effects of non-ideal components and models for them, layout parasitic elements in a VCO, a revised oscillator model, a method for trimless VCO analysis and simulation, and an example of a Colpitts oscillator that is constructed from low-cost, commercial components and the measured results for tuning range and phase noise versus predicted results.

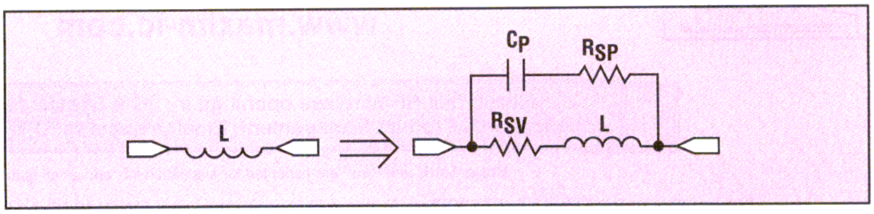
Initial analysis of the basic Colpitts configuration assumed that each component was ideal. However, when a printed-circuit-board (PCB) solution is implemented with typical surface-mount components, the real characteristics for each device must be taken into account. An examination of commonly used surface-mount components quickly reveals that they are not ideal elements, but that the elements contain amounts of parasitic resistance, capacitance, and inductance. The parasitic elements alter the frequency response of the components to the point where the effective value of the component is changed at the frequency of interest. Consequently, the oscillator frequency, tuning range, and other characteristics are affected and the real circuit departs from the operating point predicted by the first-order analysis with near-ideal components. The departure from the ideal needs to be accounted for in the design phase, in order to properly select the component values. A revised model for each component is required. The following is an examination of each component in the oscillator and a proposed circuit model for each. Again, the emphasis is on maintaining the simplest model possible in order to permit a reasonable analysis and develop some intuition in design of the oscillator circuit.

The core of a VCO is typically constructed from discrete transistors or an oscillator integrated circuit (IC). In either case, the device has finite cutoff (transition) frequency, f_T, and is typically packaged in a plastic package with metal leads (e.g., SOT-323). These factors lead to two predominate non-ideal elements in the equivalent circuit: capacitance across the base-emitter leads, and inductance in series with the base and emitter (and collector) leads of the oscillator. The capacitance results from the inherent junction capacitance and base-charging capacitance of the transistor. The full transistor circuit model would include base resistance (r_b), collector-base capacitance (C_{jc}), finite beta, etc. However, it is assumed that $f_T > f_{OSC}$, the oscillation frequency, so that r_b and C_{jc} can be considered negligible along with the other transistor parasitic elements and that the input capacitance is considered to be the dominant effect.

The inductance is a result of the parasitic bondwire and lead inductance of the package and is therefore modeled as a single lumped inductor. This lumped inductance can also include series inductance from the pin to capacitors C_1 and C_2. There are other parasitic elements, such as additional transistor parasitic elements and package shunt capacitance and mutual inductance, but their effects will be ignored for the purpose of this discussion. Figure 8 shows a revised model for the transistor that includes the parasitic capacitance (C_{pi}) and inductance (L_p). Inductance L_p is typically 1.5 to



9. This revised varactor model is employed in the new trimless VCO design for tuning purposes.



10. This revised inductor model is also part of the new trimless VCO design.

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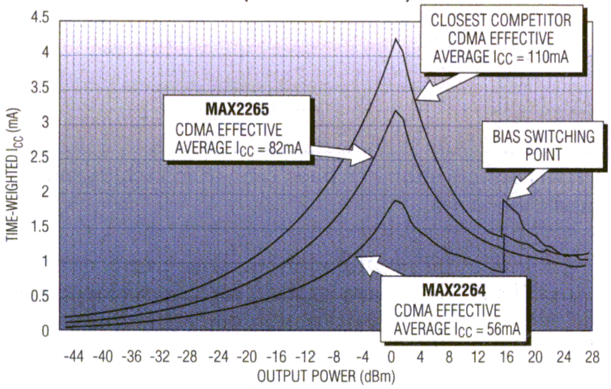

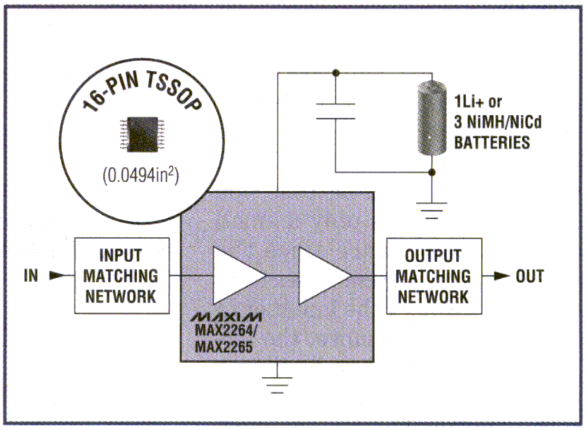

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PART	CDMA AVERAGE I_{CC} (mA)	FREQUENCY (MHz)	EFFICIENCY @ HIGH POWER (CDMA)	EFFICIENCY @ MEDIUM POWER (CDMA)	EFFICIENCY @ 30dBm (TDMA)
MAX2264	58	824 to 849	32%	12% (16dBm)	N/A
MAX2265	82	824 to 849	37%	7% (16dBm)	41%
MAX2266	52	824 to 849	32%	17% (16dBm)	N/A
MAX2267	56	887 to 925	30%	12% (17dBm)	N/A
MAX2268	80	887 to 925	35%	7% (13.6 dBm)	N/A
MAX2269	50	887 to 925	30%	17% (17dBm)	N/A

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2.0 nH while capacitance C_{pi}) is typically greater than 1 pF. The base-emitter capacitance is typically greater than 1 pF for $C_{jc} + C_b$.

The parasitic capacitance, C_{pi}, and parasitic inductance, L_p, have a significant impact on the frequency response/input impedance of the active circuit amplifier. These elements must be considered and modeled to properly predict the equivalent input capacitance and negative resistance of the Colpitts oscillator configuration.

With capacitances C_1 and C_2 connected to the emitter and base leads, a revised analysis can be performed to determine the equivalent input impedance of the active circuit. For $\omega < L_pC_{pi}$, the inductor on the base side in series with C_{pi} has only a small effect on the impedance since the majority of signal current flows from the gm stage through the inductor in the emitter side. Therefore, the circuit can be simplified to facilitate analysis by including only the inductor in the emitter lead on the ideal model and provide a more intuitive approximate result. Although the majority of the signal current flows through the emitter lead, the capacitance C_{pi} should be included in the calculation of the capacitance. A reasonable approximation is $C_{1X} = C_1 + C_{pi}$. Circuit analysis shows that the inductance modifies the equivalent input impedance from the ideal model case:

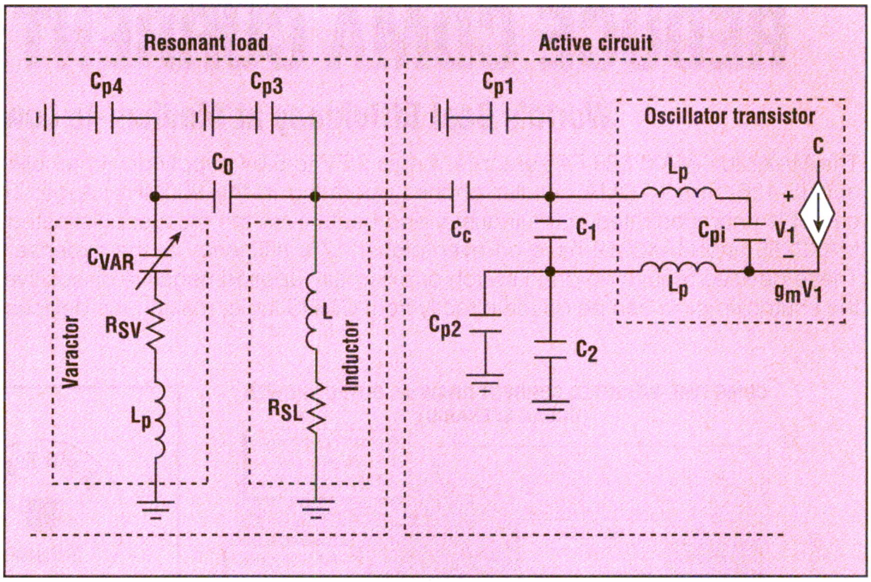
$$Z_{in} = -j[(C_1 + C_2)/wC_1C_2] + (g_m / w^2C_1C_2) \quad (14)$$

to a revised model case:

$$Z_{in} \cong -j\{[(C_{1\times} + C_2)/\omega C_{1\times}C_2] - [A/(1+A^2)] \times (gm/\omega C_{1\times}C_2)\} + [1/(1+A^2)] \times (gm/\omega^2 C_{1\times}C_2) \quad (15)$$

where $A = \omega g_m L_p$

The inductor actually makes the input capacitance appear larger and the negative resistance appears smaller. The equivalent capacitance along with negative resistance may be expressed by the following equation as:



11. The basic Colpitts VCO configuration has been refined to include the realistic effects of parasitic elements.

$$C_{EQ} = 1/\{(1/C_{12}) - [A/(1+A^2)] \times (gm/\omega C_{1\times}C_2)\} \quad (16)$$

and

$$-R_{EQ} = -R\,[1/(1+A^2)] \quad (17)$$

During oscillation, the current flowing in the oscillator transistor is varying versus time (typically like a half-wave rectified sine wave) and therefore the instantaneous transconductance, g_m, is varying with time. At equilibrium, the effective large-signal transconductance, G_m, is lower than the DC bias value of g_m and is only that necessary to sustain the loop gain to 1 + δ. As a result, has a reduced affect on modifying the input impedance than at its DC bias point.

One approximation which could be used for G_M is discussed in ref. 5:

$$G_M \approx n/R_{EQ} \text{ where } n = [(C_C + C_{12})/C_C] \times [(C_{1\times} + C_2)/C_2]$$
$$C_{12} = C_{1\times}C_2/(C_1 + C_2) \text{ in the... } (18)$$

The large-signal G_m should then be substituted for g_m in the previous equations.

Detailed simulation of the full circuit reveals that the expressions above offer a reasonable estimate of the actual equivalent input impedance. These approximations are used later to develop a revised set of design equations for the oscillator.

The varactor is essentially a positive-negative (PN) junction diode with specially tailored capacitance-versus-voltage characteristics. As with all diodes, the device has a finite static series resistance. It determines the effective capacitor and tank Q. The varactor is typically implemented as a discrete device in a plastic package (such as a SC-79 package). As with the transistor, there is a parasitic lead and bondwire inductance in series with the varactor device. These two non-ideal effects—the series inductance and the series resistance—must be included to properly predict the oscillation frequency and the tank Q (which impacts the phase noise, startup, and oscillation amplitude) In particular, the series inductance is a critical parasitic to model, because it strongly changes the effective capacitance of the varactor. (It forms a series resonant circuit that can occur very near the desired oscillation frequency.) Figure 9 shows a revised model for the varactor which includes the parasitic resistance and inductance in series with the with the anode and cathode leads. The series inductance is typically 1.5 nH while the series resistance is typically 0.5

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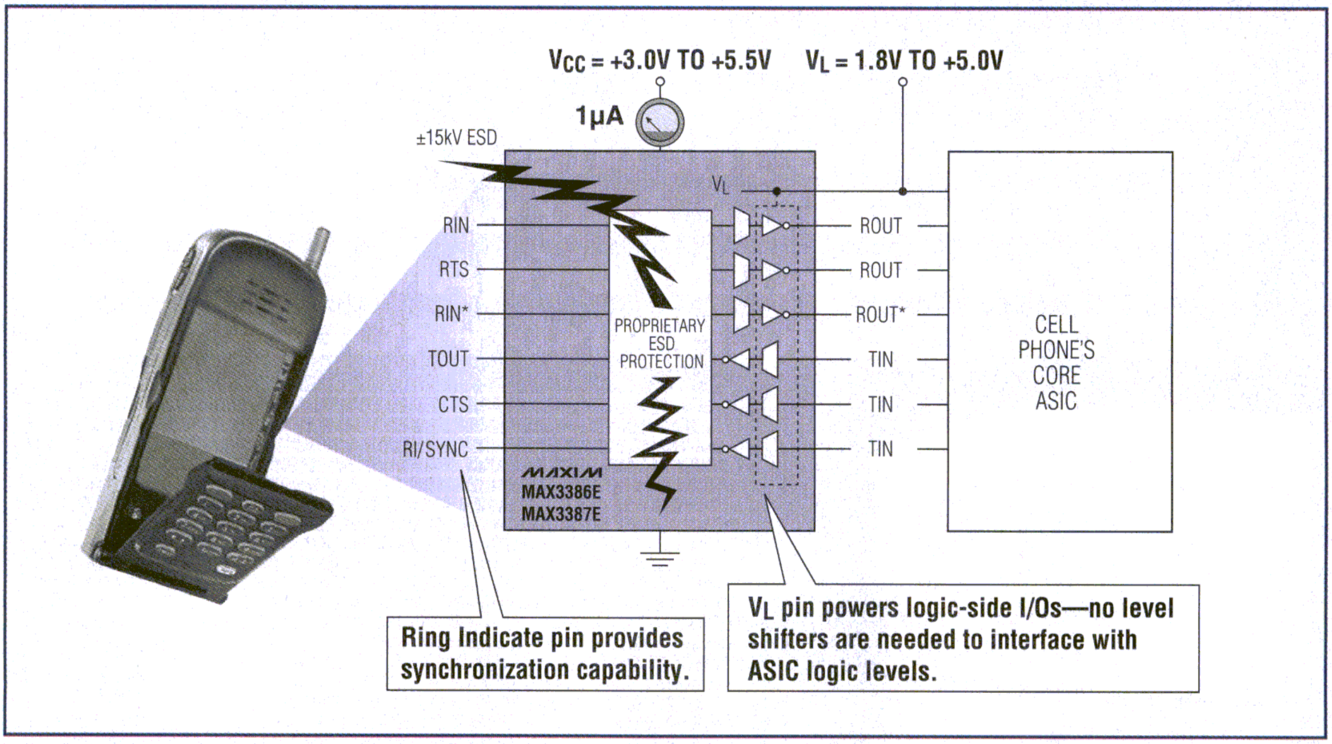

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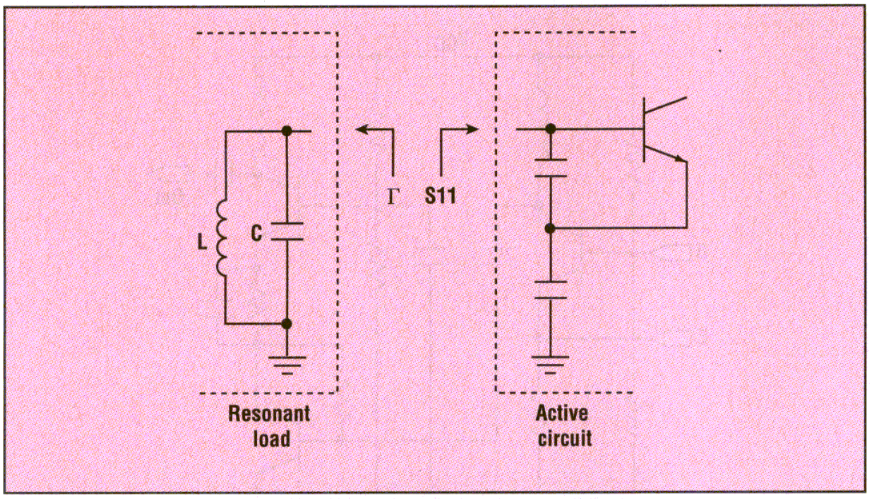


12. This model treats an oscillator as an active circuit with a resonant load.

to 1.0 Ω.

The primary inductor in the tank circuit has a self-resonant frequency that may affect the frequency of oscillation. A relatively simple model can be used to describe the inductor below the self-resonant frequency. Figure 10 shows the revised model for the inductor. The series resistance (R_s) models the loss in the inductor that sets the Q. Capacitance (C_p) models the finite self-resonant frequency. Some manufacturers are supporting this model for their commercial devices.[6] However, many cost-effective surface-mount inductors that are available today have sufficiently high self-resonant frequencies that it is reasonable to consider the inductor to have negligible parasitic capacitance. This permits the inductor to be modeled as purely an inductance and a series resistance. The series resistance of the inductance does need to be modeled to accurately describe the tank Q.

COUPLING CAPACITORS

The feedback and coupling capacitors are high-quality RF components. Typically, the capacitors are very small (0603, 0402, even 0201) multilayer ceramic surface-mount capacitors. That technology's small size inherently provides very-high frequency performance and nearly ideal frequency characteristics. Therefore, the capacitors are considered ideal for the purposes of this second-order design.

A potentially troublesome non-ideal factor in the PCB level oscillator design has to do with the parasitic capacitances and inductances that are associated with the component solder pads and interconnect traces. These parasitic elements must be extracted from the actual PCB layout but are typically not available at the time of design, because the layout has not been started/completed. However, it is important to include them in the oscillator circuit model to accurately predict the oscillation frequency and tuning range, so a first cut layout and analysis of the parasitic element values are needed. A choice must be made between modeling the parasitic elements with transmission lines or lumped-element equivalents. Strictly speaking, the traces/pads are transmission lines, but the lumped element approach can provide a more intuitive method of modeling the parasitic elements and is valid for compact layouts where the interconnects are short (< 40 mil) and wide (>20 mil). In general, if traces are short then the connection could be approximated as just a shunt capacitance to ground. This permits the simple addition of parasitic shunt capacitors at the connection nodes. The parasitic capacitance at the connection points can be approximated by a parallel plate capacitance, C_{pad}, with the plate area equal to the total pad/trace area.

$$C_{PAD} = \varepsilon_r \varepsilon_o \times (A/t) = 1.3 \times 10^{-15} \times (A/t)\, pF/mil\ (for\ FR4) \quad (19)$$

where:

A = the capacitor plate area (in square mil), and

t = the board thickness (in mil).

The active circuit negative resistance for the PCB-level oscillator design is:

$$-R_{NEQ} = -R_N\left[1/(1+A^2)\right] \quad (20)$$

where

The resonant load capacitance can be found from:

$$A = \omega G_m L_p C_{VAREQ} = \left[C_{VAR}/(1-\omega^2 L_p C_{VAR})\right] + C_{p4} \quad (21)$$

$$C_{VEQ} = (C_0 C_{VAREQ}/C_0 + C_{VAREQ} + C_{VAREQ}) + C_{p3} \quad (22)$$

The resonant frequency or frequency of oscillation can be found from:

$$f_o \sim 1/\left[2\pi_{TEQ}{}^{0.5}\right] \quad (23)$$

$$C_{TEQ} = C_{VEQ} + C_{IN} \quad (24)$$

The quality factor (Q) of the resonant tank circuit, Q_T, can be found from:

$$Q_T = T_{TEQ}/2\pi L \quad (25)$$

$$R_{TEQ} = R_{QL} \,||\, R_{QC} \quad (26)$$

$$Q_C = 1/2\pi C_V R_S \quad (27)$$

The amplitude of the oscillation (the RMS voltage) can be found from:

with

$$R_{QC} = Q_C{}^2 \times R_{SC} Q_L = 2\pi L R_{SL}$$

$$R_{QL} = Q_L{}^2 \times R_{SL} V_O = 2 I_Q R_{EQ} \times \left[J_1(\beta)/J_0(\beta)\right] \times V_{peak} \quad (28)$$

The loop gain can be found from:

where

$\left[J_1(\beta)/J_0(\beta)\right] \approx 0.7$ *the ratio of the Bessel functions*

$$Loop\ gain = g_m R_{EQ}(1/n) \quad (29)$$

where

$$n \approx \left[(C_C + C_{12\times})/C_c\right] \times \left[(C_{1X} + C_{2X})/C_{2X}\right] \quad (30)$$

The start-up criteria are given by:

$$g_m / C_1C_2 >> R_{EQ} / Q_T^2$$
$$\text{for a minimum } 2{:}1 \text{ ratio} \quad (31)$$

The phase noise can be found from:

$$\text{Phase noise} = I_n^2 \times (1 / V_o^2) \times (f_o / 2Q_o^2) \times \left[R_{EQ}^2 / (f - f_o^2\right] \quad (32)$$

where:
f_o = the frequency of oscillation,
C_{VAR} = the varactor capacitance,
Q_L = the inductor quality factor,
Q_T = the tank quality factor,
R_{EQ} = the equivalent tank parallel resistance,
g_m = the oscillator bipolar transistor transconductance,
V_0 = the RMS tank voltage,
C_T = the total tank capacitance,
C_0 = the varactor coupling capacitance,
Q_V = the effective varactor quality factor,
R_S = the varactor series resistance,
I_Q = the oscillator transistor bias current, and
I_n = the collector shot noise.

One very useful method to view an oscillator circuit is as a "reflection amplifier." This intuitive concept is described in a classic article by John Boyles[7] and in a paper by Esdale.[8] The "reflection amplifier" method permits the engineer to use S-parameters for design and measurement of the oscillator. Working with S-parameters facilitates the modeling and measurement of the actual oscillator circuit and helps develop insight into the circuit's performance and potential problems.[9]

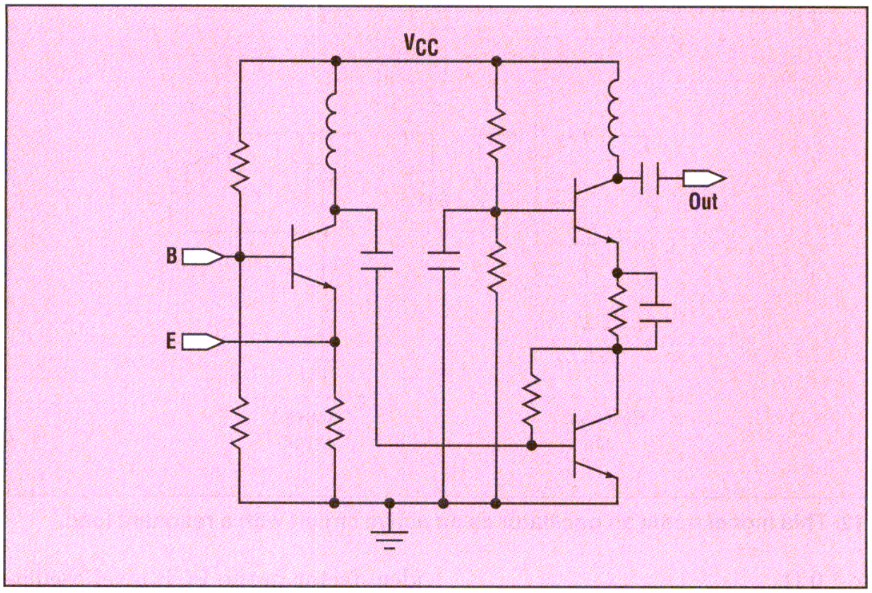
The "reflection amplifier" approach basically models the oscillator as an active circuit with a resonant load and describes the stable oscillation point in terms of the relative impedances. If the active circuit input S-parameters are plotted as $1/S_{11}$, then the values can be directly plotted on a Smith chart with the Γ of the resonant load. A convenient aspect of plotting $1/S_{11}$ is that the impedance of R and X for the active circuit can be read and multiplied by –1 to provide the correct values of the negative resistance and reactance. This method of plotting the impedances provides a graphical representation of when oscillation conditions exist.

The basic conditions for oscillation are:
1. $|1/S11| \leq |\Gamma|$,
2. ang(1/S11) = ang(Γ), and
3. the curves of $1/S_{11}$ and Γ must ultimately intersect each other and change in opposite angular directions versus frequency (this occurs at the peak-oscillator tank amplitude).

The reflection amplifier approach will be used in the remainder of this article to model, simulate, and measure the real oscillator circuit.

The calculations shown are valid as a method to approximate the initial values for the components. A spreadsheet can be developed to compute the revised component values (available on request from the author). It is important to view the circuit's true dependency versus frequency, start-up conditions, etc. Computer simulations should be used to provide a more rapid, accurate method of modifying the circuit component values that govern the oscillation behavior. Simulation is an efficient way to make circuit design trade-offs and adjustments to account for the changes caused by the non-ideal circuit elements.

The basic circuit model can be simulated with a small-signal circuit simulation, which inherently works in terms of S-parameters. A "small-signal" linear circuit simulation is, by far, the most rapid simulation mode available. It is best to use a commercial circuit simulator, such as the Advanced Design System (ADS) from Agilent Technologies (Santa Rosa, CA), MMICAD from Optotek (Kanata, Ontario, Canada), the Serenade Suite from Ansoft (Pittsburgh, PA), and Microwave Office from Advanced Wave Research (El Segundo, CA) for this. The simulator should be set up to use the "reflection amplifier" method that was previously mentioned, using the oscillator circuit model of Fig. 11. The initial values can be derived from the revised design equations. Adjustments can be made to the component values to return the active circuit and resonant load impedances back to the values required for the desired oscillation frequency, start-up, and tuning range. In some cases, the values predicted by the small-signal circuit model are a sufficient and accurate estimation of the component values to proceed directly toward constructing the actual circuit (Fig. 12). However, when a more accurate or highly optimized design is required, it may be necessary to simulate the actual active circuit implementation with detailed models for all devices. The full oscillator circuit is then simulated with a time-domain simulator (e.g., SPICE) or a harmonic-balance simulator (e.g., Harmonica) to precisely determine the frequency tun-



13. This oscillator active circuit is based on the use of a discrete transistor.

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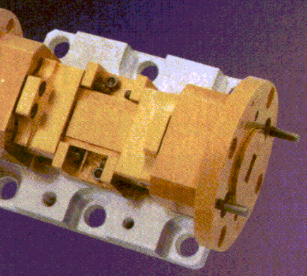
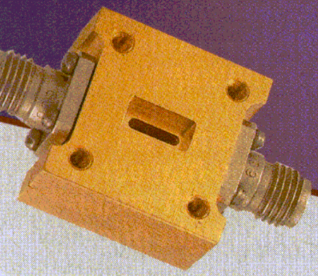


AMPLIFIERS

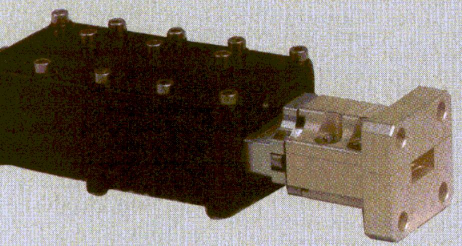
Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	I/O VSWR (Max.)	Output Power at 1dB Comp.* (dBm, Typ.)
JSW4-18002600-18-5A	18-26	28	1.0	1.8	2.0:1/2.0:1	5
JSW4-26004000-25-5A	26-40	25	2.5	2.5	2.0:1/2.0:1	5
JSW4-18004000-32-8A	18-40	21	2.0	3.2	2.0:1/2.5:1	8
JSW4-30005000-45-5A	30-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW4-40006000-65-0A	40-60	16	2.5	6.5	2.5:1/2.5:1	0

* Higher output power options available



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	20	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	20	45
ARE3436LC1	34-36	15.5-16.5	2.7-3.3	25	4	20	60
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20



MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, min.)	Output Power* (dBm, min.)	Fundamental Feed Through Level (dBc, min.)	DC current @+15VDC (mA, nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	12	18	160
MAX2M200380	10-19	20-38	6	14	18	200
MAX2M300500	15-25	30-50	10	8	18	160
MAX4M400480	10-12	40-48	10	8	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	8	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

* Higher output power options available

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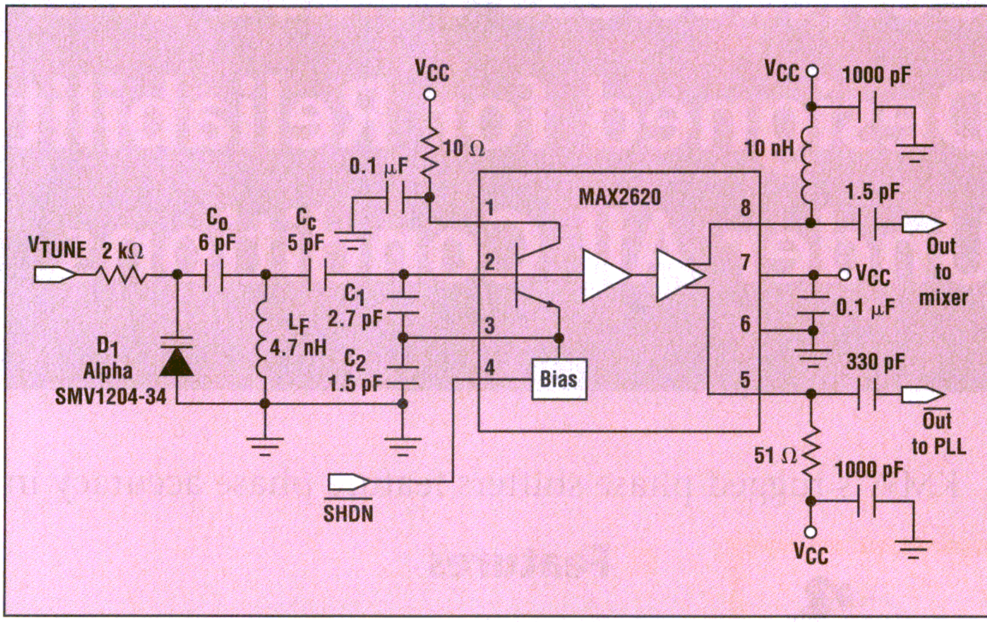
ing range and verify that the circuit design objectives can be met.

EXAMPLE CIRCUIT

Implementation of the Colpitts configuration shown in Fig. 7 is commonly accomplished with discrete transistors. Many options exist for cost-effective, high f_T transistors packaged in small plastic packages—as single and dual devices. However, in order to achieve a design that works down to a +2.7-VDC supply voltage with sufficient headroom for the oscillator device and output buffer, a three-transistor circuit is typically needed. Figure 13 shows the possible implementation of the oscillator active circuitry.



14. Based on a model MAX2620 oscillator IC, this design represents a practical implementation of the Colpitts oscillator configuration.

Discrete implementations are extremely flexible, but possess several negatives. The primary negatives of this circuit are significant variation in biasing versus temperature and supply voltage, the large number of components required to implement the oscillator active circuitry, and the relatively large PCB area that is required.

An improved alternative to the discrete transistor approach is to use an integrated oscillator IC, such as the MAX2620 from Maxim Integrated Products (Sunnyvale, CA), with an external tank circuit. The MAX2620 IC integrates the oscillator transistor, stable biasing, and an output amplifier in a small uMAX8 package to provide a convenient method of implementing the oscillator active circuitry.[10] This approach permits the designer to focus only on selecting the external passive component values, thereby confining the design task to achieve the required frequency tuning characteristics. Figure 14 shows the Colpitts oscillator configuration using the MAX2620. The frequency-setting components are all on the left side of the circuit. The components that are connected to the output ports are one possible option to implement the output matching to the load.

Referring to the revised circuit model of Fig. 11, the parasitic-element values in the component models are as follows. For the varactor, L_p = 1.5 nH, R_{sv} = 0.5 Ω, C_{var}(hi) = 8 pF, and C_{var}(lo) = 4 pF. For the inductor, L_p = 4.7 nH and R_{sl} = 0.5 Ω. For the transistor, L_p ~ 3.0 nH and Cpi = 1.1 pF. For the layout parasitics, C_{p1} = 0.2 pF, C_{p2} = 0.2 pF, C_{p3} = 0.5 pF, C_{p4} = 0.3 pF, and L_{trace} = 0.3 nH.

The component values are selected through a simple design process that is summarized below as part of the revised design process:

- Select initial values for C_1, C_2, L_f, C_c, C_o, C_{var}(hi), and C_{var}(lo) based on the revised design equations developed for C_{var}, C_v, C_{in}, and C_{12e} described in this article to achieve the require frequency tuning range required for the trimless VCO.
- Construct a more detailed small-signal circuit model using the revised models for the varactor, active circuit, and layout parasitic elements.
- Simulate the small-signal circuit model and adjust the component value to achieve the target values for C_{in}, $C_{var(hi)}$, $C_{var(lo)}$, and startup conditions (maintain loop gain and sufficient negative resistance).
- Construct the oscillator with the simulated component values.
- Measure $1/S_{11}$ and Γ (optional).
- If any fine-tuning frequency adjustment is necessary, adjust the frequency of oscillation with C_o, C_c (for an increase in frequency, decrease C_c and for a decrease in frequency, increase C_c; increase the tuning range and decrease the frequency by increasing C_o; and decrease the tuning until the tuning range and frequency limits match a particular set of requirements).

A circuit (Fig. 14) was constructed in prototype fashion to demonstrate the performance of an oscillator designed from the equations and simulation technique outlined in this article. The circuit is useful for some commercial 900-MHz industrial-scientific-medical (ISM) applications. ••

Acknowledgments

The author would like to acknowledge that there are many previous contributors to the field of oscillators that are the respected experts (Rohde, Leeson, Boyles, Hayward, Meyer, etc.). Their work has led to the advancement of oscillators in general and provided the foundation for this two-part article. My effort was simply to introduce a simple concept for a trimless VCO and to re-describe the oscillator design task in a simple, improved manner in order to permit an engineer to quickly calculate the initial component values for a PCB-based Colpitts VCO design.

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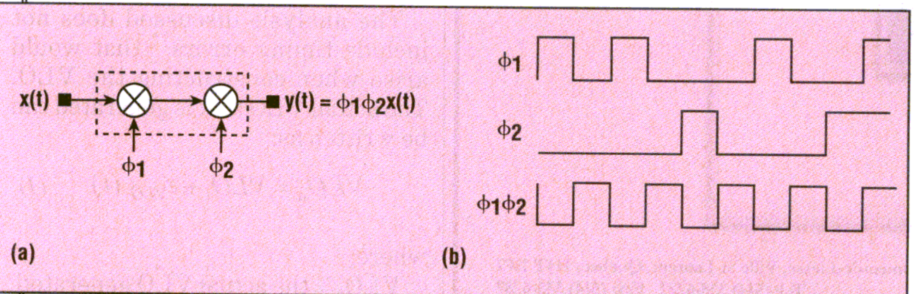
Virtual LO Tunes Direct-Conversion Receivers

This direct-conversion design uses a novel circuit to overcome 1/f noise and LO leakage into the carrier path.

Tajinder Manku
Wireless Microsystems, 4 Jacqueline Pl., Kitchener, Ontario, N2N 3K9, Canada; (519) 744-1116, FAX: (519) 746-3077, e-mail: tmanku@venus.uwaterloo.ca.

DIRECT-CONVERSION RF receivers and transmitters, unlike their superheterodyne cousins, convert RF signals to baseband, and vice versa, without an intermediate-frequency (IF) step. This confers several advantages over superheterodyne designs in terms of cost, power, and levels of integration.[1] But direct conversion is not without its problems, including 1/f noise (for receivers only) and leakage of the local-oscillator (LO) signal into the carrier path. The 1/f problem is not too serious, since bipolar devices have a 1/f corner frequency on the order of 1 kHz, while the typical bandwidth of an RF signal is much greater than 1 kHz. But the problem of the local oscillator (LO) leaking into the RF path is serious. It stems from the fact that in direct-conversion schemes, the LO is equal in frequency to the RF carrier. Therefore, when the LO leaks into the RF path, it places power directly in the RF signal band. This can modify and/or distort the information stored in the RF signal band.

This article describes a method of removing the LO-leakage problem that is associated with direct-conversion RF receivers or transmitters. To solve this problem, a "virtual LO" (VLO™) signal is generated within the RF signal. The LO signal consists of signals that contain an insignificant amount of power (or no power) at the LO frequency. Any errors that generate the virtual LO in the new design can be minimized using a closed-loop correction scheme.



1. This figure shows the virtual LO direct-conversion topology (a) while (b) shows examples of the signals ϕ_1 and ϕ_2.

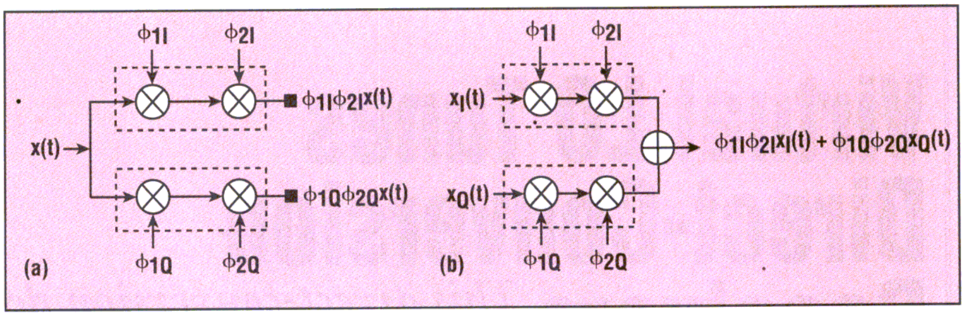
Figure 1a shows the basic VLO topology. A VLO is generated by multiplying two functions (labeled ϕ_1 and ϕ_2) within the signal path of the signal x(t). The signal x(t) can either be an RF signal or a baseband signal. If x(t) is an RF signal, the topology corresponds to a downconversion. If it is a baseband signal, the topology corresponds to an upconversion. The two functions ϕ_1 and ϕ_2 have the property that $\phi_1\phi_2$ = VLO, where VLO is a function that contains a significant amount of power at the RF carrier frequency. Figure 1b depicts possible functions for ϕ_1 and ϕ_2 . To ensure that no LO power leaks into the signal path, the criteria for selecting the functions ϕ_1 and ϕ_2 are:

1. ϕ_1 and ϕ_2 do not have any power (or a significant amount of power*) at the carrier frequency.

2. The signals that are required to generate ϕ_1 and ϕ_2 should not have a significant amount of power at the RF carrier frequency.

3. If x(t) is an RF signal, $\phi_1\phi_1\phi_2$ should not have a significant amount of power within the bandwidth of the RF signal at baseband.

4. If x(t) is a baseband signal, $\phi_1\phi_1\phi_2$ and $\phi_2\phi_2$ should not have a significant amount of power within the upconverted RF signal.



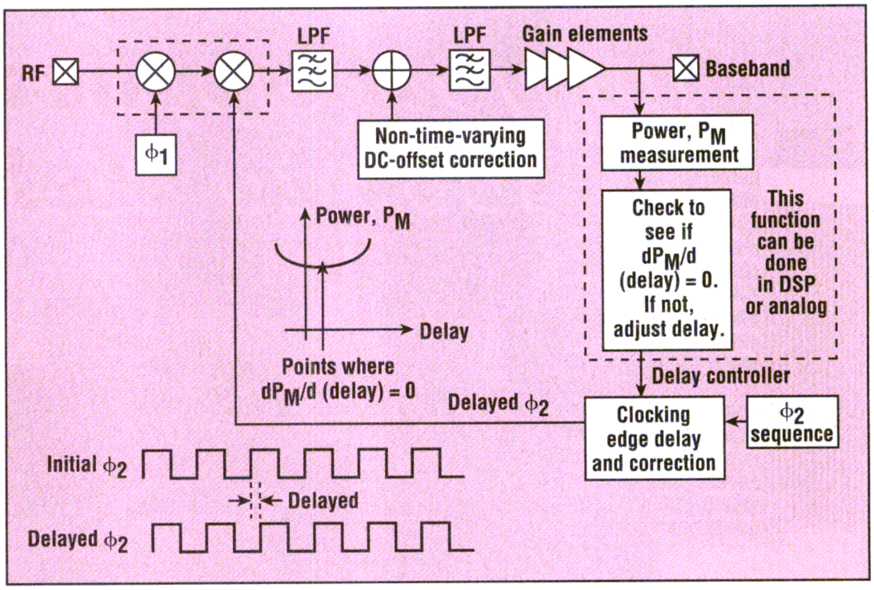
2. This figure shows the virtual LO direct-conversion receiver topology with I and Q generation (a) and virtual LO direct-conversion transmitter with I and Q transmission (b).

Conditions 1 and 2 ensure that no power is generated within the system at the carrier frequencies that would cause an equivalent LO leakage problem found in conventional direct-conversion topologies. Condition 3 ensures that if ϕ_1 leaks into the input port, it does not produce a signal within the baseband signal at the output. Condition 4 ensures that if ϕ_1 leaks into the input port, it does not produce a signal within the RF signal at the output. Condition 4 also ensures that if ϕ_2 leaks into node between the two mixers, it does not produce a signal within the RF signal at the output. Various functions can satisfy the conditions that were previously listed. However, in many modulation schemes, in-phase (I) and quadrature (Q) signals are required. In these cases, four functions have to be generated. Figures 3a and b illustrate this point for receiver (Rx) and transmitter (Tx), respectively. One method that can be used to generate the various functions in Fig. 3 is shown in Fig. 4. The signals ϕ_1 and ϕ_2 are generated by using a signal twice the frequency of the LO and a control signal, S1.

The analysis discussed does not include timing errors** that would arise when constructing the VLO. The actual VLO that is generated can be written as:

$$VLO_a = VLO_i + \varepsilon_{VLO}(t) \qquad (1)$$

where:
VLO_a = the actual VLO generated,
VLO_i = the ideal VLO without any



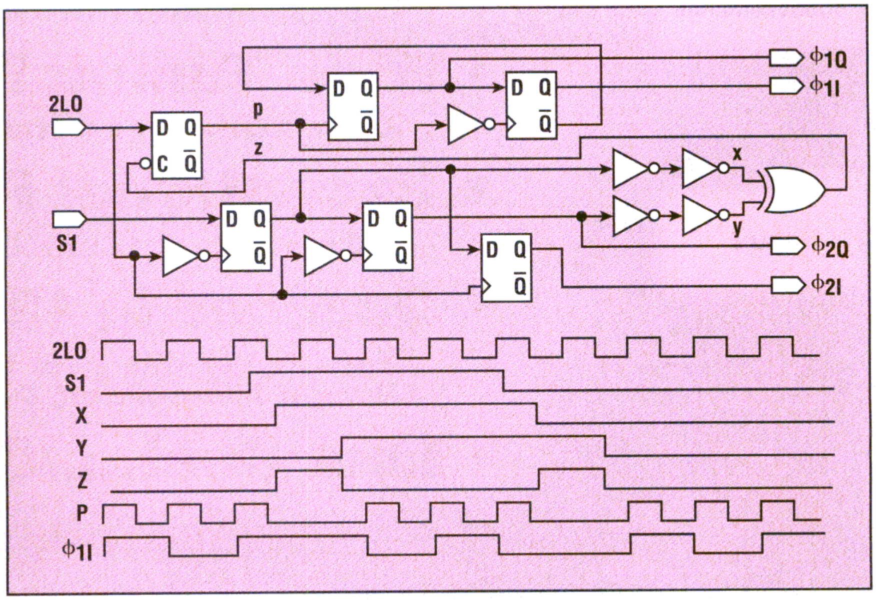
4. This is a schematic for delay-correction scheme within the Rx path.

timing error, and

$\varepsilon_{VLO}(t)$= a parameter that absorbs the timing errors. Therefore, the output signal of the virtual LO topology (denoted as y(t)) becomes:

$$y(t) = x(t) \times [VLO_i + \varepsilon_{VLO}(t)] \quad (2)$$

The term $x(t)VLO_i$ is the desired term, and $x(t)\varepsilon_{VLO}(t)$ is a term that produces aliasing power into the desired signal. For a transmitter topology, this is not a serious problem because the signal x(t) is at baseband and has a well-defined bandwidth. However, for a receiver topology, x(t) does not have a well-defined bandwidth, so this term would produce an in-band aliasing power within the order of $\overline{\varepsilon_{VLO}}^2$, which turns out to be related to the bandwidth of the RF signal divided by the unity current-gain frequency of the integrated-circuit (IC) technology where it is implemented (assuming the worst-case scenario). This may be a serious problem for some applications—the term $\varepsilon_{VLO}(t)$ can also consist of a term



3. This circuit diagram shows one possible method of generating the various signals required in Figure 2. S1 is a control signal that generates the signals ϕ_1 and ϕ_2.

that raises the noise floor of the VLO. However, by selecting ϕ_1 and ϕ_2 carefully and placing an appropriate filter at the input of the structure, the amount of aliasing power can be reduced significantly. But due to timing errors, it can never be completely eliminated. There are several ways that one could further reduce the amount of aliasing power. One method is to use a closed-loop configuration. The term $x(t)\ \varepsilon_{VLO}\ (t)$ contains two terms at baseband: aliasing power P_a, and the power of the desired signal at a reduced power level (on the order of delay error $P_{W\varepsilon}$. Therefore, the total power at baseband (denoted by $P_{M)}$ can be decomposed into three components—the power of the desired signal, P_w; the power of the aliasing terms, P_a; and the power of the desired signal arising from the term $P_{W\varepsilon}$ (this power can either be positive or negative). Therefore:

$$P_M = P_w + P_{w\varepsilon}(\tau) + P_a(\tau) \qquad (3)$$

Note that $P_{w\epsilon}$ and P_a are a function of the delay, τ. Since $|P\ | >> |P_{w\epsilon}|$, equation 3 becomes:

$$P_M = P_w + P_a(\tau) \qquad (4)$$

If the power, P_M, is measured and τ is adjusted in time, one can reduce the term P_a to zero (or close to zero). Mathematically, this can be performed if the slope of P_M with the delay τ is set to zero.

$$dP_M / d\tau = dPa(\tau) / d\tau = 0 \qquad (5)$$

The power-measurement scheme and the element blocks that are required to check if $dP_M/d\tau = 0$ can be implemented within a digital-signal-processing (DSP) unit. This plot shows that there is an optimum point where $dP_M/d\tau = 0$. The basic criterion of this scheme is that the power measurement is made over a time T_p shorter than the average time it takes for the power level of the desired bandwidth to change (this time is denoted by T_{pw}).

$$T_{pw} >> T_p \qquad (6)$$

The author has verified the basic design previously described at low frequencies using transistor-transistor-logic (TTL) parts (74 series) to generate the VLO, and a model MLT04 quad-mixer set from Analog Devices (Norwood, MA) for frequency translation. A high-frequency design has also been verified in a 35-GHz bipolar RF IC process. ••

Notes

*The amount of power generated at the carrier frequency should not affect the overall system performance of the Rx or Tx in a significant manner.

**Timing errors can be in the form of a delay or a mismatch in rise/fall times. In this paper, only delays are considered, but the same can be said for rise/fall times.

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Comparing On-Wafer Cal Techniques To 110 GHz

Even the most precise test equipment requires careful calibration methods for wafer-probe measurements at millimeter-wave frequencies.

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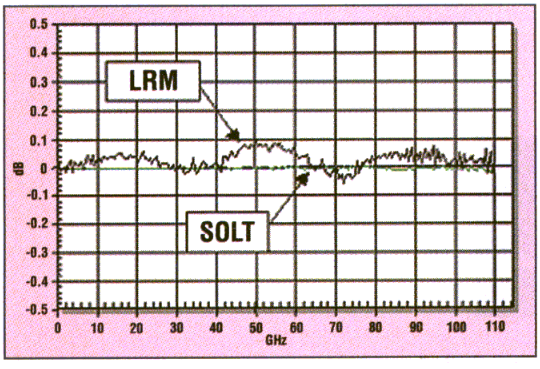
ON-WAFER measurements are supported by a variety of calibration methods for making corrected S-parameter measurements. While these methods are well-detailed at microwave frequencies, less is known about the accuracy of each calibration approach at millimeter-wave frequencies. What follows is a comparative study of the different calibration techniques at frequencies through 110 GHz.

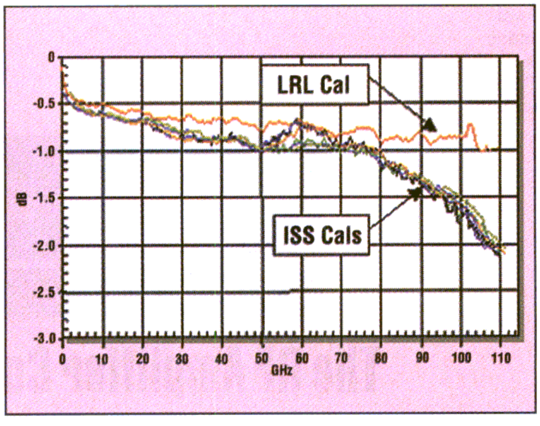
To identify the true integrity of the short-open-load-through (SOLT) calibration technique, independent verification standards are required. Remeasuring the same standards will only show the repeatability of the contact (Fig. 1). The SOLT calibration is not self-consistent and the open-circuit response shows a perfect reflection, whereas the line-reflect-match (LRM) calibration method is self-consistent and errors can be identified by examining the magnitude of the S-parameter, S_{ii}. It is not a safe assumption to believe that SOLT is more accurate because it looks like a perfect open.

In order to compare the various calibration approaches, three different calibration standard substrates were used. A gallium-arsenide (GaAs) substrate was used for the National Institute of Standards and Technology (NIST) multiline (LRL) calibration,[1] while two alumina substrates were used for the SOLT, LRM, and line-reflect-reflect-match (LRRM) calibrations. One alumina substrate was 625 μm thick and the other was 250 μm thick. As a recommendation from ref. 2, the thin impedance standard substrate (ISS) included a layer of radiation-absorption material (RAM) between the ISS and the probe station's metal chuck surface.

In making these comparisons, a major limitation was found to be the lack of a reliable precision reference measurement to 110 GHz. An extrapolation was made from the results of ref. 3 to cover the higher frequency band. The NIST LRL calibration standards are not a modeled 50-Ω



1. Measurement of open standard after calibration falsely shows SOLT to be perfect, which is a result of the SOLT calibration forcing the reflections to be 0 dB.



2. These S_{21} log-magnitude measurements were made on the NIST 3.2-mm line.

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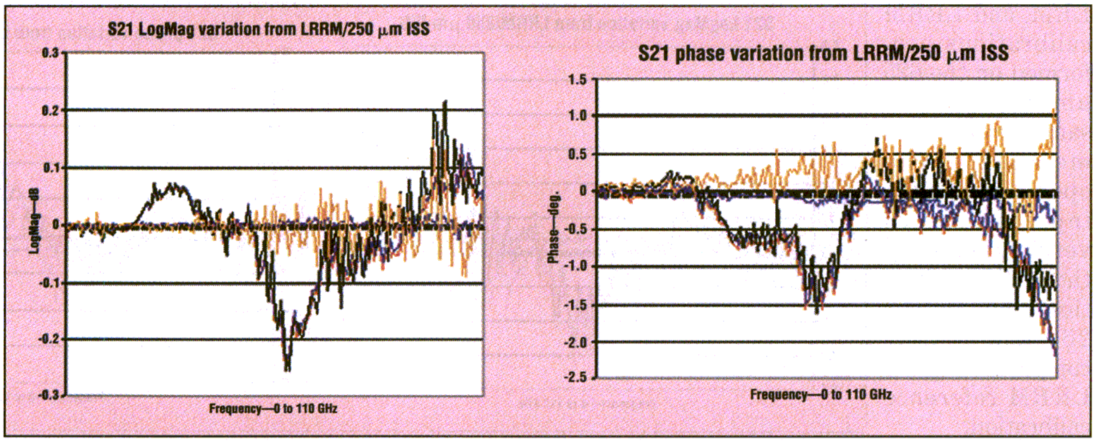
transmission line to 110 GHz and an impedance mismatch to 50-Ω calibrations can be expected. The LRL calibration-reference planes were at the center of the 500-μm through line, and the reference impedance, Z_o, was in relation to this line. To compare the common calibration methods used by engineers for on-wafer microwave measurements, several calibrations were performed using the following methods: SOLT, LRM, LRL, and LRRM with Auto Load Inductance Compensation.[4] Measurements were collected, using each resulting calibration coefficients, of active and passive devices to determine if a measurement difference is apparent by using different techniques. A commercially available software package was used to perform calibrations and recording measurements.[5]



3. These measurements show the log magnitude (left) and phase (right) variations of the line using the LRRM/250 μm ISS as reference (for ISS calibrations only).

The open-standard measurements using the SOLT calibrations coefficients indicate a near-perfect reflection measurement, since only a repeatability measurement of the contact is being performed. The thinned 250 μm ISS and layer of RAM reduced the magnitude of error on LRM and LRRM calibrations. The large error using the 625-μm-thick ISS was due to the substrate moding being more significant at millimeter-wave frequencies. The 250 μm ISS pushes the substrate moding above 110 GHz. This now meets the commonly used-error limits of ±0.1 dB for open-circuit verification.

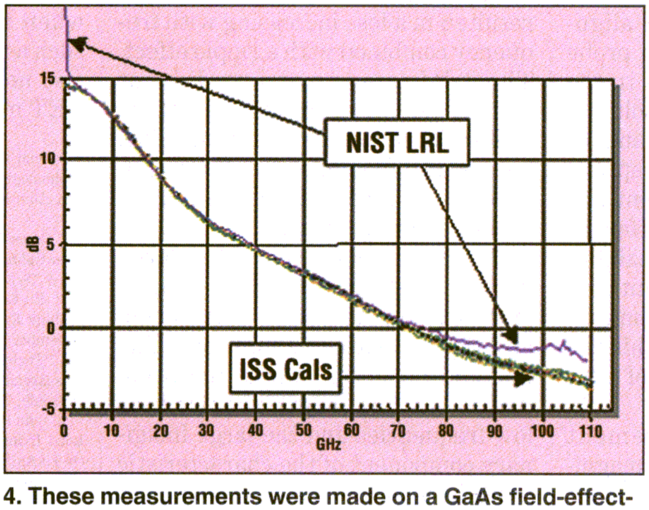
A more reliable way to verify the integrity of the calibration is to measure an independent verification standard. For this purpose, a 3.2-mm open stub and 3.2-mm line of the NIST reference substrate were used. The ISS calibrations (LRM, LRRM, and SOLT), using the 625-μm-thick and 250-μm-thick substrates, show a ripple effect. This is due to the line not being exactly at 50 Ω and representing an impedance mismatch in the case of the 50-Ω ISS calibrations. The LRL calibration shows a more linear response, but a phase and magnitude offset is present due to the reference plane being in the center of the LRL through standard and not the probe tips.

The GaAs line measurement shows the LRL being comparable to the ISS-based calibrations to 70 GHz, where afterwards the ISS calibrations show greater loss. This may be a result of the mismatched line acting as a lowpass filter for the 50-Ω calibrations.

The ISS calibrations have approximately the same deviation from the LRL measurements (Fig. 2). Using the LRRM calibration as a reference, the variation of the LRM and SOLT calibrations can be observed. The 625-μm ISS and SOLT calibrations show greater variation in phase and magnitude (Fig. 3). The phase variation of the ISS calibrations from the LRL calibration shows a linear phase change due to the reference planes of the LRL calibration being at the center of the 500-μm through standard and not at the tip of the probes, as with the ISS calibrations.

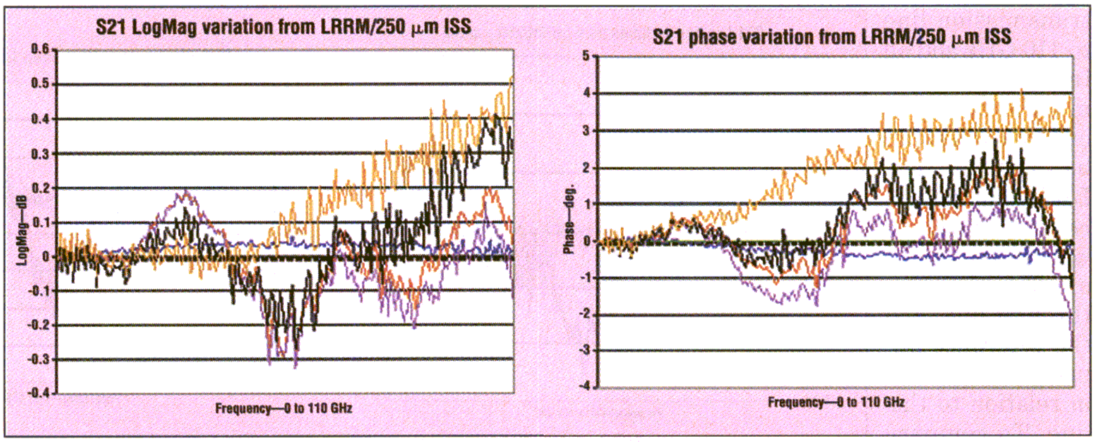
Measurement accuracy very much relies on the calibration and the measurement application. Figure 4 shows measurements made on a GaAs field-effect transistor (FET). The SOLT, LRM, and LRRM calibrations are grouped together. The only stray measurements are the NIST LRL calibration. The difference between the LRL and other calibrations is probably not due to the inaccuracy of the ISS-based calibrations. It is likely due to the inaccuracy of the LRL calibration due to the change in the pad parasitic element values, the change of effective dielectric constants, and the low-end limitation of the calibration due to the restrictions of long-line standards.

The SOLT calibration performed on the 250 μm ISS indicates a linear increase in magnitude and phase (Fig. 5). The SOLT,



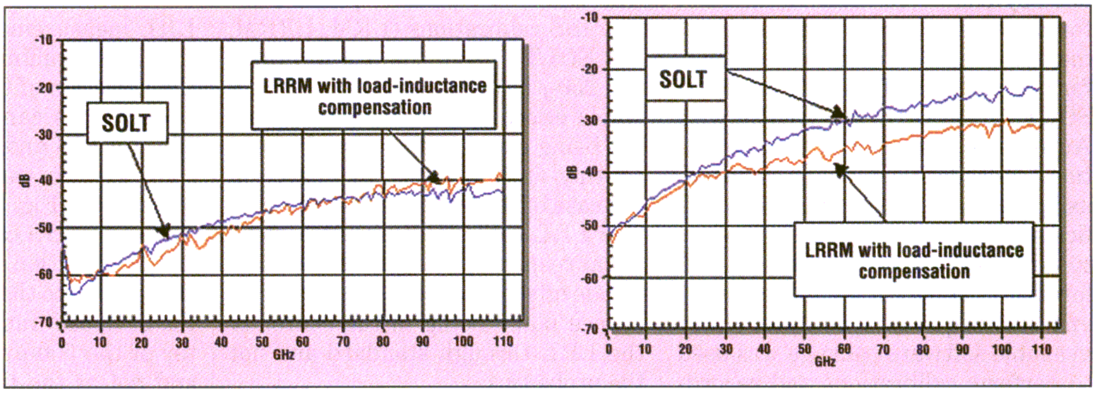
4. These measurements were made on a GaAs field-effect transistor (FET) device.

LRM, and LRRM calibrations performed on the 625 μm ISS shows the same errors when measuring the open circuit during calibration verification. Only the LRM calibration made on the 250 μm ISS is comparable to the LRRM reference calibration.



5. These measurements of the S^{21} log magnitude (left) and phase (right) of the GaAs FET were made with reference to a LRRM calibration using 250 μm ISS.

The need to make an accurate calibration and measurement is equaled by the requirement to make repeatable calibrations and measurements. As shown in Fig. 6 (left and right), the worst-case error bounds occur for repeating two identical calibration techniques. The results show that the LRRM calibration with load-inductance compensation was more repeatable than SOLT, which was particularly sensitive when using different sets of standards.



6. The worst-case errors for calibration repeatability were gauged with the same set of standards (left) and with two different sets of standards (right).

A total of eight LRRM calibrations were performed using the same set of ISS standards, but replacing the probes manually on the ISS alignment mark. Even though the probe placement was not exact due to the limitation of the optics and resolution of the positioners, the open-standard verification has a worst-case spread of 0.15 dB. The same experiment was repeated but using eight different sets of standards. The repeatability of the calibration decreased, but only marginally, to 0.2 dB. All of the calibration verifications were within the general recommended limits of ±0.1 dB to 110 GHz.

Analysis of the measurement results showed differences in magnitude and phase for the devices under test (DUTs). The extent of the differences was found to be dependent on the DUT and calibration technique used. From the measurements made of the open stub and line, on the GaAs NIST reference material, the results approximated what was expected. The ISS calibrations did not have the same Z_o value as the GaAs line. This resulted in a loss increasing with frequency combined with a ripple effect. The LRL measurement did not exhibit the ripple, due to the Z_o of the calibration being the same as the line, but had an offset in phase and magnitude due to the incorrect positioning of the reference planes.

The FET results identified large variations at low and high frequencies between the LRL calibration and the ISS-based calibrations. The low-end variation was a limitation due to the line length required for low frequencies and the large imaginary component of the characteristic impedance at low frequencies due to conductor resistance. The high-frequency variations were a result of differences in pad parasitic-element values between the calibration standard and the DUT.

The 625-μm-thick ISS exhibited a larger error in magnitude when verifying the calibration using an open standard. This error is noticeable when measuring a reflective DUT, such as an open or open stub, and was also noticeable on the S_{21} value of a FET measurement.●●

Acknowledgment

Special thanks is due to the technical staff of Agilent Technologies (Santa Rosa, CA), the former Santa Rosa Systems Division of Hewlett-Packard Co.

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Selecting wireless RF transmission lines

Ideal RF transmission-line components would be electrically "invisible," routing signals through a system without adding loss or gain. But in reality, transmission-line components do exhibit loss and reflections at junctions with bad impedance matches and, thus, they must be selected and assembled with care. An application note from Andrew Corp. (Orland Park, IL) provides an overview of transmission-line components and guides specifiers through key characteristics and performance parameters.

Transmission lines can be judged in terms of electrical and mechanical integrity. Indicators of system-level electrical integrity include connectors, antennas, and cables with proper impedance match, cable conductors that are solid, impedance measurements that are consistently at 50 Ω, components that mate tightly with proper tolerances, and performance measurements that reveal low insertion loss and low VSWR. Indicators of system-level mechanical integrity include tight fits between components, lack of in-field fabrication to compensate for mismatched parts, lack of deterioration in the system due to environmental effects, prevention of water migration, and properly fitting weatherproofing materials.

The 16-page application note provides recommendations for minimizing system-level attenuation and VSWR by properly specifying cables and connectors, and even details techniques for reducing intermodulation distortion (IMD). Copies of the application note are free, from: **Andrew Corp., 10500 West 153rd St., Orland Park, IL 60462; (800) 255-1479, (708) 349-3300, FAX: (800) 349-5444, Internet: http://www.andrew.com.**

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Understanding jitter and wander in high-speed networks

Network operators rely on tight synchronization and good phase stability of their clock and data signals in order to provide high performance. Unfortunately, a number of factors prevent perfect synchronization, due to the jitter and wander of digital sources. An application note from Wandel & Goltermann GmbH & Co. (Eningen, Germany), "Synchronization—Jitter-Wander: Basic principles and test equipment," helps to explain these parameters and how they can impact the overall performance of a high-speed telecommunications network.

Jitter is used to designate periodic or stochastic deviations of the significant instants of a digital signal from ideal, equidistant values. When compared to a perfect square-wave signal from a reference clock, the transitions of a digital signal will often occur too early or too late because of these deviations. Slow jitter (of 10 Hz or less deviations) is usually referred to as wander.

Jitter (phase variations greater than 10 Hz) is usually measured by comparing a signal of interest to a relatively jitter-free reference signal. The unit of jitter amplitude is the unit interval, which corresponds to the error of the width of 1 b. To accurately measure jitter requires test equipment capable of acquiring data for minutes at a time.

The 32-page application note explains how to make jitter and wander measurements, and describes basic jitter and wander parameters, including phase hits (which are jitter peaks that exceed an given amplitude) and root-mean-square (RMS) jitter. The literature shows how jitter can accumulate in data regenerators, and provides measurement techniques for determining the maximum tolerable jitter (MTJ) for a particular telecommunications or data-communications network. Other measurements cover the jitter-transfer function (JTF), mapping jitter, pointer jitter, as well as a variety of ways to evaluate wander. The note provides several block diagrams with sample test systems for performing these different measurements, along with a comparison of the jitter/wander measurement requirements set forth in the latest International Telecommunications Union (ITU) recommendations (0.171 and 0.172).

The 32-page booklet also includes an appendix with a thorough listing of global standards for jitter and wander, including specifications from ANSI, Bellcore, and the ITU. Copies of Application Note 71, "Synchronization—Jitter-Wander: Basic principles and test equipment" are free, from: **Wandel & Goltermann GmbH & Co., Marketing International, Postfach 1262, D-72795 Eningen, Germany; (49) 7121-86-1616, FAX: (49) 7121-86-1333, e-mail: info@wago.de, Internet: http://www.wg.com.**

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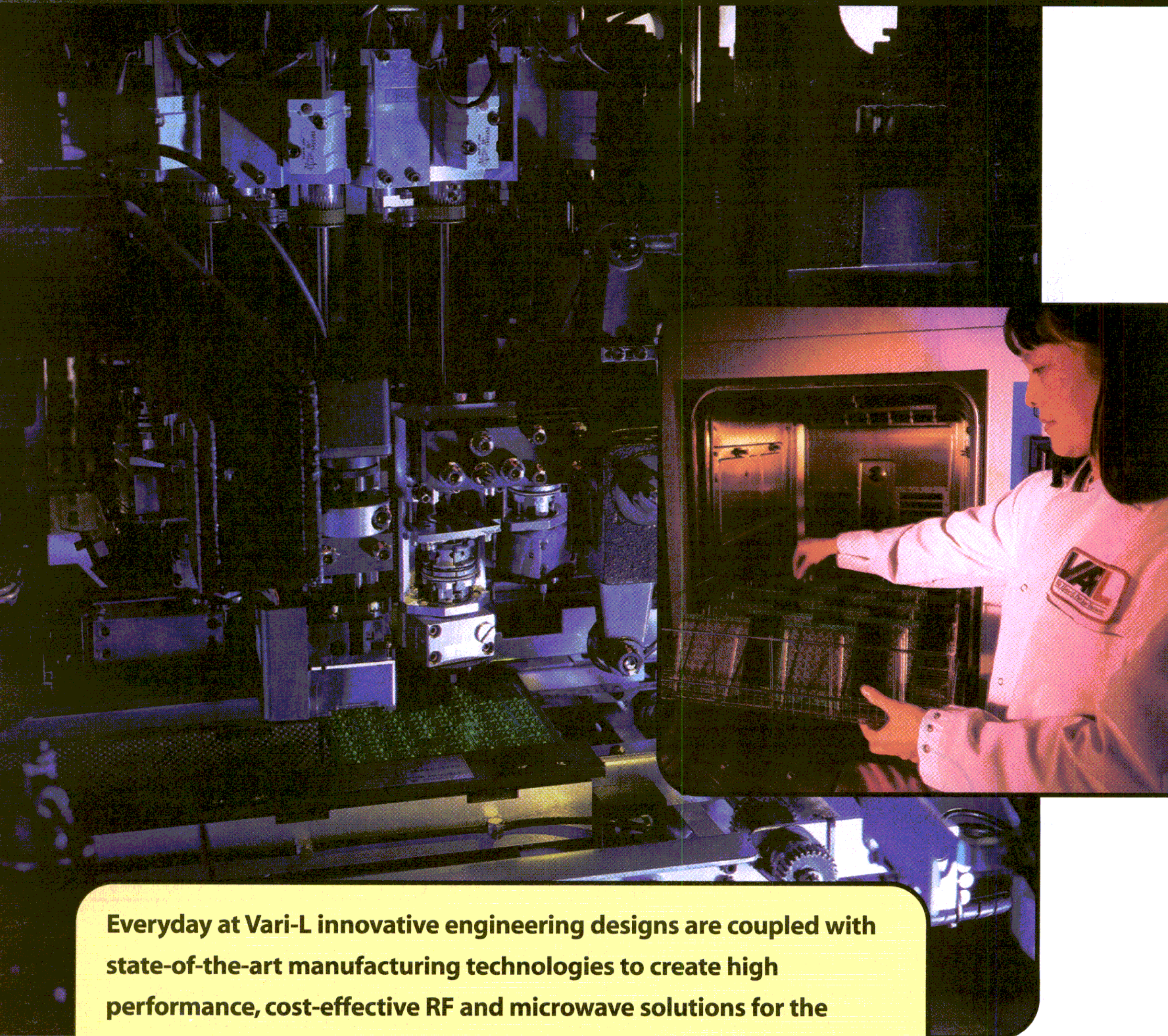
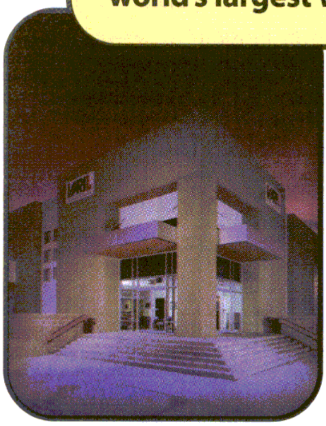


Everyday at Vari-L innovative engineering designs are coupled with state-of-the-art manufacturing technologies to create high performance, cost-effective RF and microwave solutions for the world's largest wireless equipment companies.



At Vari-L, we are dedicated to research and development. Our exceptional commitment to innovation has resulted in eight new patents in the last three years alone. Since 1953, our products have been utilized in many diversified and demanding applications ranging from satellite and aerospace systems, CATV and fiber optic transmission systems to wireless base stations and handsets.

Our intensive investment in state-of-the-art manufacturing technology gives us the ability to offer low cost product realization through automated assembly, handling and testing. Recent expansions in our automated production systems have created a projected Year 2000 manufacturing capacity in excess of 12 million units housed within Vari-L's 80,000-square foot facility in Denver, Colorado.

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Instrument Emulates Cable-Network Impairments

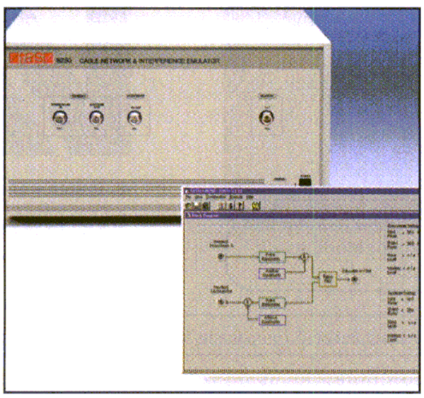
This tool can recreate the performance characteristics faced by cable modems and other equipment in a cable-network system.

Mike Pellegrini
Product Manager - Wired Test Systems
Telecom Analysis Systems, 34 Industrial Way East, Eatontown, NJ 07724; (732) 544-8700, FAX: (732) 544-8347, e-mail: mpell@taskit.com, Internet: http://www.taskit.com.

INTERNET access through cable modem is a rapidly growing data application. Cable modems access massive available bandwidth by sending and receiving data through the same coaxial cable that carries cable-television (CATV) signals, rather than over twisted-pair telephone wires used by dial-up and xDSL modems. For cable modems to work effectively, however, they should be thoroughly tested with a new type of system, the TAS 8250 cable network & interference emulator from Telecom Analysis Systems, Inc. (Eatontown, NJ).

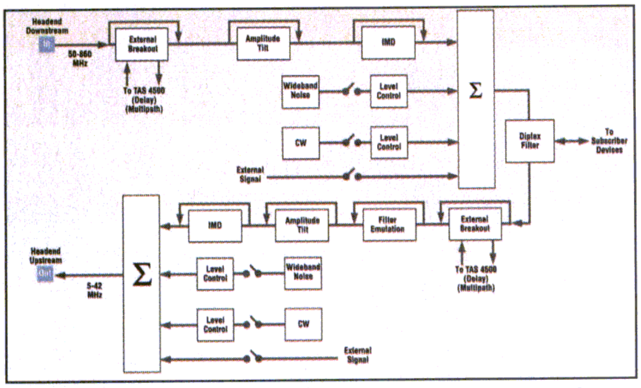
The TAS 8250 cable network & interference emulator (Fig. 1) combines the functionality of several instruments to accurately model the characteristics of a hybrid-fiber/coaxial (HFC) network. The TAS 8250 recreates real-world cable-network conditions to allow the transmission performance of cable modems and cable-modem termination systems (CMTS) to be reliably evaluated. Other cable-network communications equipment, such as Internet Protocol (IP) telephony products, CATV set-top boxes, and high-definition-television (HDTV) equipment, can also be tested with the TAS 8250.

TAS 8250 provides wideband channel emulation of the downstream (50-to-860-MHz) and upstream (5-to-42-MHz) frequency bands in a single, integrated instrument (Fig. 2). The instrument combines additive impairments such as wideband noise and continuous-wave (CW) interference with key cable-network characteristics such as amplitude tilt, network filter emulation, and intermodulation distortion (IMD). A user can independently control the level, frequency, and burst-timing characteristics of all impairment conditions in the upstream and downstream channels. An input connector allows specialized test conditions to be injected into the simulated cable channel and integrated with the instrument. The TAS 8250 quantifies the effects of cable-network impairments in a controllable environment, detecting problems early in the design process.



1. The TAS 8250 cable network & interference emulator emulates the conditions faced by cable modems and other cable-network equipment.

Recent market estimates indicate that the number of cable-modem subscribers in the US and Canada will pass 1 million during 1999. This number represents less than 3 percent of the 32 million homes that have access to high-speed cable data networks, which indicates that there is still huge growth potential in the cable-modem market. Internet service providers (ISPs) such as @Home and Road Runner, who have partnered with CATV affiliates, such as AT&T and Time Warner, to provide high-speed data services,



2. This block diagram shows the various functional components of the TAS 8250 cable network and interference emulator.

continue to report steady growth rates in their subscriber base as they roll-out cable-modem service in more areas.

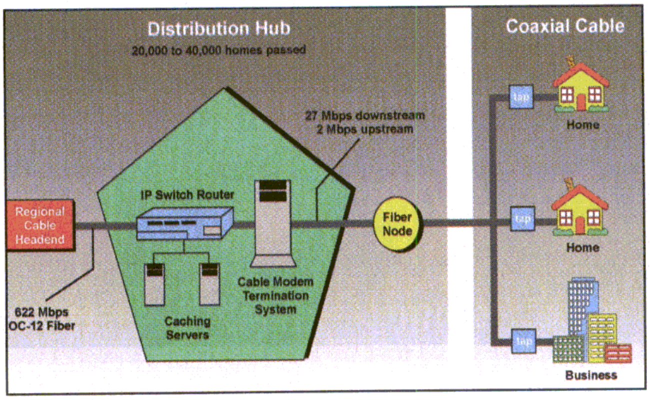
The move to retail distribution of cable modems will help drive the growth of the cable-modem market over the next few years. Retail availability of cable modems accelerates product acceptance and drives down the price of cable modems. Since 1988, when cable system operators formed the Multimedia Cable Network System Partners (MCNS) consortium and Cable Television Laboratories (CableLabs), the cable industry has been laying the groundwork for the move to retail. CableLabs developed the Data Over Cable Service Interface Specifications (DOCSIS) to document standard design criteria for cable modems as well as Cable Modem Termination Systems (CMTS). Consumers who purchase a DOCSIS-compliant cable modem through a retail outlet can be confident that the modem will interoperate with the DOCSIS-compliant CMTS that is used on their cable system. As a comparison, the 56-kb/s modem market experienced greatly increased product acceptance when a standardized, interoperable technology (V.90) replaced the competing, proprietary technologies (x2 and K56Flex).

CableLabs also established the process to test products for DOCSIS certification and to indicate product compliance in a public manner. Cable-modem and CMTS vendors submit their products to CableLabs for a battery of tests that determine whether the product complies with DOCSIS and interoperates with other DOCSIS products. CableLabs then grants the use of the CableLabs-certified sticker to vendors that successfully complete the certification process. More than 10 vendors, including 3Com, Cisco, Samsung, and Toshiba, have already achieved this certification for their version 1.0 DOCSIS cable-modem products, with many others still in the certification process.

Cable modems allow a computer user to send and receive information over a cable network. A CMTS is located at the head end of the cable system and provides the interface where cable modems access the Internet. A CMTS performs functions such as bandwidth allocation and power-level regulation while transmitting and receiving data to and from the cable modems. Both the cable modem and the CMTS modulate digital signals using techniques such as quadrature-phase-shift-keying (QPSK) modulation and quadrature amplitude modulation (QAM).

Transmission between cable modems and the CMTS occurs in two separate frequency bands. On most US cable systems, downstream (CMTS-to-cable-modem) data occupy 6-MHz channels between 50 and 860 MHz. Upstream (cable-modem-to-CMTS) data occupy smaller bandwidth (200-kHz-to-3.2-MHz) channels between 5 and 42 MHz. The downstream channel, having been used to transmit television signals that require superior transmission channel characteristics, supports complex techniques such as 64-QAM and 256-QAM. Less-complex, more-robust modulation schemes, such as QPSK and 16-QAM, are used in the upstream channel to counteract the effects of ingress—undesired signals that leak into the cable system.

A modern cable network that supports broadcast television and high-speed data service combines fiber-optic and coaxial cable transmission facilities (some older systems are all coaxial cable). Fiber-optic lines carry signals from the cable-modem termination system (typically located at the distribution hub) to the fiber node (Fig. 3). Fiber-optic transmission lines carry signals over much greater distances than coaxial cables with fewer amplifiers. Reducing the number of amplifiers used on a cable system increases the channel capacity, improves the signal quality, and reduces maintenance costs. Once signals reach the fiber node they are converted to coaxial cable lines, which carry the signals through the neighborhood and to the home. Between 500 and 1000 cable service subscribers are usually served by a single fiber-optic node on coaxial cable lines.



3. This diagram illustrates how a distribution hub is linked to thousands of subscribers through coaxial and fiber-optic cables.

Noise, or carrier-to-noise (C/N) ratio, has traditionally been the primary cable-network impairment used to evaluate cable-modem performance. However, this approach ignores many other cable-network impairments that have an equal or more severe effect on performance. Additional impairments include ingress of "bursty" noise or interference, group-delay distortion, amplitude distortion and tilt, and intermodulation

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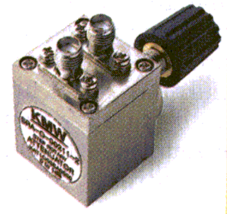

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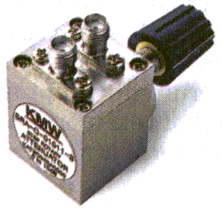

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Operating Type	Break-Before-Make		Make-Before-Break	
Frequency Range	DC ~ 3GHz	DC ~ 3GHz	DC ~ 3GHz	DC ~ 3GHz
Insertion Loss (max.)	0.2dB	0.2dB	0.2dB	0.2dB
VSWR (max.)	1.15:1	1.15:1	1.15:1	1.15:1
Incremental Attenuation Range (dB)	0 ~ 1	0 ~ 10	0 ~ 1	0 ~ 10
Attenuation Step (dB)	0.2	1	0.2	1
Nominal Impedance	50 ohm		50 ohm	
I/O Port Connector	SMA(F) / SMA(F)		SMA(F) / SMA(F)	
Average Power Handling	2W @ 2GHz		2W @ 2GHz	
Temperature Range	-55°C ~ +85°C		-55°C ~ +85°C	
Dimension (inch)	1.93*1.56*1.51		1.93*1.56*1.51	

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VSWR (max.)	1.25 : 1	1.25 : 1	1.25 : 1
Attenuation Range (max.)	4dB @ 1GHz	13dB @ 2GHz	25dB @ 3GHz
Nominal Impedance	50ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	2W @ 2GHz & 25°C, without Heat-Sink		
Temperature Range	-55°C ~ +85°C		
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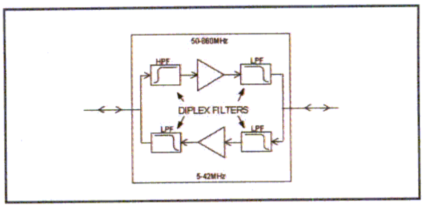
distortion (IMD).

Noise and interference from a variety of sources (ingress) distort data transmission on the cable network, particularly in the upstream frequency band. Many devices, including common household appliances, emit signals in the 5-to-42-MHz upstream frequency bands. These undesired signals may leak into the cable system through poorly shielded drop cables or through the communications devices attached to the cable network within the home. Increased ingress reduces the C/N characteristics in the cable-communications channel, which, in turn, causes more transmission errors or forces the modems to use a slower, less-complex modulation scheme. In addition, ingress is typically impulsive in nature in that the interfering signals appear for short intervals at significant power levels. Downstream transmission is not affected as severely by these impairments, since cable operators have had to design networks to provide superior channel characteristics to support unidirectional television-signal transmission and reception.

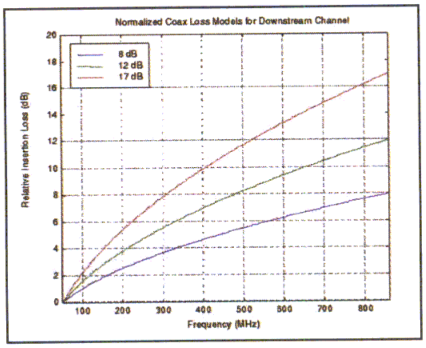
Amplifiers are employed on the cable network to reverse the loss that occurs as signals travel over the coaxial cable (Fig. 4). Each amplifier has associated diplex filters that block signals at certain frequencies before and after the amplifier. When multiple amplifiers are used on a cable network, the group delay and amplitude distortion responses of the diplex filters combine to produce an overall group delay and amplitude distortion shape. This impairment is primarily a problem in the upstream direction, where the lowpass filters typically have a corner frequency of approximately 42 MHz and combine to produce increasing group delay and amplitude distortion in the region of 30 to 42 MHz. Variable delay characteristics at different frequencies in the upstream channel interfere with the time-dependent modulation schemes.

Amplifiers also generate another impairment on the cable network known as intermodulation distortion (IMD). This impairment compresses the outer constellation points of a digital signal. A constellation is a collection of points in a 2-dimensional display where each point represents a specific amount of received information. Compression of the outer points in the cable modem's signal constellation—where transmitted power is at its peak—causes the receiver to misinterpret one constellation point as another. The end result is an increased bit-error rate (BER) as the information represented by a constellation point is altered during transmission over the cable plant. Another IMD effect is the generation of composite-second-order (CSO) and composite-triple-beat (CTB) signals. These CSO/CTB signals represent second- and third-order harmonic signals of the various analog and digital carriers on a cable network. Some CSO/CTB signals may fall at or near the frequency being used for cable-modem service, interfering with the data transmission.



4. A bidirectional cable network includes a variety of amplifiers and diplexer filters, which introduce distortion and other performance impairments.

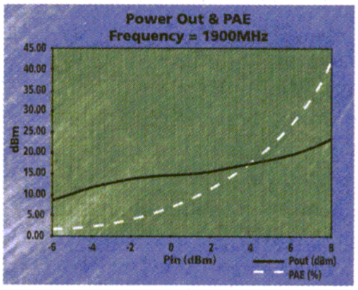
The distance between the cable-modem subscriber and the CMTS dictates the amount of coaxial cable where the digital data signals must travel. Longer runs of coaxial cable produce a more severe signal-level slope, or amplitude tilt, across the downstream and upstream frequency bands. Amplitude tilt is characterized by increasing loss as the frequency increases (Fig. 5). As a result, signals at higher frequencies are attenuated more than signals at lower frequencies, with the severity of amplitude tilt depending on the design of the system.

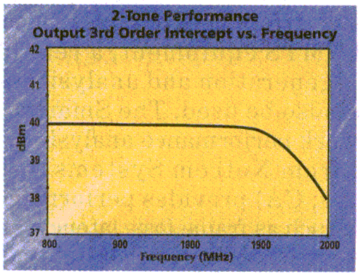


5. These downstream coaxial amplitude tilt models can be created with the TAS 8250.

Cable-modem testing is currently performed in a variety of environments, including field testing on cable networks, testing on in-house cable networks, and using test equipment that generates specific impairments. Each approach requires a significant investment in manpower and time to set up and conduct the tests; these are valuable engineering resources that would be better used to address product issues. Precisely controlling impairments and the repeatability of the test environment are also issues. The ideal solution would combine the best characteristics of these three environments—an application-specific laboratory instrument that provides precise control of real-world cable-network impairments in a repeatable environment.

The broadband nature of the cable network allows many cable modems to share the same communications media. This means that multiple cable modems are connected to the CMTS through a shared communications link. The TAS 8250 provides the critical mix of features that are required to test the performance of cable modems and cable-modem termination systems in this shared environment. Wideband channel emulation of upstream and downstream characteristics allows TAS 8250 to be used in point-to-point (1 CMTS and cable modem), point-to-multipoint (1 CMTS and many cable modems), and multipoint-to-multipoint (multiple CMTS and cable modems) applications. Point-to-point testing is typically performed to focus on the transmission performance of a device in the engineering or design verification stages of product development. Point-to-multipoint testing can be used to load a CMTS with multiple subscribers to evaluate performance degradation. Multipoint-to-multipoint testing can be used examine in-





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Offering significant advantages over existing competitive MESFET technology, the SXH-1 is a highly efficient GaAs Heterojunction Bipolar Transistor power amplifier housed in a low-cost surface-mountable plastic package.

This GaAsHBT amplifier is fabricated using molecular beam epitaxial growth technology, which produces reliable and consistent performance from wafer to wafer and lot to lot. The SXH-1 was specifically designed for use as drivers stages for infrastructure equipment in the 50-2000MHz cellular, ISM and narrowband PCS bands. Operating at a stingy 95ma of current, the SXH-1 is an ideal choice for multi-carrier as well as digital applications.

Performance Matrix
SXH-1

Freq. (MHz)	Gain (dB) Typ.	S11 Typ.	S22 Typ.	P1dB (dBm)	TOIP (dBm)	Voltage	Current (mA) Typ.
800-960	20.0	1.5:1	1.9:1	22.0	39.0	5.0	95.0
1800-2000	14.5	1.5:1	1.7:1	22.0	39.0	5.0	95.0

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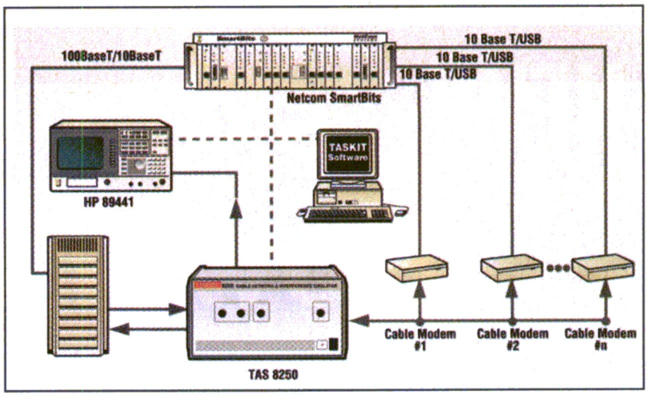
teroperability issues between products from multiple vendors. The TAS 8250 provides a wide range of input/output (I/O) power levels to allow single or multiple cable modems and CMTS to be connected to the simulated cable network.

The TASKIT/8250 for Windows software provides a powerful, easy-to-use graphical interface for controlling the 8250's parameters. TASKIT software greatly reduces test setup time by displaying all upstream and downstream channel parameters on only two simple menus. This software further integrates the test bench by controlling a model 89441 vector signal analyzer (VSA) from Agilent Technologies (Santa Rosa, CA). TASKIT/8250 software contains command libraries to initiate measurement actions in the 89441 VSA and pass the critical information to the 8250 for use in setting power levels, C/N, and carrier-to-interference (C/I) ratios.



6. The TAS Cable-ATS automatic cable-modem test system includes the TAS 8250, a model 89441 VSA from Agilent Technologies, and SmartBits network performance analysis system from Netcom Systems.

In order to accurately measure the effect of cable-network impairments on the performance of cable modems and CMTS equipment, a reliable data-generation and analysis tool must also be used. The SmartBits network performance analysis system from Netcom Systems (Calabasas, CA) provides performance tests such as frame loss, latency, and sequence tracking to accurately measure data-transmission performance. The Cable-ATS system (Fig. 6) combines the TAS 8250 with the Netcom Systems SmartBits system to enable automatic cable-modem performance test measurements in the presence of cable-network impairments. TASKIT/cable test software automatically sets impairment conditions, executes performance tests, and records results in an easy-to-read format. **Telecom Analysis Systems, 34 Industrial Way East, Eatontown, NJ 07724; (732) 544-8700, FAX: (732) 544-8347, e-mail: mpell@taskit.com, Internet: http://www.taskit.com.**

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High-Speed GaAs ICs Network At 10 Gb/s

Three additions to a line of optical-communications components include a multiplexer, a demultiplexer, and a limiting amplifier.

JACK BROWNE

Publisher/Editor

BANDWIDTH and speed are two parameters that go hand in hand in the design of high-speed digital communications networks. A line of gallium-arsenide (GaAs)-based components from Oki Semiconductor (Sunnyvale, CA) provides both, operating at optical carrier rates of 10 Gb/s (OC-192). The OC-192 line, introduced last year (see *Microwaves & RF,* June 1999, p. 134), has just been augmented with the addition of a 16:1 multiplexer, a 1:16 demultiplexer, and a limiting amplifier.

The model KGL4221 multiplexer and the model KGL4222 demultiplexer (see figure) are designed to translate and transfer slower-data-rate signals through an optical network. The KGL4221 16:1 multiplexer, for example, can combine 16 parallel input signals operating at the Synchronous Optical Network (SONET) rate of 622 Mb/s into a single serial output signal at 10 Gb/s. Conversely, the KGL4222 1:16 demultiplexer can translate a high-speed 10-Gb/s serial signal into 16 parallel output signals at 622 Mb/s. The integrated circuits (ICs) are designed for clock signals to 10 GHz, although versions are available for operation at data rates up to 12.5 Gb/s.

The optical components are fabricated with a 0.2-μm gate-length, ion-implanted GaAs metal-semiconductor field-effect-transistor (MESFET process. The process achieves impressive propagation time of 10 ps/gate. Gold (Au) metallization and three-level-metal interconnections are used to achieve high circuit densities. The KGL4221 and the KGL4222 are supplied in a 48-pin ceramic package. By employing the firm's unique memory-cell flip-flop (MCFF) and common-gate-bias flip-flop (CBFF) technologies, the devices are able to achieve the high-speed operation without a penalty in power consumption. The mutliplexer typically consumes 3-W power with a +2-VDC supply while the demultiplexer typically consumes 2.4-W power with a +2-VDC supply.

The model KGL4217 limiting amplifier is designed to minimize clock and data-signal losses in optical receivers operating to 10 Gb/s by providing stable output levels for a wide range of input levels. The KGL4217 handles input signals over a range of 50 to 600 mV peak-to-peak. Using direct-coupled FET logic (DCFL) for high-speed operation with low power consumption, the limiting amplifier restricts power consumption to a maximum of 250 mW at +2 VDC. The KGL4217 limiting amplifier is supplied in a 24-pin ceramic package. **Oki Semiconductor, 785 North Mary Ave., Sunnyvale, CA 94086-2909; (408) 720-1900, FAX: (408) 720-1918, Internet: http://www.okisemi.com.**

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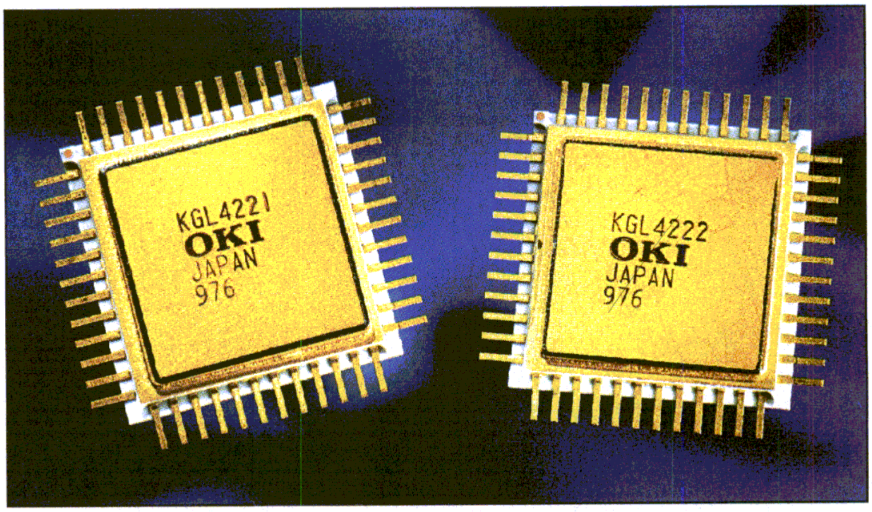


The KGL4221 16:1 multiplexer and the KGL4222 1:16 demultiplexer are designed for parallel-to-serial and serial-to-parallel data-signal transfers, respectively, in high-speed data networks.

PRODUCT TECHNOLOGY

Signal Analyzer

Signal Analyzer Checks Transmitters To 10 Gb/s

This modular measurement solution supports multirate optical and electrical testing of telecommunications and data-communications components and systems.

JACK BROWNE
Publisher/Editor

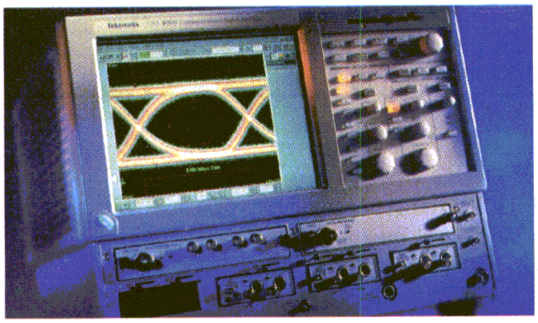
COMMUNICATIONS systems continue to gain in speed, forcing instrument makers to answer with high-performance measurement solutions. The CSA8000 communications signal analyzer from Tektronix, Inc. (Beaverton, OR) is one of these solutions, capable of evaluating telecommunications and data-communications components and transmitters through 10 Gb/s. The instrument offers outstanding signal fidelity, with short-term trigger jitter of typically 1 ps and timebase stability of typically better than 0.1 PPM.

The CSA8000 (see figure) features a modular architecture with a mainframe that accepts plug-in modules. A total of eight measurement channels is possible at one time—two optical and six electrical channels. In addition to operating with optical modules for compliance test to 10 Gb/s and 30-GHz bandwidth, the CSA8000 can be configured with electrical modules with bandwidths to 50 GHz. The vertical resolution for optical and electrical modules is 14 b maximum. Using a direct-trigger function, the sensitivity is typically 50 mV from DC to 4 GHz.

Optical modules for the CSA8000 (with integral optical reference receivers) include the 80C01 for long wavelengths from 1100 to 1650 nm at data rates to 10 Gb/s and optical bandwidths to 20 GHz, the 80C02 for long wavelengths from 1100 to 1650 nm at data rates to 10 Gb/s and optical bandwidths to 30 GHz, and the 80C03 for broad wavelengths from 700 to 1650 nm at data rates to 2.5 Gb/s and optical bandwidths to 2.3 GHz. Electrical modules include the 80E02 dual-channel sampling module with 12.5-GHz bandwidth, the 80E04 dual-channel sampling module with 20-GHz bandwidth and time-domain-reflectometry (TDR) capability, and the 80E05 dual-channel sampling module with 50-GHz bandwidth.

The CSA, which is part of the company's 8000 series of sampling oscilloscopes, performs a variety of optical measurements including optical signal-to-noise ratio (SNR), Q factor, extinction ratio, and mean launch power. It offers a variety of built-in predefined measurement masks for optical carrier rates OC-1 (951.84 Mb/s) through OC-192 (10 Gb/s) as well as for Gigabit Ethernet (at 1.25 Gb/s) and Fibre-Channel rates FC-133 (132.81 Mb/s), FC-266 (265.6 Mb/s), FC-531 (531.2 Mb/s), and FC-1063 (1062.5 Mb/s). The CSA8000 delivers a total of 42 automated measurement functions and statistical functions, and automatically generates waveform histograms, eye diagrams, and other graphical displays.

The CSA8000 is equipped with a 10.4-in. (26.416-cm) diagonal color screen with 16-b color resolution (65,536 different colors) and 640 × 480-pixel video resolution. The instrument offers a variety of communication ports, such as GPIB, parallel port, universal-serial-bus (USB) port, and serial RS-232C port, as well as an Ethernet local-area-network (LAN) connection. The CSA8000 supports an open Windows 98 environment for ease of data exchange and program development. Most data analysis can be performed using commercial software packages. P&A: $19,500 (CSA8000 mainframe), $17,100 and up (optical sampling modules), and $10,500 and up (electrical sampling modules). **Tektronix Measurement Group, P.O. Box 3960, Portland, OR 97208-3960; (800) 426-2200 code 1172, FAX: (503) 222-1542, Internet: http://www.tektronix.com.**



The CSA8000 communications signal analyzer can evaluate the performance of transmitters operating at data rates to 10 Gb/s.

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PRODUCT TECHNOLOGY

Math Software

Math Software Is Ready For The Millennium

This popular mathematics software has been enriched with new features and operating power, as well as an enhanced "Internet-ready" graphical user interface.

ALAN ("PETE") CONRAD
Special Projects Editor

MATHEMATICAL analysis programs are invaluable for studying complex engineering problems, such as antenna patterns and RF propagation. One of the leading software tools in this arena, MathCAD from Mathsoft, Inc. (Cambridge, MA), has recently been upgraded to MathCAD 2000, with new functions and features that allow operators to tackle a wide array of technical problems, from the most basic to the most complex. The program's enhanced visualization capabilities provide instant insight into calculations and functions.

MathCAD 2000 (see figure) combines computing power with a flexible word processor and presentation tool. Operators can integrate text, math, and graphics into a single worksheet in order to visualize, illustrate, and annotate calculations. The program, which uses standard mathematical notation (rather than command-line programming), automatically and efficiently updates results. The software can be used to create technical documents that follow manufacturing standards, such as ISO9000. The software can also integrate other applications, such as Microsoft Excel and MATLAB.

Improvements to MathCAD 2000 include the capability to produce quick three-dimensional (3D) plots (by defining and function and graphing it), and a built-in Polyhedron function (with 80 predefined forms) that can be used to quickly generate a 3D polyhedral plot. Additional graphic capabilities include bar charts, x-y plots, polar plots, scatter plots, and surface plots.

New curve-fitting functions include specialized nonlinear curve fits

The MathCAD 2000 startup menu brings users to a "Resource Center" with tutorial articles and reference information.

such as linear, exponential, logarithmic, and sinusoidal curve fitting. New Boolean operators now accept Boolean expressions as arguments and generate truth values as results.

Making corrections has become easier with MathCAD 2000. Users can now track down the source of an error with an error-tracing navigation tool. The tool is easy to use. When an error message appears, an operator need only click on the math region indicated by the error message then choose the "Trace Error" choice from the pop-up menu. Another new feature of MathCAD 2000 is the inclusion of Intergraph's SmartSketch LE, a two-dimensional (2D) drawing application.

MathCAD 2000 users can create MathCAD Electronic Books from their MathCAD worksheets. An electronic book is a set of hyperlinked MathCAD worksheets with a table of contents and index. These Electronic Books make it easy to distribute and store all files pertaining to a particular project. A variety of ready-made MathCAD Electronic Books covering electrical engineering is also available from MathSoft.

MathCAD 2000 runs on any IBM personal computer (PC) or compatible machine with a 90-MHz or faster Pentium-grade microprocessor, Windows 95/98/NT operating system, 32-Mb minimum (48 Mb recommended) random-access memory (RAM), compact-disc-read-only-memory (CD-ROM) drive, and SVGA or higher graphics card. A minimum of 290-MB available hard-disk memory is required, along with a mouse or other pointing device. P&A: $999.95 (MathCAD 2000 Premium) and $499.95 (upgrade from previous versions). **MathSoft, Inc., 101 Main St., Cambridge, MA 02142; (617) 577-1017, FAX: (617) 577-8829, Internet: http://www.mathsoft.com.**

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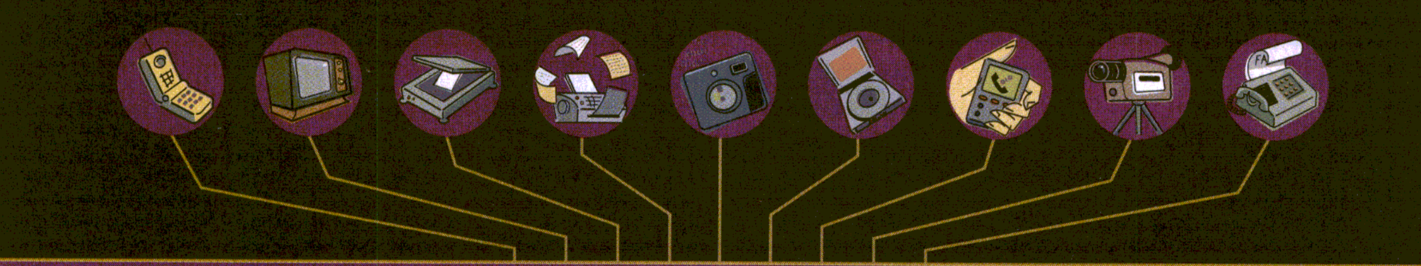

Radio-Transceiver IC

Transceiver ICs Advance Bluetooth Applications

Taking advantage of a power-efficient SiGe process, this highly integrated radio IC is suitable for short-range, battery-powered wireless connectivity products.

JACK BROWNE
Publisher/Editor

BLUETOOTH may become the largest single application for wireless technology. For the wireless connectivity specification to reach universal acceptance, however, low-cost radio integrated circuits (ICs) will be needed. One of these devices is the PH2401 radio-transceiver IC from Philsar Semiconductor (Nepean, Ontario, Canada). Based on a silicon-germanium (SiGe) process, the innovative transceiver provides high levels of RF performance in the unlicensed 2.4-GHz band while maintaining extremely low power consumption.

The PH2401 operates in the unlicensed 2.4-GHz industrial-scientific-medical (ISM) band, with a frequency range of 2400.0 to 2483.5 MHz in the US, Europe, and Canada (the frequency range varies somewhat in France, Spain, and Japan). It is a complete receiver and transmitter, with programmable transmitter output levels between −10 and +2 dBm and a receiver sensitivity of −84 dBm at a bit-error rate (BER) of 10^{-3}. The receiver sensitivity represents a 20-percent improvement over the Bluetooth radio-sensitivity specification of −70 dBm. Amazingly, the transmitter can achieve its power levels with a supply voltage of +1.8 VDC. At that voltage, the IC draws less than 20-mA current in receive mode, with less than 25-mW overall power consumption.

The PH2401 is a full transceiver, with receiver and transmitter chains. It is fabricated with a 0.5-μm SiGe bipolar-complementary-metal-oxide-semiconductor (BiCMOS) process, and conforms to Bluetooth Class 2 (transmit levels of −30 to +4 dBm) and Class 3 (transmit levels of −30-to-0-dBm) requirements, achieving a maximum operating range of 10 m.

The receiver portion consists of a low-noise-amplifier (LNA), downconverter mixer, automatic-gain-control (AGC) circuitry, complex intermediate-frequency (IF) filters, and a dual analog-to-digital converter (ADC) for in-phase (I) and quadrature (Q) signal paths. Digital signals from the ADCs are passed to a two-state frequency-shift-keying (2FSK) demodulator consisting of a complex phase-locked loop (PLL), Gaussian filter, and a dynamic minimum-FSK (MFSK) bit slicer for 2FSK data (symbol-time recovery is performed in a companion baseband chip). Received-signal-strength-indicator (RSSI) signals are obtained by combining the outputs of the AGC control voltages. A digital algorithm in the 2FSK demodulator supports crystal frequency-error compensation to within tens of Hertz.

The transmitter consists of a sigma-delta fractional-N frequency synthesizer with direct digital modulation. The loop bandwidth is set to 10 kHz to meet Bluetooth phase-noise requirements, requiring low-pass filtering of the modulation applied to the loop. High-frequency modulation components are added at the voltage-controlled-oscillator (VCO) modulation tuning port.

The PH2401 can operate with a number of different crystal frequencies (initially 10, 13, 19.2, 19.68, and 19.8 MHz) due to its 16-b fractional-N synthesizer. The fractional-N design allows the synthesizer to be tuned to within 125 kHz (or within 500 PPM) of the desired channel, without relying on a specific frequency or type of crystal.

The PH2401, which does not require any external shielding, is a low-cost transceiver that forms a good starting point for a cost-effective Bluetooth system design. It supports the standard Bluetooth frequency-hopping rate of 1600 hops/s over 79 channels, with a maximum bit rate of 1 Mb/s. Variations of the PH2401 are also available: the PH2401A is specifically targeted at headset applications, with an ADC and voltage pump to support low-power audio operation, while the PH2401B, which includes a baseband clock, is suitable for mobile telephone as well as laptop-computer applications. P&A: less than $5.00 (large volume); 3 months (samples). **Philsar Semiconductor, 146 Colonnade Rd. South, Nepean, Ontario K2E 7Y1, Canada; (800) 551-2319, (613) 274-0922, FAX: (613) 274-0915, e-mail: info@philsar.com, Internet: http://www.philsar.com.**

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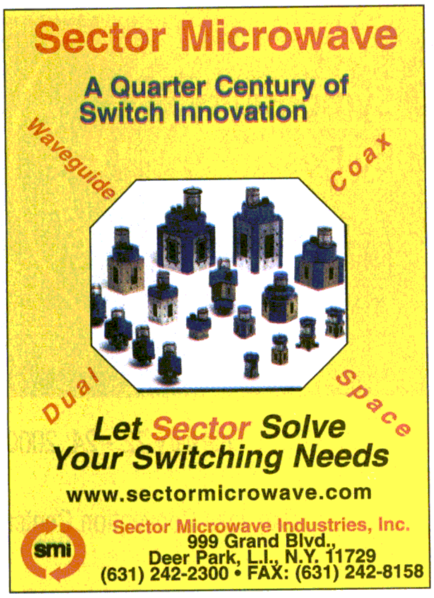

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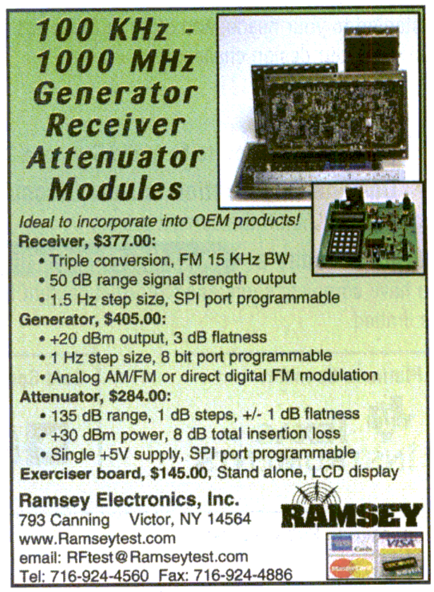

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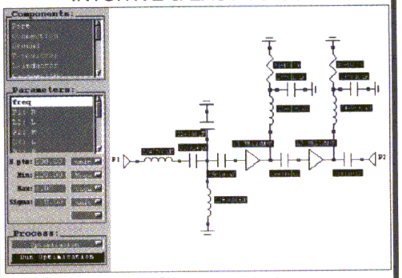

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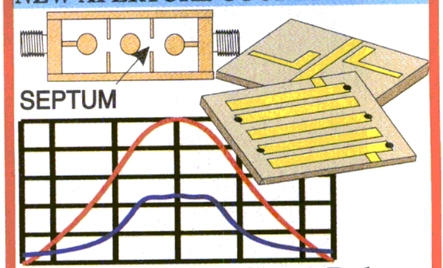

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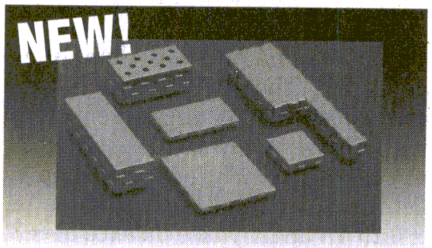

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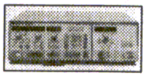
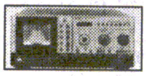

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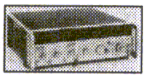


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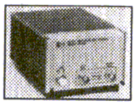
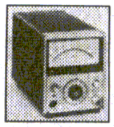

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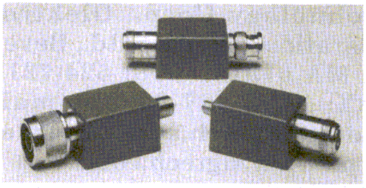

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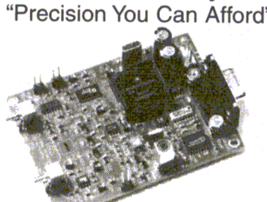

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MMIC mixers cover 14 to 31 GHz

Three monolithic-microwave-integrated-circuit (MMIC) mixers covering overlapping bandwidths from 14 to 32 GHz are designed specifically for applications in local multichannel distribution system (LMDS), K/Ka-band satellite ground terminals, and point-to-point radios. Model HMC258CB1 covers 14 to 21 GHz, and models HMC264CB1 and HMC265 cover 20 to 32 GHz. Model HMC258CB1 has an intermediate-frequency (IF) range of DC to 3 GHz, a drive level of 0 dBm, a conversion loss of –10 dB, a local-oscillator (LO)/RF isolation of 40 dB, and an input third-order intercept point (IP3) of +7 dBm. Model HCM264CB1 has an IF range of DC to 6 GHz, a drive level of 0 dBm, a conversion loss of –10 dB, an LO/RF isolation of 35 dB, and an IP3 of +13 dBm. Model HCM265CB1 has an IF range of 0.7 to 3.0 GHz, a drive level of –4 dBm, a conversion loss of +3 dB, an LO/RF isolation of 20 to 40 dB, and an IP3 of +10 dBm. The mixers employ metal-semiconductor-field-effect-transistor (MESFET) and pseudomorphic-high-electron-mobility-transistor (PHEMT) technology, and offer subharmonic LO inputs. Housed in ball-grid-array (BGA) surface-mount-technology (SMT) ceramic packages, the MMICs operate at +5 VDC at temperatures from –55 to +85°C. **Hittite Microwave Corp., 12 Elizabeth Dr., Chelmsford, MA 01824; (978) 250-3343, FAX: (978) 250-3373, Internet: http://www.hittite.com.**

CIRCLE NO. 94 or visit www.mwrf.com.

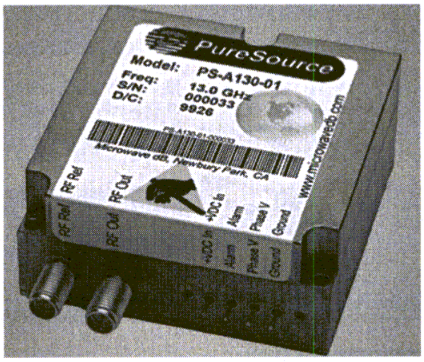
VCO covers 1520 to 1600 MHz

The model ROS-1600PV voltage-controlled oscillator (VCO) generates frequencies from 1520 to 1600 MHz when tuned over a voltage range of +0.5 to +5.0 VDC. The oscillator offers a typical output power of +7 dBm. Typical tuning sensitivity ranges from 25 to 38 MHz/V. Its 3-dB modulation bandwidth is 1 MHz. Typical phase noise is –75 dBc/Hz at 1-kHz offset, –100 dBc/Hz at 10-kHz offset, and –120 dBc/Hz at 100-kHz offset. Pulling is rated at 10 MHz peak-to-peak at 12 dBr and pushing is rated at 3 MHz/V. The oscillator typically draws 25-mA current from a +5-VDC power supply and operates at temperatures from –55 to +85°C. **Mini-Circuits Corp., P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, FAX: (718) 332-4661, Internet: http://www.minicircuits.com.**

CIRCLE NO. 95 or visit www.mwrf.com.

Oscillators span 9 to 13 GHz

The PureSource line of internally and externally referenced phase-locked oscillators covers frequencies from 9 to 13 GHz. They boast excellent frequency stability and low phase noise and are ideal for high-speed digital radio and other applications. The internally referenced oscillators are available with reference frequencies of 33 to 110 MHz. They have a frequency-stability-versus-



temperature rating of ±2 PPM, and their aging factor over 10 years is ±2 PPM. Phase noise at 12 GHz is –70 dBc/Hz at 100-Hz offset, –105 dBc/Hz at 10-kHz offset, and –133 dBc/Hz at 1-MHz offset. The externally referenced oscillators are available for external reference frequencies of 33 to 110 MHz. Their phase noise at 12 GHz is 20 log N +3 dB for offsets from 100 Hz to 1 MHz. For both types of oscillators, the standard output power is +16 dB, and the power-output-stability-versus-temperature rating is ±1 dB. Variation in power output from unit to unit at +25°C is ±1 dB. Maximum harmonics are –40 dBc, and maximum spurious non-harmonics are –80 dBc. Reference-port output power is 0 ±3 dB. The standard phase-lock voltage ranges from 0 to +5 VDC, but can be customer specified from 0 to +10 VDC. The oscillators typically draw 250 mA from a +12-VDC power supply and operate at temperatures from –40 to +80°C. **Microwave dB, Inc., 950 Lawrence Dr., Newbury Park, CA 91320; (805) 499-0410, FAX: (805) 498-0054, Internet: http://www.microwavedb.com.**

CIRCLE NO. 96 or visit www.mwrf.com.

Filter bank spans three bands

A switched filter bank contains three filters in one package and switches from one to the next through a transistor-transistor-logic (TTL) control interface. The center frequencies of the three filters are 960, 1000, and 1040 MHz. Each filter has a 3-dB bandwidth of 50 MHz and a 1-dB bandwidth of at least 25 MHz. Isolation between the filters is 65 dB within ±70 MHz of center frequency. Insertion loss is 7.5 dB and VSWR is 1.7:1. Reverse isolation is greater than 40 dB, ripple is 0.25 dB, and group delay is no more than 4 ns at ±14 MHz. The filter bank draws 100 mA from a +5-VDC power supply. **E.S. Microwave, LLC, 8031 Cessna Ave., Gaithersburg, MD 20879; (301) 519-9407, FAX: (301) 519-9418, Internet: http://www.reactel.com.**

CIRCLE NO. 97 or visit www.mwrf.com.

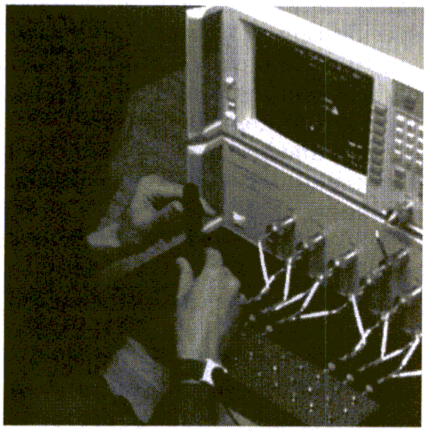
Power source extends microwave analyzers

A power source is now available for the 6800 series microwave system analyzers. The Option 030 power source provides a minimum of +10 dBm of leveled power at frequencies to 24 GHz and can be used as a substitute local oscillator (LO) in mixer and converter measurements. It increases the 6800 series analyzers' dynamic range in the scalar- and tuned-input modes by 5 dB, yielding as much as 90 dB for filter and passive-component testing. The testers combine synthesized source, scalar, and spectrum analysis for testing components. **IFR Corp., 10200 West York St., Wichita, KS 67215-8999; (800) 835-2352, Internet: http://www. ifrinternational.com.**

CIRCLE NO. 98 or visit www.mwrf.com.

Multiport testsets evaluate RF components

The model 87050E multiport testsets evaluate the performance of 50-Ω RF components in high-volume production lines. The testsets are designed to work with the company's 8712E series of network analyzers for measuring devices with as many as 12 ports to frequencies reaching 3 GHz. The multiport test system allows all of the transmission paths



and port reflection characteristics of a multiport device to be completely characterized with a single set of connections to a device's ports. This can reduce typical test times by eliminating the need to constantly connect and reconnect components. The testset system has two calibration routines: testset and self. The testset calibration routine requires the user to connect short, open, and load standards once to each measurement port. The self-calibration routine performs automatic, periodic calibrations using the testset's internal calibration standard to correct system drift. **Agilent Technologies, Inc., 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; (800) 452-4844, Internet: http://www.agilent.com.**

CIRCLE NO. 99 or visit www.mwrf.com.

GaAs switches cover DC to 3.5 GHz

A series of positive-bias, nonreflective, single-pole, multi-throw, gallium-arsenide (GaAs) switches operates from DC to 3.5 GHz. The switches are ideal for applications such as cellular/personal communications systems (PCS), wideband code-division multiple access (WCDMA), wireless local loop (WLL), industrial-scientific-medical (ISM), and community-access television (CATV)/direct broadcast (DBS). The switches operate from a single positive bias of +5 VDC and have transistor-transistor-logic (TTL)/complementary metal-oxide semiconductor (CMOS) compatibility. They incorporate on-chip logic-decoder drivers. Isolation is 30 to 50 dB and insertion loss is 0.5 to 1.0 dB over the operating temperature range of –40 to +85°C. The switches are available in three configurations—an SP4T in a 16-lead, quad small-outline package (QSOP) (HMC241QS16), an SP6T in a 24-lead QSOP (HMC252QS24), and an SP8T in a 24-lead QSOP (HMC253QS24). **Hittite Microwave Corp., 12 Elizabeth Dr., Chelmsford, MA 01824; (978) 250-3343, FAX: (978) 250-3373, Internet: http://www.hittite. com.**

CIRCLE NO. 100 or visit www.mwrf.com.

Programmable noise generator aids testing

The model MX-2000 programmable general-purpose-interface-bus (GPIB) noise generator is dedicated toward testing IMT-2000 devices. It features filtered noise from 1800 to 2200 MHz that is calibrated for absolute power over a 90-dB dynamic range. The calibration data are supplied on an ASCII format on a floppy disk or as an e-mail file attachment for loading onto an automatic-test-equipment (ATE) controller. **Micronetics Wireless, Inc., 26 Hampshire Dr., Hudson, NH (603) 883-2900, FAX: (603) 882-8987, Internet: http://www. micronetics.com.**

CIRCLE NO. 101 or visit www.mwrf.com.

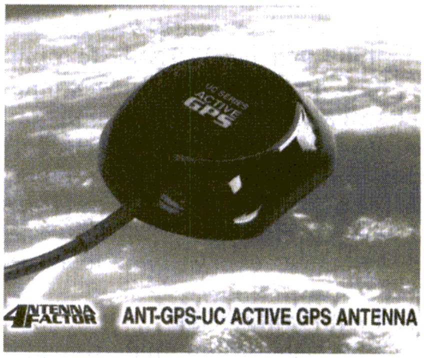
Varactor diodes offer low series resistance

Models SMV1763-079 and SMV1770-079 silicon hyperabrupt-junction varactor diodes offer low series resistance and high capacitance ratio, making them ideal for use in low-phase-noise voltage-controlled oscillators (VCOs) in wireless systems to 2.5 GHz. Model SMV1763-079 exhibits a typical series resistance of 0.5 Ω at a reverse voltage of +1 VDC and a frequency of 900 MHz. At a tuning voltage of 0.5 VDC, a reverse voltage of 0.5 VDC, and a frequency of 1 MHz, its typical tuning capacitance, C_T, is 6.7 pF. Raising the tuning and reverse voltages to +2.5 VDC lowers the typical tuning capacitance to 2.5 pF. This yields a typical capacitance ratio, CTR, of 2.5. Model SMV1770-079 exhibits a typical series resistance of 0.4 Ω at a reverse voltage of +1 VDC and a frequency of 470 MHz. At a tuning voltage of 0.5 VDC, a reverse voltage of 0.5 VDC, and a frequency of 1 MHz, its typical tuning capacitance, CT, is 23.6 pF. **Alpha Industries, Inc., 20 Sylvan Rd., Woburn, MA 01801; (781) 935-5150, FAX: 617) 824-4564, Internet: http://www. alphaind.com.**

CIRCLE NO. 102 or visit www.mwrf.com.

Ultra-compact antenna serves GPS

The model ANT-GPS-UC is an ultra-compact antenna specifically designed for Global Positioning System (GPS) applications. The antenna is enclosed in a tiny 1.79 × 2.0 × 0.56-in. (4.55 × 1.42-cm) fully weatherized housing and can be mounted with its magnetic base or screw



receptacles. The antenna is an active device that draws 22-mA current from a +3- to +7-VDC power supply. Overall system gain is 26 dB and noise figure is 2 dB. Original-equipment-manufacturer (OEM) customers can choose from several termination styles, including SMA, RP-SMA, SMB, MCX, or BNC. **LINX Technologies, Inc., 575 SE Ashley Pl., Grants Pass, OR 97526; (541) 471-6256, FAX: (541) 471-6251, Internet: http://www. linxtechnologies. com.**

CIRCLE NO. 103 or visit www.mwrf.com.

Microwave instrumentation

A manufacturer of microwave-instrumentation products is profiled in a brochure. In addition to standard service offerings, the brochure covers all aspects of the company's customer-support programs including range relocation, range-probe service, equipment refurbishment, range-operation services, operator training, software-maintenance programs, and mechanical-alignment services. **Microwave Instrumentation Technologies, LLC;** *(800) 848-7921, (678) 475-8300, FAX: (678) 475-8391, Internet: http://www.MITechnologies.com.*

CIRCLE NO. 63 or visit www.mwrf.com

Power dividers

A 152-page catalog details power dividers, directional couplers, high-power dual directional couplers, diode detectors, directional detectors, waveguide couplers, as well as 90- and 180-deg. hybrids. Waveguide adapters; coaxial terminations; low-, medium-, and high-power waveguide terminations; coaxial attenuators; continuously variable attenuators; as well as interdigital and bandpass filters are also offered. Connectorized isolators and circulators, drop-in isolators and circulators, voltage and digitally controlled PIN-diode attenuators, PIN-diode and electromechanical switches, free-run and phase-locked oscillators, as well as power amplifiers (PAs) are specified. **Microwave Communications Laboratories, Inc.;** *(727) 344-6254.*

CIRCLE NO. 64 or visit www.mwrf.com

EM compatibility

A 40-page design guide provides an overview of electromagnetic-compatibility (EMC) theory and offers approaches to solving EMC problems. Application flow charts are included. **Tecknit;** *(908) 272-5500, Internet: http://www.tecknit.com.*

CIRCLE NO. 65 or visit www.mwrf.com

COTS program

A brochure contains information concerning a commercial-off-the-shelf (COTS) quality program to support the US government's COTS initiative. The solutions offer a cost-effective approach to qualifying standard capacitor products for enhanced reliability applications. The COTS program provides customers with a choice of several different screening packages including options to support specific customer requirements. Applications include ruggedized commercial products, military (ground, naval, airborne), and space/satellite. **American Technical Ceramics;** *(516) 622-4700, FAX: (516) 622-4748, e-mail: sales@atceramics.com, Internet: http://www. atceramics.com.*

CIRCLE NO. 66 or visit www.mwrf.com

SDH/SONET

A customer magazine covers topics including synchronous-digital-hierarchy (SDH)/Synchronous Optical Network (SONET) test equipment, mobile radio testing (including cell phones), digital television analysis, and testing of cable-television (CATV) installations. Background articles look at trends in Category 6 local-area-network (LAN) cabling and testing to Level III accuracy. **Wandel & Goltermann GmbH & Co.;** *+49 7121 86-1616, FAX: +49 7121 86-1333, e-mail: info@wwgsolutions.com, Internet: http://www. wwg-solutions.com.*

CIRCLE NO. 67 or visit www.mwrf.com

Microwave components

A selection guide highlights components for point-to-point and point-to-multipoint microwave radios to 60 GHz. Industrial-scientific-medical (ISM) band products, amplifiers, switches, frequency-generation products, mixers, and attenuators for applications from DC to 80 GHz are presented. **Richardson Electronics Ltd.;** *(800) 348-5580, (630) 208-2200, FAX: (630) 208-2550, e-mail: info@rell.com, Internet: http://www. rell.com.*

CIRCLE NO. 68 or visit www.mwrf.com

Tuning tools

A company's line of insulated tuning tools is featured in an engineering bulletin. The bulletin includes data on several models which were recently added to the line. These tools were designed to fit the narrower slots in the newest miniaturized trimmer capacitors. **Sprague-Goodman Electronics, Inc.;** *(516) 334-8700, FAX: (516) 334-8771, e-mail: info@spraguegoodman.com.*

CIRCLE NO. 69 or visit www.mwrf.com

Data-conversion ICs

A product selection guide includes products for data-conversion and signal-processing integrated circuits (ICs). Product charts detail information such as resolution, sample/conversion rate, power dissipation, linearity, as well as input/output (I/O) specifications. The guide covers analog-to-digital converters (ADCs), digital-to-analog converters (DACs), video DACs, comparators, video-line drivers and processors, as well as track-and-hold amplifiers. **Signal Processing Technologies, Inc.;** *(800) 643-3778, Internet: http://www. spt.com.*

CIRCLE NO. 70 or visit www.mwrf.com

Test equipment

An 18-page catalog highlights reconditioned test equipment, including pulse generators, logic analyzers, plotters, meters, RF signal generators, spectrum analyzers, and oscilloscopes. Impedance analyzers, network analyzers, power supplies, audio analyzers, signal generators, and data acquisition (DAQ) are also covered. Pricing information is included. **Test Equipment Connection Corp.;** *(800) 615-8378, (407) 804-1780, FAX: (800) 819-TEST, (407) 804-1277, Internet: http://www.4test equipment.com.*

CIRCLE NO. 71 or visit www.mwrf.com

Measurement/automation

A brochure details the PXI Systems Alliance, a group of more than 50 worldwide product manufacturers and systems integrators that share a common commitment to make users successful with CompactPCI-based measurement and automation. PXI benefits and applications, PXI/CompactPCI specifications, the PXI Systems Alliance Charter, and membership requirements are discussed. Images of PXI systems and products built by Alliance are covered. **PXI Systems Alliance;** *(800) 258-7022, FAX: (512) 683-9300, Internet: http://www. pxisa.org.*

CIRCLE NO. 72 or visit www.mwrf.com

RF switches

A 120-page catalog covers a line of RF/microwave electromechanical switches. Stocked switches, custom-part switches, switch assemblies and matrices, cellular single-pole, double-throw (SPDT) switches, switchable combiners, and switchable divider/power combiners are highlighted. **Narda Microwave-East;** *(516) 231-1700, FAX: (516) 231-1711, e-mail: nardaeast@L-3COM.com, Internet: http://www.nardamicrowave.com.*

CIRCLE NO. 73 or visit www.mwrf.com

Adapters and attenuators

Adapters, attenuators, bias tees, circulators, coaxial cable assemblies, coaxial connectors, and DC blocks are featured in a 162-page catalog. Coaxial contacts, detectors, directional couplers, fuse holders, isolators, limiters, phase trimmers, switches, and terminations are also included. Outline drawings are provided. **Pasternack Enterprises;** *(949) 261-1920, FAX: (949) 261-7451, e-mail: sales@pasternack.com, Internet: http://www.pasternack.com.*

CIRCLE NO. 74 or visit www.mwrf.com

Multichip modules

A brochure details automated contract-manufacturing capabilities for multichip modules (MCMs) and other advanced high-density electronics assemblies. Each step of the manufacturing process is explained and illustrated. **Natel Engineering Co., Inc.;** *(800) 590-5774, FAX: (800) 590-5764, Internet: http://www.natelengr.com.*

CIRCLE NO. 75 or visit www.mwrf.com

Voltage tester

A four-page brochure describes a withstanding voltage tester. Specifications that are provided include output voltage range, analog accuracy, measuring range, as well as upper cutoff current range. Features are included. **Kikusui Electronics Corp.;** *(045) 593-7570, FAX: (045) 593-7571, Internet: http://www.kikusui.co.jp/.*

CIRCLE NO. 76 or visit www.mwrf.com

Isolators and circulators

A 44-page catalog focuses on isolators and circulators as well as high-power terminations. Custom capabilities as well as subsystems are also described. Outline drawings are provided along with an engineering reference. **Renaissance Electronics Corp.;** *(978) 263-4994, FAX: (978) 263-4944, e-mail: sales@rec-usa.com, Internet: http://www.rec-usa.com.*

CIRCLE NO. 77 or visit www.mwrf.com

Atomic standards

A 12-page technical catalog details a company's rubidium (Rb) atomic-frequency standards. Complete electrical specifications, mechanical outlines, and environmental specifications are presented. **FEI Communications, Inc.;** *(516) 794-4340, FAX: (516) 794-4340, Internet: http://www.freqelec.com.*

CIRCLE NO. 78 or visit www.mwrf.com

Chip attenuators

A 28-page catalog covers a line of resistive products. The catalog highlights high-frequency resistors and chip attenuators. Information on thick- and thin-film chip resistors is included. **State of the Art, Inc.;** *(800) 458-3401, FAX: (814) 355-2714, e-mail: marketing@resistor.com, Internet: http://www.resistor.com.*

CIRCLE NO. 79 or visit www.mwrf.com

Antenna design

Antennas, feeds, components, and subsystems are detailed in a 134-page catalog. Application notes, information on testing services, and an index are included. Specifications, notes, and options are provided. **Seavey Engineering Associates, Inc.;** *(781) 829-4740, FAX: (781) 829-4590, e-mail: info@seaveyantenna.com, Internet: http://www.seaveyantenna.com.*

CIRCLE NO. 80 or visit www.mwrf.com

EMI shielding

A brochure contains information about products for electromagnetic-interference (EMI)-shielding solutions. Input/output (I/O) panel gaskets, conductive silicones, metal-wire-mesh gaskets, combination gaskets, EMI-shielding tape, and air-vent panels are described. **Advanced Performance Materials, Inc.;** *(314) 344-9300, FAX: (314) 344-9333, Internet: http://www.apmemi.com.*

CIRCLE NO. 81 or visit www.mwrf.com

DMMs and DAQ

A 44-page catalog focuses on digital multimeters (DMMs), handheld multimeters, multimeter accessories, data acquisition (DAQ), DAQ modules, counters, as well as power meters and sensors. Power supplies, function generators, RF signal generators, programmable pulse generators, oscilloscopes, and mixed-signal oscilloscopes are detailed. **Agilent Technologies;** *(800) 452-4844, e-mail: hptm_CustomerCare@hp.com, Internet: http:// www.hp.com/go/bi.*

CIRCLE NO. 82 or visit www.mwrf.com

Capacitors and resistors

A short-form catalog offers information on capacitors, resistors, filters, timing devices, thin-film products, and piezoelectric devices. A line of connector products as well as ferrites is featured. **AVX Corp.;** *(843) 946-0414, FAX: (843) 946-0626, e-mail: lit@avxcorp.com, Internet: http:// www.avxcorp.com.*

CIRCLE NO. 83 or visit www.mwrf.com

Coaxial cables

A 16-page catalog features low-loss wireless communications cables, including coaxial antenna feeders, jumper cables, and low-inductance power cables. Product descriptions, are included. **Montrose/CDT;** *(800) 346-6626, FAX: (508) 793-9862, e-mail: sales@mont rose-cdt.com, Internet: http://www. montrose-cdt.com.*

CIRCLE NO. 84 or visit www.mwrf.com

Frequency control

A 120-page catalog covers products used in wired and wireless telecom, video, audio, computers and peripherals, as well as industrial and consumer applications. Application information, features, specifications, outline drawings, environmental test conditions, taping/packaging specifications, and standard frequencies are presented. **Jauch USA;** *(301) 497-7670, FAX: (301) 776-7979, e-mail: sales@jauchusa.com, Internet: http://www.jauchusa.com.*

CIRCLE NO. 85 or visit www.mwrf.com

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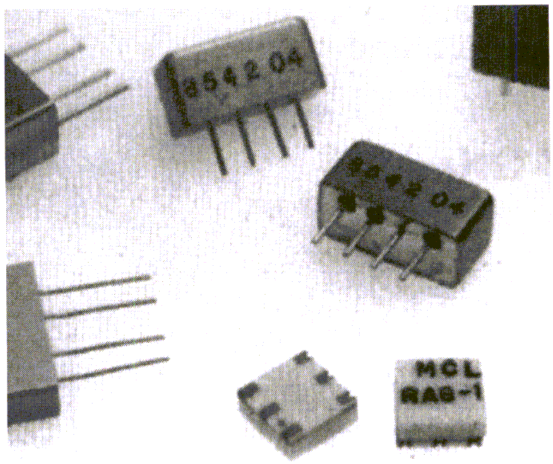

Fourteen years ago, the move toward miniaturization took hold in the world of mixers with the introduction of a line of surface-mount mixers from Mini-Circuits (Brooklyn, NY). The mixers, which fit into a package measuring only 0.25 in.^{2} (1.61 cm^2), served applications to 500 MHz.

Microwaves & RF February Editorial Preview

Issue Theme: Semiconductors

News

Advances in semiconductor technology have enabled the continuing growth of markets for wireless and portable-electronic products during the last decade. How much further can semiconductor technologies evolve? And is the low-cost packaging available to kep pace with the dropping prices of semiconductors? Don't miss this Special News Report on semiconductors in the February issue of *Microwaves & RF*.

Design Features

Technical articles in February will explore some of the uses for semiconductors, including low-noise amplifiers (LNAs). An author from M/A-COM, for example, will outline LNA design techniques and performance trade-offs. Additional articles will continue a series on the design and simulation of phase-locked loops (PLLs), examine the use of confidence-interval analysis in wireless measurements, and delve into the construction of high-frequency analog switches.

Product Technology

February's Product Technology section will highlight a new generation of heterojunction-bipolar-transistor (HBT) amplifiers based on a unique indium-gallium-phosphide (InGaP) process technology. The monolithic-microwave-integrated-circuit (MMIC) amplifiers offer wide bandwidths with extremely high gain and simple, single-supply operation.

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and another...

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- 90° & 180° Hybrids
- Fixed Attenuators
- Power Dividers
- Terminations
- Phase Shifters
- DC Blocks
- Filters

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and another . . .

Waveguide Components

- Terminations
- Couplers
- Attenuators
- Switches
- Adapters & Transitions
- Bends & Twists
- Flexible
- Horns
- Custom Assemblies

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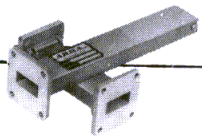

and another . . .

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- TTL Compatible
- Low Insertion Loss

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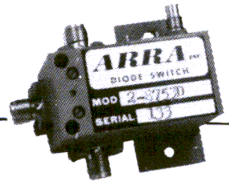

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- High Power Components
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- Motor Drives

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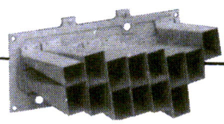

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