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Microwaves & RF

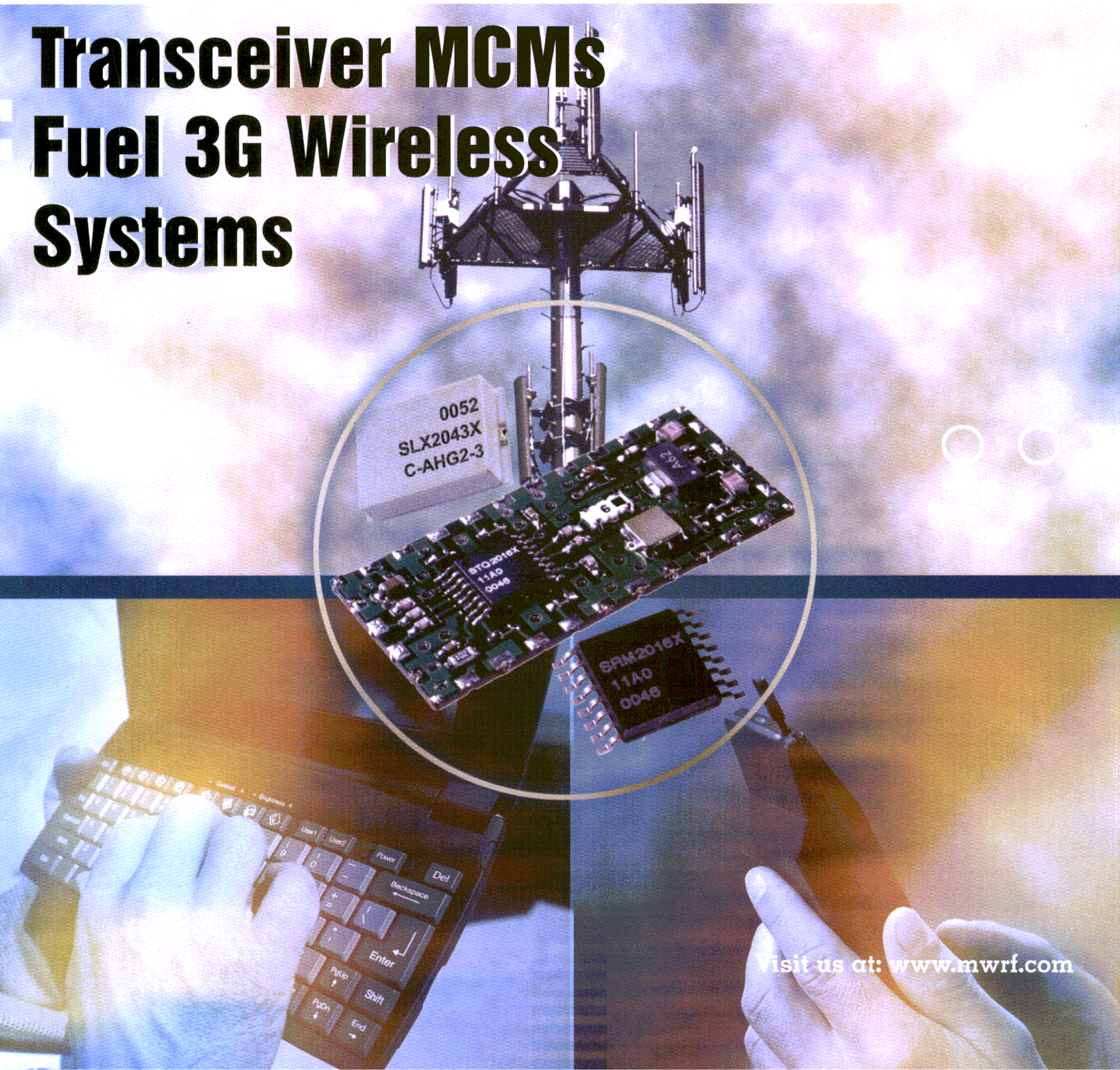
Fiber-Optics Issue

NEWS
Fiber-optic technology drives to 10 Gb/s and beyond

DESIGN FEATURE
Simulation method identifies multipath tracking errors

PRODUCT TECHNOLOGY
Testset records and analyzes Bluetooth signals

Transceiver MCMs Fuel 3G Wireless Systems



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FEBRUARY 2001 VOL. 40, NO. 2

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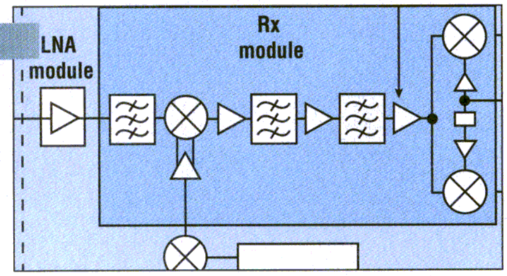
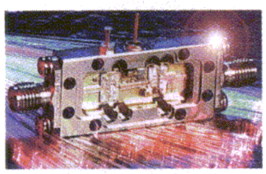
COVER FEATURE



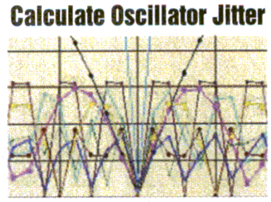
DEPARTMENTS

NEWS



SPECIAL REPORT

DESIGN FEATURES



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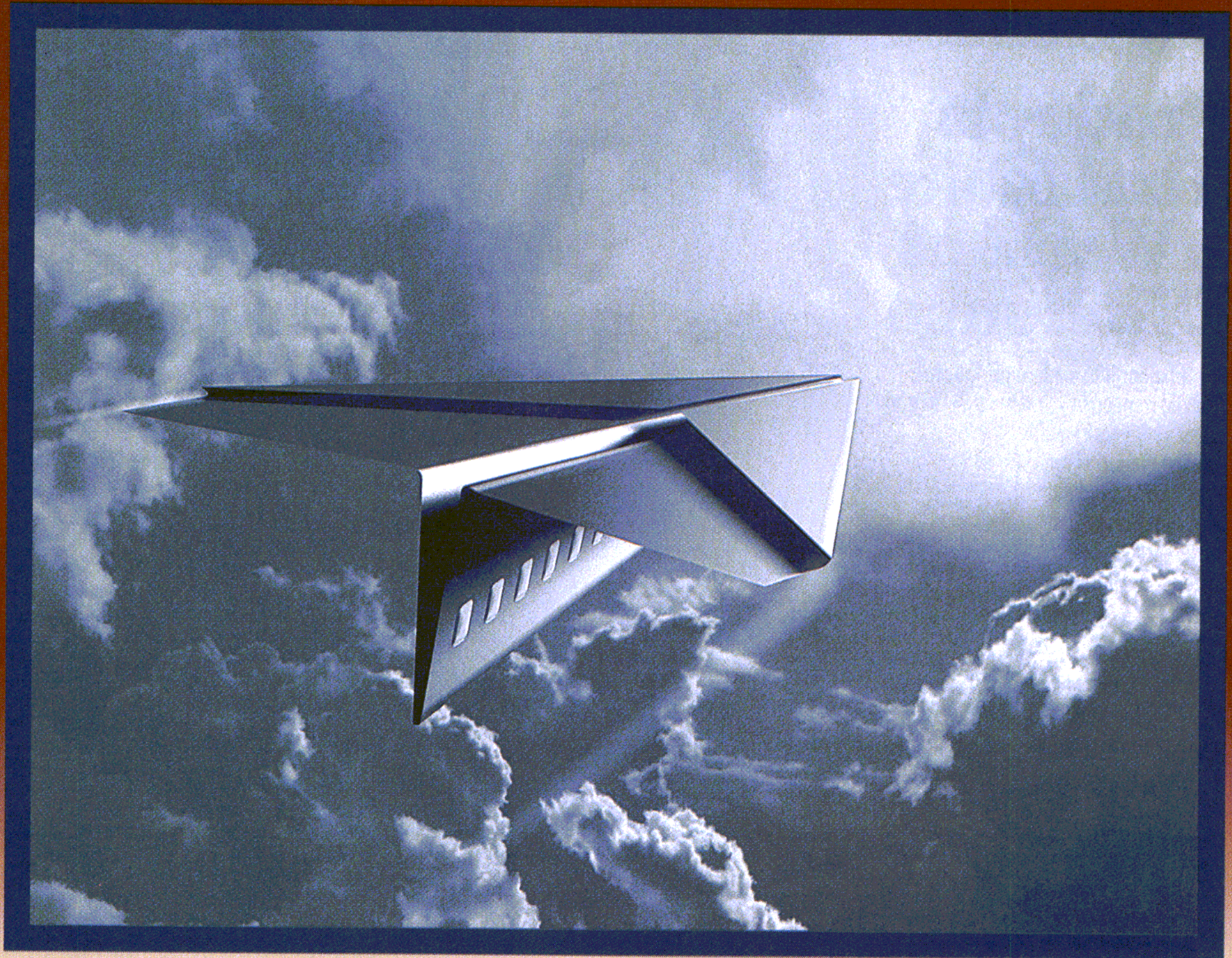

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NGA-386	0.1-5.0	4.0	35.0	20.8	14.5	25.8	144
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	0.1-6.0	5.0	80.0	19.9	18.9	39.6	121
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.

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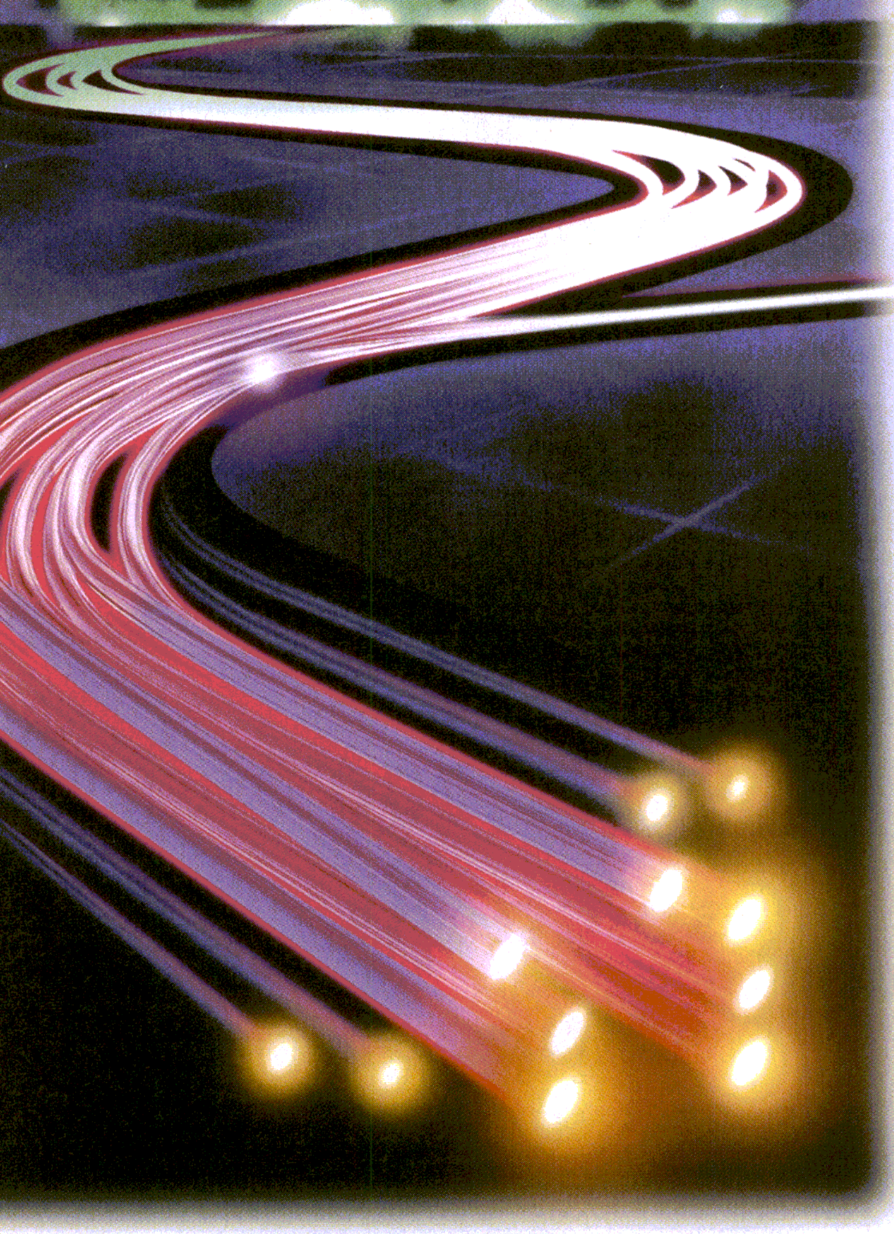

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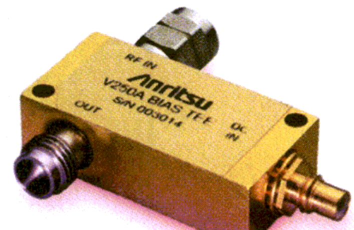

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POOR CONTENT

To the editor:

In your September 2000 issue, an article was written by Joseph Mazzochette that appeared with the title "New Materials Make Microwave Components Safer For Users." The author's thesis is that his company's products are somehow safer because of their materials of construction. Yet, references supplied by the author himself, on the article's first page, confirm the fact that the main premise of the article is totally bogus.

For example, in the last full paragraph on the first page, it says, "As a solid ceramic of the size used in most electronic applications there is no risk of inhalation...."

I find it surprising that your magazine would publish such an article.

Edwin F. Johnson, Ph.D.
Sunnyvale, CA

VACUUM TUBE

To the editor:

I just read the article "Power Devices Stake Their Territories" by Barry Manz in the November issue (p. 125). It was a good article. Now, I am not a fan of Al Gore either, but a 12AU7 vacuum tube is not a rectifier. Sure, it could be used as a rectifier, but it is a twin triode. So, while poking fun at Gore, please make sure your facts are straight. Keep up the good work, since I really did enjoy your point that tubes are not out of our current design horizon.

John Severyn

MILLENNIUM

To the editor:

In response to December 2000's editorial (p. 17), I would suggest that 2000 was the last year of the old Millennium and the first year of the new Millennium.

Pragmatically, the whole thinking on "there was no year zero, so the century, millennium starts with the xx01 year" assumes that there was no year zero. This particular view also ignores that there was also no year one, year two, etc., at least up to four and, practically, up to about year 435 or so, when the whole mythological calendar was created.

So capitalize the religious Millennium and celebrate it this year, and lowercase the secular millennium and go on a basis where a century is the 100 years that have the same initial digits.

Larry Mclellan
Maxim

Please comment

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

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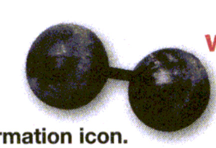

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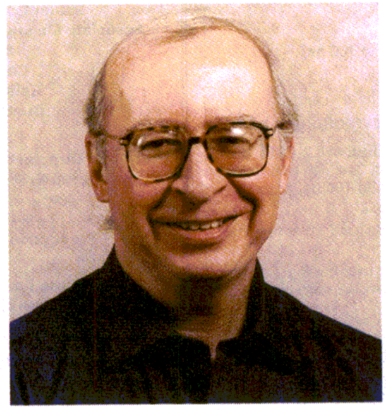
THE LIGHT AT THE END OF THE TUNNEL?



Optical communications represents one of the fastest-growing segments of the electronics industry. And for good reason—this technology offers communications bandwidths that go beyond the wildest imaginations of the most seasoned RF radio designers. While RF designers must cope with channel widths in terms of kilohertz and megahertz, optical-communications integrators have the luxury of channel spacing in terms of gigahertz, and links supporting data rates of 10 Gb/s and more.

Optical communications, of course, is "wired" communications, which sets it apart from wireless communications devices with their inherent flexibility and portability. But wireless systems are limited in bandwidth. Even highly touted millimeter-wave systems such as local multichannel-distribution system (LMDS) deliver total bandwidths in the neighborhood of 1 GHz. The total is then divided among multiple users and services until the actual bandwidths available to a single user will be limited in direct proportion to the system operator's profit margin.

True, optical-communications (fiber-optic) systems are tied down by the nature of their infrastructures. They rely on long runs of glass fibers, usually underground, in order to form an optical network. Despite requiring these somewhat permanent installations, fiber-optic systems represent the majority of communications networks being installed in new office-building construction in this country, rather than wireless infrastructures. Yes, wireless technology will certainly dominate all those communications applications requiring mobility and portability. But in terms of raw bandwidth, wireless technology is getting closer to the limits of current phase-based modulation schemes. On the other hand, fiber-optic technology, with advances in dense-wavelength-division-multiplexing (DWDM) technology (which essentially assigns different carriers to their own wavelengths within a single fiber), is only scratching the surface for increasing the efficiency of bandwidth use.

So why write about fiber-optic technology in a microwave magazine? It may be overly simplistic to say that fiber-optic and microwave technologies are one and the same. Suffice it to say that they are companion technologies that have been proven to work well together in common systems. And for microwave companies accustomed to manufacturing components with fine dimensions, where physical distances translate into quarter wavelengths, fiber-optic technology is a logical extension. Many of the companies that supply microwave products already know this, such as Agilent Technologies (Santa Rosa, CA), ANADIGICS (Warren, NJ), Anritsu (Morgan Hill, CA), California Eastern Laboratories (Santa Clara, CA), Fujitsu (Santa Clara, CA), Maxim Integrated Products (Sunnyvale, CA), and Oki Semiconductor (Sunnyvale, CA). In the next several years, more microwave manufacturers will recognize the opportunities for them in optical communications, and they will continue to blur the line between microwave and fiber-optic products. And this magazine will do its best to keep pace with the changes.

Jack Browne

Publisher/Editor

Microwaves & RF

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Demand For Semiconductors Will Reach $440 Billion In 2004

CLEVELAND, OH—Global demand for semiconductors and passive electronic components is projected to increase by 9.5 percent per year through 2004 to approximately $440 billion (see table). Fueling gains will be the ongoing globalization of information technology (IT), in particular further development of the world Internet infrastructure and the advent of new generations of handheld and wireless information-processing systems. Electronic content is rising in a myriad of original-equipment products in virtually all countries. Semiconductor demand will increase by more than 10 percent annually to $360 billion in 2004, while passive-component growth of approximately seven percent per year will provide a worldwide market of $76 billion. These and other trends are presented in *World Electronic Components*, a study from The Freedonia Group, a Cleveland-based industrial market-research firm.

World electronic components demand (billions of US dollars)

Item	1994	1999	2004	Percentage of annual growth 99/94	04/99
Electronics components demand	178.0	277.7	436.5	9.3	9.5
North America	71.9	119.5	175.6	10.7	8.0
Western Europe	29.2	45.0	67.4	9.0	8.4
Japan	36.1	38.3	59.2	1.2	9.1
Other Asia/Pacific	35.6	65.9	118.5	13.1	12.5
Rest of world	5.3	8.9	15.9	10.9	12.3

Freedonia Group, Inc. (Cleveland, OH)

The best growth prospects for electronic components will increasingly be found in developing countries where electronics-related original-equipment markets are less evolved. Many of these nations will fortify demand for consumer- and business-related electronic products and systems. Electronic-components demand will decelerate in the US and most other industrialized countries from unsustainably rapid recent rates, although growth markets, such as third-generation (3G) mobile phones and Internet-related products, will provide some offsetting support. The long-suffering Japanese market will exhibit some recovery from an extended period of weakness.

High-end integrated-circuit (IC) devices hold particularly good prospects, including advanced variants on the former such as microcontrollers and digital signal processors (DSPs). More commodity-type products, such as discrete semiconductors, memory ICs, and passive components in general, will exhibit somewhat slower growth. However, there are pockets of above-average growth potential in most segments, including Flash-memory ICs that are used in wireless phones, set-top boxes, and other more dynamic applications, such as integrated passive components, which incorporate the features of different passive components in a single package.

E-Mode GaAs Technology Is Qualified

PHOENIX, AZ—Motorola's Semiconductor Products Sector, a supplier of RF gallium-arsenide (GaAs) circuits, has completed qualification of its true enhancement-mode (E-mode) heterostructure field-effect-transistor (FET) wafer process. This advanced single-power-supply GaAs process is engineered to provide cost-effective performance in linear transmitter (Tx) and receiver (Rx) circuits for low-voltage portable wireless applications.

"Motorola's advanced E-mode GaAs technology provides advantages over depletion-mode pseudomorphic-high-electron-mobility-transistor (PHEMT) devices," says Karl Johnson, director of Motorola's Compound Semiconductor Technologies Laboratory. "Because of its low off-state leakage current, this true enhancement-mode device eliminates the drain-supply switch required for depletion-mode PHEMT and metal-semiconductor-field-effect-transistor (MESFET) devices."

The first products using this E-mode GaAs technology are expected to be available to the merchant market this month. The devices are scheduled to be manufactured in Motorola's Compond Semiconductor-1 (CS-1) 6-in. wafer-fabrication facility in Tempe, AZ. The CS-1 fab completed conversion from 4-to-6-in. (10.16-to-15.24-cm) wafers in June 2000, making it the largest RF GaAs facility in the world.

"The E-mode GaAs technology helps to reduce the cost and size of the end product by eliminating both the negative voltage generator and the drain-supply switch within the handset power-amplifier section," says Jim Oakland, manager of design and technology for Motorola's Wireless Transmitter Solutions Division.

DSP And RF Chip Sets Will Be Supplied For GSM Handsets

NORWOOD, MA—Analog Devices, Inc. has announced that Siemens AG, a Global System for Mobile Communications (GSM) handset manufacturer, has selected Analog Devices' SoftFone digital-signal-processor (DSP)-based GSM baseband processor and Othello direct-conversion RF chip set for use in their next generation of GSM phones and terminal products. These new phones will feature extended battery life and include advanced GSM network features such as general-packet-radio-service (GPRS) wireless Internet access.

"We are pleased that a well-established, top-tier GSM handset supplier like Siemens has chosen our GSM solution, including the SoftFone DSP and Othello," says Jerry Fishman, president and CEO of Analog Devices.

The Analog Devices GSM solution includes the SoftFone and Othello chip sets, an advanced RF power-control integrated circuit (IC), and a highly-integrated battery/power-management chip. The flexible architecture of the DSP-based SoftFone baseband processor is entirely random-access-memory (RAM) based, reducing development time and enabling its use in multiple applications. The SoftFone chip set includes an Analog Devices DSP processor, ARM™ microcontroller, on-chip system static RAM (SRAM), a state machine for system timing, and an advanced bus-arbitration system.

Analog Devices' Othello chip set, announced in late 1999, is the first open-market direct-conversion GSM RF chip set. Direct-conversion technology eliminates many of the discrete components, such as surface-acoustic-wave (SAW) filters, found in traditional superheterodyne receivers (Rxs).

Traffic-Safety Technology Website Is Launched

ENGLEWOOD, FL—Safety Warning System, L.C. has announced the launch of its new Internet website, www.safetyradar.com. Developed by scientists at the Georgia Tech Research Institute, the Safety Warning System™ (SWS) is a transmitter-receiver (Tx-Rx) system that alerts motorists over one mile in advance of any one of a number of potential road hazards. SWS Txs broadcast coded signals triggering one of 64 preprogrammed messages in SWS-enabled Rxs that are situated in motorists' vehicles. The Rx produces an audible alert followed by a light-emitting-diode (LED) display of the text message, with some models also delivering a vocalized announcement of the message. First introduced in 1996, there are an estimated 10 million SWS-enabled radar detectors (Rxs) on the road today.

Visitors to the safetyradar.com website can view the current list of SWS text messages, read about SWS Tx locations in their area, and learn about the technology and the history behind the SWS.

According to Janice Lee, president of SWS, L.C., "The new Safety Warning System website is a wonderful opportunity for motorists, state- and local-government officials, and lawmakers to learn more about the SWS, an exciting innovation in traffic safety that can potentially save lives on our nation's roadways." Lee also states, "We are so excited about the new SWS website because it is a one-stop resource where motorists can learn more about the many safety benefits of the Safety Warning System and also find out how they can help to get SWS transmitters installed in their areas."

Wireless Data Users Rate Device Satisfaction Highly

SAN FRANCISCO, CA—Telephia, Inc., the standard for competitive marketing information and network-performance intelligence, released survey data from the largest independent study of its kind indicating that wireless consumers across the US are more satisfied with the data capabilities of their wireless devices than they were five months ago.

Consumers who use the wireless data capabilities of their mobile phones, personal digital assistants (PDAs), laptops, and two-way pagers responded with an average satisfaction rating of seven based on a 10-point scale where "1" is "extremely dissatisfied" and "10" is "extremely satisfied."

While the average level of satisfaction by mobile-phone users (from 6.0 to 7.0) and PDA users (from 6.0 to 7.1) saw the largest increases, users of two-way pagers reported the highest overall satisfaction rating (7.3). Satisfaction data for laptop users were not tested in the previous study but received an overall rating of seven in the current study. In addition, more than 65 percent of users gave an overall satisfaction rating of "7" or above for their devices.

$54 Billion Market Is Forecast For DWDM

NEWPORT, RI—The dense-wavelength-division-multiplexer (DWDM) systems market will grow with a compound annual growth rate (CAGR) of 43 percent through 2005 when the market will reach 54 billion, according to KMI Corp.'s report, "World-wide Markets for Dense Wavelength Division Multiplexing (DWDM)."

This growth reflects several trends: a maturation of the long-distance segment of the DWDM equipment market, stiffening competition that will lead to price pressures, and shorter-distance products in the market. By 2005, the short-distance segment will exceed $9.6 billion and represent 18 percent of the market.

The DWDM systems market jumped from $4.2 billion in 1999 to $8.9 billion in 2000, according to KMI estimates. From $1.7 billion in 1997, the market has grown at a 73-percent CAGR over the last four years.

The DWDM market boomed from 1999 to 2000, as several indicators suggest. The number of vendors offering DWDM system-level products grew from approximately 15 in 1999 to more than 30 in 2000, despite some high-profile acquisitions in the industry. The number of carriers that have deployed DWDM rose from 75 in 1999 to 175 in 2000. The number of publicly announced contracts for DWDM also approximately doubled from 75 in 1999 to 150 in 2000.

Bluetooth And 802.11b Dual-Mode WLAN Solution Is Being Co-Developed

IRVINE, CA—Intersil and Silicon Wave announced that development is underway for dual-mode wireless local-area-network (WLAN) solutions that will allow laptops and other devices to wirelessly connect to a company LAN or to companion devices.

The goal of the Intersil/Silicon Wave co-development effort is to yield a series of dual-mode solutions, all of which marry a fully compliant Bluetooth radio with a WECA Wi-Fi-certified IEEE 802.11b-compliant radio on the same platform. The initial platforms offered will be Cardbus 32 and MiniPCI. An additional goal is to employ dynamic switching so that both radios can use a common antenna. These dual-mode radios will be substantially smaller than two stand-alone solutions.

Intersil has already developed several reference designs for IEEE 802.11b-based systems and Silicon Wave was first to market with their Odyssey Radio Solution for Bluetooth connectivity. Development teams made up of experts from each company are developing a complete reference design that solves all design, operating, and manufacturing issues involved to have both of these advanced technologies on the same card.

Kudos

The American National Academy of Television, Arts, and Science has given its Emmy Award to Video Quality Analyzer DVQ from Rohde & Schwarz. DVQ received the award in the category "Advanced picture-quality measurement technology for digital TV" due to its principle requiring no reference signal...Merrimac Industries, Inc. announced that it has been granted another patent for its Multi-Mix™ Waveguide Filter from the US Patent and Trademark Office entitled "Multilayer Dielectric Evanescent Mode Waveguide Filter." These filters are typically found in wireless applications such as base stations, mobile radios, pagers, point-to-point, and point-to-multipoint radios, and local multipoint-distribution service (LMDS)...Avnet, Inc. ranked 13th in *eWeek* magazine's FastTrack 500 list for 2000. In compiling its list, *eWeek* rewards companies for having deployed e-business technologies such as customer-relationship management applications, significant e-commerce applications, Internet-enabled data warehouses, and high-speed networking...The Wireless Communications Association (WCA) announced special awards for two distinguished former public officials who have provided vision and leadership in advanced communications. The Lifetime Regulatory Vision award goes to Dale Hatfield , who retired on December 8, 2000 as Chief of the Office of Engineering and Technology at the Federal Communications Commission (FCC). A separate award for Technical Vision and Industry Service by an individual largely working in the private sector goes to Vivian & Associates president Dr. Weston E. Vivian, an independent consultant who played a pioneering role in the growth of broadband wireless worldwide...Repeater Technologies announced that the US Patent and Trademark Office has issued US patent number 6,125,129 to the company for a delay-combiner system for code-division-multiple-access (CDMA) repeaters and low-noise amplifiers (LNAs). The patented technology is a core element of the company's receive-diversity technique for CDMA repeaters.

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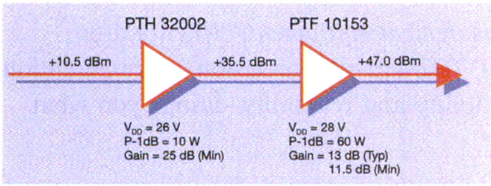

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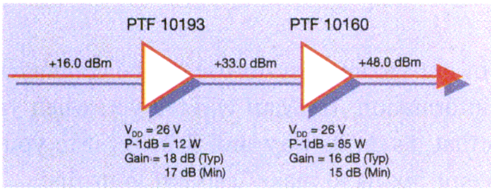

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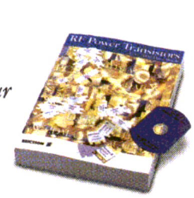

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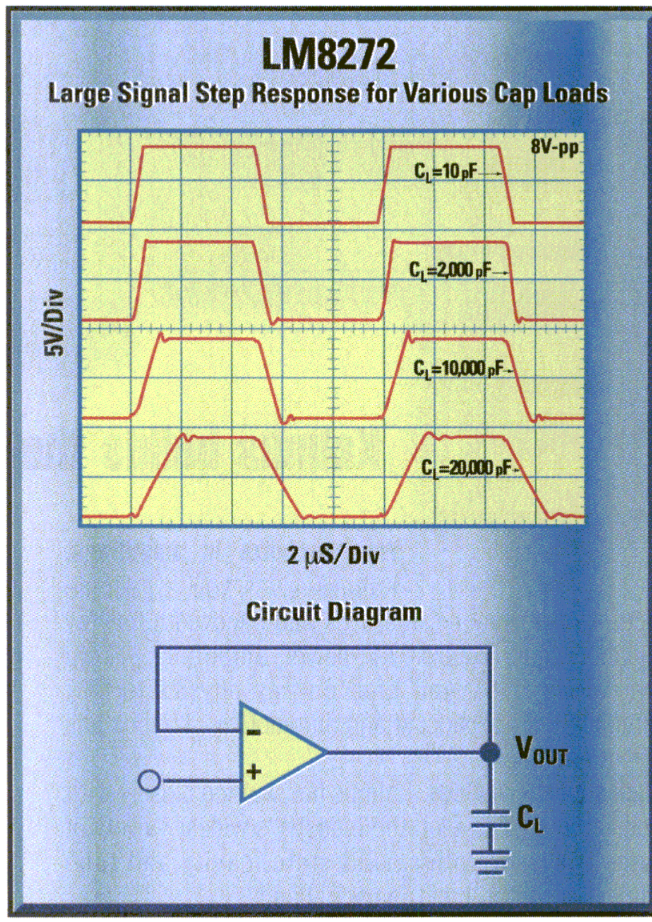

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NEWS

Fiber-Optic Technology

A wide range of components and test solutions is available to support system developers pursuing 10-Gb/s fiber-optic communications links.

Fiber-Optic Technology Drives To 10 Gb/s And Beyond

ALAN CONRAD
Special Projects Editor
JACK BROWNE
Publisher/Editor

DEMAND for data at higher speeds continues to push communications technology, notably in the components used for forming fiber-optic networks. While systems operating at Synchronous Optical Network (SONET) rates of 622 Mb/s were once considered the state of the art in high-speed optical communications, system integrators are now pushing for rates of 10 Gb/s and beyond in support of customers' needs for faster Internet access and data transfers.

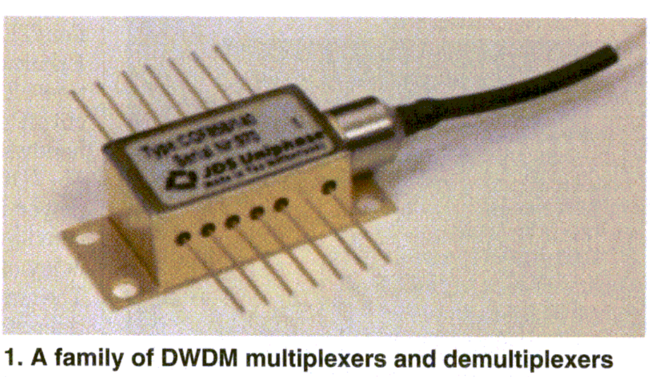
While most current, high-speed optical systems operate at maximum data rates of 2.5 Gb/s (OC-48), trends such as the growth of in-home offices (with requirements for high-speed data access) and the increasing use of the Internet, e-mail, and an increase in videoconferencing contribute to the demands for faster data rates. While fiber-optic links represent an initially high investment to install cable, the use of glass fibers to transmit information through light pulses offers several advantages over wired and wireless communications systems.

For example, fiber-optic links provide almost unlimited bandwidth, with the regulatory restrictions faced by wireless communications for bandwidth occupancy. Once fiber-optic cables are installed, the data rate of the link can be increased as faster optical sources and photodetectors become available. And fiber-optic communications systems, since they are based on the transmission and reception of light pulses, are immune to the effects of electromagnetic interference (EMI) and RF interference (RFI).

High-speed optical links are useful for analog and digital applications. On the analog side, companies such as Anacom Systems Corp. (Piscataway, NJ) supply high-speed optical transceivers and modules for use with RF wireless systems. For example, the company offers an optical link for connection of a remote antenna to a wireless base-transceiver station (BTS), as well as systems for integration with wireless local loops (WLLs), cellular-communications systems, and personal-communications-services (PCS) systems. Last year, MITEQ, Inc. (Hauppauge, NY) introduced a series of analog fiber-optic links with better than 1-GHz bandwidths for in-building cellular and antenna-remoting applications (see *Microwaves & RF*, April 2000, p. 133).

Optical-communications technology is attractive to service providers due to its massive bandwidths. Channel spacings of 50, 100, and 200 GHz are typical in International Telecommunications Union (ITU)-approved optical-communications systems—with bandwidths far beyond the realm of wireless systems. As an example, AC Technology (Santa Clara, CA) provides a series of multiplexers for dense-wavelength-division-multiplexing (DWDM) systems with 200-GHz communications bandwidths. The firm's four- and eight-channel multiplexers employ thin-film coating and proprietary design of nonflux metal-bonding micro-optics packaging to achieve optical add-and-drop channel capabilities at 200-GHz ITU channel spacings.

JDS Uniphase (San Jose, CA) provides a family of DWDM functional blocks,



1. A family of DWDM multiplexers and demultiplexers based on advanced fiber Bragg grating filters and mature thin-film technology supports 2.5-Gb/s OC-48 as well as 10-Gb/s OC-192 systems. (Photograph courtesy of JDS Uniphase, San Jose, CA.)

including multiplexers and demultiplexers (Fig. 1). Based on mature thin-film filter components and advanced fiber Bragg grating filters, the modules are assembled using proprietary packaging techniques and are completely passive, thus there is no need for temperature control. Designed with epoxy-free optical paths for high reliability, modules are available for channel spacings of 50, 100, and 200 GHz for use in 2.5-Gb/s OC-48 systems as well as in 10-Gb/s OC-192 systems.

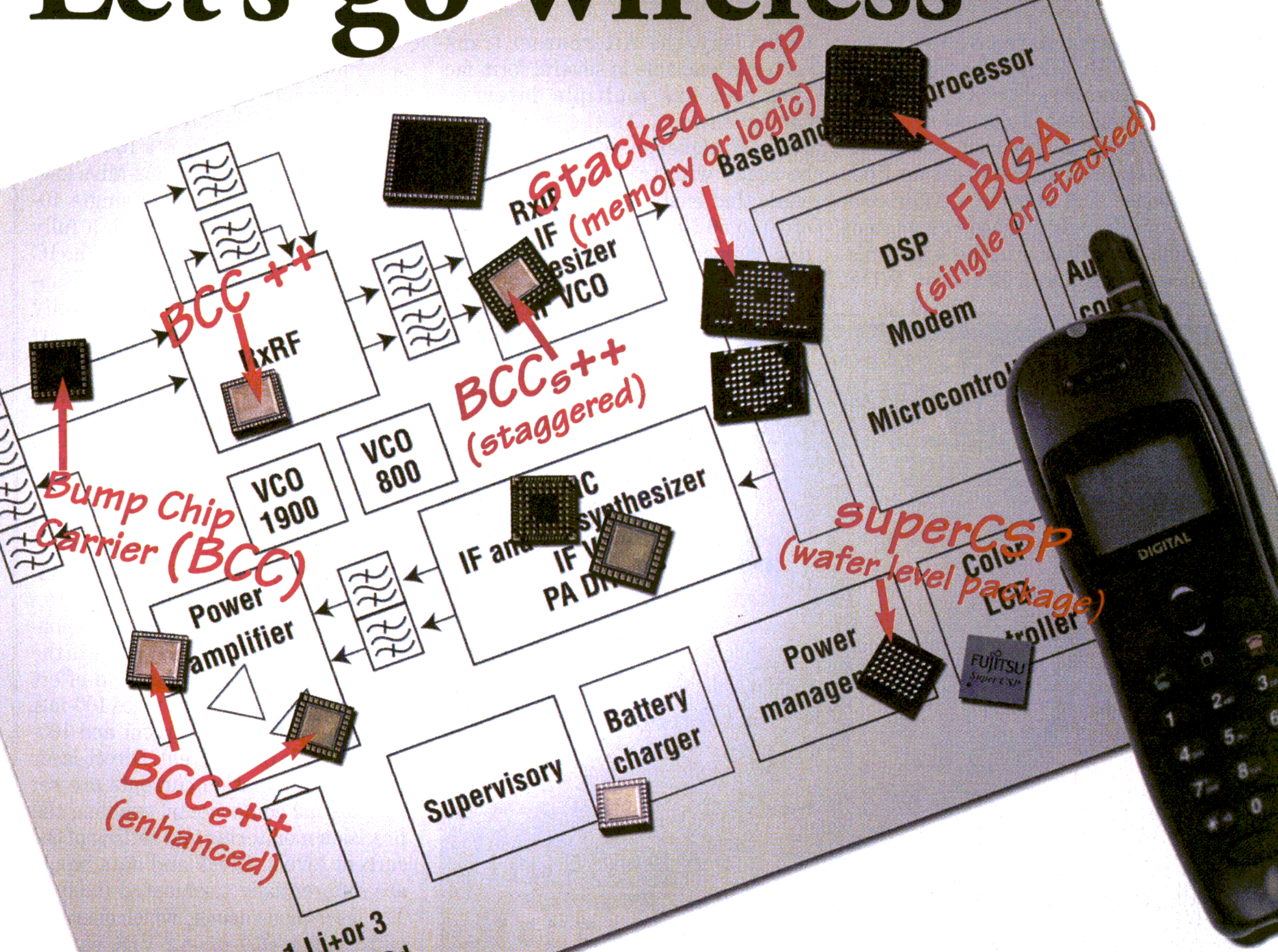
The build-up of optical-communications systems has created some opportunities for traditionally "microwave" manufacturers. Companies such as Veritech Microwave (South Plainfield, NJ), B&H Electronics (Monroe, NY), and CTT Wireless (Santa Clara, CA) supply broadband amplifiers for use in optical-communications systems.

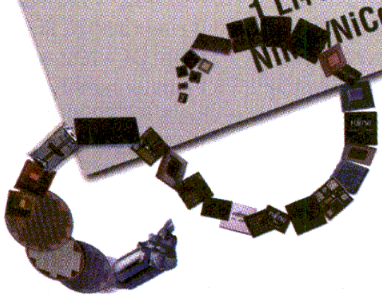
Veritech Microwave supplies a variety of components for 2.5- and 10-Gb/s terrestrial WDM optical-communications systems, including optical-modulation drivers. Designed for excellent phase performance, these modulation drivers provide stable output levels with temperature. The output levels are adjustable, permitting the designer to maximize extinction ratio. The modulators include internal DC regulation and reverse voltage protection.

One traditional microwave company to recently enter the optical-communications sector is CTT (Santa Clara, CA), through the creation of its CTT Wireless business. The CTT Wireless part of the company now offers a series of wideband driver amplifiers and subsystems in support of OC-192 and faster architectures. An example unit provides 18-dB gain from 10 MHz to 15 GHz with a gain flatness of 62.2 dB (Fig. 2). The amplifier provides at least +10-dBm output power across the full bandwidth.

With the maturation of OC-48 (2.5-Gb/s) technology, a growing number of firms are now offering standard components for OC-192 (10-Gb/s) use. Leading suppliers at the integrated-circuit (IC) and module levels include ANADIGICS (Warren, NJ), Fujitsu (Santa Clara, CA), Oki Semiconductor (Sunnyvale, CA), Vitesse Semiconductor (Camarillo, CA), and WJ Communications (City, CA). ANADIGICS, for example, offers the model ATA7601D1 transimpedance amplifier (TIA) for SONET OC-192, 10-Gb/s Ethernet, and 10-Gb/s DWDM applications. The TIA, with a low-frequency cutoff of 30 kHz, achieves a typical bandwidth of 9 GHz. It operates from a +5-VDC supply with 325-mW typical power dissipation. It features optical sensitivity of –19.5 dBm and group delay of ±25 ps from 1 MHz to 9 GHz. The amplifier, which provides differential outputs for good low-noise performance, achieves a differential output voltage of 400 mV. Discovery Semiconductors (Princeton Junction, NJ) also offers semiconductor-level devices based on PIN-diode technology, for 10-

Let's go wireless





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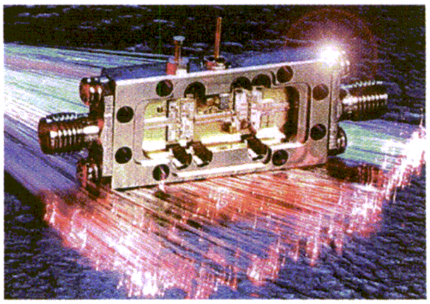
and 40-Gb/s optical receivers (Rxs).

Blaze Network Products (Dublin, CA) has addressed one of the limitations of high-speed optical networks such as Gigabit Ethernet—transmission distance over multimode fiber backbones. The company's Afterburner™ multimode transceiver enables gigabit-level data transmission at distances up to 2 km. Based on WDM technology, the Afterburner transceiver is available in several form factors and has multiple interface configurations. As the market migrates to higher speeds, Blaze hopes to be ready with transceivers and port cards that enable backbone capacities of 10 to 50 Gb/s, as well as cost-effective, high-speed photonic solutions for backplanes, traces, and converters.

Vitesse Semiconductor Corp. offers several gallium-arsenide (GaAs) integrated circuits (ICs) designed for use in 10-Gb/s optical systems. The model VSC8073, for example, is a 16-b multiplexer that combines 16 622-Mb/s low-speed input signals into a single 10-Gb/s high-speed signal. With a fully differential low-speed interface, the IC operates from a –5.2-VDC power supply and is supplied in a thermally enhanced plastic package. Its counterpart, the model VSC8074 16-b demultiplexer, accepts a 10-Gb/s high-speed serial data stream and demultiplexes it into 16 differential parallel 622-Mb/s outputs. The device includes a differential 622-Mb/s clock input.

The firm also offers the model VSC7990, a 10.7-Gb/s laser-diode driver with enough bandwidth to accommodate forward error correction (FEC) in 10-Gb/s serial Ethernet applications. Users have direct access to the laser modulation and bias field-effect transistors (FETs), with up to 100-mA available modulation current and 100-mA available bias current. Direct-laser bias and modulation currents are set by external components, enabling the precision monitoring and setting of the current levels. Clock and data inputs are differentially terminated in 50 Ω. The laser-diode driver, which operates with a single +5.0- or –5.2-VDC supply, achieves a typical rise time of 25 ps. A two-chip OC-12 to OC-192 optical transmitter (Tx) can be easily implemented using the VSC7990 and the company's VSC8171 10-Gb/s multiplexer/clock-recovery unit.

Vitesse's VSC7226-01 quad 8-b parallel-to-serial transceiver and



2. Wideband-modulation driver amplifiers such as this unit support transmissions in OC-192 optical-communications networks. (Photograph courtesy of CTT Wireless,

VSC7226-02 quad 8-b serial-to-parallel transceiver can be used for high-bandwidth interconnection between busses, backplanes, or other subsystems. By combining four of the Gigabit Ethernet-compliant transceivers, more than 20 Gb/s of raw duplexed data transfer is possible. Each channel of the VSC7226-01 can operate at a maximum data-transfer rate of 1920 Mb/s (8 b at 240 MB/s) or a minimum data-transfer rate of 760 Mb/s (8 b at 95 MB/s). Each channel of the VSC7226-02 can operate at a maximum data-transfer rate of 2500 Mb/s (8 b at 312.5 MB/s) or a minimum data-transfer rate of 960 Mb/s (8 b at 120 MB/s). The VSC7226-01 and VSC7226-02 can also be configured to operate as four nonencoded 10-b transceivers.

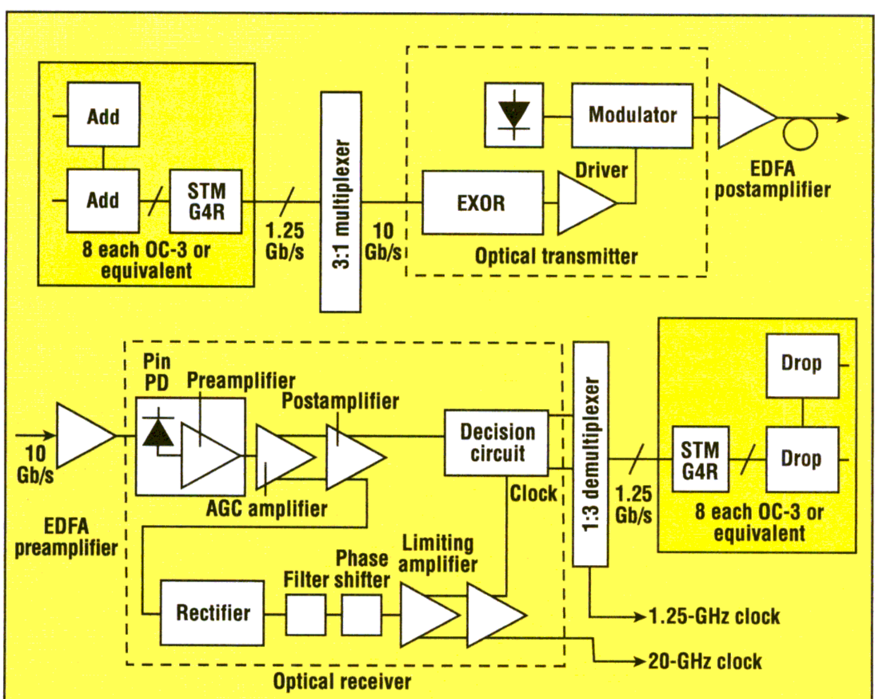
WJ Communications, Inc. (San Jose, CA) also recently introduced the model SA1137 modulation driver in support of OC-192 systems. Designed for clock rates from 9.9 to 12.4 Gb/s, the modulation driver features a +3 to +8 VDC peak-to-peak output with 25-ps rise/fall time. Ideal for driving lithium-nitrous-oxide $(LiNiO)_3$ optical modulators, the SA1137 includes an integral optical-modulator DC bias port, output voltage detector, output level control, and crossover adjustment.

Conexant Systems (Newport Beach, CA) offers a four-channel serial transceiver capable of 12.5-Gb/s operation. By combining four 3.125-Gb/s channels on a single chip, the firm was able to fabricate the OC-192 device using a 0.25-μm complementary-metal-oxide-semiconductor (CMOS) process. Four of the 12.5-Gb/s chips can be combined to achieve data rates to 50 Gb/s without additional synchronization circuitry.

Network Elements, Inc. (Beaverton, OR) recently introduced the SmartModule family of modules for 10-Gb/s Gigabit Ethernet applications. Modules include clock/data-recovery units and optical-electrical-optical converters.

SYSTEM SOLUTIONS

How are these components incorporated into 10-Gb/s systems (Fig. 3)? Hitachi (Brisbane, CA), for example, offers the advanced-multiservice-network (AMN) product family for 10-Gb/s transmissions and beyond. All members of the AMN product family are managed by a sophisticated Element-Management System (EMS) operating on a common platform.



3. This block diagram shows the types of components and modules needed in the construction of an OC-192 10-Gb/s optical-communications system. (Diagram courtesy of Oki Semiconductor, Sunnyvale, CA.)

The company's AMN 5192 is a next-generation Synchronous Optical Network (SONET) OC-192 transport system designed to address a full range of applications from long-haul transmission to metropolitan rings. It combines basic OC-48, OC-12, and OC-3 multiplexing with a wide variety of advanced functions for high reliability and economic use in today's expanding telecommunications networks. The system offers a full 20-Gb/s tributary-drop capacity per node and extra traffic protection-channel access (PCA), effectively increasing total throughput to 40 Gb/s.

Hitachi's AMN 6100 is an advanced OC-192 DWDM optical-transport system. The unidirectional AMN 6100 system can deliver a full 1.28-Tb/s data rate in each direction. It provides the capability, scalability, high-reliability, and interface flexibility from OC-12 to OC-192. The AMN 6100 has an open architecture, which enables carriers to transport all types of traffic including voice, video, and data.

WorldCom (Clinton, MS) is testing a next-generation DWDM transmission system that carries 88 10-Gb/s channels in each of two transmission bands for a total of 176 10-Gb/s channels. The system, based on the FLASHWAVE OADX architecture from Fujitsu Network Communications, Inc. (Richardson, TX), is part of an evaluation program called the "Terabit Challenge" being conducted by WorldCom. According to WorldCom's CTO, Fred Briggs, "The Terabit Challenge allows vendors to showcase their products while allowing WorldCom to test network solutions."

Lucent Technologies (Murray Hill, NJ) offers a comprehensive family of system and modular solutions for 10-Gb/s optical communications that is known as the WaveStar product line. In fact, the firm's WaveStar TDM 10G system is a multishelf architecture that can combine a variety of OC-3, OC-12, and OC-48 traffic onto an OC-192 line for transport to distant OC-192 multiplexers. Since the system is designed to work with an embedded base of 2.5-Gb/s OC-48 networks, it provides a flexible and cost-effective solution for upgrading current optical-communications systems to next-generation requirements.

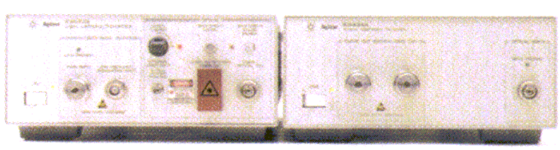
In fact, the company is already marketing its WaveStar TDM 40G system, which is designed to deliver 40 Gb/s of capacity with a single laser over a single wavelength on a single fiber-optic cable. The firm also offers the WaveStar OLS 40G system, which uses 16 different wavelength DWDM channels to achieve 40-Gb/s capacity.

Nortel Networks OPTera long-haul optical-line systems are transport platforms based on DWDM systems coupled with optical amplifier solutions to provide transport solutions that are scalable to 1.6 Tb/s. They can transport optical signals to 4000 km without opto-electronic signal regeneration. The architecture supports systems at 622 Mb/s through beyond 40 Gb/s.

Although the growth of 10-Gb/s standard devices and modules is strong, the push for 40-Gb/s technology may be even stronger. Last September, for example, the giant German electronics firm Siemens (Munich, Germany) teamed with Corning (Corning, NY) to demonstrate a 40-Gb/s system. The demonstration, held at the European Conference on Optical Communications (ECOC) 2000 at the International Congress Centre (Munich, Germany), unveiled the next level of time-division-multiplexed (TDM) SONET/synchronous-digital-hierarchy (SDH) signals and DWDM transmission and highlighted the optical-fiber and photonic components needed for reliable communications at 40 Gb/s. Incorporating Raman and other DWDM technologies, the system combined Siemens' transmission equipment and DWDM terminals with Corning's LEAF optical fiber, erbium-doped fiber amplifier (EDFA), Raman amplifiers, and other optical-layer products.

During the demonstration, eight channels of simulated live traffic were transmitted error free at 40 Gb/s over four 100-km spans (400 km) of LEAF fiber. According to Dr. Hans-Joachim Grallert, senior vice president of development for optical networks at Siemens Transport Networks, "We are working together to move advanced 40-Gb/s technology out of the research laboratories and into the market as a robust and reliable product offering. Through this effort, we are one step closer to accommodating the rapidly increasing bandwidth and traffic demands of today's communication market."

For the 40-Gb/s system test bed at ECOC 2000, Siemens used a unique, patented Rx concept and high-performance Txs in order to transmit signals over the four 100-km channels without the use of FEC. When FEC is used, the TransXpress Infinity Multichannel Transport System (MTS) system supports 80 40-Gb/s channels over a 1000-km distance. The system achieves good economy by reducing the number of expensive regenerators. "By increasing the data rate to 40 Gb/s per wavelength and reducing the number of regenerators, Siemens and Corning have reduced both investment and operational costs for customers," according to Siemens' Grallert.



4. The 83433A lightwave Tx and the 83434A lightwave Rx are designed for evaluating optical components and systems at data rates through 10.7 Gb/s. (Photograph courtesy of Agilent Technologies, Santa Rosa, CA.)

Of course, as component and system manufacturers push for higher data rates, they force test-equipment suppliers to stay one step ahead. Instrument suppliers such as Advantest America (Santa Clara, CA), Agilent Technologies (Santa Rosa, CA), Anritsu Co. (Morgan Hill, CA), Opto-Electronics, Inc. (Buffalo, NY), and Tektronix (Beaverton, OR) have developed effective test solutions even as data rates have pushed beyond 2.5 Gb/s. For example, the 83433A lightwave Tx and the 83434A lightwave Rx from Agilent Technologies are designed for evaluating optical components and systems at data rates through 10.7 Gb/s (Fig. 4). The 83433A lightwave Tx can generate optical waveforms at OC-48 and OC-192 rates, with modulation of optical waveforms from 2.4 to 10.7 Gb/s. Given the appropriate data-input signals, the Tx can generate STM-64/OC-192- and STM-16/OC-48-compliant eye patterns. It employs a 1552.52-nm internal distributed-feedback (DFB) laser with a Mach-Zehnder modulator and is compatible with external-polarization-controlled tunable-laser source (TLS) at wavelengths from 1530 to 1565 nm. The 83434A lightwave Rx employs a PIN-diode-based architecture with a wavelength range from 1300 to 1600 nm and –16-dBm sensitivity.

The OTS9010 portable SONET/SDH optical test set from Tektronix provides network-equipment manufacturers and network operators with the capability of analyzing DWDM systems at 10 Gb/s. Using a modular format with plug-in cards, the instrument is well-suited for multichannel testing. It incorporates a Microsoft Windows NT operating system. The instrument generates a variety of test patterns and uses a built-in test Rx to evaluate bit-error rates (BERs) through 10^{-14}. A variable Rx-threshold function supports testing at lower BERs and then extrapolates the data to 10^{-14} in order to speed testing.

Optical-communications systems usually imply the use of fiber-optic cables, but there are exceptions. Optical wireless technology is a method of using point-to-point laser beams to transfer large amounts of data. One originator of this technology, TeraBeam Networks (Seattle, WA), has installed medium-distance systems in Seattle to demonstrate the technology. The company also recently teamed with Lucent Technologies (Murray Hill, NJ) to explore the potential for optical wireless communications. One attractive feature of this technology is that networks can be easily moved and reconfigured On the downside, optical wireless systems are somewhat limited in distance, especially in fog, and tracking between terminals is necessary to maintain alignment as changes occur due to environmental-temperature variations. One firm that is helping to overcome the limitations of optical wireless communications is LaserWireless, Inc. (Lancaster, PA), which incorporates remote diagnostic capabilities into its systems to minimize misalignment between network nodes. ••

AFS SERIES...

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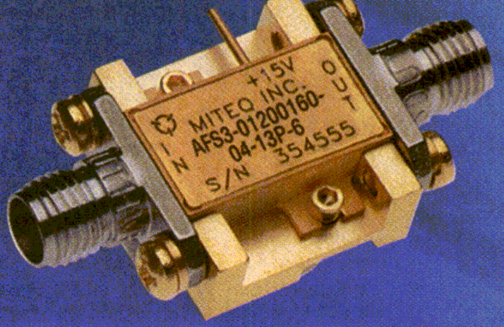

Model Number	Frequency Range (GHz)	Gain (Min./Max.) (dB)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	VSWR Input (Max.)	VSWR Output (Max.)	Output Power @ 1 dB Comp. (dBm, Min.)	Nom. DC Power (+15 V, mA)
TEMPERATURE COMPENSATED AMPLIFIERS								
AFS3-01000200-15-TC-6	1–2	36-40	1.00	1.5	2.0:1	2.0:1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

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

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

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

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

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

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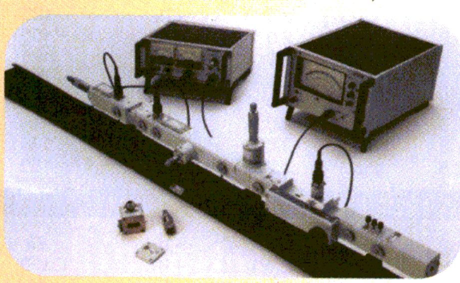
Two low-frequency directional couplers operating below 1 GHz can handle average power levels to 500 W, and peak power levels to 5 kW. They are ideal for sampling power with a negligible effect on the transmission line and very low intermodulation (IM) products. The model LCHP-0205-xx-x operates from 250 to 500 MHz and has a maximum insertion loss of 0.15 dB. The model LCHP-0510-xx-x operates from 500 to 1000 MHz and exhibits a

maximum insertion loss of 0.20 dB. Both couplers have a minimum directivity of 25 dB, and a maximum primary and secondary VSWR of 1.15:1. The couplers have a nominal coupling of 20 or 30 dB, an accuracy of ± 1.25 dB, and IM products of better than –130 dBc. **RLC Electronics, Inc., 83 Radio Circle, Mt. Kisco, NY 10549; (914) 241-1334, FAX: (914) 241-1753, Internet: http://www.rlc-electronics.com.**

For more information, visit www.mwrf.com

Microwave training bench teaches basics

The Oritel BDH R100 training bench allows students to perform basic microwave experiments from 8.5 to 9.6 GHz. It is designed to train industrial or military students in the basics of practical microwave circuits. The system helps students learn to measure wavelength, standing-wave ratio, impedance, and attenuation, and allows them to observe detector and Gunn-oscillator characteristics. The kit includes a Gunn-diode oscillator, a ferrite oscillator, a PIN-diode modulator, a variable attenuator, a wave-



meter with curve, a slotted line, an impedance adapter, a waveguide-to-coaxial adapter, a coaxial detector, an adapted load, and a short circuit. Each of these components is integrated onto a waveguide attachment with interlocking lugs, which allows them to connect to each other in various configurations. The kit also includes a bench rail and guide supports to hold the configuration in place, along with detailed training documentation. **Chauvin Arnoux, 190 rue Championnet, 75876 Paris Cedex 18, France; (33) 01 44 85 44 85, FAX: (33) 01 46 27 73 89, Internet: http://www.chauvin-arnoux.com.**

For more information, visit www.mwrf.com

Free software simulates filters

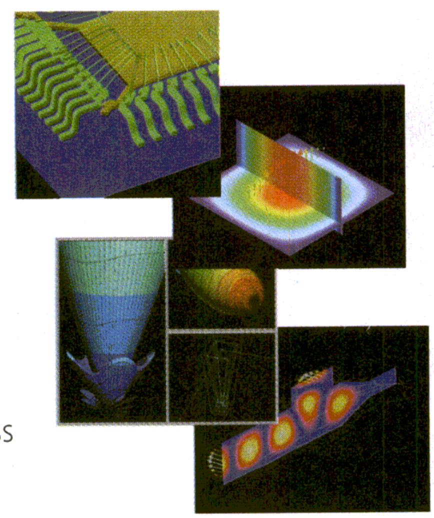
FilterExpress V4.0 is a digital-filter-design software package that is freely downloadable from the manufacturer's website. It allows communications-system designers to quickly create most common filter configurations. The new version includes a simulator known as FilterSim, which can be used to simulate the behavior of a filter during the design process. It allows designers to rapidly develop and evaluate digital-signal-processing (DSP)-based filters of almost any kind, including processor-efficient, multi-rate designs. The user can program the numeric precision of these software tools to optimize a filter for its target DSP hardware. **Systolix, Inc., 10 Carver Lane, Sunol, CA 94586; (925) 863-2542, FAX: (925) 862-0650, Internet: http://www.systolix-dsp.com.**

For more information, visit www.mwrf.com

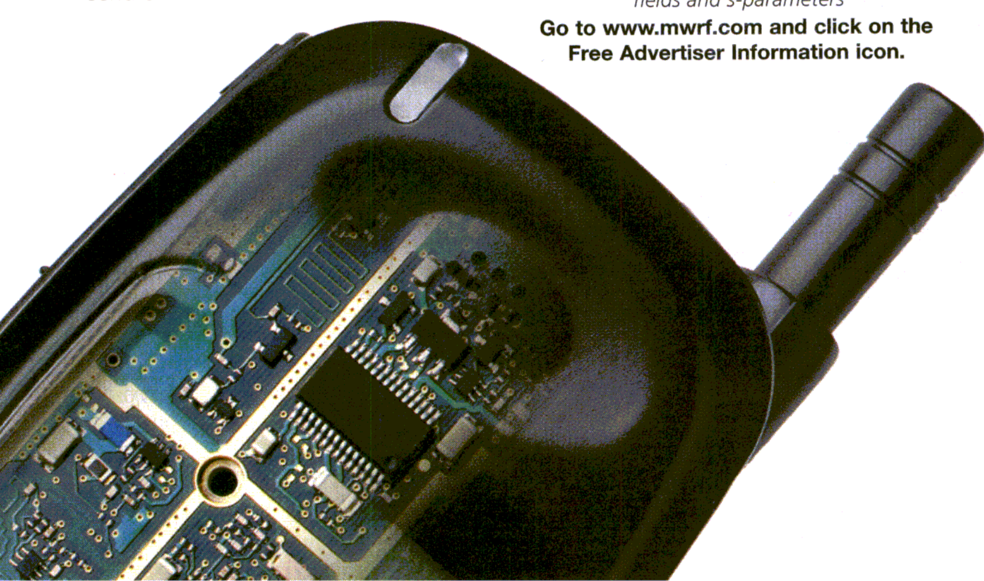
Spectrum analyzer goes anywhere

The model MS2711A is a fully functional handheld spectrum analyzer that measures 10 × 7 × 2.25 in. (25.40 × 17.78 × 5.715 cm) and is powered by a lightweight nickel-metal-hydride (NiMH) battery. Its total weight, including battery, is 4 lbs. (1.8 kg). The analyzer allows field engineers and technicians to locate, identify, record, and solve communication-system problems. It measures signals from +20 to –97 dBm at frequencies from 100 kHz to 3 GHz. The analyzer's resolution bandwidth can be set to 10, 30, 100, or 1000 kHz and has an accuracy of ± 20 percent. **Anritsu Co., 1155 East Collins Rd., Richardson, TX 75081; (972) 644-1777, FAX: (972) 644-3416, Internet: http://www.us.anritsu.com.**

For more information, visit www.mwrf.com



Use Ansoft HFSS to calculate and optimize fields and s-parameters



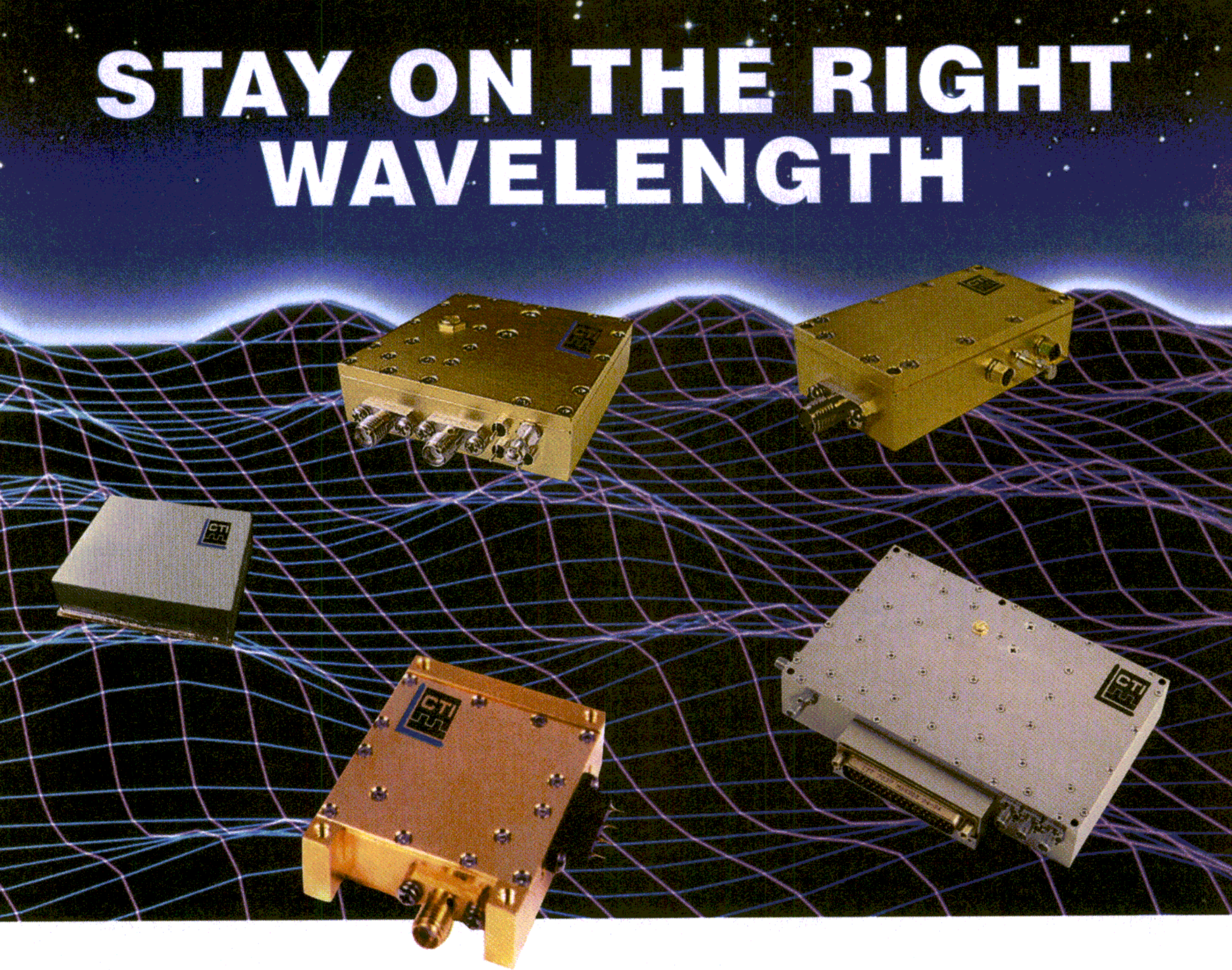
Cell Phones Send Mixed Signals

Sales of cellular phones are projected to top a hefty 400 million units in 2000, yet investment analysts and manufacturers themselves express lukewarm feelings about industry prospects for 2001. So great are expectations for the high-flying wireless industry that any failure of a company to meet its sales or growth forecasts is punished swiftly in financial markets. A case in point is Nokia Corp. (Espoo, Finland), the world's leading mobile-phone manufacturer.

Nokia sold 128 million handsets in 2000 and finished the year with a market share of 31.6 percent, gaining share strongly over its competitors in the fourth quarter, when one-third of sales are generated. Unfortunately for the company, it had forecasted approximately 135 million units and one analyst had projected 140 million. Moreover, Nokia committed the unpardonable sin of stating that the total market was growing more slowly than some analysts had predicted. The most optimistic forecasts called for approximately 440 million phones, but that was reduced by 20 million, and finally Nokia placed its final count for the year at 405 million. Despite its solid performance—particularly with respect to its competitors—Nokia's stock fell to more than $5 per share to close at $37 on January 8.

Even greater suffering befell Motorola, Inc. (Schaumburg, IL), the world's number two phone manufacturer. Sensing problems, the company sent out warning signals prior to the end of its fourth quarter that sales and earnings would fall short of expectations. The prophecy came true—sales dropped to $10 billion; this was $0.5 billion less than anticipated and earnings per share were 15 cents, off 12 cents from projections. Punishment in the market was severe. Shares hit an eight-year low of $21.75 in early January, a drop of 65 percent from their 52-week high. Moreover, Motorola is raising red flags for the first quarter of 2001, projecting a further drop in sales to the range of $8.8 billion and a decline in earnings to 12 cents. The company attributed its lackluster showing to slowing semiconductor sales and delays in lowering wireless phone production costs. If that was not enough misfortune, Motorola gave up 2.3 points in market share to Nokia, dropping to 13.3 percent, less than half of the leader's share.

The handset-production business at the third-largest manufacturer, LM Ericsson (Stockholm, Sweden), was sluggish as it also gave up market share to Nokia, falling 0.6 percent to 9.7 percent. Ericsson's phone manufacturing problems have been building for the past six months as reported earlier (see "Ericsson Stumbles In Wireless," *Microwaves & RF*, September 2000, p. 40).••



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Contracts

Merrimac Industries, Inc.—Was awarded a $1 million contract from Lockheed Martin Corp. for the Global Positioning System (GPS) Antenna Retrofit Program. The Antenna Retrofit program is designed to enhance the output power of older satellites for broader coverage and superior accuracy.

SAL, Inc.—Announced the award of a contract from JMAR Research (JRI), a subsidiary of JMAR Industries in San Diego, CA, for the building of an XRS 2000NanoPulsar™ X-Ray Lithography system. This initial phase is valued in excess of $1 million. SAL and JRI are targeting markets that require the manufacture of high-performance semiconductor devices with critical dimensions of 130 to 70 nm.

Scientific-Atlanta—Fox Cable Networks Group has selected a PowerVu Plus™ content distribution system from Scientific-Atlanta to deliver programming to all cable headends using one digital platform. The multimillion-dollar contract calls for Scientific-Atlanta to install two systems in Los Angeles and Houston, both capable of transmitting multiple channels of compressed digital video programming.

ADC—Announced a $16 million contract for supplying GVT Brazil with a complete broadband-access bundled solution for connecting subscribers in the southern and central regions of Brazil.

Motorola, Inc.—Has been awarded a general-packet-radio-service (GPRS) network-supply contract by China Mobile Communications Corp. (China Mobile). Under the terms of the deal, Motorola will deliver its GPRS high-speed mobile data network to four major Chinese cities.

EMS Technologies, Inc.—Received an order worth $4.3 million from Boeing Space Systems to design, manufacture, and test a Ka-band multi-element transmit antenna for the ANIK F2 satellite. The ANIK F2 satellite is being built by Boeing Space Systems, formerly Hughes Space and Communications, for Canada's national satellite operator, Telesat Canada, Inc.

Fresh Starts

Channel Master—Opened its new international operations center in Wan Chai, Hong Kong. Channel Master Asia Ltd. will be responsible for the procurement of Channel Master products, and will also provide management supervision and technical assistance to the company's manufacturing facilities and subcontractors throughout Asia. Additionally, the Hong Kong office will provide customer service and sales support.

DaimlerChrysler and Vishay Intertechnology, Inc.—Signed a licensing agreement that will enable Vishay to undertake the high-volume manufacture of semiconductor products using DaimlerChrysler's silicon-carbide (SiC) technology.

Crystalline Materials Corp.—Has changed its name to CMC Wireless Components. The company is located in Phoenix, AZ and manufactures aluminum-nitride (AlN) packaging materials for the RF, microwave, and telecommunications industries.

RF Micro Devices, Inc.—Announced the opening of a new engineering design center in Pandrup, Denmark. The new facility is expected to house a team of senior RF engineers.

StratEdge—Purchased the assets of Package Technologies, Inc. (PTI) of Taunton, MA. PTI designs and manufactures state-of-the-art hermetic glass-to-metal seal, flatpack, plastic-equivalent packages (PEPs), and metal packages for telecommunications.

Telephia and Invertix Corp.—Announced that they will share new proprietary technology to track the performance of the wireless Internet. The partnership will produce a new product providing the first continuous, end-to-end, quality-of-service measurement system for wireless data networks.

Intersil—Announced that its CommLink digital downconverter has been selected for use in Siemens AG's cellular base stations, planned as part of an expanded mobile-communications network in China. The CommLink HSP50216 is Intersil's first device specifically designed for third-generation (3G) cellular protocols and integrates four channels into a single circuit.

TRW, Inc. and SpaceBridge Networks Corp.—Have formed a partnership to develop broadband wireless-access products. The agreement advances SpaceBridge's development of next-generation modems and provides TRW with an exclusive license to SpaceBridge's proprietary technology for extremely fast digital data switching aboard spacecraft.

APLAC Solutions Corp.—Has established an office in Irving, TX, a Dallas suburb. APLAC provides integrated-circuit (IC) and board-level models and precise methods to analyze nonlinear circuit behavior.

Sunrise Telecom—Has been selected by Korea Telecom as the preferred vendor for digital-subscriber-line (DSL) field-test equipment for its nationwide asymmetric-DSL (ADSL) deployment. Korea Telecom selected the SunSet xDSL for use in installation of ADSL circuits after several months of benchmark testing and field-trial evaluation.

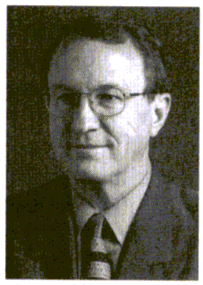
AirNet Communications Corp.—Has been chosen by Oklahoma-based MBO Wireless, Inc. to deploy one of the nation's first wireless general-packet-radio-service (GPRS) solutions. AirNet's broadband, software-defined AdaptaCell™ base station will enable MBO to offer its customers enhanced data services such as mobile-commerce applications, multimedia services, general wireless Internet messaging, and WAP services using GPRS.

SaRonix—Added an E-store, a link from its main website, as a convenience to design engineers, where they can purchase parts, in limited quantities, using a credit card.

SignalSoft Corp.—Announced that Swiss cellular operator Orange has licensed SignalSoft software in order to deploy location-based services. By integrating SignalSoft's products into its network, Orange will be able to bring advanced, location-enabled applications to its mobile customers.

Renaissance Electronics Corp.—Charles A. McCauley to vice president and general manager; formerly vice president of sales and marketing. Also, Rich Crabtree to vice president of sales and marketing; formerly director of sales/director of new business components at Signal Technology Corp.

EiC Corp.—Jerry L. Curtis to president and COO; formerly president and COO at Optek Technology, Inc.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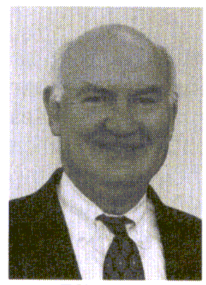

TOWATER

Trompeter Electronics—Glen Towater to regional sales manager for the Southeast; formerly employed in sales positions with Cinch Connectors and Molex, Inc.

American Technical Ceramics (ATC)—Joseph Tierney to product manager; formerly product manager at RF Power Components.

The Society of Cable Telecommunications Engineers (SCTE)—Ginny Nagle to manager of marketing communications; formerly account executive, writer, and publicist at Alvaré Associates, Inc. Also, Stephen P. Oksala to vice president of standards; formerly director of standards management for Unisys Corp.

Certicom—Dr. Dennis J. Charlebois to senior vice president for corporate development; formerly president of DRS Technologies Data Systems Group.

Tel^x—Jonathan Lawrence to CFO; formerly an investment banker with Houlihan, Lokey, Howard & Zukin.

U.S. Wireless Corp.—Dipesh Shah to vice president of engineering; formerly employed as senior manager in wireless applications and performance at Lucent Technologies' Bell Laboratories.

Bomar Interconnect Products, Inc.—Joe Noonan to national accounts specialist; formerly president of Bow Electronic Solders.

Rockwell Collins—Douglas C. Wagner to manager of media relations; formerly strategic marketing manager for Five Transportation and Parking.

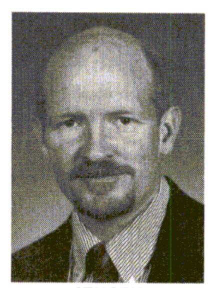
Aetesyn Communication Products, LLC—Michael Sullivan to vice president of quality assurance; formerly quality director.

CTS Corp.—Matthew W. Long to assistant treasurer; formerly employed as corporate controller for Morgan Driveaway.

MRSI—Peter Cronin to sales engineer; formerly process engineer for Lockheed Martin.

Yuasa, Inc./EnerSys, Inc.—Larry B. Axt to vice president of procurement and operations; formerly director of corporate purchasing. Also, Steven J. Weik to vice president of technology and engineering; formerly director of special projects.

American Microsystems, Inc. (AMI)—Brent Jensen to CFO; formerly corporate controller.


JENSEN


ARNEY

VertexRSI—Stephanie M. Arney to product sales manager at the State College, PA facility; remains as human resources manager.

Cambridge Display Technology (CDT)—Keith Bergelt to senior vice president of strategy, business development, and intellectual property (IP); formerly director of corporate strategy and general manager of strategic intellectual-asset management at Motorola.

iVoice—Craig M. Abrams to sales manager; formerly corporate vice president at Imperial Copy Products.

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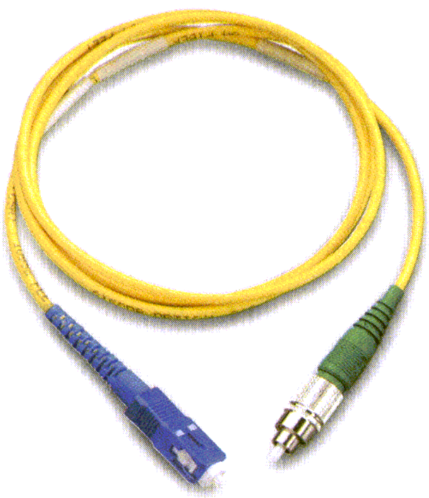

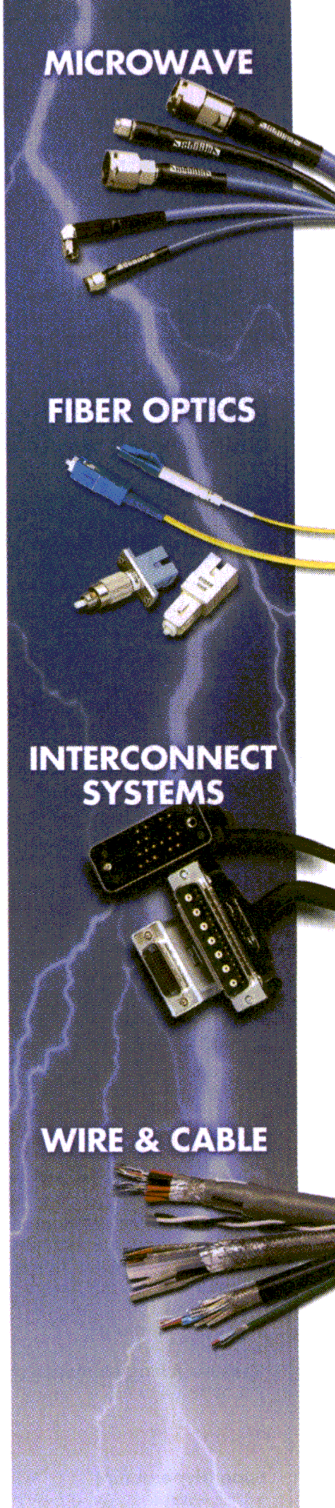

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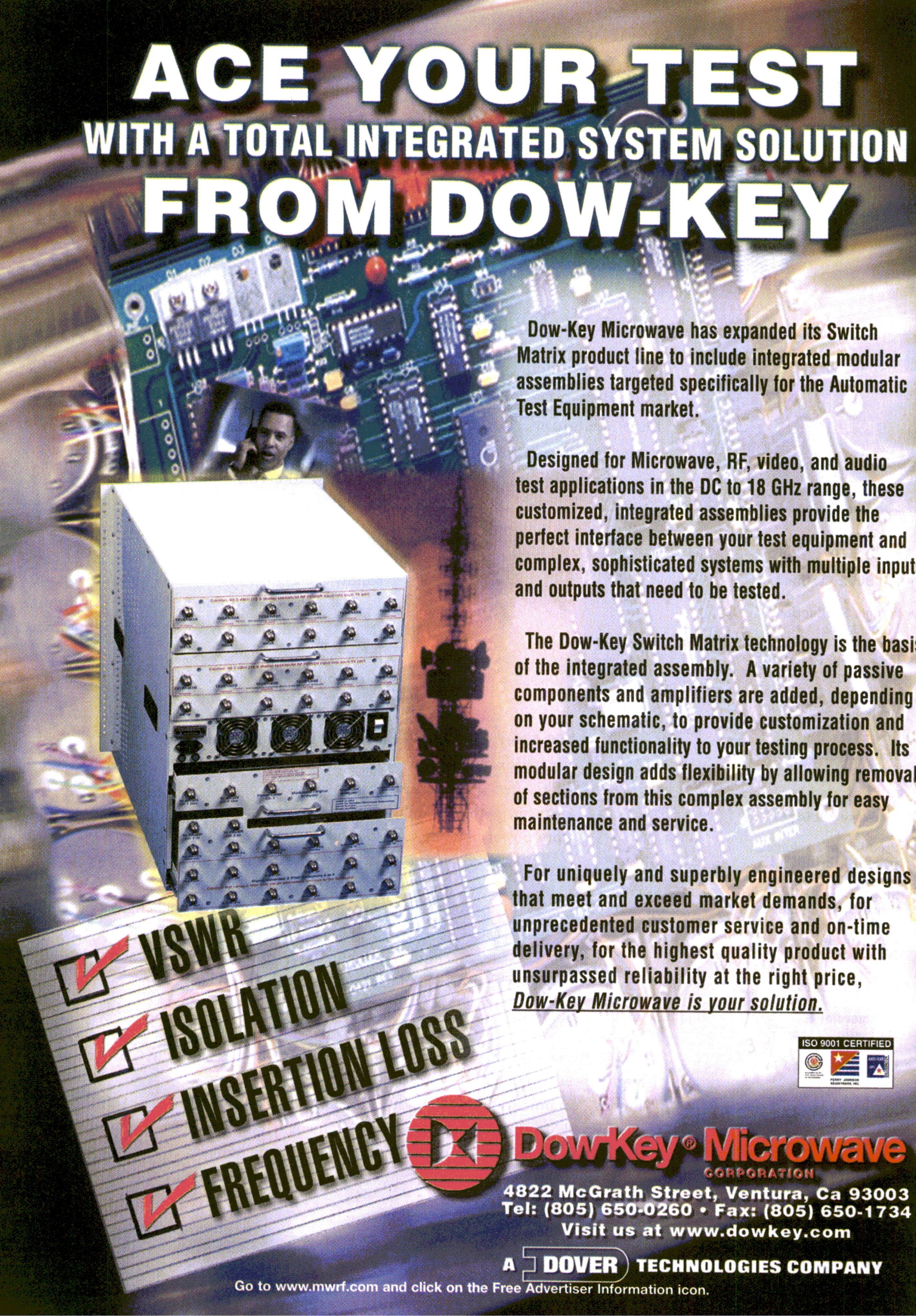
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Baseband ADC boosts dynamic range for channel selection in GSM radios

The rapidly expanding market for personal communications devices such as Global System for Mobile Communications (GSM) handsets is driving the demand for low-cost, low-power receiver (Rx) chips. One method of saving power and cost is to eliminate the intermediate-frequency (IF) channel-select filter and perform channel selection on chip at baseband. A group of Italian engineers has developed a low-power, analog-to-digital converter (ADC) to digitize the desired channel and the adjacent-channel interfering signals. Angelo Nagari, Alessandro Mecchia, Ermes Viani, Sergio Pernici, Pierangelo Confalonieri, and Germano Nicollini of SGS-Thomson Microelectronics (Milan, Italy) designed the ADC to deliver the high dynamic range required to perform baseband-channel selection. It consists of two second-order, double-sampled, semi-bilinear ΣΔ modulators, followed by two digital finite-impulse-response (FIR) decimation filters targeting GSM specifications. See "A 2.7-V, 11.8-mW Baseband ADC With 72-dB Dynamic Range for GSM Applications," *IEEE Journal of Solid-State Circuits*, June 2000, Vol. 35, No. 6, p. 798.

Ground-plane thickness affects DRA characteristics

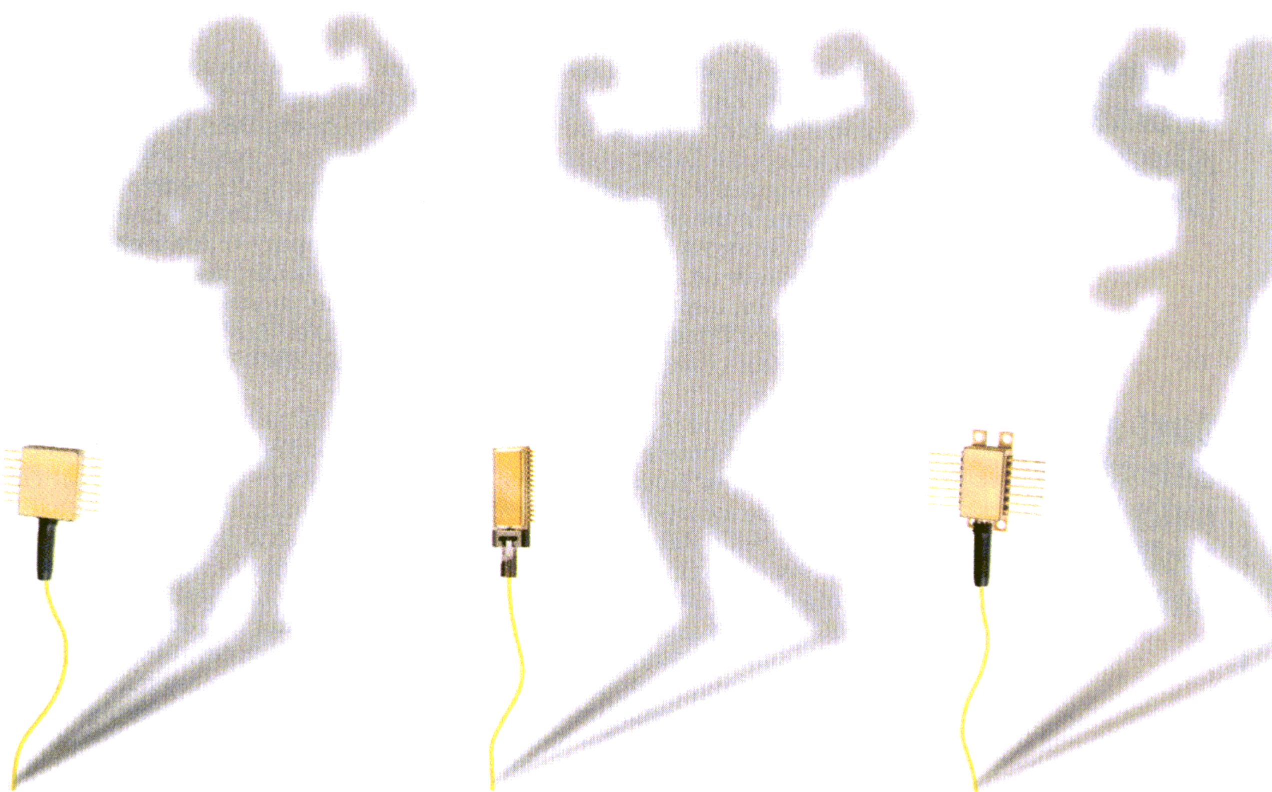
Traditionally, dielectric resonator antennas (DRAs) have used a coaxial probe and a closed-loop wire-feed probe to couple with the electric and magnetic fields from the transmitter (Tx). A recent improvement is to excite the DRA through a narrow slot, which allows the DRA to be integrated directly onto a circuit. But this configuration usually requires a thick ground plane to dissipate the power generated by the active components of the circuit. Zhi Ning Chen of the National University of Singapore, and Kazuhiro Hirasawa of the University of Tsukuba, Japan explore the effect of ground-plane thickness on the electrical characteristics of a hemispherical DRA, including input resistance, resonance frequency, and impedance bandwidth. See "On the Effect of Ground-Plane Thickness on an Aperture-Coupled Dielectric Resonator Antenna," *RF and Microwave Computer-Aided Engineering*, July 2000, Vol. 10, No. 4, p. 271.

Dual-element antenna reduces nulls in multipath environments

In cities, mobile-phone users often encounter multipath interference, which occurs when a mobile phone receives the intended signal and one or more unintended reflections of the signal from the walls of buildings. One way to reduce multipath interference is to use a dual-element antenna. William F. Young of Sandia National Laboratories, Benjamin Belzer of Washington State University, and Robert G. Olson of the IEEE Power Engineering Society have developed a dual-element antenna that consists of a dipole that is terminated with a parallel loop and a capacitor. The antenna has a single feed at a point on the loop opposite the capacitor and does not require external combining circuitry. The capacitor creates a phase shift between the dipole current and loop current, thereby greatly reducing the probability of deep nulls in the received signal when the antenna is used in areas where standing-wave patterns occur. See "A Two-Element Antenna for Null Suppression in Multipath Environments," *IEEE Transactions on Antennas and Propagation* August 2000, Vol. 48, No. 9, p. 1161.

Subharmonically injection-locked VCO achieves wide bandwidth

The desire for RF and microwave transceivers with wide bandwidth and less susceptibility to jamming is driving the trend toward higher operating frequencies. The key to this trend is the oscillator, which usually includes a phase-locked loop (PLL). But the operating frequency of a PLL is limited by the frequency divider. Traditionally, designers have circumvented this problem by using a frequency multiplier or a dual-loop PLL synthesizer. But the former suffers from low conversion efficiency, and the latter requires complicated circuitry. The subharmonically injection-locked oscillator offers an alternative to these approaches, but its bandwidth spans less than five percent. However, Quan Xue of the City University of Hong Kong has designed a subharmonically injection-locked PLL that achieves a relative bandwidth of 30 percent. It consists of a 1-GHz PLL synthesizer, a 4-GHz, dual-gate field-effect transistor (FET) voltage-controlled oscillator (VCO), an injection-matching lowpass filter (LPF), a matching highpass filter (HPF) at the output port of the 4-GHz VCO to reject the injection signal, and a voltage converter to regulate the 1-GHz PLL controlling the voltage of the 4-GHz VCO. See "A Subharmonically Injection-Locked Dual-Gate FET VCO Frequency Synthesizer," *Microwave and Optical Technology Letters*, September 5, 2000, Vol. 26, No. 5, p. 294.



Simulation Method Identifies Multipath Tracking Errors

A mathematical model determines how multipath reflections cause errors in tracking radars.

V.G. Borkar, A. Renuka, and A. Ghosh
Government of India, Ministry of Defense
Research Centre IMARAT
Vigyana Kancha, Hyderabad-500069, India
A.K. Kapoor
Defense Research and Development Laboratory
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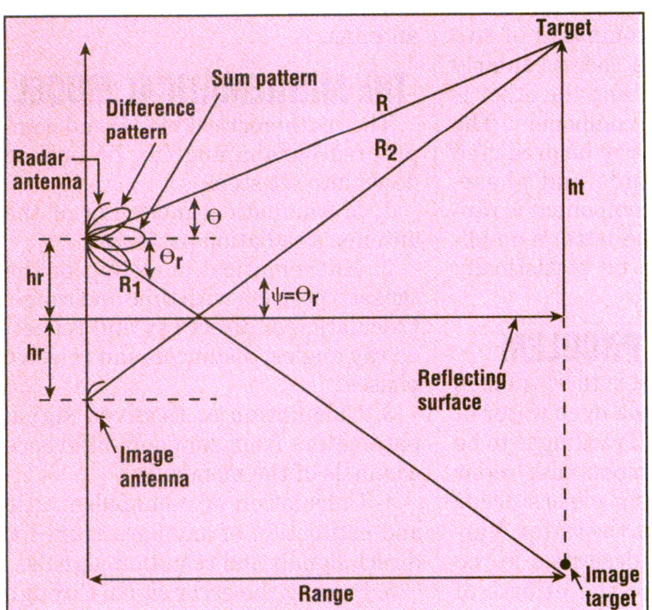
TRACKING-RADAR performance degrades considerably in the elevation plane for low-flying targets.[1] This is because the multipath phenomenon creates serious problems for tracking radars at low elevation angles. A reflected signal from the sea surface or ground enters through the main lobe of the antenna and the resultant signals fluctuate drastically. In a communications system, the result is a loss of a link for a time, but for a tracking radar, it is a continuous system failure.

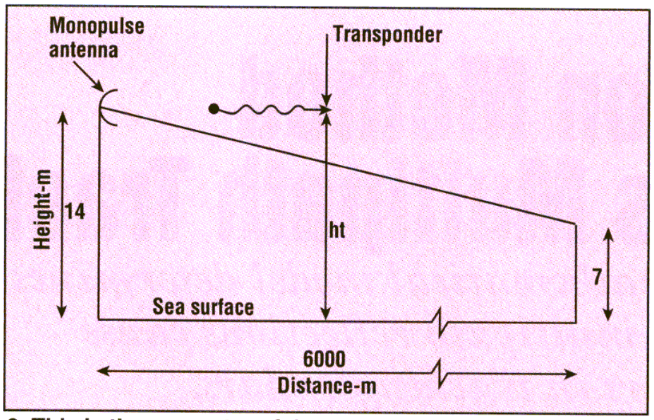
A number of techniques are described in the literature to reduce the effects of multipath. This article will describe a method of simulation to calculate the effects of multipath on tracking errors at millimeter-wave frequencies. The method is extended to examine the effectiveness of off-axis tracking in a multipath environment. The simulation results are presented for different angles of off-axis tracking. Experimental results are also presented for off-axis tracking at Ka-band (26.5 to 40 GHz).



1. In a monopulse radar system, multipath propagation means that the return wave from the target takes two separate paths (multipath)—direct and reflected.

MONOPULSE RADAR

Monopulse tracking systems are superior to sequential lobing and conical scanning and are used generally for better angular accuracy.[2] Monopulse is the term used to describe a method by which radar-tracking information is derived from the same radar return. A monopulse radar antenna generates a set of three radiation patterns simultaneously in space to achieve an accurate estimate of a target location at two orthogonal coordinates.



2. This is the geometry of the antenna position and path of the target used to develop the theoretical simulations and practical experiments.

The patterns are the sum (Σ), delta elevation (Δ_1), and delta azimuth (Δ_z). The Σ beam has maximum gain along the boresight axis. The Δ_1 beam produces a null response along the azimuth plane centered on the boresight axis. The signal increases with increasing angle from the boresight axis in the elevation plane. The ΔA_z produces a null response along the elevation plane centered on the boresight axis and the signal increases with increasing angle in the azimuth plane.

A function called the monopulse ratio is defined as the difference-channel vector divided by the sum-channel vector signal or Δ/Σ. The difference-channel signal is in phase on one side of the boresight, but is antiphase on the other side. So the monopulse ratio provides the measurement of the angle of arrival of an electromagnetic (EM) wave as well as its direction.

Figure 1 shows the simplified geometry of multipath propagation through monopulse antenna-radiation patterns. A wave can propagate to the antenna from the target through two separate paths—a direct path and a reflected path. The reflected signal is composed of two components. One is the specularly reflected component and the other is a diffused reflected component. The specular component can be predicted in terms of amplitude and phase, where the diffused component is random in behavior. The latter's amplitude and phase can be statistically approximated.

A TRACKING PROBLEM

A low-flying target is to be tracked in a transponder mode over water at Ka-band frequency. Tracking is to be carried out with a monopulse radar system. But tracking errors occur due to reflection from the water. Various techniques are described in the literature to reduce the effects of multipath and to make the system acceptable within some limits. These include off-axis tracking, frequency agility, signal-processing techniques, and asymmetrical monopulse patterns.[1]

A mathematical model known as TRINS1 was developed to calculate the received signals after multiple reflections into the sum and difference channels of the monopulse system. The resultant sum and difference signals are used to calculate the monopulse ratio. A moving target is assumed to be the source of radiation. The monopulse antenna is assumed to be fixed. The variation of monopulse ratio (monopulse errors) are calculated with and without considering multipath with time and range. These parameters are calculated for various off-axis angles of the antenna.

THE MATHEMATICAL MODEL

The mathematical model and computer programming can be broken down into six steps.

1. Mathematical modeling of the antenna's radiation patterns.
2. Mathematical modeling of the target's position with time and range. Calculation of direct ray and reflected ray angles, distances, and relative phases.
3. Calculation of received signal parameters from sum and difference channels of the monopulse.
4. Calculation of monopulse ratio and estimation of angular errors for direct signals and resultant signals.
5. Passing the error signal through the filters used in the system.
6. Repeating the calculations for various off-axis angles and representing the data in graphical form.

A multimode corrugated horn is the basic structure used to generate the monopulse radiation patterns. A mathematical program has been developed to generate the monopulse patterns. These radiation patterns are used to simulate the received powers from the transponder signal. Figure 2 shows the geometry of the antenna position and path of the target (a moving target is assumed). The specular-reflection coefficient, ρ, is calculated with the following equations:[1]

$$\rho = \rho_0 \rho_s \qquad (1)$$

where:

ρ_0 = the Fresnel reflection coefficient for a smooth surface, and ρ_s = the specular scattering coefficient.

There are two values for ρ_0. For vertical polarization, ρ_{0v}, is given by:

$$\rho_{0v} = \frac{\varepsilon_c \sin\psi - \left(\varepsilon_c - \cos^2\psi\right)^{\frac{1}{2}}}{\varepsilon_c \sin\psi + \left(\varepsilon_c - \cos^2\psi\right)^{\frac{1}{2}}} \qquad (2)$$

For horizontal polarization, ρ_{0h}, is given by:

$$\rho_{0h} = \frac{\sin\psi - \left(\varepsilon_c - \cos^2\psi\right)^{\frac{1}{2}}}{\sin\psi + \left(\varepsilon_c - \cos^2\psi\right)^{\frac{1}{2}}} \qquad (3)$$

The specular scattering coefficient, ρ_s, is determined from:

$$\rho_s^{\,2} = \exp\left[-\left(\frac{4\pi\,\sigma_h \sin\psi}{\lambda}\right)^2\right] \qquad (4)$$

The complex dielectric constant, ϵ_c, is given by:

$$\varepsilon_c = \frac{\varepsilon}{\varepsilon_0} - j\,60\,\lambda\,\sigma \qquad (5)$$

For Eqs. 2 through 5, the following definitions apply:

$\epsilon/\{\epsilon_0$ is the relative dielectric constant of the reflecting medium, and σ is its conductivity. ψ is the grazing angle (Fig. 1), σ_h is the root-mean-

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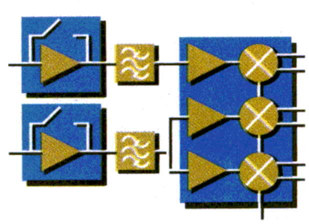
Performance Table

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

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

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



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square (RMS) value of the sea-wave height, and λ is the wavelength of the EM wave.

Direct and reflected signal strengths received by the sum and difference channels of the antenna are calculated using the radar-range equation and proper values of reflection coefficients. These values are given by the following equations:

Δ_d = the direct signal strength received by the elevation difference channel.

$$\Delta_d = \frac{P_t\, G_t\, G_{r\Delta\theta}}{4\,\pi R^2} \quad (6)$$

Δ_r = the reflected signal strength received by the elevation difference channel.

$$\Delta_r = \frac{P_t\, G_t\, G_{r\Delta\psi}\, \rho^2}{4\,\pi\left(R_1 + R_2\right)^2} \quad (7)$$

Σ_d = the direct signal strength received by the sum channel.

$$\Sigma_d = \frac{P_t\, G_t\, G_{r\Sigma\theta}}{4\,\pi R^2} \quad (8)$$

Σ_r = the reflected signal strength received by the sum channel.

$$\Sigma_r = \frac{P_t\, G_t\, G_{r\Sigma\psi}\, \rho^2}{4\,\pi\left(R_1 + R_2\right)^2} \quad (9)$$

Therefore, the monopulse ratio or error signal, ϵ_r, is defined by combining Eqs. 6 through 9 to yield:

$$\varepsilon_r = \frac{\Delta_d + \Delta_r\, e^{j\phi r}}{\Sigma_d + \Sigma_r\, e^{j\phi r}} \quad (10)$$

where:

ϕ_r = the relative phase between the direct and reflected rays,

P_t = the transmitted power of the transponder on the target,

G_t = the gain of the antenna used with the transponder,

$G(_r\,\Delta\Theta)$ = the gain of the receiving monopulse antenna for the difference channel in the Θ direction,

$G(_r\,\Delta\,\psi)$ = the gain of the receiving monopulse antenna for the difference channel in the ψ direction,

$G(_r\,\Sigma\,\Theta)$ = the gain of the receiving monopulse antenna for the sum chan-

nel in the Θ direction, and

$G(_{r}\Sigma(\psi)$ = the gain of the receiving monopulse antenna for the sum channel in the ψ direction.

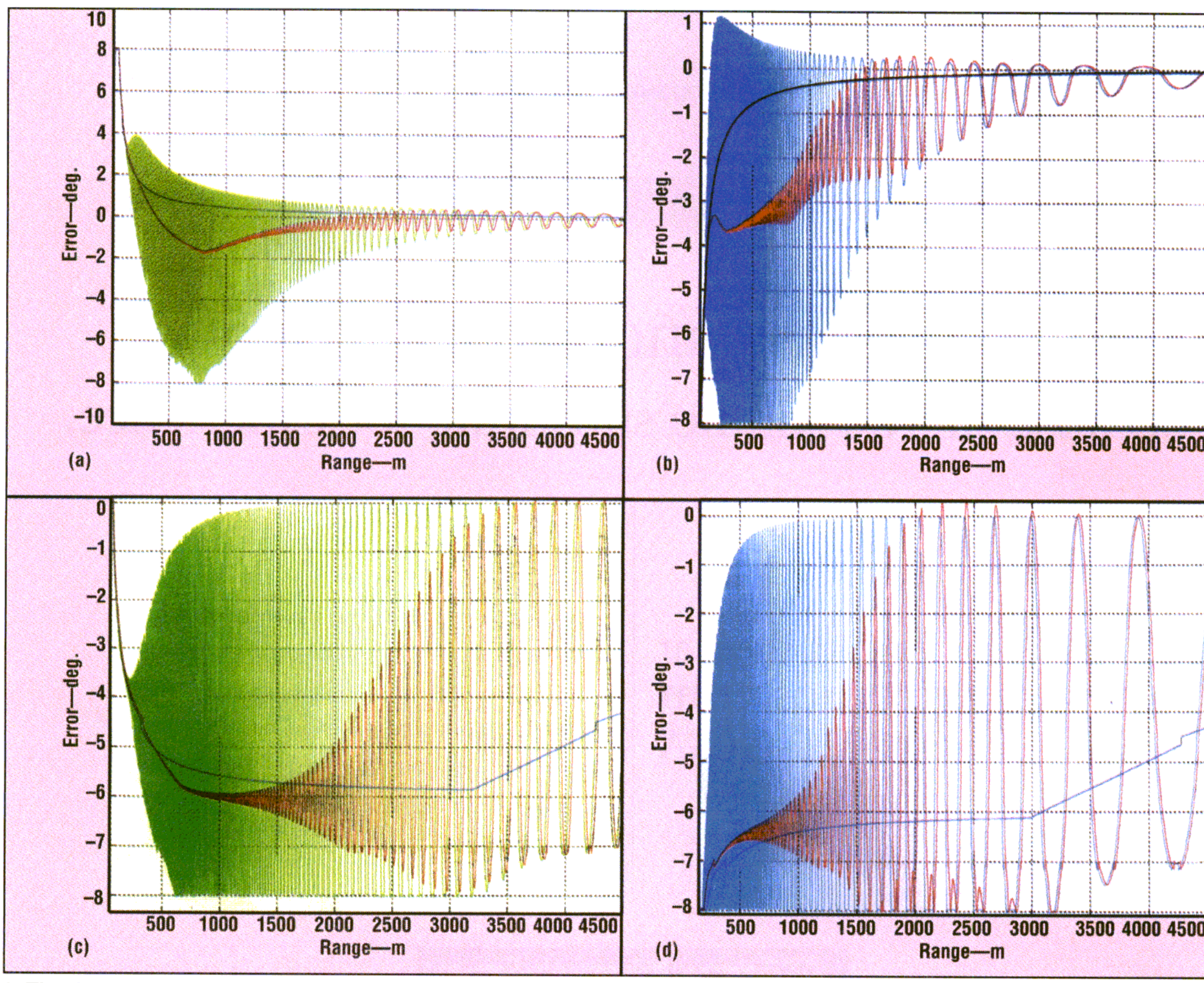
COMPARING RESULTS

In the theoretical case, target position is calculated every 1 ms and an error signal is calculated. Errors are passed through the filters in the system. Figures 3a, b, c, and d show the theoretical variation of the error signal with time and range. Figures 3a and b show these errors for the no off-axis case with the height of the transponder at 22 m and 7 m, respectively. Figures 3c and d show the errors for an off-axis of 0.75 of 3 dB of beamwidth, also with transponder heights of 22 m and 7 m, respectively.

An actual target was flown under the conditions shown in Fig. 2. A monopulse radar system generated the elevation angular errors. The experimentally recorded errors are shown in Figs. 4a and b. Figure 4a illustrates the error signals for the no off-axis case at heights varying at 22 m and Fig. 4b shows the errors for an off-axis of 0.75 of 3-dB beamwidth and heights varying around 7 m. Figure 4 shows curves for both of the actual measurements—pink and black—and curves generated theoretically—blue and red.

As these figures illustrate, at close ranges—0 to approximately 2000 m—the angle between the direct and reflected signals is comparatively large, which makes an estimation of the angle of arrival with multipath to be error prone. The difference between the real angle and the estimated angle is called the bias due to multipath. As the distance (range) to the target increases, the angle between the direct and reflected signals decreases, which decreases the multipath bias.

At short range, the rate of change-of-path difference between the direct and reflected signals is large, making the variation of the monopulse error signal very high. In Fig 4a, black shows how the experimentally measured error is high at short range (–1 to –5 deg.) up to 2000 m. Note that



3. The theoretical results for normal (on-axis) operation at a height of 22 m are shown (a). The blue curve is the expected error without multipath, and green is the calculated error with multipath. The same parameters are shown in (b), but for a height of 7 mm. Off-axis curves show the variation of the error signal at 0.75 percent of the 3-dB beamwidth of the antenna. The curves shown are the same parameters as in 3a and b for heights of 22 m (c) and 7 m (d).

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Performance Table

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HMC313	DC - 6.0 DC - 6.0	5.0 7.0	47 82	13.6 19.3	28.9 33.0
HMC314	0.7 - 4.0	5.0	185	18.0	29.5
HMC315	DC - 7.0 DC - 7.0	5.0 7.0	31 50	12.0 16.5	26.8 31.0
HMC323 & HMC324	DC - 3.0	7.5	57	16.8	30.0
HMC326MS8G	3.4 - 3.6	5	125	24	36.0

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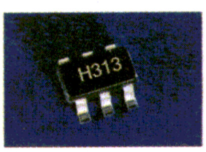

HMC313

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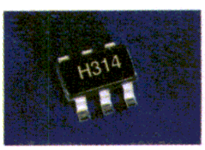
10 dB GAIN



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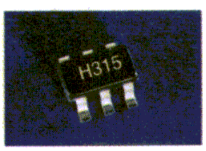

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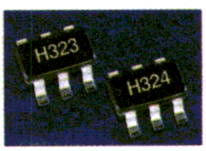

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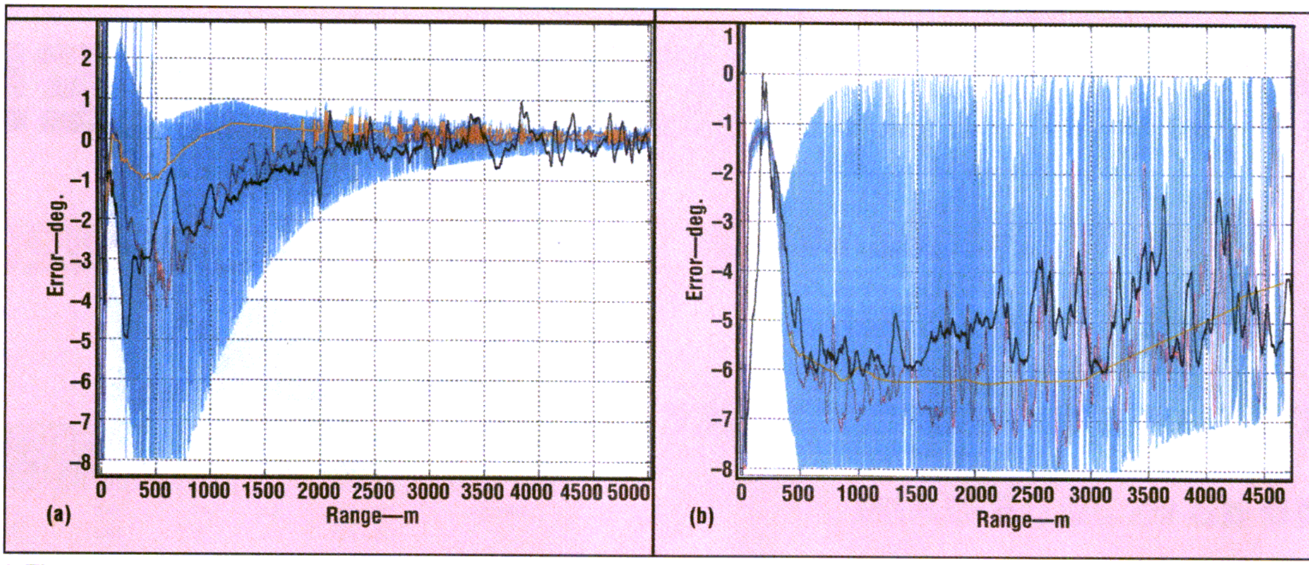

4. The experimental results that can be compared to the theoretical results of Fig. 3 are illustrated. A height of 22 m, and on-axis operation is shown in (a) while a height of 7 m and 0.75 percent of the 3-dB beamwidth is provided in (b). The black curves in (a) and (b) represent the experimentally measured error signal.

this curve follows the general trend of blue, the theoretically calculated error signal with multipath. Also note that target height makes a significant difference in the error. Figure 4a uses a target height of 22 m, while Fig. 4b uses a height of 7 m.

If the monopulse error signal is passed through a lowpass filter at short range, the filtering action is effective at providing a slowly varying output. However, at long range, where the rate of change-of-path difference is low, the error signal varies slowly. Thus, the filtering action of the lowpass filter is less effective.

At long range, the received signal strength gradually begins to fall below the sensitivity of the monopulse radar-tracking receiver (Rx), so the variation in amplitude of the monopulse errors decreases.

In the off-axis case (Figs. 3c and d, and 4b), the direct signal is received from a zone of higher gain in the antenna's radiation pattern compared to the normal case. Hence, the reflected signal is received from a zone of lower gain in the radiation pattern. This has the effect of reducing multipath bias in off-axis tracking. Experimental, as well as theoretical results prove that off-axis tracking improves the angles of estimation at short range—up to approximately 1500 m—compared to normal tracking. Compare Fig. 4a with 4b, and Fig. 3a with 3c. ••

Acknowledgement

The authors are grateful to Dr. Sivathanu Pillai and Mr. K.V.S.S. Prasada Rao for their continuous inspiration for improving our results. We also thank Mr. P. Chottopadhayay, Cmde. B. Kannan, and Mr. R. Das for their continuous help in pursuing the project.

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OFDM for Wireless Multimedia Communications

Richard van Nee
Ramjee Prasad

Orthogonal frequency-division multiplexing (OFDM) is a communications technology common to wireless local-area networks (WLANs), but it is also used in digital audio broadcasting and in some video applications. OFDM for Wireless Multimedia Communications is a single source to help readers understand this technology and how it is used for proper bandwidth in modern communications systems. The text provides design guidelines and a base for engineers to assess the performance of wireless OFDM systems. The book describes the OFDM-based WLAN standards, and examines the basics of direct-sequence and frequency-hopping code-division multiple access (CDMA). It also examines OFDM applications, including wireless asynchronous-transfer-mode (ATM) communications systems.

Chapter 1 presents a general introduction to wireless broadband multimedia-communication systems (WBMCS), multipath propagation, and the history of OFDM. Other subjects include standardization and frequency bands with a summary of European advanced-communications-technologies (ACT) projects, along with a comparison of IEEE and high-performance-radio local-area-network (HIPERLAN) standards. Other topics include the safety of microwave and millimeter-wave sources, infrared (IR) exposure, and multipath propagation.

Chapter 2 begins with an introduction to OFDM principals. It reviews the generation of subcarriers modulated by phase-shift keying (PSK) or quadrature amplitude modulation (QAM). Other subjects include the choice of OFDM parameters, including bit rates, delay spreads, and bandwidths, along with Fast Fourier transforms (FFTs) and inverse-FFT (IFFT) techniques.

Chapter 3 explains how coding and interleaving can be used to mitigate the effects of frequency-selective fading channels. QAM is also introduced as an appropriate modulation technique for OFDM subcarriers.

Synchronization of the symbol clock and carrier frequency is the subject of Chapter 4. Topics include OFDM sensitivity to synchronization errors and packet-transmission synchronization.

Chapter 5 subjects include coherent detection, one- and two-dimension (2D) channel estimators, decision-directed channel estimation, differential amplitude and phase-shift keying (DAPSK), and differential detection in the time and frequency domain.

Peak-to-average-power (PAP) ratio of OFDM is the subject of Chapter 6. Topics include PAP distribution ratio, methods to reduce PAP ratios, clipping and peak windowing, coding, scrambling, and peak cancellation. Other issues include PAP reduction codes, generating complementary codes, determining the number of orthogonal subsets, and symbol scrambling.

Chapter 7 explains the basics of direct-sequence and frequency-hopping CDMA and is included to prepare the reader for combination applications of OFDM and CDMA. Chapter 8 describes the advantages and disadvantages of multicarrier-CDMA (MC-CDMA) systems.

Orthogonal frequency-division-multiple-access (FDMA) and frequency-hopping CDMA are the subjects of Chapter 9. A review illustrates how OFDM and frequency hopping can be combined to achieve a multiple-access system with similar advantages as direct-sequence CDMA.

Chapter 10 describes various applications for OFDM systems. Subjects include digital audio broadcasting, digital video streaming, wireless ATM, and the IEEE 802.11 WLANs, as well as ETSI applications and broadband-radio-access-network (BRAN) standards. (2000, 260 pp., hardcover, ISBN: 0-89006-530-6, $95.00.) **Artech House, 685 Canton St., Norwood, MA 02062; (800) 225-9977, (781) 769-9750, FAX: (781) 769-6334, e-mail: artech@artechhouse.com.**

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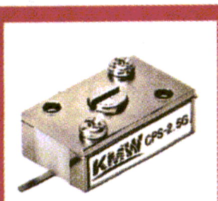
Dimension (inch)	A type : 1.496*1.102*0.457 B type : 1.225*1.102*0.457		



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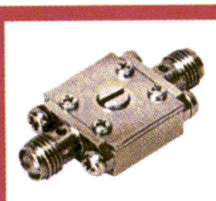

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VSWR (Max.)	1.3:1	1.3:1	1.3:1	1.25:1	1.25:1	1.25:1
Incremental Phase Shift	30 degree min. @ 2GHz			35 degree min. @ 2GHz		
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Evaluate Noise In GSM PAs

This article describes a method for evaluating noise in GSM PAs that is based on the two-tone approach and statistical analysis in the frequency domain.

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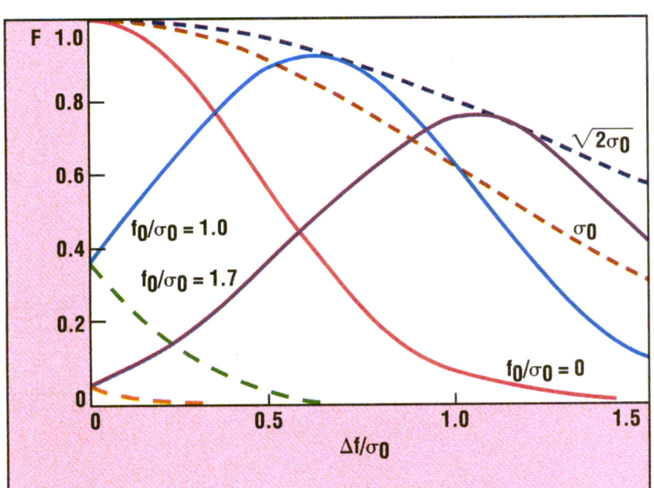
GLOBAL System for Mobile Communications (GSM) is becoming ever more popular in the world, due mainly to the advantages of the Gaussian-shaped signals involved. Usually, the Gaussian-like GSM signals have a constant envelope, making them more robust and resistant to the parasitic out-of-channel spectral regrowth than non-constant-envelope, code-division-multiple-access (CDMA)-like signals. However, due to nonlinearity in power amplifiers (PAs), Gaussian-like signals do not perform as well as nonconstant-envelope, "flat-power-spectrum," CDMA-like signals with respect to the growth of in-channel noise. Moreover, one cannot perform direct, in-channel noise measurement on GSM due to the presence of a useful signal.

This article presents a method of evaluating the growth of in-channel noise caused by the PA in GSM systems. The method is based on the two-tone intermodulation-distortion (IMD) approach and statistical analysis of signal in the frequency domain. It discovers the frequency offset at which one must measure different-order IMD products to evaluate the noise. By controlling the IMD at specified frequencies, it is possible to minimize the total in-channel noise power. Baseband matching must be considered on the first order for PA tuning.



1. This graph shows the result of weighting coefficients $F_3(f_0)$ for two different frequency offsets.

Consider a statistical signal with a Gaussian average-power spectrum that is given by the following equation:

$$P(\omega) = P_0 e^{\frac{(\omega-\Omega)^2}{\beta^2}} \quad (1)$$

The value P_0 determines the maximum power-spectrum density at a frequency $\omega = \Omega$, and coefficient β defines the spectrum dispersion:

$$\sigma^2 = P_0\sqrt{\pi}\beta \quad (2)$$

The value σ can be easily found out by knowing that $\alpha = B_bT$ of a Gaussian filter used in GSM systems where B_b is the filter bandwidth, and T is the period of the baseband signal:

$$\sigma_0 \approx \frac{1}{1.77} B_b = \frac{1}{1.77} \times \frac{\alpha}{T} \quad (3)$$

If the envelope of a signal and the average power P_{av} are constants, the power-spectrum density represents the probability density *g(f)* at which the spectral component having average power P_{av} appears at the particular frequency *f*. The probability of a spectral component having power P_{av}

appearing at the frequency f_1 is equal to $g(f_1)df_1$. And, at the frequency f_2, it is equal to $g(f_2)df_2$. If this signal is passing through a nonlinear element, these simultaneous power components at frequencies f_1 and f_2 create instantaneous IMD products with the probability $g(f_1)g(f_2)df_1df_2$. The frequency spacing $f_1 - f_2$ determines the frequency offsets f_0 at which the different orders' IMD products appear. If one denotes the *n*-order IMD products as IMD^0_n and drives the PA's input with two continuous-wave (CW) signals with equal carrier levels, one can define the output power spectrum shape as:

$$\begin{aligned} P_{out}(f_0) &= P_{in}(f_0)G(f_0) + \sum_{n=2}^{\infty} IMD_n^0(f_0)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(f_1)g(f_2)df_1df_2 \\ &= P_{in}(f_0)G(f_0) + \sum_{n=2}^{\infty} IMD_n^0(f_0)F_n(f_0) \end{aligned} \quad (4)$$

where:

$G(f_0)$ = the gain of the PA at a certain input signal level, (for the frequencies of interest $n=2m-1$ and m is an integer > 2), and f_0 is the fixed frequency offset from the center frequency of a spectrum. The function $F_n(f_0)$ is the weighting function for each order of IMD product considered, specified at a fixed input-drive level. The total noise spectral component at frequency f_0 is comprised of the IMD products defined in Eq. 4 and the proper noise of a PA (without input signal) with a spectral density of N_0 is:

$$N(f_0) = IM_3 + IM_5 + IM_7 + \ldots + N_0 \quad (5)$$

The total in-channel noise power is:

$$N_{\Sigma} = \int_{-\Delta f/2}^{\Delta f/2} N(f_0)df_0 \quad (6)$$

The limits $\Delta f/2$ and $-\Delta f/2$ determine the channel bandwidth encountered from the center frequency.

The weighting function $F_n(f_0)$ in Eq. 4 comprises the self-convolution procedures in the frequency domain. The self-convolution of a Gaussian signal is also a Gaussian one. As an example, Fig. 1 shows the result of the appearance of weighting coefficients $F_3(f_0)$.

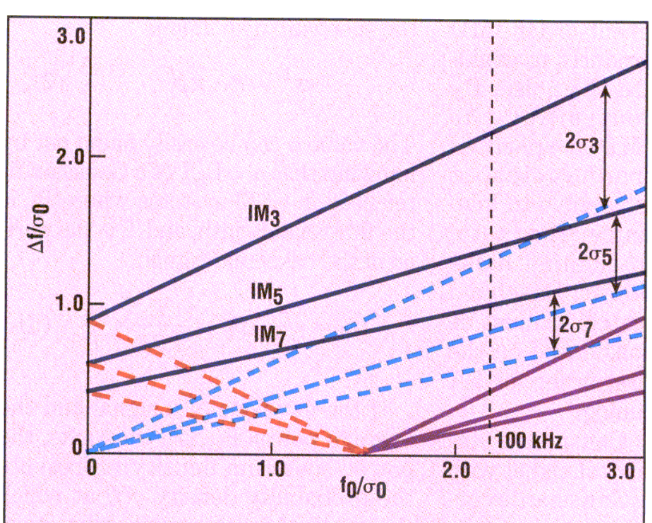
$F_n(f_0)$ is equal to the square restricted by the appropriate curve and x-axis. The term Δf is the frequency spacing at which IM_3 is defined. Figure 1 presents only one half of the spectrum. The noise-power spectral component at a fixed frequency offset is created by two-tone IMD products from the different frequency spacing. For each IMD order, the root-mean-square (RMS) deviation of the frequency spacing is determined by the following:

$$\sigma_3 \approx 0.445\sigma_0 \approx \frac{e}{2\times 3}\sigma_0;$$
$$\sigma_5 \approx \frac{2}{n+2}\sigma_0 = \frac{2}{7}\sigma_0;$$
$$\sigma_7 \approx \frac{2}{n+3}\sigma_0 = \frac{2}{10}\sigma_0; \quad (7)$$

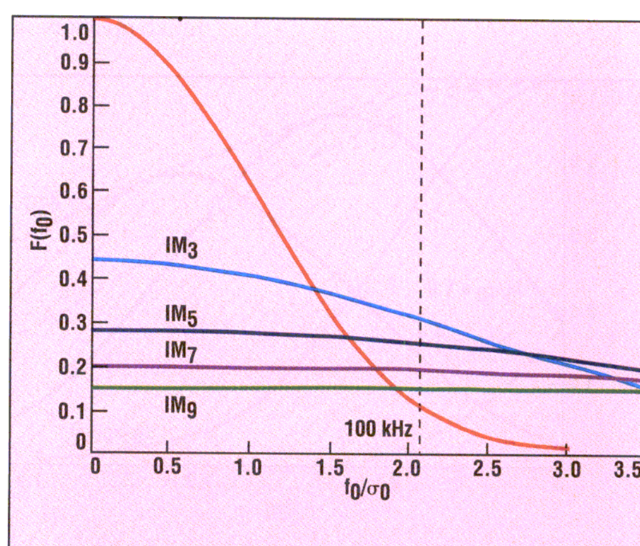
The frequency spacing at which the IMD contribution to the noise power is maximum at the specified frequency offset can be determined by using the following:

$$\Delta f_3\left(IMD_3^{max}\right)/f_0 = \frac{3}{n+2} = \frac{3}{5}\ for\ IM_3;$$
$$\Delta f_5\left(IMD_5^{max}\right)/f_0 = \frac{3}{n+3} = \frac{3}{8}\ for\ IM_5;$$
$$\Delta f_7\left(IMD_7^{max}\right)/f_0 = \frac{3}{n+4} = \frac{3}{11}\ for\ IM_7 \ldots \quad (8)$$

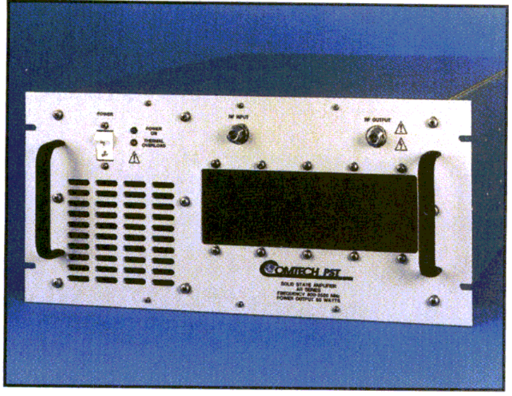
Note that one must measure IMD (with equal two-tone drive levels) at 4-dB back-off from the total output-power level. (Remember that the maximum spectral density of the Gaussian



2. In this graph, the dashed lines show the two-tone frequency spacing versus the frequency offset. The graph also shows the power margins $\pm 2\sigma_n$.



3. This graph shows the weighting functions $F_n(f_0)$ for several orders of IMD.



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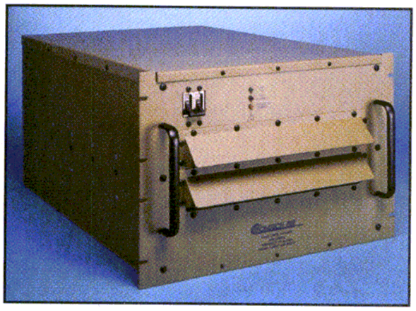

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signals is 4 dB less than the total power.) The dashed lines in Fig. 2 show the frequency spacing in Eq. 8 versus the frequency offset. The figure also shows margins of $\pm 2\sigma_n$ that comprises more than 95 percent of the total power determined by the second term in Eq. 4 if the variations of IMD through Δf are absent. For the Gaussian filter with $\alpha = 0.3$ specified in the GSM standard,[1] $\sigma_0 \approx 45.9$ kHz. In this case, one must measure IMD at the following frequency spacings to evaluate the noise-power spectral component at the center frequency of a signal: 0 to 40.85 kHz for IM_3, 0 to 26.23 kHz for IM_5, 0 to 18.36 kHz for IM_7, etc. At other frequencies of a signal, one must choose the other margins. As an example, at ±100-kHz offset from the center frequency, one must define IMD at the following frequency spacings: 19.15 to 100.85 kHz for IM_3; 11.27 to 63.73 kHz for IM_5; 8.91 to 45.63 kHz for IM_7, etc. Special care should be taken for frequency spacings at which the noise power may be maximum, such as 60 kHz for IM_3, 37.5 kHz for IM_5, 27.27 kHz for IM_7, etc.

The weighting functions $F_n(f_0)$ in Eq. 4 are presented in Fig. 3. Their shape is also Gaussian with different dispersions, calculated as:

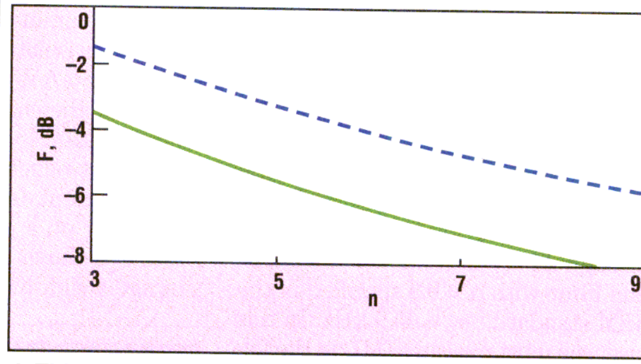
$$\sigma_{33} = \left|(n-2)\sqrt{2}+1\right|\sigma_0 = \left(\sqrt{2}+1\right)\sigma_0 \text{ for } IM_3;$$

$$\sigma_{55} = \left|(n-3)\sqrt{2}+1\right|\sigma_0 = \left(2\sqrt{2}+1\right)\sigma_0 \text{ for } IM_5;$$

$$\sigma_{77} = \left|(n-4)\sqrt{2}+1\right|\sigma_0 = \left(3\sqrt{2}+1\right)\sigma_0 \text{ for } IM_7 \ldots \qquad (9)$$

The maximum values of each IMD-related noise-power spectral component occur at the center frequency of a signal and they are related to the carrier-power maximum spectral density by the rule of Eq. 7. This is in contrast to "flat-spectrum," CDMA-like signals, where the maximum noise-spectral density occurs at the channel margins.

Assuming the constancy of IMD products through the frequency spacings previously discussed, one can conclude that the in-channel noise-power distribution is not additive white Gaussian noise (AWGN). It decreases slightly at the channel margins, especially for the IM_3-related noise power. One can introduce an average weighting coefficient for each IMD order, depending on a channel bandwidth. Figure 4 shows the maximum and average weighting coefficients for the full 200-kHz GSM channel bandwidth. One can conclude that the CDMA-like signals are more resistant to the in-channel noise growth imposed by the PA's nonlinearity than the Gaussian signals. This is due to the different spectrum statistics for both cases. Remember that for out-of-channel spectral regrowth, the calculations reach an opposite conclusion.



4. This graph shows the maximum and average-weighting coefficients for the full 200-kHz GSM channel bandwidth.

The weighting functions in Fig. 3 represent the "clipping" noise power imposed by a PA's nonlinear characteristic, and this noise is distributed through frequencies and divided on different terms. Usually, each term varies insignificantly throughout the frequencies of interest. The major portion of clipping power appears outside of the channel margins, contributing to spectral regrowth.

Taking into account the maximum values of the noise-spectral components placed at the signal's center frequency (Fig. 3), one should consider PA baseband-matching networks starting from near-zero frequencies. It is evident that for Class AB and Class B PAs, the IMD-related in-channel noise power is usually higher than for Class A over almost the entire power range. However, at mid- and high-power levels close to saturation, the AB and B amplifiers can have a slight improvement in in-channel noise level compared with Class A amplifiers due to "sweet spot" operation.[4] But it is very difficult to get the "sweet spots" for several IMDs at a fixed power level and over the wide range of frequency spacing. Thus, the improvement in noise power is not as great as the improvement in the out-of-channel adjacent-channel-power reduction (ACPR) at a fixed frequency offset.

At the 4-dB backoff used for the method proposed here, it works for "slightly linear" PAs almost up to saturation for the total output power. In this case, the amplitude-modulation-phase-modulation (AM-PM) characteristic can be excluded from consideration.

Transient-response characteristics for pulsed operation are not included in the current analysis.

Indeed, for exact results, the multiple self-convolutions of a signal described in Eq. 4 should be considered. However, the simplified approach presented here takes into account the first convolution procedure, and Eq. 4 represents the main contribution of IMD to noise growth.●●

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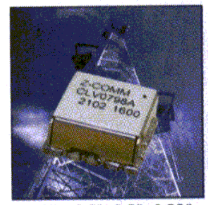
CLV0950E	865	1035	1-10	27	-114	-11	5.0	24
CLV0915A	902	928	0-4	17	-108	-30	3.0	10
CLV1085E	1050	1086	0.5-4.5	21	-112	-20	5.0	20
CLV1385E	1370	1400	0.5-4.5	18	-110	-20	5.0	20
CLV1550E	1500	1600	0.5-5.0	44	-106	-35	5.0	22
CLV2465E	2436	2496	1-4	26	-107	-20	5.0	25



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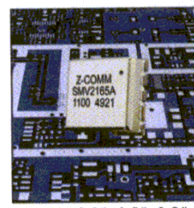
SMV0162A	125	200	0.7-8.3	12	-100	-6	5.0	36
SMV1570L	1540	1600	0.5-2.5	128	-90	-15	2.7	9
SMV2165A	2118	2218	0-3	148	-91	-10	3.3	16
SMV2390L	2290	2485	0-4	116	-90	-11	5.0	16
SMV2660L	2620	2700	0.5-4.5	90	-91	-17	5.0	21



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USSP2330	2300	2360	0.5-2.5	0±3	-83	-15	2.7	8

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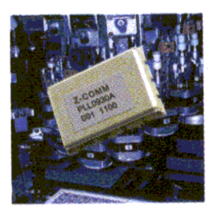
PLL0210A	200	230	100	0.50	-105	3.5±2.5	+5	25
PLL0930A	900	960	100	0.75	-101	3±2	+5	40
PLL1260A	1230	1290	1000	0.75	-102	1±2	+5	40
PLL1456A	1420	1490	1000	0.75	-103	1±2	+5	40
PLL2710A	2670	2740	1000	1.25	-98	1±4	+5	30



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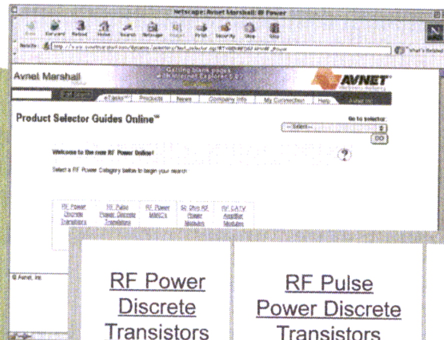

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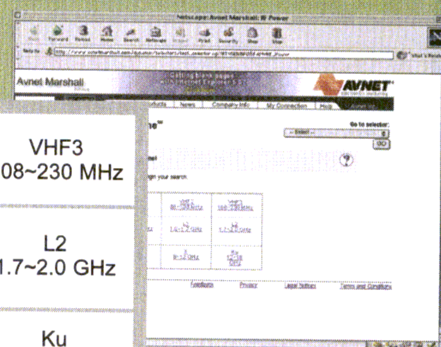
UHF1 230~512 MHz	UHF2 512~1000 MHz	L1 1.0~1.7 GHz	L2 1.7~2.0 GHz
S 2.0~4.0 GHz	C 4~8 GHz	X 8~12 GHz	Ku 12~18 GHz



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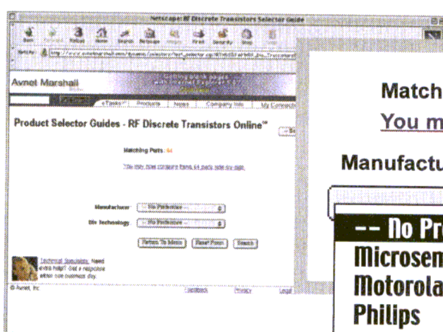

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- Motorola
- Philips
- STMicroelectronics

Die Technology:
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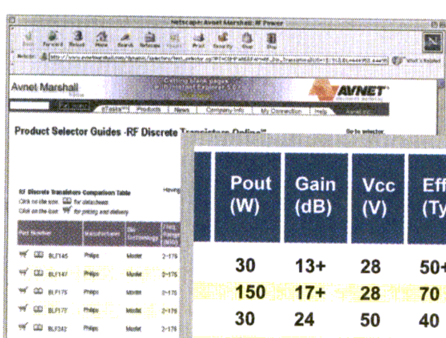
- LDMOS
- MOSFET



3. After finding the parts that match your selection criteria, the tool also allows for side-by-side comparisons of similar components:

Pout (W)	Gain (dB)	Vcc (V)	Eff. (Typ)%	RTHj-c (C/W)	Test Freq. (MHz)	Z	Class	Description	Pkg Style	Application
30	13+	28	50+	2.6	175	-	A/B	Comm Source	SOT123	FM Broadcast
150	17+	28	70	0.8	28/108	-	AB/B	Comm Source	SOT121	SSB/FM
30	24	50	40	2.6	28/108	-	A/AB/B	Comm Source	SOT123	SSB/FM
150	20	50	35+	0.8	28/108	-	AB/B	Comm Source	SOT121	SSB/FM
5	16	28	60	11	175	-	A/B	Comm Source	SOT123	FM Broadcast

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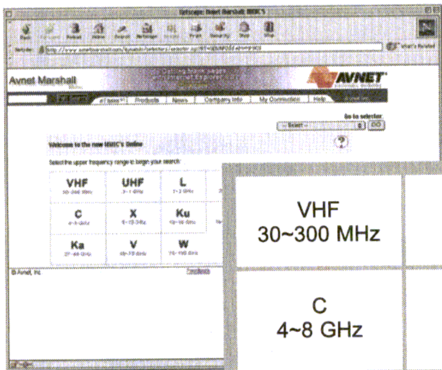

VHF 30~300 MHz	UHF .3 ~1 GHz	L 1~2 GHz	S 2~4 GHz
C 4~8 GHz	X 8~12 GHz	Ku 12~18 GHz	K 18~27 GHz
Ka 27~40 GHz	V 40~75 GHz	W 75~110 GHz	

① To begin, select the upper frequency range for your search:

Matching Parts: 6

You may now compare these 6 parts side-by-side

Manufacturer:

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- EIC
- Infineon
- Maxim
- Motorola
- Philips
- Stanford

Function:

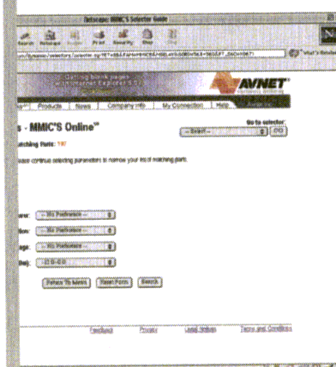
- -- No Preference --
- Gainblock
- LNA
- Power Amp
- Variable Gain Amp

Power (dBm):

- -- No Preference -
- -12.0~0.0
- 0.1~9.0
- 18.0~24.0
- 24.1~37.8
- 9.1~17.9

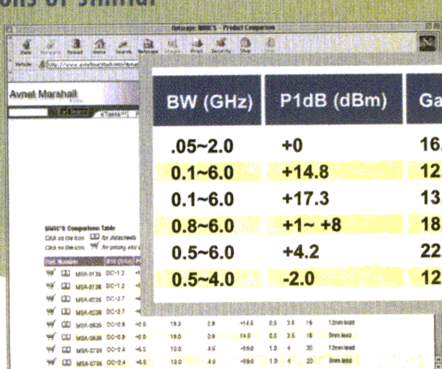
Package:

- -- No Preference --
- 100milstrip
- 145milstrip
- 200milstrip
- 70milstrip
- 85mil SM
- 85milstrip
- SO-8Cer
- SO-8Plstc
- SOT-143
- SOT-25
- SOT-343
- SOT-36
- SOT-363
- SOT-89
- chip



② To narrow the search, provide performance specifications and/or select a specific manufacturer:

③ After finding the parts that match your selection criteria, the tool also allows for side-by-side comparisons of similar components:



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

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Understand The Basics Of Microstrip Directional Couplers

This exposition on directional couplers offers designers the important theory, characteristics, and equations needed for microwave applications.

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DIRECTIONAL couplers play key roles in balanced and double-balanced mixers, balanced amplifiers, dividers, combiners, phase shifters, attenuators, modulators, discriminators, and feed networks in antenna arrays. A directional coupler is a reciprocal four-port device which provides two outputs when a signal is applied to its input. A hybrid network (or 3-dB directional coupler) is a special class of directional coupler in which the signals at the two output ports are equal.[1,2,3,4] The important characteristics of directional couplers are coupling, directivity, isolation, matching, insertion loss, phase and amplitude balance, power split, and bandwidth.

A directional coupler can have three different types of directivity (Fig.1).[4] In this article, port 1 is chosen as input to the coupler. An ideal directional coupler should have an infinite directivity. In an actual directional coupler, the isolated port is never completely isolated due to mismatching of terminations, losses, discontinues and manufacturing tolerances.

Phase balance is the relative phase difference of output waves. Quadrature (90 deg.) and in-phase-out-of-phase (0-deg. or 180-deg.) directional couplers are the most popular devices (Fig.1).

For the purposes of analysis and calculation, symmetry is a very important characteristic of directional couplers. There are three types of symmetry: complete (axes XX and YY), XX-axis partial symmetry, and YY-axis partial symmetry. Connections between types of symmetry, directivity and phase differences are shown in Fig 1.[4]

Parameters of actual directional couplers differ from the ideal due to the mismatching of termina-

Table 1: Characteristics of ring and two-branch hybrids

Parameters	Hybrid ring	Two-branch hybrid
Input (port1) reflection coefficient	$-\dfrac{2\Gamma_2\Gamma_3\Gamma_4 + \Gamma_2 + \Gamma_3}{2 + \Gamma_4(\Gamma_2 + \Gamma_3)}$	$-\dfrac{2\Gamma_2\Gamma_3\Gamma_4 + \Gamma_3 - \Gamma_4}{2 + \Gamma_2(\Gamma_4 - \Gamma_3)}$
Insertion loss (dB)	$20 \log \dfrac{\varphi_1}{\sqrt{2}(1 + \Gamma_2)(1 + \Gamma_3\Gamma_4)}$	$20 \log \dfrac{\varphi_2}{\sqrt{2}(1 + \Gamma_3)(1 + \Gamma_2\Gamma_4)}$
Coupling (dB)	$20 \log \dfrac{\varphi_1}{\sqrt{2}(1 + \Gamma_3)(1 + \Gamma_2\Gamma_4)}$	$20 \log \dfrac{\varphi_2}{\sqrt{2}(1 + \Gamma_4)(1 - \Gamma_2\Gamma_3)}$
Isolation (dB)	$20 \log \dfrac{\varphi_1}{(1 + \Gamma_4)(\Gamma_2 - \Gamma_3)}$	$20 \log \dfrac{\varphi_2}{(1 + \Gamma_2)(\Gamma_3 + \Gamma_4)}$
Directivity (dB)	$20 \log \dfrac{\sqrt{2}(1 + \Gamma_3)(1 + \Gamma_2\Gamma_4)}{(1 + \Gamma_4)(\Gamma_2 - \Gamma_3)}$	$20 \log \dfrac{\sqrt{2}(1 + \Gamma_4)(1 - \Gamma_2\Gamma_3)}{(1 + \Gamma_2)(\Gamma_3 + \Gamma_4)}$

tions, losses, discontinuities, as well as manufacture tolerances.

The two most popular ring directional couplers are of length $3/2\Lambda$ and Λ, where Λ is the guide wavelength. In the case of perfect input matching of the ring coupler of length $3/2\ \Lambda$ (Fig. 2a),

$$Y_1^2 + Y_2^2 = 1 \qquad (1)$$

where:

$Y_1 = z_0/z_1$ and $Y_2 = z_0/z_2$ are normalized admittances of the ring coupler (Fig. 2a).

The scattering matrix of the ring coupler is:[5]

$$[S] = -i \begin{bmatrix} 0 & Y_1 & Y_2 & 0 \\ Y_1 & 0 & 0 & Y_2 \\ Y_2 & 0 & 0 & -Y_1 \\ 0 & Y_2 & -Y_1 & 0 \end{bmatrix} \qquad (2)$$

It follows from Eq. 2 that arg $S_{12}/S_{13} = 0$ and arg $S_{42}/S_{43} = \pi$, i.e., the ring is an in-phase-out-of-phase directional coupler. Since $S_{14} = S_{23} = S_{32} = S_{41} = 0$ and $|S_{11}| = |S_{22}| = |S_{33}| = |S_{44}| = 0$, the four-port network will have ideal directivity of type II (Fig.1) and perfect matching.

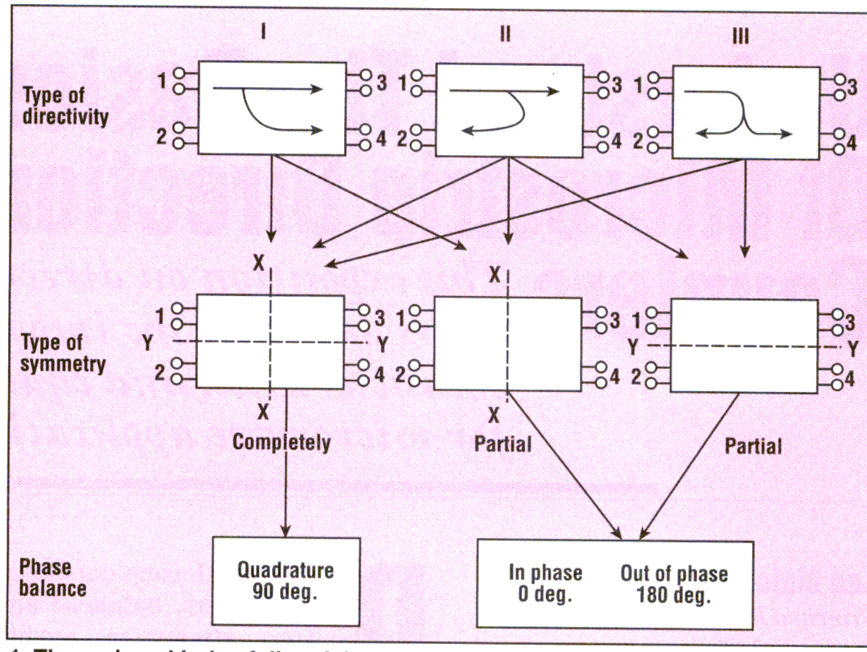
The simplest hybrid ring has equal segment admittances $Y_1 = Y_2$, which by substitution in Eq. 1, yields:

$$Y_1 = Y_2 = {}^{1}\!/\!_{\sqrt{2}} \qquad (3)$$

Usually the ring coupler is loaded by terminations at ports 1, 2, 3, and 4 with reflection coefficients $\Gamma_1, \Gamma_2, \Gamma_3, \Gamma_4$. Characteristics of ring couplers versus reflection coefficients are shown in Table 1, where:

$$\phi_1 = 2(1 + \Gamma_2\Gamma_3\Gamma_4) + (1 + \Gamma_4)(\Gamma_2 + \Gamma_3) \qquad (4)$$

Graphs of operating parameters of the hybrid ring versus termination reflection coefficients are shown in Fig. 3. Absolute values of reflection coefficients of terminations connected to adjacent ports (with respect to the input) mainly affect the input matching, while the isolation is determined by relative values of reflection coefficients. It should be noted that the previously discussed characteristics of the ring coupler do not account for power dissipated as a result of conductor, dielectric, and radiation losses.



1. The various kinds of directivity, symmetry and phase balance that a directional coupler can have are shown here.

Define the resistive losses in terms of normalized attenuation:

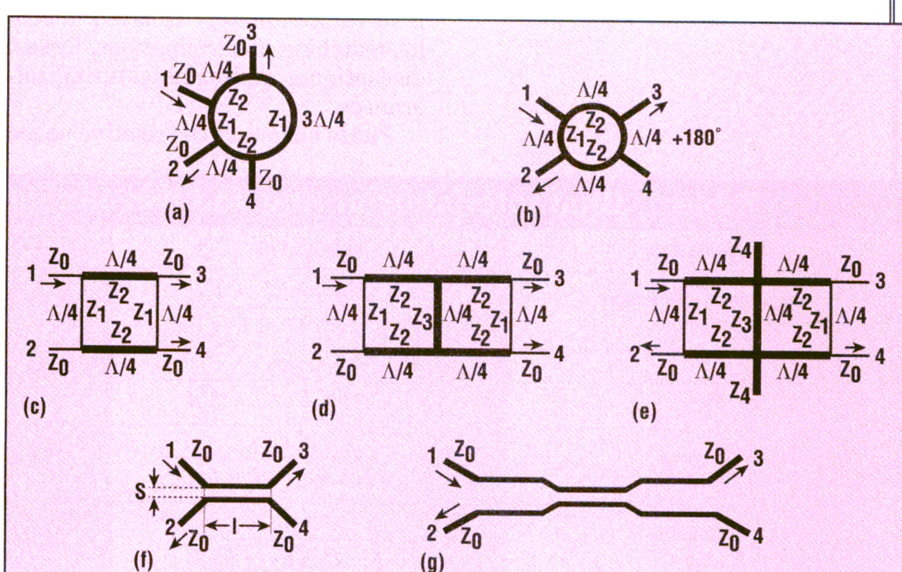
$$\alpha l = \frac{\pi}{Q\Lambda} l \ (Nepers) \qquad (5)$$

where:

$Q = \beta/2\alpha$ is the quality factor of a 1/4-wave resonator which is shorted at one end and $\beta = 2\pi/\Lambda$ is the phase constant.

Characteristics of planar ring couplers depend on transmission line losses (Table 2).[4,7]

Consider the influence of fabrication tolerances on parameters of the hybrid ring. The results of calculations of the hybrid ring on microstrip line with a relative permittivity of substrate $\epsilon = 9.8$ are provided in



2. Directional couplers fall into three basic architectures: ring couplers (a and b), branch couplers with either two or three branches (c, d, and e), and coupled lines (f and g).

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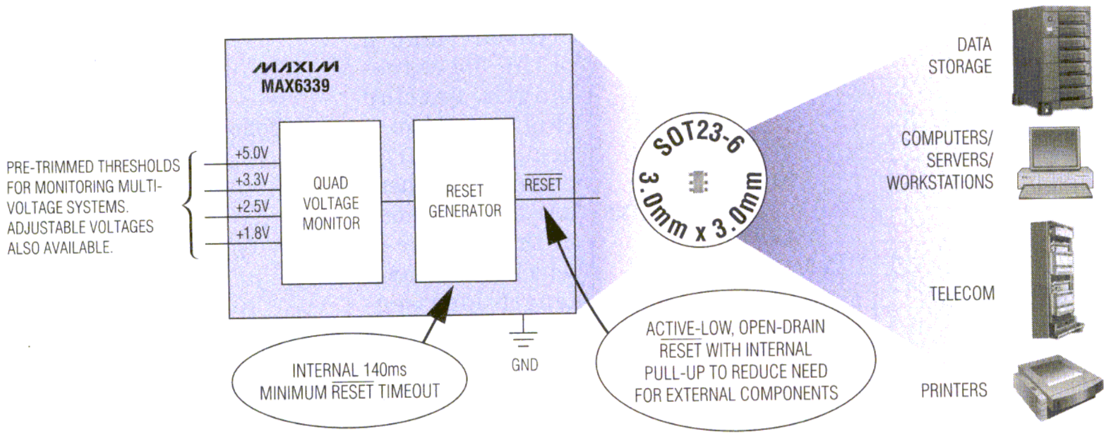

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MAX6339E/F	✓		✓	✓			1	E	F
MAX6339G/H	✓		✓		✓		1	G	H
MAX6339I/J	✓	✓		✓	✓		0	I	J
MAX6339K/L		✓		✓			2	K	L
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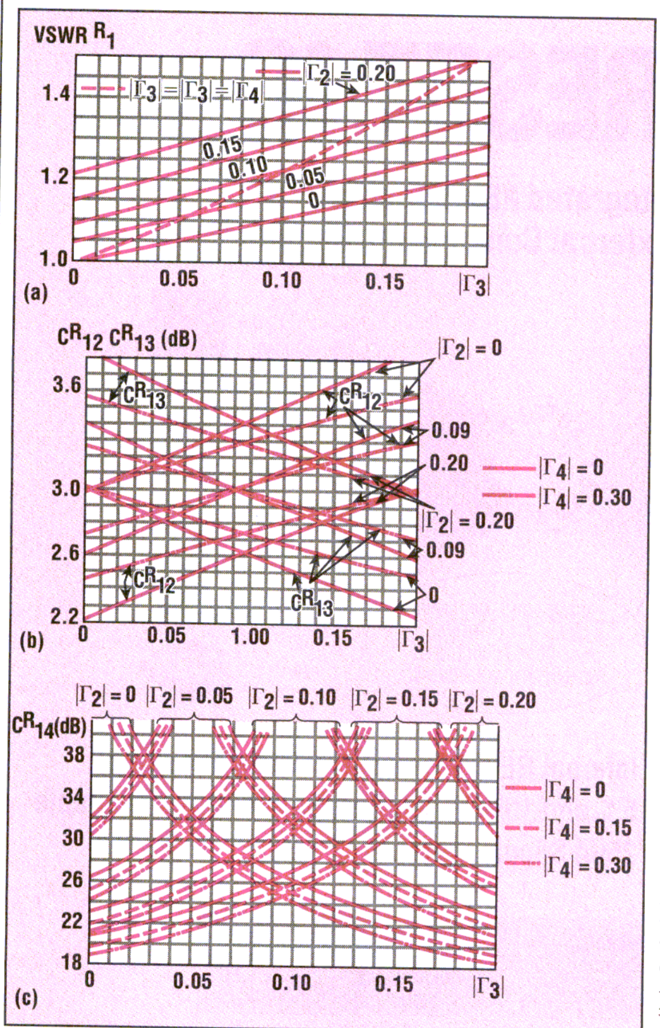

3. These curves show the matching (a), insertion loss (b), and isolation (c) of a hybrid-ring as a function of termination reflection coefficients ($|\Gamma_1$, $|\Gamma_2$, $|\Gamma_3$, and $|\Gamma_4$).

Fig. 4,[8]

$$\Delta X = \Delta W/\Delta h$$

where:

ΔW = the width of the microstrip line, and

h = the thickness of the substrate.

In the ring directional coupler, it is often necessary to account for the influence of discontinuities where the coupler connects to the input and output lines. This is most important for the high-frequency range when the size of the discontinuities is more than 1/10 the height of the guide wavelength. This type of discontinuity is equivalent to a T-connection. The characteristics of isolation, VSWR, and insertion losses of the hybrid ring with discontinuities and without discontinuities are shown in Fig. 5.[6,8]

The ring coupler of length $3/2\Lambda_0$ has the disadvantage of a narrow bandwidth (approximately 20 percent) due to the increased length of the 3/4-wavelength section (Fig. 2a). Also, it occupies a large circuit area. There are modifications of this coupler in which a 1/2-wavelength-long segment of the 3/4-wavelength section is replaced by a 1/4-wavelength section with a fixed 180-deg. phase shifter (phase inverter (Fig. 2b).[9] This Λ ring coupler has perfect isolation and is independent of frequency. The phase difference between the two output ports (0 deg. or 180 deg.) is also independent of frequency. In practice, bandwidth is equal to one octave.

The branch-line coupler (Fig. 2c to e) consists of a main line which is coupled to a secondary line by $\Lambda_0/4$-long branches spaced by $\Lambda/_0/4$.[10,11] The bandwidth of the branch-line coupler can be enlarged by increasing the number of branches.

Most commonly used is the two-branch coupler (Fig. 2c). In the case of perfect matching of input port 1, element S_{11} must be equal to zero which yields:

$$Y_1^2 = Y_2^2 - 1 \qquad (6)$$

where:

$Y_1 = 1/Z_1$, and $Y_2 = 1/Z_2$ are admittances normalized with respect to the input admittance Y_0.

A two-branch coupler is ideally matched if Eq. 6 and its scattering matrix is:

$$[S] = -\frac{1}{\sqrt{1 + Y_1^2}} \begin{bmatrix} 0 & 0 & i & Y_1 \\ 0 & 0 & Y_1 & i \\ i & Y_1 & 0 & 0 \\ Y_1 & i & 0 & 0 \end{bmatrix} \qquad (7)$$

It follows from Eq. 7 that:

$$S_{12} = S_{21} = 0$$
$$arg\left(\frac{S_{13}}{S_{14}}\right) = \frac{\pi}{2} \qquad (8)$$

which means that the two-branch coupler has an ideal directivity of Type 1 (Fig. 1) and that there exists an inherent 90-deg. phase difference between the output ports.

For the 3-dB coupler (hybrid), the normalized admittances of two segment lines are provided by:

$$Y_1 = 1, \; Y_2 = \sqrt{2} \qquad (9)$$

Isolation of the hybrid ring has wider bandwidth than the isolation of the two-branch hybrid. Two-branch hybrid isolation is usable only over approximately a 10-percent bandwidth.

Consider the parameters of a two-branch hybrid where the terminations have reflection coefficients Γ_1, Γ_2, Γ_3, Γ_4.[4] The main parameters of the two-branch hybrid are shown in Table 1, where:

$$\phi_2 = 2(1 + \Gamma_2\Gamma_3\Gamma_4) + (1 - \Gamma_2)(\Gamma_3 - \Gamma_4) \qquad (10)$$

The graphs of two-branch hybrid parameters versus modules of termination reflection coefficients are shown in Fig. 6.

Comparing parameters of the two-branch coupler with those of the ring coupler with mismatched terminations leads to the following conclusions. In the ring coupler, isolation is better, but matching is worse than in the two-branch coupler. If the output ports have identical terminations,

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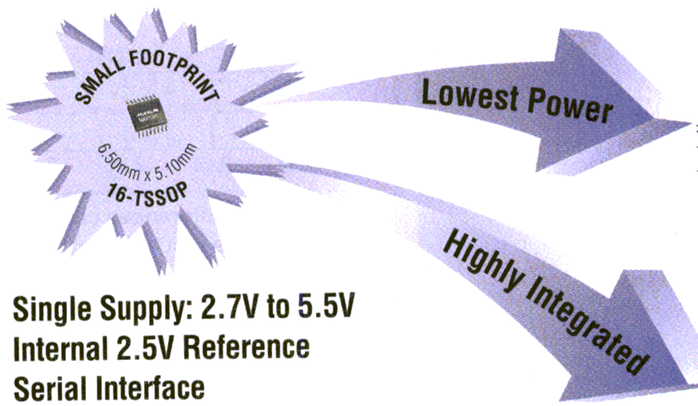

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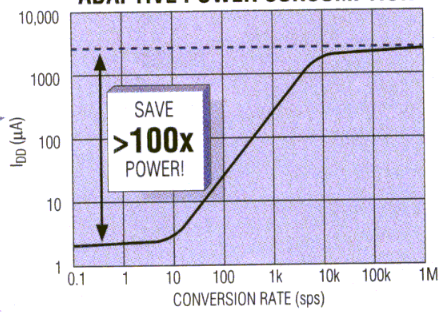

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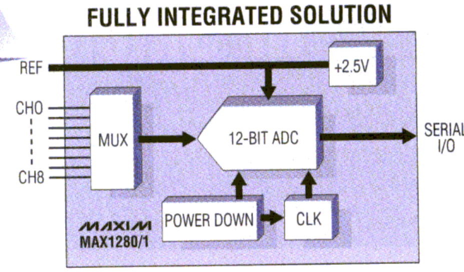

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MAX1281	12	8	300	Serial	+2.7 to +3.6	10.5	20-TSSOP
MAX1282	12	4	400	Serial	+4.5 to +5.5	20	16-TSSOP
MAX1283	12	4	300	Serial	+2.7 to +3.6	10.5	16-TSSOP
MAX1284*	12	1	400	Serial	+4.5 to +5.5	20	8-SO
MAX1285	12	1	300	Serial	+2.7 to +3.6	10.5	8-SO
MAX1080	10	8	400	Serial	+4.5 to +5.5	20	20-TSSOP
MAX1081	10	8	300	Serial	+2.7 to +3.6	10.5	20-TSSOP
MAX1082	10	4	400	Serial	+4.5 to +5.5	20	16-TSSOP
MAX1083	10	4	300	Serial	+2.7 to +3.6	10.5	16-TSSOP
MAX1084	10	1	400	Serial	+4.5 to +5.5	20	8-SO
MAX1085	10	1	300	Serial	+2.7 to +3.6	10.5	8-SO

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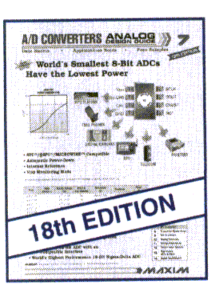

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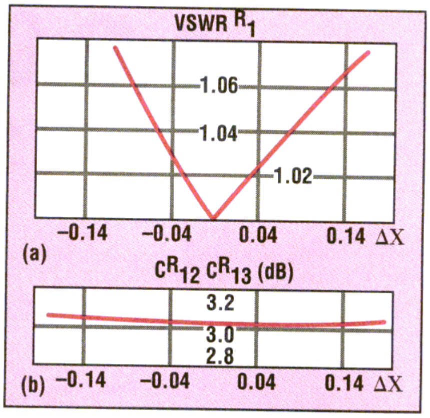


4. Fabrication tolerances can affect the parameters of a hybrid ring as shown here by curves of dimensional changes and their effect on matching (a) and insertion loss (b).

the ring coupler isolation is ideal, but input matching is not, while for the two-branch coupler, matching is perfect, but its isolation is not.

Consider the parameters of a branch hybrid with losses. The two-branch hybrid with ideal matching of all ports has the characteristics shown in Table 1.[4] The power split in the two-branch hybrid, $(C^B{}_{13}-C^B{}_{14} = 0\}$, unlike the hybrid-ring power split (see Table 2), does not depend on losses. This is generally characteristic of full symmetry couplers.

Figure 7 shows the graphs of microstrip two-branch hybrid parameters versus $\Delta X = \Delta W/\Delta\ h$ for a relative substrate dielectric constant of 9.8. Figures 4 and 7 show that the two-branch hybrid is more sensitive to production tolerances than the hybrid ring.

PARAMETERS OF ACTUAL DIRECTIONAL COUPLERS DIFFER FROM THE IDEAL DUE TO MISMATCHING OF TERMINATIONS, LOSSES, DISCONTINUITIES, AND MANUFACTURING TOLERANCES.

Table 2: Characteristics of planar couplers vs. transmission-line losses

Parameters	Hybrid ring	Two-branch hybrid	Coupled-line coupler
VSWR	$\frac{13\sqrt{2}\alpha l + 4}{11\sqrt{2}\alpha l + 4}$	$\frac{1 + 3.62\alpha l}{1 + 1.21\alpha l}$	-
Insertion loss (dB)	$20 \log \frac{6\sqrt{2}\alpha l + 2}{4\alpha l + \sqrt{2}}$	$3.01 + 20 \log(1 + 2.414\alpha l)$	$10 \log \frac{1}{1 - K^2} \times \left(\frac{8\alpha l + Z_{0e} + Z_{0o}}{4\alpha l + Z_{0e} + Z_{0o}}\right)$
Coupling (dB)	$20 \log \frac{6\sqrt{2}\alpha l + 2}{3\alpha l + \sqrt{2}}$	$3.01 + 20 \log(1 + 2.414\alpha 1)$	$10 \log \frac{1}{K^2} \times \left(\frac{8\alpha l + Z_{0e} + Z_{0o}}{4\alpha l + Z_{0e} + Z_{0o}}\right)$
Isolation (dB)	$20 \log \frac{12\sqrt{2}\alpha l + 4}{\sqrt{2}\alpha l}$	$6.02 + 20 \log\left(1 + \frac{0.414}{\alpha l}\right)$	-

Consider the effect of discontinuities which arise in T-connections between branches, connecting lines, and input/output (I/O) lines. In general, all I/O lines at these T-connections have different characteristic impedances. Analysis of the effects of discontinuities shows that working parameters of the two-branch coupler (Fig. 8) are more sensitive to them than ring-coupler characteristics (Fig. 5).

The branch coupler has the advantage of adjacent output ports which permit combining them in the planar design. For example, a balanced mixer that has the two-branch coupler and two diodes in output ports 3 and 4 can have one planar output intermediate-frequency (IF) port.

Consider the three-branch coupler whose circuit view is shown in Fig. 2d. Similar to the two-branch coupler, the three-branch coupler has the ideal directivity of type I.

$$S_{12} = S_{21} = 0 \qquad (11)$$

Thus, it is evident that port 2 is isolated and waves reaching port 3 and port 4 have a differential 90-deg. phase shift:

$$\arg \frac{S_{14}}{S_{13}} = \frac{\pi}{2} \qquad (12)$$

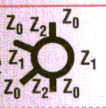
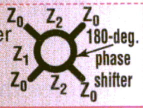
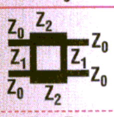
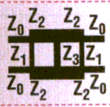
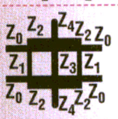
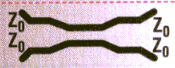
Several remarks on the three-branch coupler are in order. The bandwidth of the three-branch coupler is similar to that of the ring coupler, however, its parameters, to a great extent, depend on discontinuities and tolerances of line dimensions.

The three-branch coupler has a larger bandwidth than the two-branch coupler. Additional branches can expand the bandwidth even further. However, couplers with more than four branches are difficult to fabricate in microstrip because the end branches require impedances which reach the upper limits of practical realization.

The three-branch coupler with power-split regulation is shown in Fig. 2e.[12] Two open or short lines are connected to the center branch. The power split between port 2 and port 4 depends on the length of these stubs. This directional coupler has Type III directivity (Fig. 1).

One of the most useful structures of directional couplers is the four-port network formed by two coupled lines that are close enough to each other so they are coupled through electric and magnetic fields (Fig. 2f and g).

Table 3: Characteristics of print directional couplers

Directional coupler view	Type of directivity	Phase balance (deg.)	Coupling (dB)	BW (percent)	Ideal matching conditions	Hybrid equations	Independence from mismatched terminations: VSWR	Independence from mismatched terminations: Isolation	Independence from mismatched terminations: Coupling	Independence from losses
Ring coupler of length $3\lambda/2$ 	2	0 to 180	3 to 6	20	$Y_1^2 + Y_2^2 = 1$	$Y_1 = Y_2 = 1/\sqrt{2}$	2	1	1	2
Ring coupler of length λ 	2	0 to 180	3	Octave	$Y_1^2 + Y_2^2 = 1$	$Y_1 = Y_2 = 1/\sqrt{2}$				
Two-branch coupler 	1	90	3 to 6	15	$Y_1^2 = Y_2^2 - 1$	$Y_1 = 1; Y_2 = \sqrt{2}$	1	2	2	3
Three-branch coupler 	1	90	3	20	$Y_3 = 2Y_2^2 Y_1 / (1 + Y_1^2)$	$Y_1 = 1; Y_2^2 - Y_3 = 0$				
Three-branch coupler with power-split regulation 	3	90	Variable	20	$Y_3 = 2Y_2^2 Y_1 / (1 + Y_1^2)$	$Y_1 = 1; Y_2^2 - Y_3 = 0$				
Coupled-line coupler 	2	90	3 to 30	Octave	$Z_{0e} Z_{0o} = 1$		1	2	2	1
 Three-stage coupled-line coupler	2	90	10 to 30	Two octave	$Z_{0e1} Z_{0o1} = Z_{0e2} Z_{0o2} = Z_{0e3} Z_{0o} = 1$					

A coupler can be represented by independent even and odd modes. The final results are obtained by superposition of the two modes. In the even-mode case, currents in both lines are equal and co-directional. In the odd-mode case, currents are equal and opposite. According to the mirror-reflection method, it is possible to calculate homogeneous coupled lines with normalized characteristic impedances Z_{0e} (even mode) and Z_{0o} (odd mode) [the last suffix identifies the mode].

Perfect matching ($S_{11} = 0$) occurs when:

$$Z_{0e} Z_{0o} = 1 \tag{13}$$

The scattering matrix of the ideally matched coupler and its frequency characteristics can be derived from:[4]

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & 0 \\ S_{12} & 0 & 0 & S_{13} \\ S_{13} & 0 & 0 & S_{12} \\ 0 & S_{13} & S_{12} & 0 \end{bmatrix} \tag{14}$$

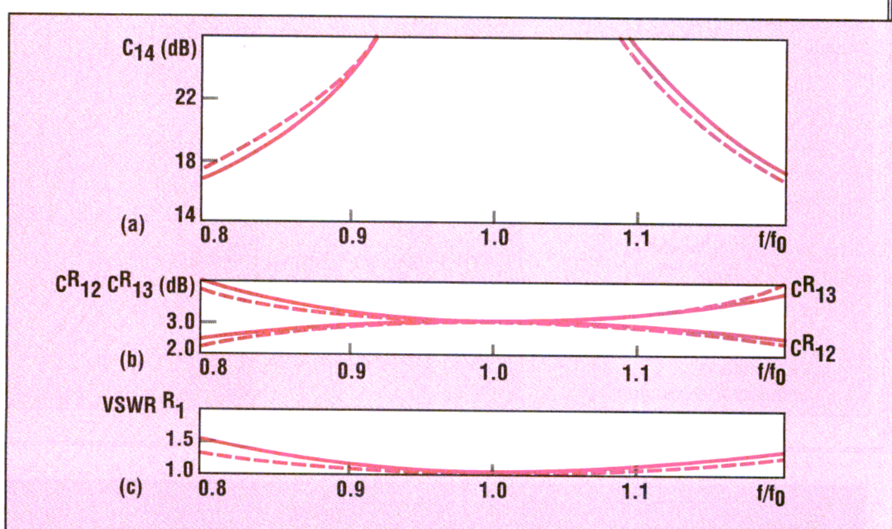
where:

$$S_{12} = i(Z_{0e} - Z_{0o}) \sin\Theta \,/\, 2\cos\Theta + i(Z_{0e} + Z_{0o}) \sin\Theta \tag{15}$$

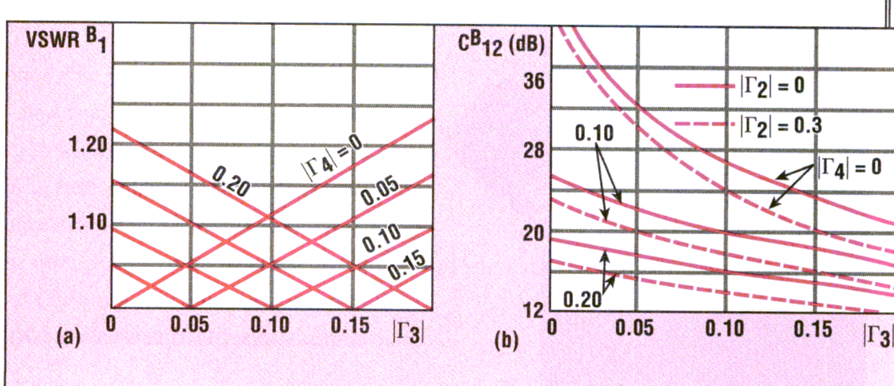
$$S_{13} = 2 \,/\, 2\cos\Theta + i(Z_{0e} + Z_{0o}) \sin\Theta \tag{16}$$

where:

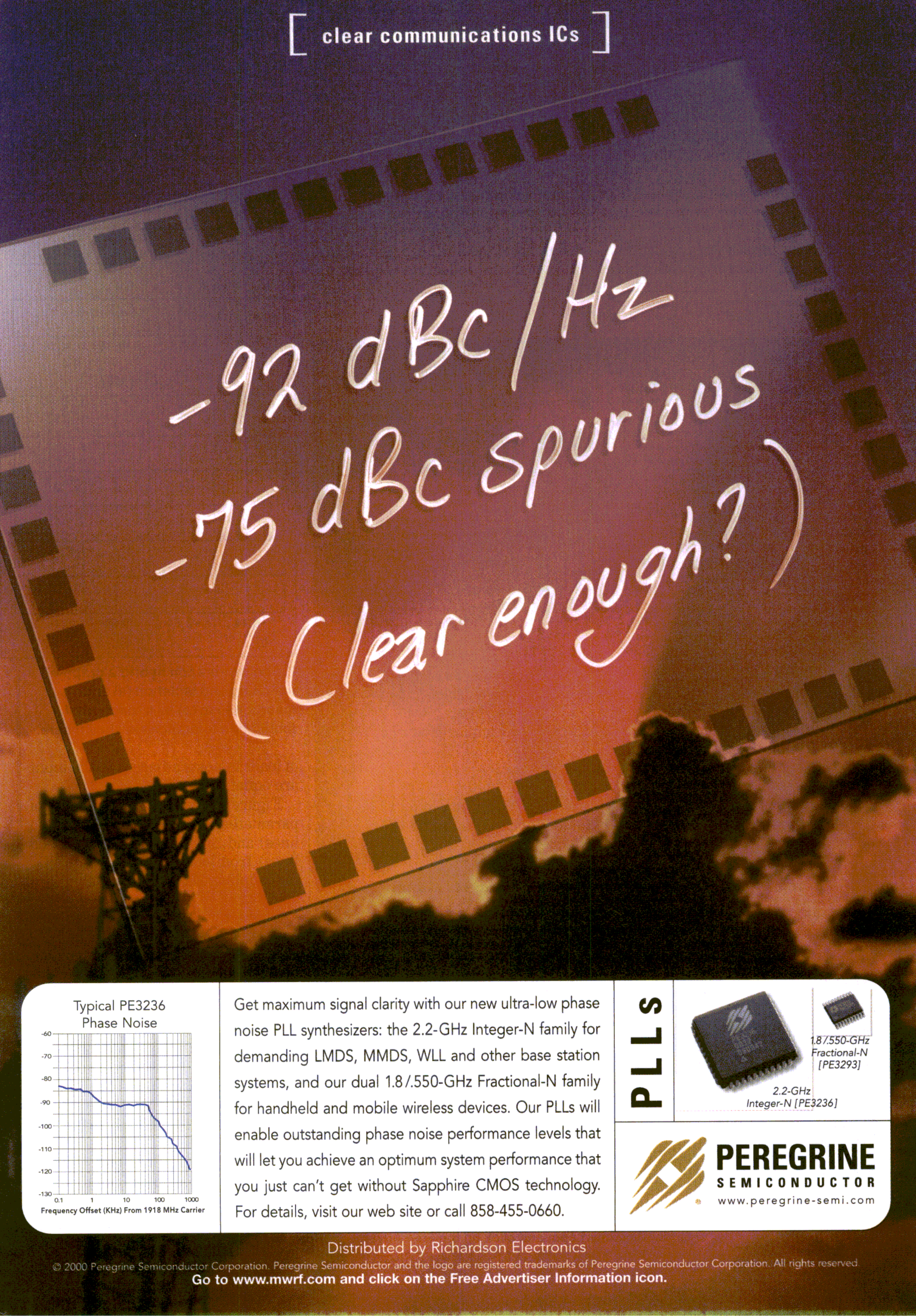
the suffix "o" denotes the midband operating frequency, $\Theta = 2\pi l/\Lambda$ = the electrical length of the coupled lines, and



5. Discontinuities have an effect on a hybrid ring as illustrated by curves of isolation (a), insertion losses (b), and VSWR (c) [solid lines]. The dashed lines are plots without discontinuities.



6. These plots are of matching (a) and isolation (b) versus reflection coefficients for a two-branch hybrid.



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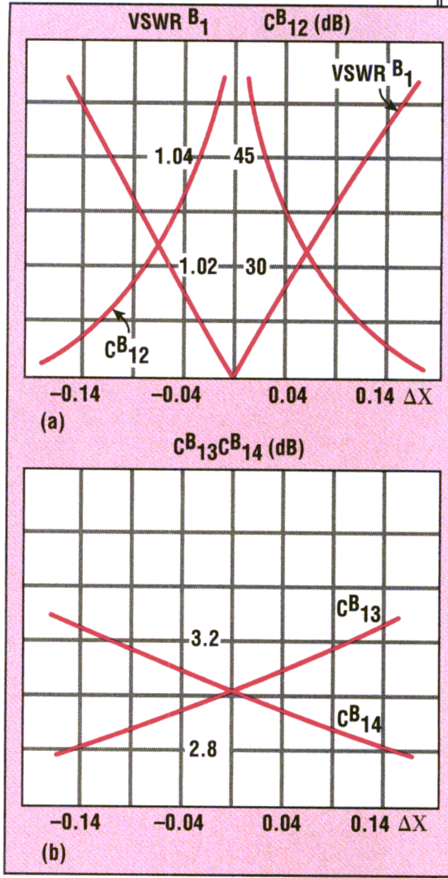
Λ = the guide wavelength.

The real directional coupler coupling (C_{12}) and insertion loss (C_{13}) will be a combination of coupling loss, conductor loss, dielectric loss, mismatch loss, discontinuities loss, along with loss due to production tolerances.

The characteristics of coupled-line couplers will be investigated where terminations have reflection coefficients Γ_1, Γ_2, Γ_3, Γ_4 that are connected correspondingly to ports 1, 2, 3, and 4.

The plot of the $VSWR_1$ as a function of reflection coefficients $|\Gamma_2|$ and $|\Gamma_4|$ of output terminations is shown in Fig. 9a.[4] As illustrated, the best matching of the 3-dB coupler is realized when the reflection coefficients



7. The two-branch hybrid's graph of matching and isolation (a) and insertion loss (b) as a function of fabrication tolerances is shown here.

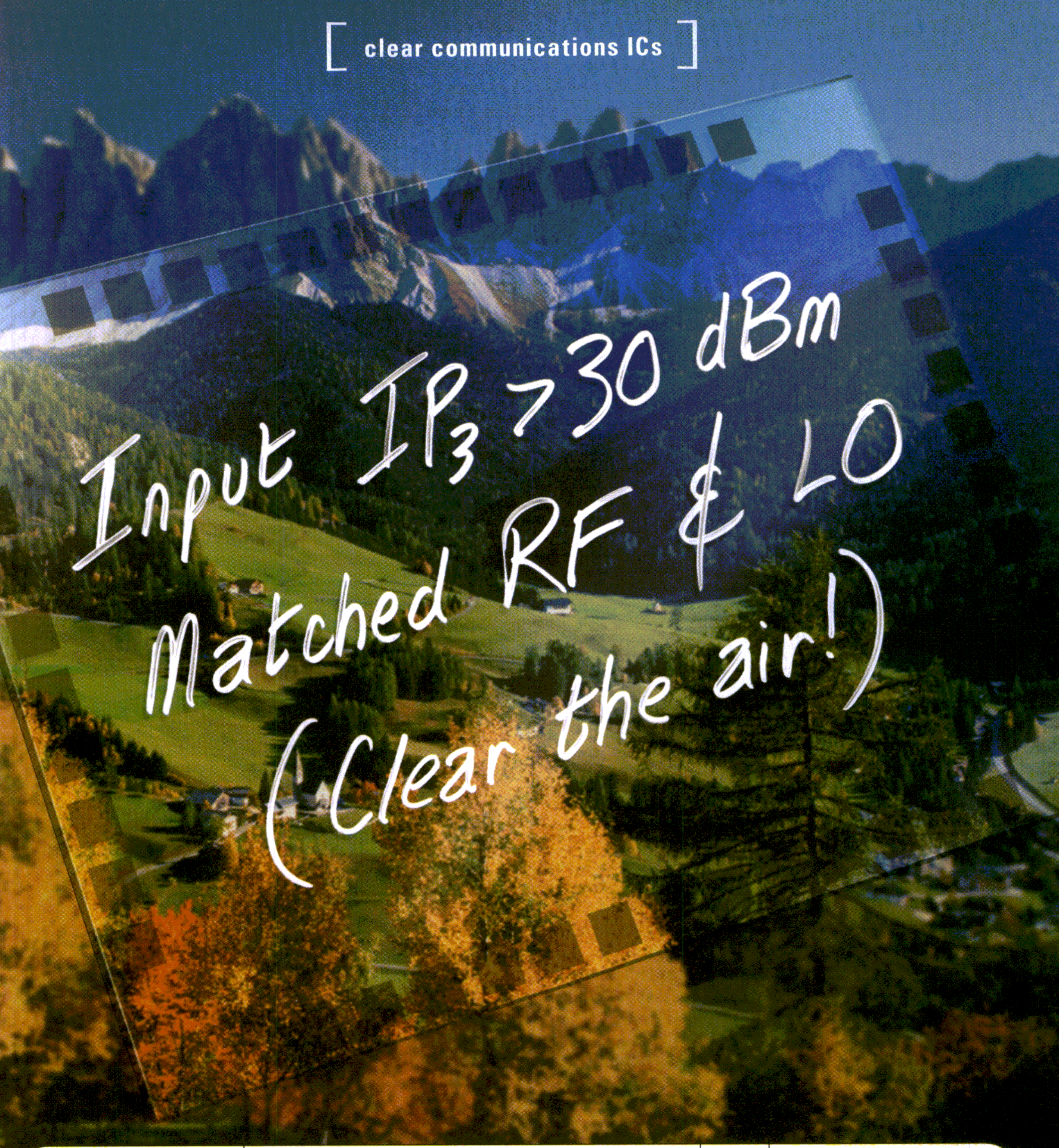
of loads in ports adjacent to the input are equal.

Figure 9b shows the dependence of parameters $\Delta C_{12} = C_{12} - C^0_{12}$ (solid lines) and $\Delta C_{13} = C_{13} - C^0_{13}$ (dashed lines) from coefficients $|\Gamma_2|$ and $|\Gamma_3|$ for coupling of $C^0_{12} = 3$ dB and $C^0_{12} = 20$ dB.

Characteristics of directivity versus reflection coefficients $|\Gamma_2|$ and $|\Gamma_3|$ are plotted in Fig. 9c. For a particular C^0_{12}, curves corresponding to different values of $|\Gamma_2|$ diverge in a fan-like pattern as $|\Gamma_3|$ decreases.[4]

Table 2 defines the main performance parameters of directional couplers, taking losses in lines into account. The line losses of the two-branch hybrid and the coupled-line coupler vary identically with the losses in the lines.

Table 3 illustrates the performance, matching conditions, equations, and other characteristics of the



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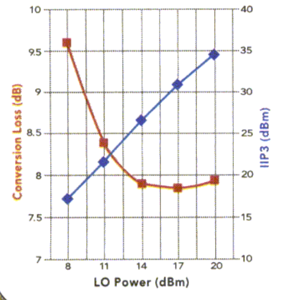

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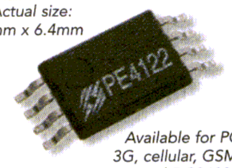

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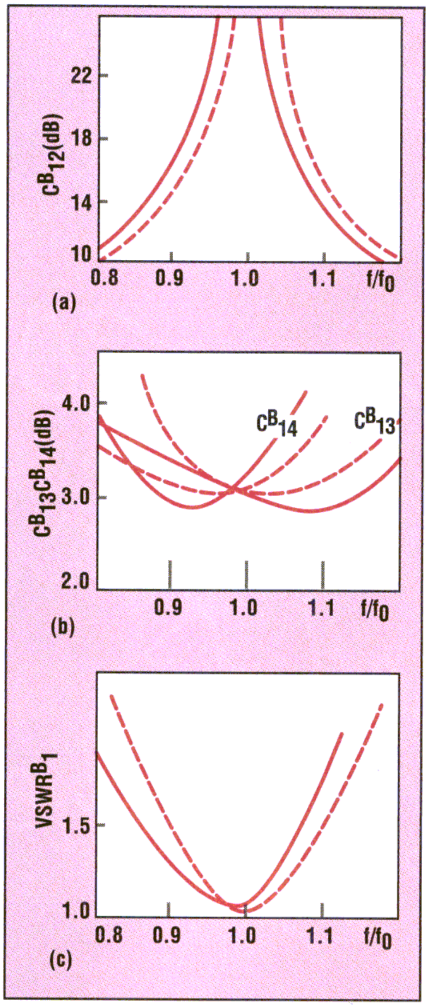
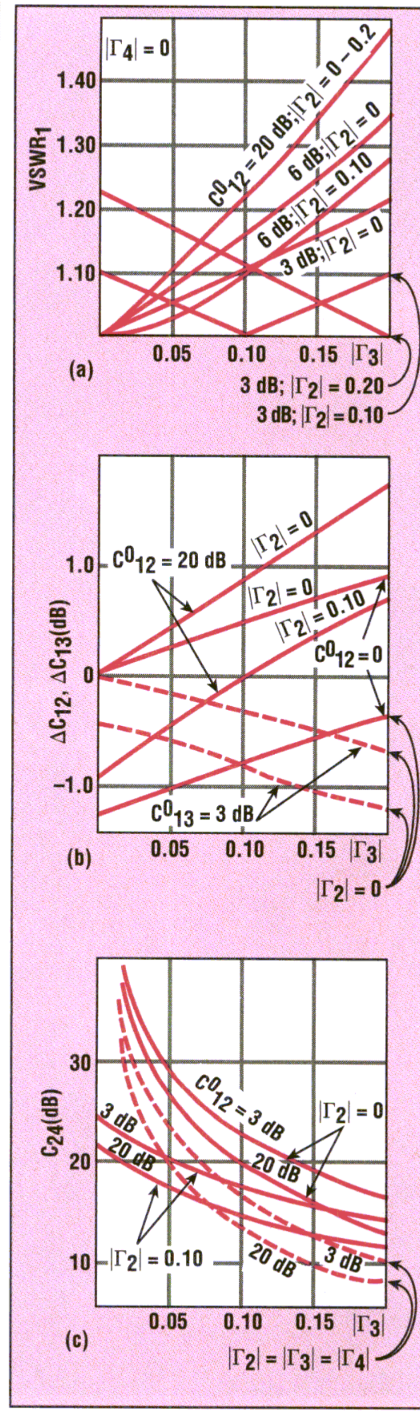


8. These three curves illustrate the effect of discontinuities (solid lines) on isolation (a), insertion loss (b), and matching (c) as a function of frequency. The dashed lines show the effects on these parameters without discontinuities.

print directional couplers that are shown in Fig. 2. ●●



9. The coupled-line directional coupler's VSWR (a), deviation of coupling and insertion loss (b), and directivity (c) as a function of reflection coefficients at the coupler's output ports are provided by these graphs.

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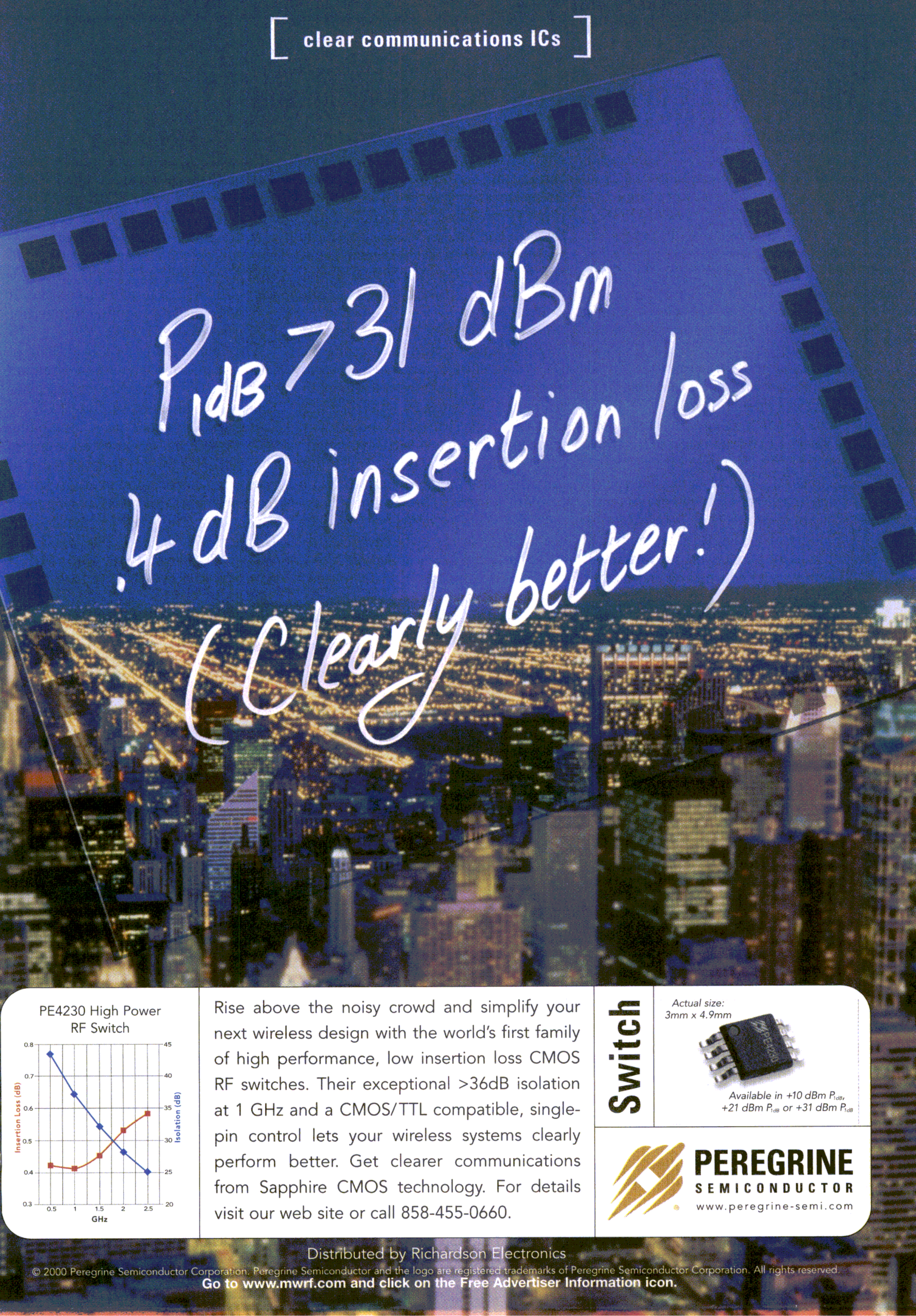

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Fundamentals of Digital Television Transmission

Gerald W. Collins

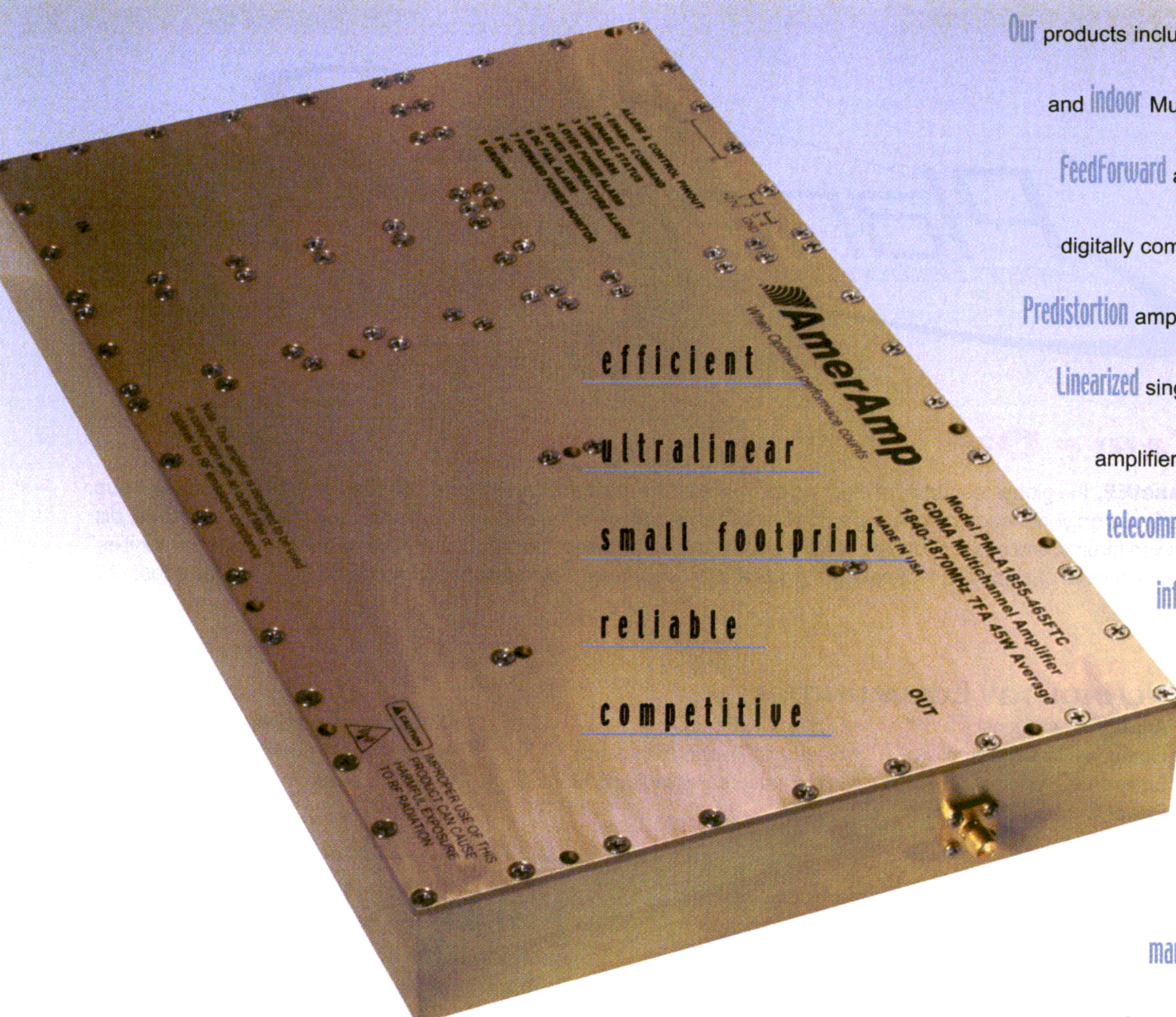
Digital television (DTV) has been available on an experimental basis in the US market for approximately two years, but it is scheduled to be the only TV transmission/reception vehicle available to the public by 2006. To further the transition from analog to DTV now underway, engineers in broadcasting, telecommunications, and other communications technologies can obtain a good overview of what this new world will look like in *Fundamentals of Digital Television Transmission.*

This is not a designers' handbook, but rather, an introduction to the principles of DTV focusing on the transmission of the digital signal. There are no schematics of RF power amplifiers (PAs) or circuits that generate the DTV signals. Chapters 1 through 3 spell out the standards, performance objectives, and how coding and modulation are accomplished in the digital realm. Chapter 4, "Transmitters For Digital Television," gets to the heart of the author's goal of describing the transmission process from a block-diagram perspective. In Chapter 5, this theme is continued with a discussion of RF elements for DTV transmission. Included here are descriptions of various types of filters, cavities, and combiners.

Chapter 6 presents the key criteria for selecting a transmission line for DTV. This subject has two facets: the electrical performance and nonelectrical factors (such as wind loading, installation time and cost, and whether the line needs to be pressurized). The transmission line feeds into the antenna, so Chapter 7 is a presentation of the essential elements of DTV antenna systems. The electrical topics covered include antenna patterns, gain and directivity, power handling, and frequency response. Antenna-mounting considerations are also covered.

How the signal travels from transmitter (Tx) to receiver (Rx) is the subject of Chapter 8, "Radio Wave Propagation." The chapter is mostly a summary of well-known propagation subjects such as refraction, multipath, ground reflections, and fading, but it is useful because it connects all these subjects together in the context of DTV.

The final chapter is a brief look at the test and measurement requirements for DTV. The chapter describes those tests that are unique to DTV (compared to those used for analog TV). As might be expected, most of the material falls into the realm of power measurements, average power measurements, and peak power measurements. (2001, 267 pp., hardcover, ISBN: 0-471-39199-9, $69.95). **John Wiley & Sons, Inc., 605 Third Ave., New York, NY 10158; (212) 850-6336.**



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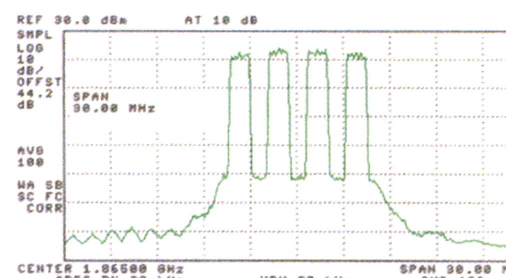

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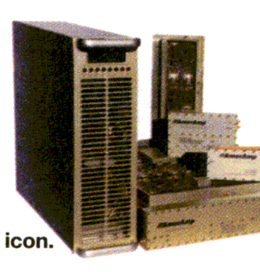

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A Primer On Using PIN Diodes In VCAs

Part 2 of two parts

Part 2 of this tutorial discusses the π-configured PIN-diode approach to implement a voltage-controlled attenuator for microwave applications.

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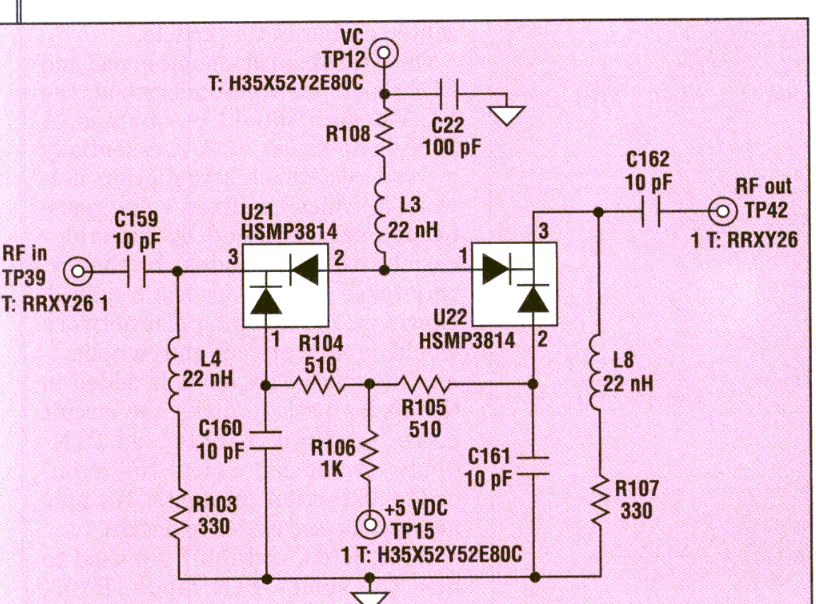
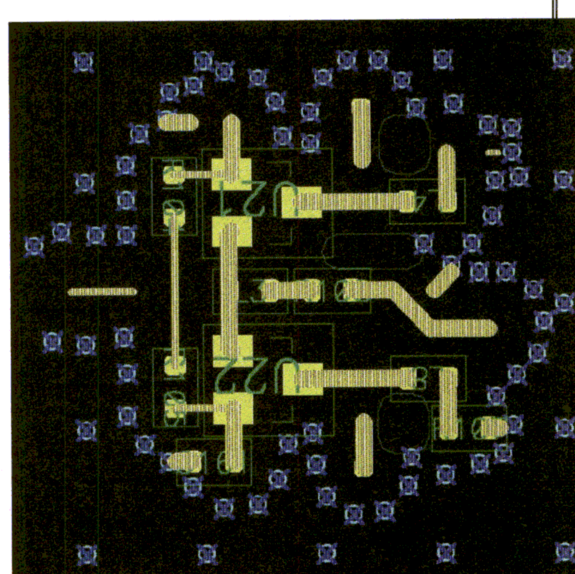
THERE are many ways to implement a voltage-controlled attenuator (VCA), but it typically involves the use of some variable-impedance device. This variable impedance device can be a metal-semiconductor field-effect transistor (MESFET) operating as a voltage-variable resistance in its linear region, or it can be a PIN diode operating as a current-controlled resistance. PIN diodes offer the advantages of high power-handling capability, more design freedom, low distortion, and low cost. Last month, Part 1 of this tutorial presented two classic microwave design approaches using one or more PIN diodes—the resistive-line approach and the constant-impedance approach. This month, Part 2 presents the π-configured, PIN-diode approach, and discusses the advantages and disadvantages of all three designs.

Finally, the π-configured PIN-diode-based VCA is a well-known design approach dating back to the vacuum-tube era. Figures 14 and 15 show the schematic and layout of a 2.45-GHz design. The major components of the design consist of four PIN diodes. Since it is a discrete design using plastic-packaged PIN diodes, it is very inexpensive to build.



14. The schematic for the π-configured VCA is shown here.



15. This is the circuit-board layout of the π-configured VCA.

The size of the circuit is smaller than a US quarter. Since all four diodes dissipate attenuated power, its power-handling capability is better than its transistor-based counterpart. Good input and output matching can be achieved with careful design. With good matching performance, the VCA behaves as an absorptive termination where no incoming signal is reflected back to the source. Reflected signal is highly undesirable in most applications, especially in high-power applications.

Before getting into the π-configured PIN-VCA design, a brief introduction of fixed attenuation pad and PIN diodes will help the transition from a fixed attenuation pad to a PIN-diode-based VCA.

Commonly used fixed-attenuation pads are either T- or π-configured resistive networks. An π-configured pad is presented here. Typical requirements for an attenuation pad are: good input/output (I/O) port match to 50 Ω and precise attenuation. List 1 shows the standard design equation put into a MathCad file. R_s and R_l are the termination values. In this case, 50 Ω are used for both ports. The desired attenuation value is entered in decibels. The output will be the value for the three π-configured resistances. Rc is the middle-series resistance, while Rb and Ra are the shunt resistances on the side. A few experiments will provide more intuition to the design. The attenuation pad at attenuation levels of 2, 10, 20, and 30 dB are calculated and tabulated. The results are listed in Table 3.

Using the resistance values provided in Table 3, precise attenuation and perfect port matching can be achieved. The table also reveals a trend. As attenuation increases, the series resistance increases and shunt-resistance decreases. Intuitively, it makes perfect sense. If 0-dB attenuation is needed, the series resistance will be 0 Ω, while the shunt resistance will be infinite. At the other extreme, infinite attenuation will require the series resistance to be infinite and the shunt resistance to be 0 V.

Armed with knowledge of the fixed attenuation pad and intuition on how series and shunt resistances behave, the only remaining question for the VCA will be how the variable resistance is achieved. The answer is the PIN diode. The theory is presented earlier in this article.

Once the fixed attenuation pad and PIN diode are well-understood, the VCA design should be obvious. A PIN-diode-based VCA is essentially a fixed-resistance attenuation network in which the fixed value resistances are replaced by variable-resistance PIN diodes. In theory, only three PIN diodes are required. However, the resulting bias network would be cumbersome and complicated. One more PIN diode is added in the series path to make the circuit more balanced. A balanced PIN-diode circuit can cancel the even-order distortion products. Its bias network is also easier to design.

R108, R103, and R107 are used to bias the series PIN diode. R103, R107, R104, R105, and R106 are used

(continued on p. 132)

Table 3: Attenuation of the π network for differnet resistance values

Attenuation (dB)	Resistances (Ω) Rc	Ra	Rb
2	11.63	436.2	436.2
10	71.15	96.25	96.25
20	247.5	61.11	61.11
30	789.7	53.27	53.27

Table 4: Components used in the π attenuator

Component	Part No./Value	Quantity	Vendor
PIN	HSMP3814	2	Agilent
Capacitor	10 pF	4	AVX
Capacitor	100 pF	1	AVX
Inductor	22 nH	3	Coilcraft
Resistor	61.9 Ω	1	KOA
Resistor	510 Ω	2	KOA
Resistor	1 kΩ	1	KOA
Resistor	330 Ω	2	KOA

LIST 1

$$R\_s = 50 \quad R\_L = 50$$

$$G\_s := \frac{1}{R\_s} \quad G\_L := \frac{1}{R\_L}$$

$$Att\_dB := 6\ dB \quad Att\_N(Att\_dB) := \frac{Att\_dB}{8.686}$$

$$Gc(Att\_N) = \frac{\sqrt{G\_s \times G\_L}}{\sinh(Att\_N(Att\_dB))}$$

$$Ga(Att\_N) := \frac{G\_s}{\tanh(Att\_N(Att\_dB))} - Gc(Att\_N)$$

$$Gb(Att\_N) := \frac{G\_L}{\tanh(Att\_N(Att\_dB))} - Gc(Att\_N)$$

$$Rc(Gc) := \frac{1}{Gc(Att\_N)}$$

$$Rb(Gc) := \frac{1}{Gb(Att\_N)}$$

$$Ra(Gc) := \frac{1}{Ga(Att\_N)}$$

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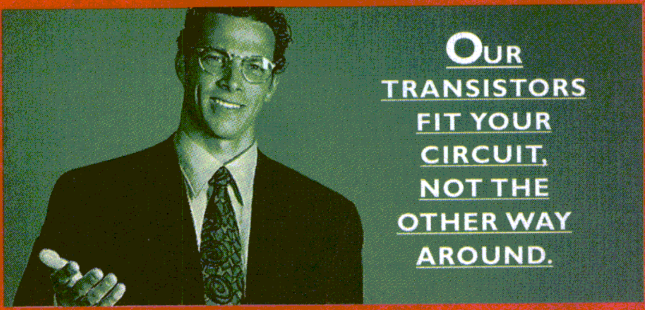

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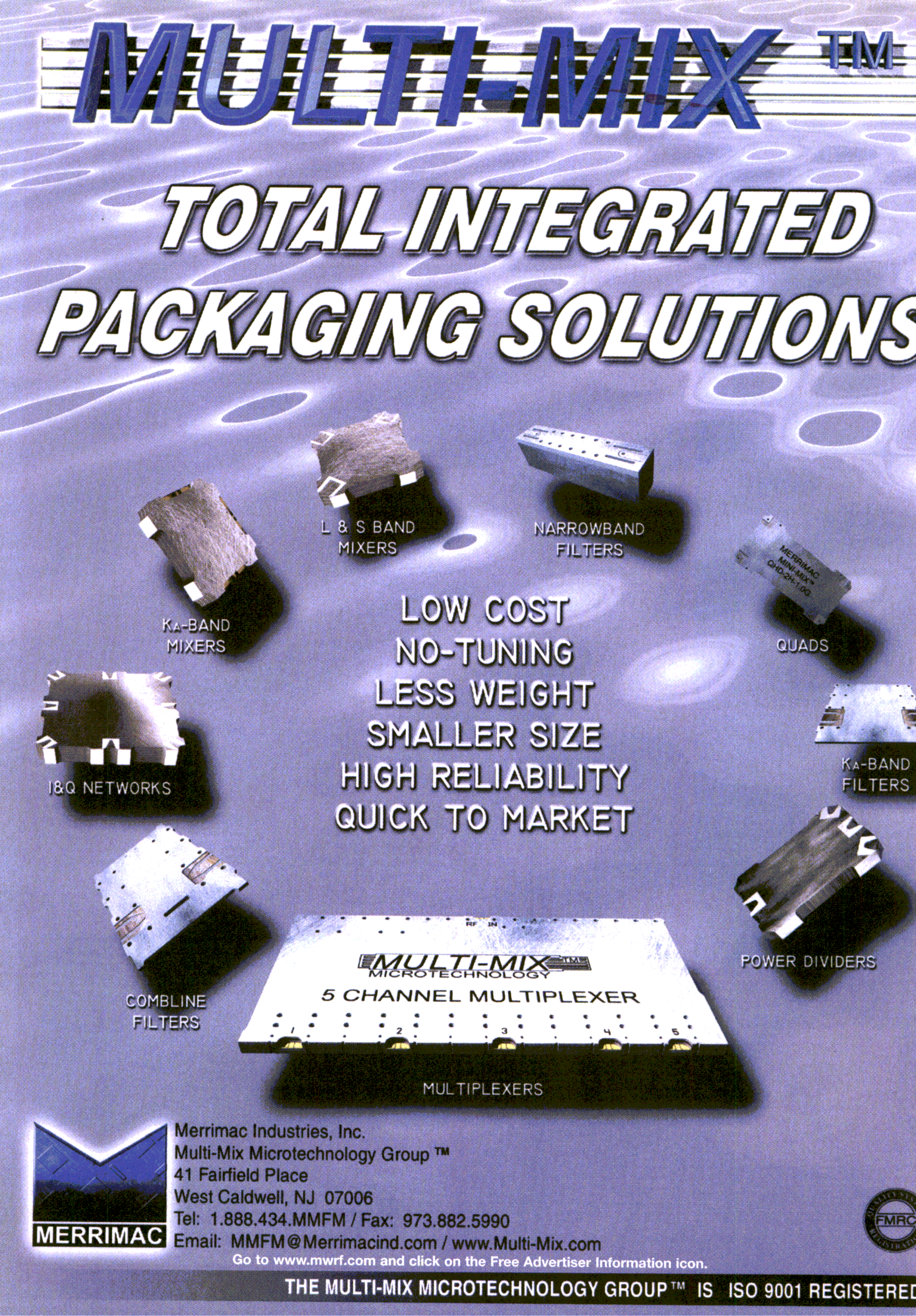
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Clarify Antenna Gain For Accurate Mobile Measurements

Understanding the true meaning of "antenna gain" can help improve the accuracy of handset measurements.

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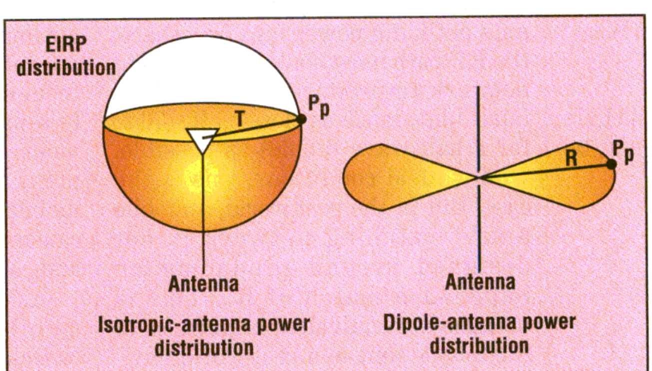
MEASUREMENT accuracy is important to mobile-telephone manufacturers and to service providers. Power and frequency are two key parameters that must be generated and measured by a mobile unit to ensure proper operation within specified limits. Accurate measurements of the power received and transmitted by the mobile unit will ensure that battery life is maximized, RF radiation is minimized, and appropriate coverage is realized.

In order to test a mobile unit, a physical or inductive connection must be made with the device's RF path. This may be occur with a physical or galvanic connection or through an inductive-antenna coupling mechanism. Each method must account for distinct RF characteristics in order to produce accurate tests. The goal is to test and calibrate a mobile unit in order to produce the most accurate signal at the antenna. When a mobile unit is tested at the galvanic connection, and the appropriate characterization of that connection's deviation from the antenna's response is not accurately taken into account, the actual response of the antenna may be compromised.

Many different technical aspects of mobile-telephone transmissions are often incorrectly lumped under the generic term "antenna gain." In order to make more accurate mobile-telephone measurements, it is first necessary to understand the true meaning of antenna gain and how it applies to mobile-telephone transmissions and testing.

Antenna gain is a term used to relate the isotropic radiative power (IRP) of a particular antenna to the peak radiated power of other antenna designs, such as dipole or monopole antennas. At times, the industry has lumped other losses and compensation factors together with antenna gain in order to relate the response of the physical RF connector to that of the antenna. This misinterpretation can cause confusion when trying to accurately determine the response of a mobile telephone through either the



1. The radiation pattern of an isotropic antenna differs from that of a dipole antenna due to the distribution of power. Antenna gain is a conversion factor used to compare patterns from different antennas.

antenna or the galvanic connection.

Antenna gain is defined as the ratio of the maximum radiated power density at a particular point from the antenna to the power density radiated by a reference antenna at the same point. The reference antenna, in most cases, is isotropic. The power that is radiated from an ideal isotropic antenna extends into space equally in all directions. It forms a sphere around the zero point of the antenna. In reality, antennas do not radiate isotropically. The dipole antenna, for example, radiates in a donut-shaped plane that extends perpendicularly to the length of the antenna.

An isotropically radiating antenna can be compared to a dipole antenna through a conversion factor known as antenna gain. The conversion factor is considered a gain conversion because the total power from the two antennas remains constant, but the power is distributed over a more compressed area with the dipole antenna (Fig. 1). The power at a point along the peak radiation path of the dipole antenna will be at a higher level than the power at an equivalent point from the isotropic antenna, at the same distance r from the antenna.

Antenna gain can be derived through some simple relationships. The isotropic power at a particular point, P_p, can be derived as:

$$P_p = P_r/4\pi r^2$$

For example, if the values of r = 100 m and P_r = 100 W are applied, Eq. 1 becomes:

$$P_p = 100\ W/[4\pi(100)^2] = 1/400\pi = 0.795\ mW/m^2 = -0.996\ dBm/m^2$$

The derivation of the antenna gain for a short dipole antenna can be shown as:

$$P_{dipole}/P_{isotropic} = G = kD,$$

with $D\lambda/2$ dipole = 1.64, and

$$k = R_r/(R_r + R_l)$$

where:
R_r = the radiation resistance,
R_c = the ohmic loss in the antenna,
k = the antenna efficiency factor, and
D = the directivity of the antenna.

Assuming that k = 1, the dipole has negligible ohmic loss, and the maximum antenna gain for a half-wave dipole antenna can be calculated from:

$$G = (1)(1.64) = 1.64 = 2.15\ dB$$

The equivalent power transmitted to the same point, P_p, from a half-wave dipole antenna is then:

$$P_p = 1.64(0.795) = 1.30\ mW/m^2 = +1.14\ dBm$$

A typical mobile telephone uses a dipole-antenna configuration to transmit RF signals, with the antenna as one pole and the body of the mobile telephone as the other pole. The impedance (radiation resistance, R_r) of the antenna facing free space is ideally matched by a matching network, in order to optimize power transmission from the mobile unit's source. In order to evaluate a mobile station under test (MSUT), a connection must be made to the RF path, either through the antenna (over-the-air coupling) or through a galvanic connection. A galvanic connection has a characteristic impedance of 50 Ω, which is interfaced to standard test equipment through 50-Ω RF cables. The RF characterization through the galvanic connection differs from the real-world use of the mobile transmission through an antenna, which radiates into free space.

Free space has a characteristic impedance of 377 Ω. In order to design a mobile telephone that transmits optimum power into free space, the RF path must contain a matching network to produce an equivalent input impedance as close to R_r (76 Ω for a half-wave dipole) as possible. Under ideal conditions, this is the case. But in the real world, a mobile unit's matching network is not designed around producing an impedance match of R_r. This is because the equivalent impedance of the mobile unit in a real-world environment can change unpredictably by placing reactive or resistive loads near the body of the telephone. A load can be a human hand or head, a car kit, or any other material that has dielectric characteristics that are different from those of free space. By having unpredictable changes in the mobile unit's equivalent impedance, mismatch in the mobile unit to RF path transition is inevitable. This mismatch will produce inefficiencies in the overall power transferred into free space, as well as power that is incident onto the antenna from free-space radiation. These effects will be predominant when testing through the antenna compared to testing at the RF connector.

This may be evident even in a precisely controlled testing environment where over-the-air testing may be a preferred method of creating an interface to the RF signal. In most mobile-telephone test environments, the mobile unit is placed within an anechoic environment that contains an RF-absorbent material that is used to reduce reflections, which are the cause of high standing-wave ratios (SWRs) within the anechoic chamber. These standing waves add in phase (constructively) and out of phase (destructively), producing inaccuracies in the observed and measured power into and out of the mobile telephone. An anechoic chamber environment can approach the conditions exhibited by free space if all power incident on the walls is absorbed. In addition, as cables, connectors, and other mounting fixtures are placed within the anechoic chamber, more variation in characteristic impedance from the original optimum impedance will be observed. Even though the mobile unit is designed to transmit and receive optimally in contact with a human operator (a large dielectric mass), test environments may not accurately represent the equivalent environment. These differences in environment will have an impact on the mobile unit's equivalent impedance, causing inaccurate RF test response and calibration factors.

As can be seen in Fig. 2, a typical mobile telephone's RF path is switched between the antenna and the galvanic connection. If testing is performed through the galvanic connection, the telephone will be tested and possibly calibrated to specifica-

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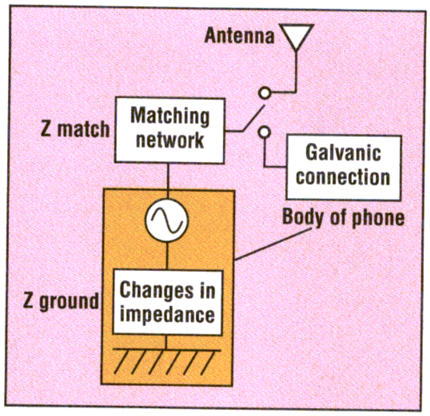
tions that will not be applicable or repeatable in the real-world use of the telephone. If the manufacturer is going to test the telephone through the galvanic connection, a characterized compensation value must be determined in order to translate the measured results into an equivalent value to represent how the mobile unit will respond through the antenna connector. The standards are not very clear on the definition of "antenna connector." It is possible to test the mobile unit through the galvanic connection and obtain desirable results. At the same time, however, the response through the antenna could be unsatisfactory from the service provider's or even the customer's point of view.

It is difficult to determine if a manufacturer's telephone design implements an optimized match through the RF antenna (real-world operation has been taken into account) or if it was optimized to perform best through the RF connector (manufacturing and calibration has been taken into account). The manufacturer may have designed the mobile's RF circuitry using three different methodologies:

1. The matching network was designed to provide optimum performance when tested through the galvanic connection. If this is the case, the calibration process must make appropriate adjustments to account for the actual response of the mobile through the antenna. Antenna gain and other galvanic-connection-to-antenna compensation factors must be taken into account.

2. The matching network was designed to provide optimum performance when operating through the antenna. This is the most desired method, but is difficult to test or verify performance of the mobile unit due to the factors previously described.

3. The matching network was designed to provide a compromise in performance between the antenna and the galvanic connection. Even if this method is used, and the mobile unit is tested and calibrated through the galvanic connection, compensations must be accounted for to ensure accurate performance through the antenna.



2. In testing a mobile telephone, the unit's RF path is typically switched between the antenna and the galvanic connection, which can generate misleading results compared to real-world use.

Many manufacturers find it easier to test to a standardized physical RF connection, due to the 50-Ω characteristic impedance of the antenna interface and the test equipment. For this reason, the minimum performance standards of mobile telephones have developed the test specifications around the galvanic connection.

The minimum performance standards for code-division-multiple-access (CDMA) mobile units (TIA/EIA-98-C specifications) require that most tests be performed through the antenna connector. Some of the tests, however, such as CDMA maximum transmit power, must fall within the bounds of an effective-IRP (EIRP) reference. In order to test "in the spirit of the standards," a correction factor must be applied to approach the true response at the point of the mobile unit's antenna. The standards, as well as many manufacturers, classify this as "antenna gain." Since the point of test is the galvanic connection, there are many factors that contribute to this overall correction factor that should be applied to the measurement result. Antenna gain is only one of these factors. To define this correction factor as antenna gain is not accurate. Antenna gain only accounts for the relation of the transmission/reception of the antenna to a particular point compared to a reference level at that same point.

A short dipole antenna will have antenna gain of no more than 2.15 dB, assuming zero ohmic loss in the antenna. In many cases, manufacturers have recommended antenna-gain compensations up to 3 dB. When considering the antenna-gain definition, if the dipole antenna is transmitting in all directions and is suffering losses, then a 3-dB gain-compensation value is highly improbable. The reason for the higher proposed antenna-gain values is because other compensation values may have been incorporated, such as:

- Galvanic-to-antenna coupling.
- Matching network mismatches between the galvanic connection and the antenna.
- Mobile calibration inconsistencies between the galvanic connection and the antenna.

In order to hold true to the definition of antenna gain, the compensation value that characterizes the difference between testing at the galvanic connection to the actual response at the antenna should be referred to as a term other than antenna gain. An appropriate term may be "galvanic-to-antenna-port compensation factor."

In summary, the term "antenna gain" is often misapplied by the high-frequency industry when used in reference to mobile-telephone manufacturing and testing. The goal of testing and calibrating an MSUT is to ensure that the telephone will operate to the satisfaction and expectations of the customers. If the telephone is tested through a galvanic connection, a compensation factor must be used to translate the measured results to that of an equivalent operation through the antenna. This compensation factor is not antenna gain, but could be more accurately called the "galvanic-to-antenna-port compensation factor." Antenna gain is still a useful parameter for producing accurate mobile-telephone measurements, but it must be additive depending on the type of test performed. ••

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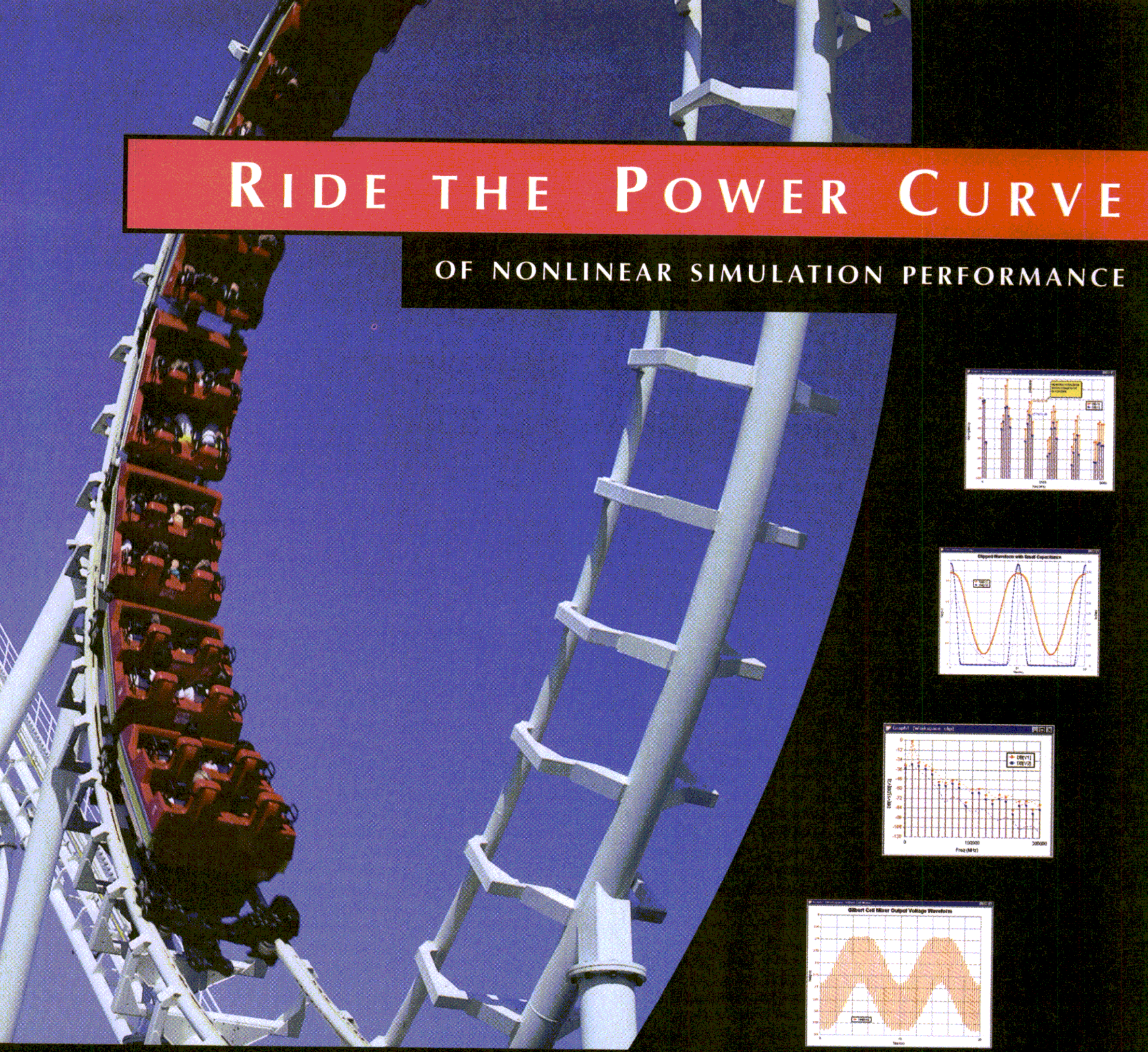

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Calculate Oscillator Jitter By Using Phase-Noise Analysis

Two types of jitter specifications can be determined by developing equations based on analyzing an oscillator's phase noise.

Part 2 of two parts

Boris Drakhlis

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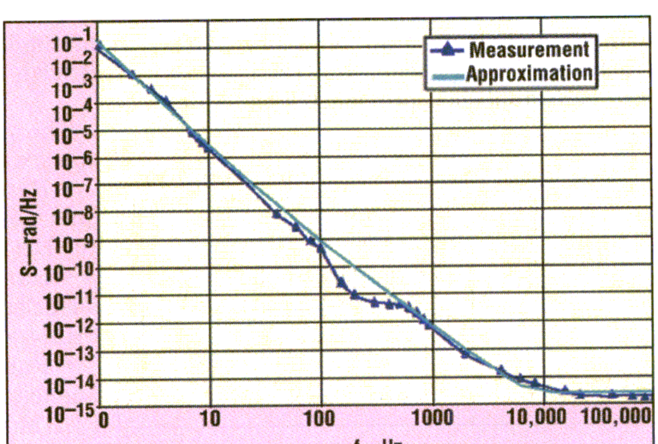
EQUATIONS that were developed in Part 1 of this article can now be used to calculate the jitter of a crystal clock oscillator. A plot of the oscillator's measured phase noise and the five noise processes used to approximate it are shown in Fig. 3.

It can be seen that the approximation fits the data well and that the five power-law noise processes model is valid for that oscillator. The following numbers describe the model:

1. White PM: $S_{\phi WPM} = 2 \times 10^{-15}$
2. Flicker PM: $S_{\phi FPM} = 2 \times 10^{-12}$
3. White FM: $S_{\phi WFM} = 1 \times 10^{-9}$
4. Flicker FM: $S_{\phi FFM} = 6 \times 10^{-4}$
5. Random walk FM: $S_{\phi RWFM} = 1.93 \times 10^{-2}$ (27)

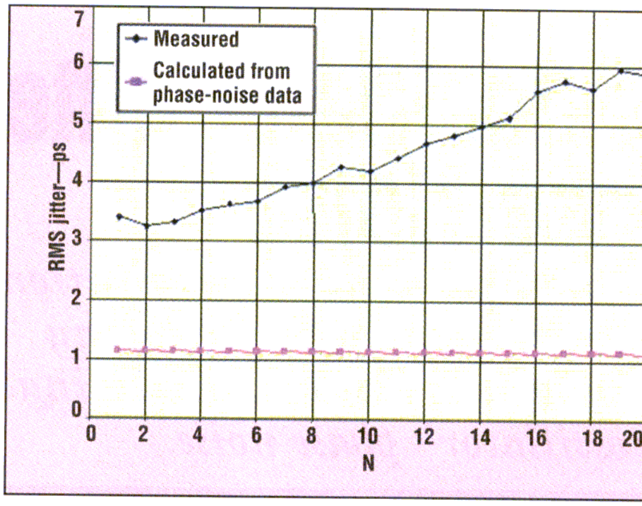


3. The measured and the five-power-law-approximated phase noise of an oscillator correlate closely as shown in the two curves.

To use Eqs. 18 to 25 one needs to establish the upper integration limit f_h. This limit could be imposed by the measurement equipment or by the device itself. Sinusoidal crystal oscillators that were previously studied usually have a buffer amplifier with a tuned tank circuit on the output.[1] The buffer-amplifier bandwidth sets f_h in these oscillators. Clock oscillators usually do not have a tuned buffer on the output. Instead, they have a wideband-output amplifier that produces a square-wave signal. Unfortunately, by tradition and also due to equipment limitations, the phase noise of the oscillators is measured close to the carrier—within 100 kHz in the case of the oscillator in question. Neither (in the author's awareness) is there data regarding the effective jitter-measurement bandwidth of the Tektronix 11801A digital storage oscilloscope (DSO).

In the absence of reliable data the jitter for $f_h = f_0$ will be calculated. For the oscillator in question, f_0 = 77.76 MHz. This frequency is much higher than the highest frequency at which the phase noise was measured (100 kHz). If the output amplifier or the DSO limits f_h to a value less than f_0, one will overestimate the phase jitter. If the contribution of the noise with Fourier frequencies is higher than the oscillator frequency is significant, one will underestimate it. It should also be noted that only the white phase modulation (PM)-induced jitter is dependent strongly on f_h, because white PM is independent of frequency. All other power-law processes are frequency dependent and go to zero at high Fourier frequencies. For that reason, the jitter that the processes are contributing is not dependent on f_h if f_h is sufficiently high.

The results of calculated and measured jitter for the first 20 periods are presented in Fig 4. It can be seen that the measured period jitter is much higher than calculated period jitter and that the rate of jitter accumulation is much higher in the measured jitter than in the calculated jitter.



4. Calculated and measured jitter in an oscillator differ significantly over 20 periods because the timebase jitter of the measuring instrument adds to the oscillator's own jitter.

As noted before, the jitter accumulation is practically independent of the measurement bandwidth. The fact that the measured accumulated jitter is much higher than the calculated jitter can be explained by the DSO's timebase jitter that is added to the oscillator jitter. From Fig. 4 one can estimate that the DSO timebase-jitter slope is approximately 0.15 ps/period of the oscillator frequency (12.86 ns in this case). This corresponds to a 12-PPM relative jitter characteristic for the DSO's timebase.

There is also a substantial difference in the value of period jitter provided by each method. To explain this, look in detail at the way jitter is measured with a DSO (Fig. 5). The 40-ns delay line is a key ingredient in the test setup since it compensates for the internal DSO delay. The delay line makes it possible to display the same signal edge on the screen that triggers the DSO. In an ideal case, the DSO measures only period jitter. Thus, the jitter of this edge (the "trigger edge") would be zero. As a result, all of the trigger-edge jitter is considered to be caused by other sources of noise. The amplitude noise of the oscillator and the DSO's internal amplifiers are the most prevalent contributors. The measured jitter of the trigger edge of the oscillator under consideration is 3.148 ps root mean square (RMS) and the measured period jitter is 3.386 ps RMS. This shows that the jitter induced by the period variations is indeed much less than the measured period jitter. To estimate this jitter, calculate:

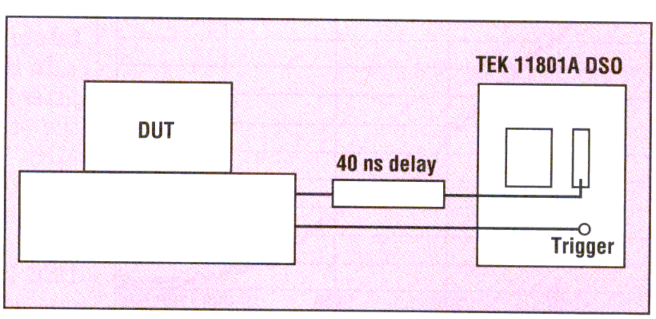
$$Phase\text{–}noise\ induced\ jitter = \sqrt{(mj_{RMS})^2 - (fe_{RMS})^2} \qquad (28)$$

This formula yields 1.247 ps RMS for this measurement case. If, in using the same formula, one subtracts the DSO's timebase jitter of 0.15 ps (established previously), the result is 1.238 ps RMS. This is close to the 1.141 ps RMS jitter that was calculated from the phase-noise plot.

The simple power-law model of the phase-noise spectral density used before is applicable only to free-running oscillators. In the case of a phase-locked loop (PLL), the output phase noise depends upon the phase noise of the reference signal, voltage-controlled-oscillator (VCO) phase noise, and the loop bandwidth. The phase-noise plot of a 65.536-MHz high-performance-complementary-metal-oxide-semiconductor (HCMOS) PLL used as a 3× multiplier of a crystal-oscillator reference frequency is shown in Fig. 6.

In addition to its phase-noise characteristics, a PLL has discrete spectral components that result from frequency modulation (FM) of the VCO by the filtered output of the phase detector. A spectrum-analyzer plot of the output signal of the PLL mentioned previously is presented in Fig. 7.

The period jitter could be numerically calculated using Eqs. 13 and 14. To gain more insight into the process of jitter generation, one can separately calculate jitter contributions of every major region of the phase-noise plot and from each of the main frequency components of the output spectrum. They can then be combined in the single plot in order to be compared with the measurement data.



5. Differences in measured and calculated period jitter can be attributed to the measurement method shown here. The 40-ns delay line is used to compensate for internal delays of the digital storage oscilloscope.

The phase noise plot is approximated as follows:

- Range 1: Fourier frequencies from 1/600 Hz to 100 Hz: $4.16 \times 10^{-3}/f^4$.
- Range 2: Fourier frequencies from 100 Hz to 700 kHz: 4×10^{-11}.
- Range 3: Fourier frequencies from 700 kHz to PLL output frequency: 1×10^{-14}.

The phase-noise-induced jitter of the PLL derived from these approximations

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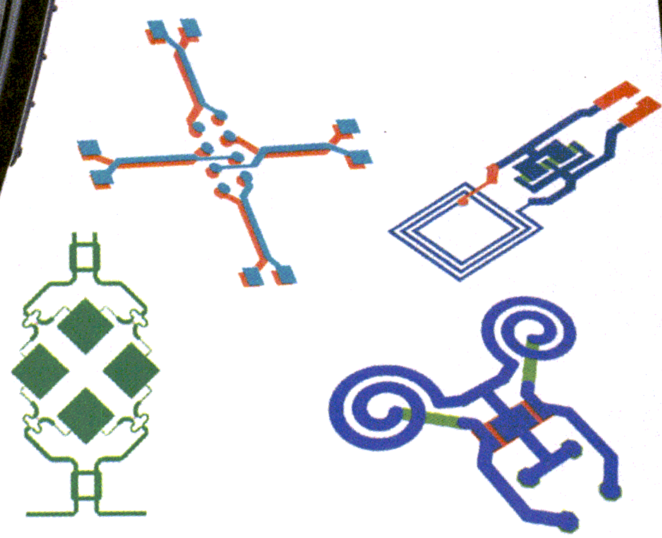

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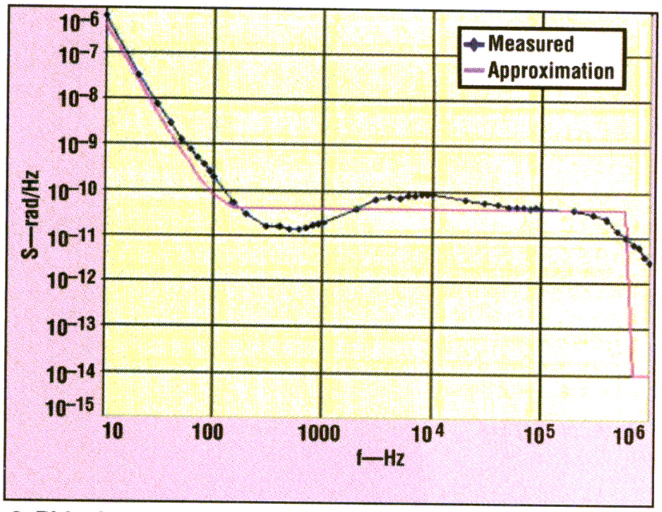
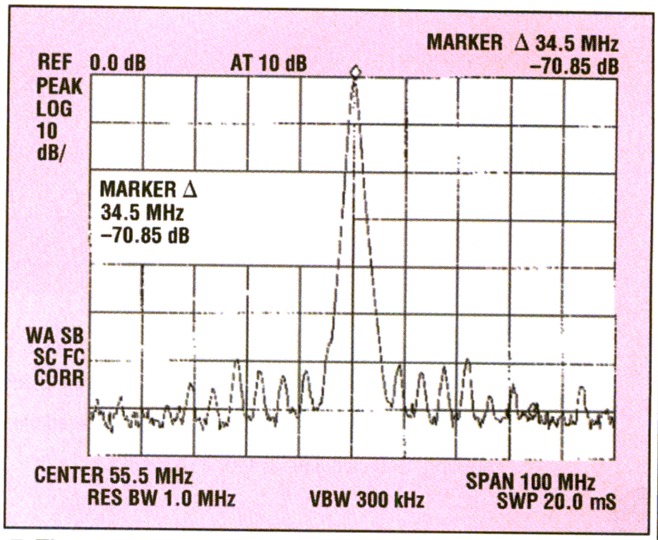


6. PLL phase noise is more complex than that of an oscillator because the PLL contains more circuit elements. This is the noise plot of a 65.536-MHz PLL multiplying a crystal oscillator by three times.

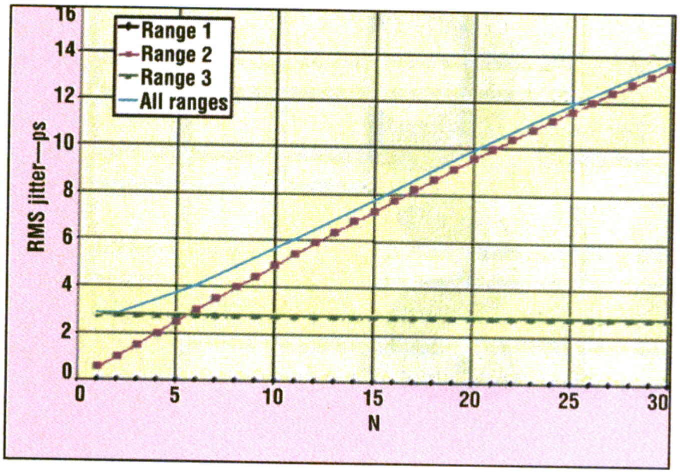


7. The output spectrum of the PLL in Fig. 6 on a spectrum analyzer displays spectral components that result from the interaction of the device's circuit elements.

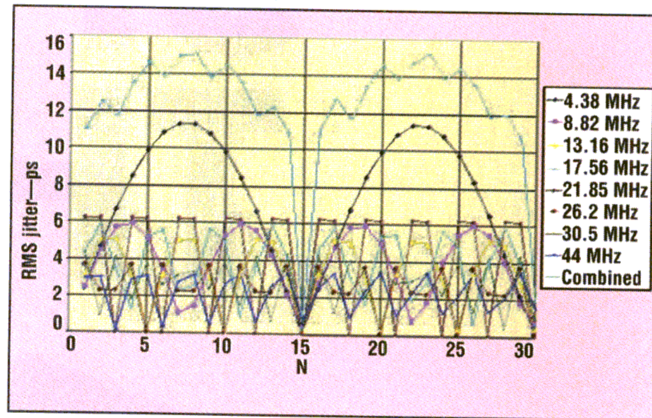
is illustrated in Fig. 8.

The strongest discrete components in the PLL output spectrum are the following:

- Fourier frequency: 4.38 MHz, sideband level L = –55.6 dBc.
- Fourier frequency: 8.82 MHz, sideband level L = –61.2 dBc.
- Fourier frequency: 13.16 MHz, sideband level L = –62.2 dBc.
- Fourier frequency: 17.56 MHz, sideband level L = –61.3 dBc.
- Fourier frequency: 21.85 MHz, sideband level L = –59.6 dBc.
- Fourier frequency: 26.2 MHz,



8. These plots of jitter show the calculated contributions from the phase noise of each of the PLL's three main frequency ranges. The plot, "All ranges," is the combination plot of Ranges 1 through 3 for comparison with measured data.



9. The induced jitter of the PLL resulting from its discrete spectral components is shown here. Only the eight strongest discrete components are plotted.

sideband level L = –65 dBc.

- Fourier frequency: 30.5 MHz, sideband level L = –64 dBc.
- Fourier frequency: 44 MHz, sideband level L = –66 dBc.

The discrete spectral-component-induced jitter is presented in Fig. 9.

The results of the DSO measurements of PLL jitter and PLL jitter calculated from all jitter sources are shown in Fig. 10.

In the PLL case there is good correlation between measured and calculated jitter. This is because the PLL jitter is much higher than the

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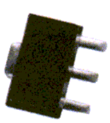

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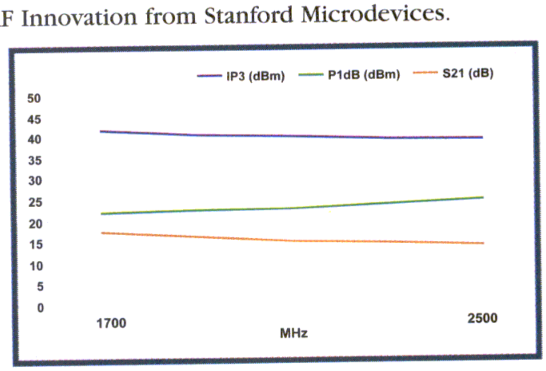

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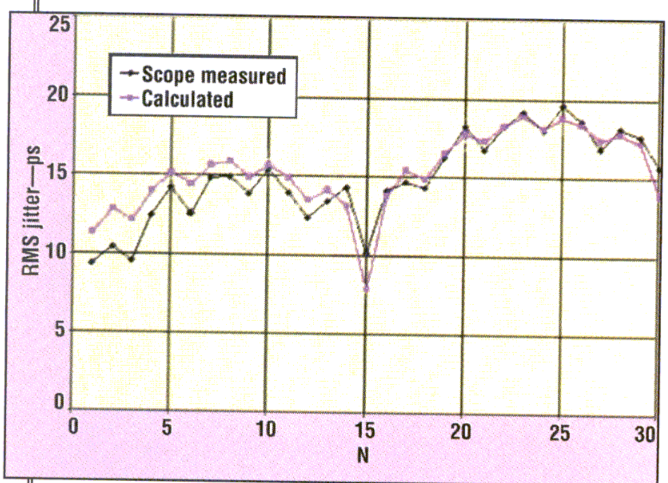
DSO's own jitter. The plot also shows that simply measuring only one-period jitter is not necessarily a good way to characterize a PLL. Jitter accumulation, evidenced by the positive slope characteristic (Fig. 10), is a phenomenon where the timing error increases with each subsequent cycle. The jitter accumulation in PLLs depends upon the exact shape of the PLL phase-noise plot and the level and quantity of discrete spectral components. It is impossible to predict this behavior by reporting only one-period-jitter data values. If the application is sensitive to the accumulated jitter, the reference oscillator must be specifically characterized for this parameter using either a DSO or test-interface assembly (TIA).



10. Measurements of the PLL jitter are compared with calculated jitter and correlate closely. Close correlation results, because the jitter of the PLL is greater than that induced by the measuring instrument.

JITTER VS. PHASE NOISE

Applications that specify the RMS value of jitter in a frequency band usually measure RMS phase jitter on the filtered output of the clock-recovery PLL phase detector. Then, the phase jitter is converted to the time domain. The measured RMS phase jitter is simply RMS phase noise in the specified frequency band. To calculate this parameter from oscillator phase-noise data, integrate the oscillator phase-noise spectral density over the specified frequency band and take the square root of the result:

$$\Delta\phi_{RMS} = \sqrt{\int_{f_1}^{f_2} S_\phi(f)df} \qquad (29)$$

where:

the specified frequency band ranges from f_1 to f_2. To convert to the time domain, note that 2π of phase is equivalent to the signal period T_0—meaning that the corresponding RMS time jitter is:

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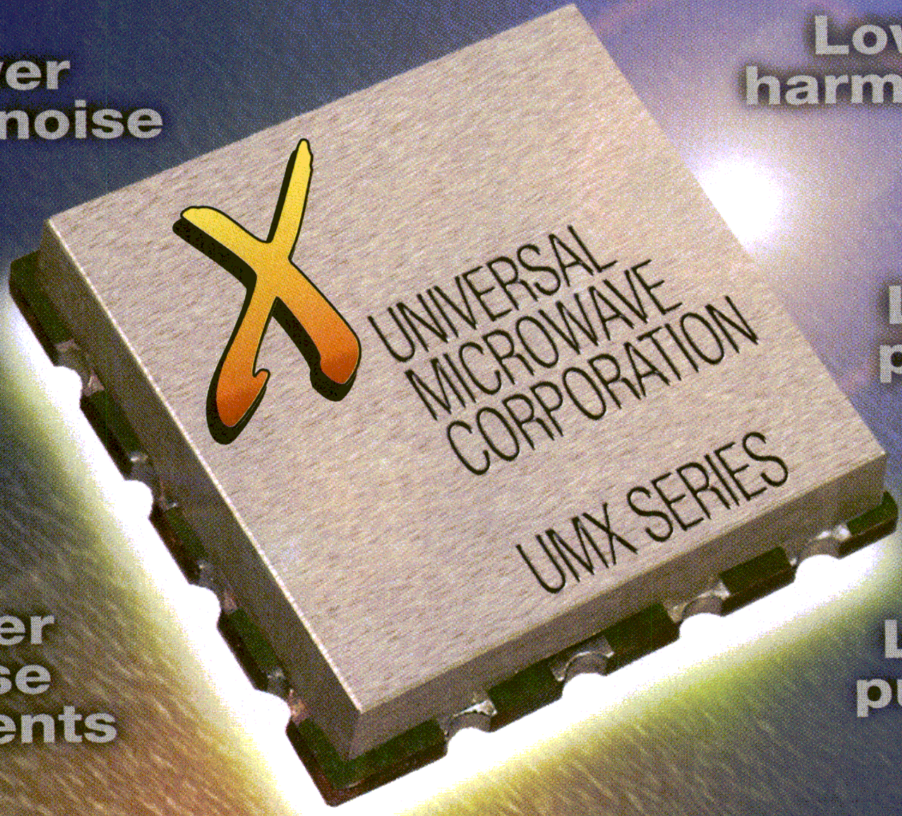

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UMX-254-D16	1800-1900	0.5-4.5	35	1.05:1	+7, ±2	-20	-110	0.8	1	5
UMX-364-D16	1860-2160	0.5-10	40	1.05:1	+5, ±2	-20	-107	0.8	2	6
UMX-270-D16	2160-2360	0.5-4.5	60	1.1:1	+5, ±2	-20	-106	0.7	2	5
UMX-315-D16	2175-2175	0.5-4.5	7	1.05:1	+7, ±2	-20	-120	0.5	2	6
UMX-333-D16	2650-2950	1-14	30	1.05:1	+5, ±2	-20	-104	1.0	3	6
UMX-375-D16	2850-2850	0.5-4.5	7	1.05:1	+7, ±2	-20	-118	0.8	2	6
UMX-331-D16	3125-3275	0.5-4.5	50	1.05:1	+5, ±2	-20	-104	1.0	3	6

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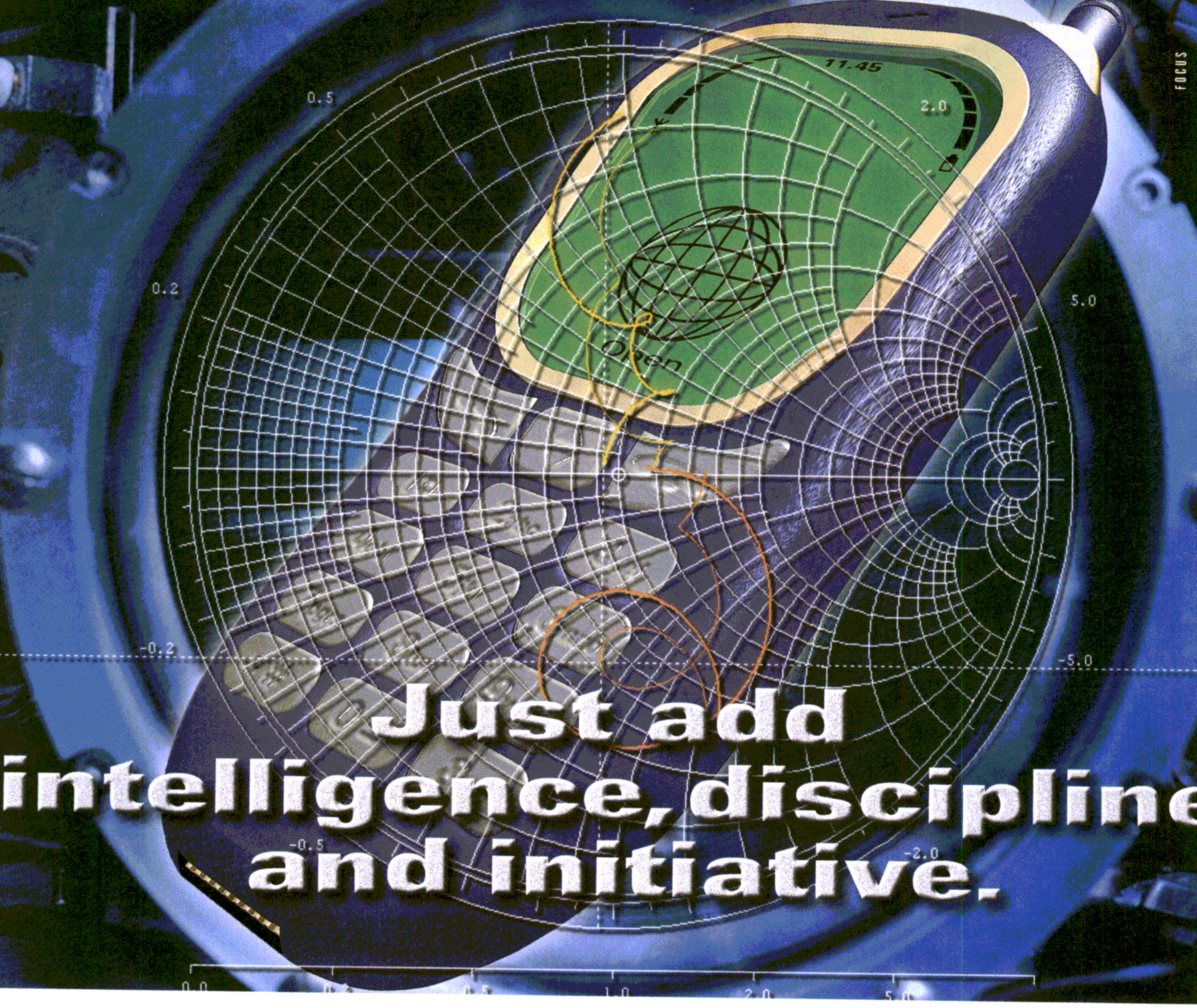
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IN ADDITION TO ITS PHASE-NOISE CHARACTERISTICS, A PLL HAS DISCRETE SPECTRAL COMPONENTS THAT RESULT FROM FREQUENCY MODULATION OF THE VCO BY THE FILTERED OUTPUT OF THE PHASE DETECTOR.

$$\Delta t_{RMS} = \frac{T_0}{2\pi} \Delta\phi_{RMS} \qquad (30)$$

These equations could also be used to estimate the required level of phase-noise floor to guarantee that RMS time jitter in a frequency band is less than the specified value. If the phase-noise floor in the specified band is independent of frequency, the result is:

$$S\phi_0 = 4\pi^2 \frac{1}{f_2 - f_1} \times \left(\frac{\Delta t_{RMS}}{T_0}\right)^2 \qquad (31)$$

For example, 155.52-MHz oscillator RMS jitter will be less than 1 ps in a 12-kHz-to-20-MHz frequency band if the phase noise of this oscillator is less than –133 dBc/Hz at any frequency in the band. Usually, the phase-measurement equipment displays L(f), which is single-sideband (SSB) phase noise. In terms of L(f), the noise-floor limit is –136 dBc/Hz. The phase-noise plot of an oscillator normally rolls down with frequency. This means that if the phase noise at f_1 is less than the calculated $S\phi_0$ value, the oscillator will meet the specification even if the phase-noise value at f_2 is not known. It should be noted that the level obtained in Eq. 31 guarantees meeting the specification. If the oscillator phase noise exceeds this level at some frequencies in the specified band, the oscillator could still meet the specification, but a full evaluation of the integral in Eq. 24 will be required. If the oscillator incorporates a PLL that has discrete spectral components in the specified band, the situation will be more complicated, but it also can be handled using the previous equations. ••

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Analog BiCMOS Design-Practices and Pitfalls

James C. Daly and Denis P. Galipeau

Analog circuit design is a craft in short supply these days, with many in the electronics industry believing that universities do not give it the emphasis accorded to digital design. Educators at the University of Rhode Island, however, are addressing the situation as evidenced by *Analog BiCMOS Design—Practices and Pitfalls*. The book is used in a senior level and graduate school course and students design and fabricate an analog integrated circuit (IC) based on the course contents (fabrication is performed at the facilities of Cherry Semiconductor Corp. in East Greenwich, RI).

As indicated by its title, the text covers analog design in the increasingly important bipolar-complementary-metal-oxide-semiconductor (BiCMOS) technology. RF BiCMOS processes, in particular, are making strong inroads in transceiver and base-station designs for wireless communications. But this book is geared toward the fundamentals of analog BiCMOS, not the specialized designs and processes needed for operation at 1 GHz and beyond.

The book opens with a chapter on the characteristics of basic devices: pseudorandom-noise (PN) junctions, bipolar transistors, MOS transistors, and Zener diodes. Chapter 2 examines models of bipolar and MOS devices, such as Gummel-Poon and the bipolar SPICE implementation. A useful section of this chapter is "Simple Small-Signal Models for Hand Calculations," covering bipolar and MOS transistors. Chapter 3 discusses current sources which, the authors point out, are the foundation of circuit design in microelectronics. The section covers current mirrors in bipolar and MOS, with design examples for each.

A short chapter is devoted to voltage references covering the basic theory of the Zener voltage reference and the bandgap reference. Chapter 5 covers basic amplifier circuits for bipolar and MOS devices—common emitter, common base, common source, etc. Bipolar circuits are covered first, followed by an equivalent analysis for MOS circuits. Chapter 6 investigates comparators, while Chapter 7 looks at the various output stages of amplifiers, such as common emitter Class A, push-pull Class B, and CMOS stages.

The "pitfalls" of analog design, from the subtitle of the book, are explored in Chapter 8. The object is to show prospective designers how IR drops, temperature effects, latchup, and other semiconductor phenomena can lead to circuit failure, often necessitating costly redesign and refabrications. (2000, 219 pp., hardcover, ISBN: 0-8493-0247-1, $79.95). **CRC Press LLC, 2000 NW Corporate Blvd., Boca Raton, FL 33431; (561) 994-0555, Internet: http://www.crcpress.com.**

Selecting A Shielding Supplier

Part 2 of 2 Parts

The quality of a shielding supplier can often be measured in terms of the level of communications and technical support offered to a customer.

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SUPPLIERS of shielding materials vary in size, product lines, and resources. But for the customer seeking a source of shielding materials, bigger is not always better, and picking the wrong shielding supplier can be financially devastating in terms of missed shipments and dissatisfied customers. In the final installment of this two-part series, the answers to several important questions help the reader to identify the strong and weak points of large and small shielding suppliers.

How good is the quality of a shielding supplier's marketing communications (i.e., literature, website, etc.)? Marketing communications are a window to the quality of a shielding supplier. For example, catalogs should be easy to follow and read, with easily discernible pictures showing product features. There should be enough information provided to make an intelligent selection on a product type. Invoices and statements should be clear, up to date, and self-explanatory. And advertising and mailing pieces should be honest and straightforward, without false claims or promises. The company's message should be clear and consistent throughout their marketing communications efforts, and their website should be uncluttered and easy to navigate so that customers and potential customers need not work hard to locate, design, and specify information.

Does the shielding supplier have the manpower to perform manual assembly? It is the extra value-added operations that can provide a customer with the total solution that can make the difference in successfully delivering a finished product on time. It could be part of an application that a machine alone cannot complete—the need for a number to be written on a part, a flange to be folded or bent, a piece to be screwed down, a thermal barrier to be installed inside a cover, Mylar to be added, capping, etc.

Does a shielding supplier have the ability to provide automated assembly operations? If a requirement involves a large quantity (generally from 10,000 to millions of pieces), and "pick-and-place" production assembly is required, then the shielding supplier should offer tape-and-reel capabilities. (see Fig. 2 in Part 1 of this article series).

Is the shielding supplier's management available to settle a dispute? Hopefully, any discrepancies or disputes regarding samples, orders, invoicing, etc., can be settled at the salesperson or technician level. However, if there is a need for a supervisor's intervention, the shielding supplier's management should be available to intervene and settle any disagreement quickly and to the satisfaction of the customer.

How good is the integrity of the packaging for the shielding products? It is very important to know how your product will be packaged. Is there flexibility in packaging an order differently depending on your project requirements? If it shipped perfectly but was delivered damaged, you will have problems at the 11th hour, which can seriously affect delivery. Does your supplier have packaging standards available to you? Do they monitor shipping and packaging on every order?

Does a shielding supplier always keep a customer informed on industry trends and new products? Most shielding suppliers maintain a customer mailing list. Some send information regularly, such as newsletters, mailers, and product announcements. A customer should receive information from a qualified shielding supplier on a regular basis, at least several times each year, in addition to receiving information on a supplier's new products and developments at their website or in trade publications such as *Microwaves & RF* and *Wireless Systems Design.*

If a shielding supplier does not have a solution available, do they recommend another company's product? This may be rare, but there are some suppliers that will refer a customer to another, competitive shielding company when the other company can provide the proper solution. A supplier that considers a customer's interests ahead of their own is invaluable.

How flexible is a shielding supplier's production line? No design is static. Can a shielding supplier accommodate a special request for a custom modification? Many suppliers stock only standard shielding materials, and custom requests add penalties in artwork costs, time, and tooling costs. Shielding suppliers with diversified product lines can modify a design quickly, easily, and inexpensively, providing a total solution to an application.

FLEXIBLE TERMS

How flexible are a shielding supplier's contractual terms? When a product development runs late, it may be necessary to process an order overnight. Dealing with a shielding supplier that is willing to accept a major credit card may be an advantage when an order for shielding materials must be filled quickly. A purchase order can sometimes take up to two weeks to process, excess time which can endanger a production or development schedule.

Is the shielding supplier innovative (i.e., do they hold any patents)? Always look more seriously at the company that introduces new quality products on a regular basis, perhaps one to three per year. With technology changing so rapidly, it is important to introduce products that can (separately or together) offer application solutions. If a company has a patented product, one can be ensured that there was something unique and important about the product to warrant a patent.

CONSISTENT PRICING

How consistent is a shielding supplier's pricing? Is their pricing competitive for samples, prototypes, and production runs? Is it consistent or does it vacillate depending on an immediate need or crisis? Does a shielding supplier raise prices during a rush delivery or does their pricing remain consistent and fair?

To what level of quality does the shielding supplier perform? Testing is quite expensive. Some shielding suppliers have test labs on premise and many have started or are already phasing them out because they are so expensive to maintain. They prefer to have outside testing labs perform this function—labs that are readily available and at a more reasonable cost than the onsite group. It is generally more cost-efficient to deal with a supplier who has reliable outside laboratories available and can supply the necessary test capabilities when required. Even the highest-priority measurement tasks can be victimized by internal test-lab scheduling quirks.

What level of product quality does the shielding supplier offer? This is the foundation of any company's reputation—their product quality. A qualified supplier should deliver a consistently reliable product whether it is a custom solution or an off-the-shelf product.

This list has attempted to address most of the questions faced by an engineer or technician in need of a shielding supplier. For those questions that remain unanswered, readers are invited to contact the author.●●

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Event Showcases Products For Bluetooth Developers

Thousands of developers and manufacturers with a vested interest in the spread of Bluetooth-enabled devices gathered last December in San Jose, CA.

JACK BROWNE
Publisher/Editor

BLUETOOTH™ may become one of the largest wireless applications ever created. But before that can happen, further education is needed among design engineers on how to partition their integrated circuits (ICs), how to package modules inexpensively, and how to performance measurements quickly and easily. For that reason, thousands of potential Bluetooth product designers gathered last December in the San Jose Convention Center (San Jose, CA) to be part of the Bluetooth Developers Conference.

Held from December 5-7, 2000, the Bluetooth Developers Conference featured several keynote addresses, technical presentations, and a bustling exhibition area. Open only to Bluetooth developers (and not to the general public), the event offered keynote addresses from Frank Spindler Jr., vice president of the Architecture Group for Intel (Santa Clara, CA); Greg Waters, wireless vice president for the Microelectronics Group of Lucent Technologies; and Paul Chellgren, vice president for business development and product management for the Americas region of Nokia Mobile Phones. The technical sessions were formed into five conference tracks: Bluetooth specification (and its impact on more than 11 industries), Bluetooth industry development and applications (with financial analysis), Bluetooth software (including stacks and applications), Bluetooth silicon (Si) and hardware, and Bluetooth solutions (with presentations on developers kits and case studies). Key sponsors of the event included Cambridge Silicon Radio (CSR; Cambridge, England), Conexant Systems, Inc. (Newport Beach, CA), Ericsson Microelectronics (Richardson, TX), Philips Semiconductors (San Jose, CA), Silicon Wave (San Diego, CA), and Texas Instruments (Dallas, TX). The Bluetooth Developers Conference was managed by Key3Studios, a division of Key3Media Group, Inc. (Foster City, CA), [www.key3media. com].

The exhibition area represented a miniature, single-hall precursor to what larger, future Bluetooth events might hold. More than 60 booths offered hardware, software, and test equipment from various Bluetooth Special Interest Group (SIG) members aimed at encouraging the development of next-generation Bluetooth consumer products. The Bluetooth SIG includes promoter companies 3Com (Santa Clara, CA), Ericsson Mobile Communications AB (Lund, Sweden), IBM (Armonk, NY), Lucent Technologies (Allentown, PA), Microsoft Corp. (Redmond, WA), Motorola (Schaumburg, IL), Nokia Group (Finland), and Toshiba (Irvine, CA), along with more than 2000 Adopter/Associate member companies.

Bluetooth is a low-cost radio standard essentially developed by Ericsson to replace wires between personal computers (PCs), cellular telephones, and peripheral devices. It is based on spread-spectrum techniques using license-free industrial-scientific-medical (ISM) frequencies at 2.4 GHz and can operate at distances up to 100 m.

As might be expected, many of the exhibitors displayed building-block components for assembling a Bluetooth radio. Perhaps the best-established of these building blocks is the Bluetooth Radio from Ericsson Microelectronics. The model PBA 313 04 transceiver requires only an antenna, a reference crystal, and digital control functionality to form a complete Bluetooth radio. The assembly is based on a proprietary Si bipolar-complementary-metal-oxide-semiconductor (BiCMOS) application-specific integrated circuit (ASIC) and includes an antenna filter, along with transmit and receive baluns on the ceramic carrier. The radio, which is suitable for embedded applications in code-division-multiple-access (CDMA) cellular telephones, is supplied in a compact self-shielded ceramic ball-grid-array (BGA) package measuring only 10.2 × 14.0 × 1.8 mm. The company also supplies starter and developer kits, and a Bluetooth Module which is a complete radio/baseband unit suitable for embedded applications.

Similar to Ericsson's Bluetooth Radio, Lucent's model W7020 radio subsystem is a complete integrated transceiver that includes an antenna filter and transmit and receive baluns. It provides better than –75-dBm receiver (Rx) sensitivity and operates from a +2.7-VDC supply. The W7020 requires only an external antenna and a 13-MHz reference crystal or clock signal for radio operation. Similar to Ericsson's solution, the W7020 is designed for use with a digital baseband IC.

The modular approach was also popular at the Philips booth, where representatives shared information on their BGB100 "plug-and-play" Bluetooth radio module. Using a near-zero intermediate-frequency (IF) radio architecture, the module includes a transceiver chip, an antenna filter, a transmit/receive (T/R) switch, transmit and receive baluns, and a voltage-controlled-oscillator (VCO) resonator. Integrated on a low-temperature-cofired-ceramic (LTCC) substrate, the circuit is connected to a main printed-circuit board (PCB) through a land-grid-array (LGA) package. The Rx sensitivity is better than –80 dBm, using an IF of 1 MHz. The module, which measures 12.25 × 9.8 × 1.9 mm and works with a baseband controller, requires only an external antenna and a reference clock.

Samsung Electronics (Kyungki-Do, Korea) offered a Bluetooth module that provided RF, baseband, and host interface functions. Based on Si BiCMOS technology, the transceiver is designed for use with the company's 16-b CalmRISC low-power microprocessor core. The module is supplied with fully supported CalmRISC application software-development tools.

Bluetronics (Norrkoping, Sweden) offered the IRMBB2 Bluetooth radio module, one of the first Bluetooth IC solutions with an integrated antenna. The firm integrates a patch antenna with passive components, such as capacitors, inductors, and baluns, on the interconnection substrate to form a complete CMOS/BiCMOS radio module. The Bluetooth module and integrated antenna fit on a plastic substrate measuring only 17 × 19 × 3 mm. The module provides an operating range of 10 m with 0-dBm transmit power. The BGA module incorporates the Bluetonium BCM2001B CMOS radio IC from Broadcom, along with the patch antenna, a bandpass filter, a switch, baluns, and decoupling capacitors.

Atmel Corp. (San Jose, CA) displayed their complete RF/baseband Bluetooth solution in the form of the T2901 RF transceiver IC and the AT76C55X baseband/controller IC. The former is a complete transceiver with an integrated frequency synthesizer and VCO while the latter has an embedded ARM processor, dedicated voice codec hardware, and internal static random-access memory (SRAM). The firm also supplies the T7024 RF front-end amplifier with +23-dBm typical output power, for boosting the operating range of the T2901 from 10 to 100 m.

Fujitsu Microelectronics (San Jose, CA) offered technology for effectively packaging Bluetooth integrated solutions. The firm's lines of ball-chip-carrier (BCC) packages provide very-high die-to-package ratios since they are close in size to the semiconductor die that they protect. A variety of package pin counts is available for designs with good thermal characteristics, low self-inductance, and low mutual inductance and capacitance. The BCC packages maintain good signal integrity at frequencies past 10 GHz and data rates past 10 Gb/s.

BUILDING KITS

CSR promoted the CASIRA Bluetooth developer's kit. Based on the company's BlueCore single-chip Bluetooth solution, the kit provides hardware and software developers with all the Bluetooth "ingredients" that they need to assemble a final Bluetooth product design. On the hardware side, the kit includes a module with the BlueCore chip; Flash memory; a crystal reference; the antenna; and a motherboard with the host input/output (I/O) connections; man/machine-interface elements, such as RS-232 and universal-serial-bus (USB) drivers and connectors, and an audio codec. On the software side, the kit offers a full Bluetooth protocol stack running on the BlueCore chip. The protocol stack is reconfigurable for different partitions between the Bluetooth host and host controller. The kit also includes BlueChat, which is a simple PC-based host application, example source code in C language, and a Flash-memory programming utility program. The kit is also supplied with a pair of headsets, digital cables, and power supplies.

BrightCom Technologies (Carlsbad, CA) displayed several single-chip Bluetooth protocol processors, including the IntelliBLUE BIC2000 and BIC2101 models. The BIC2000 incorporates the Bluetooth baseband and protocol stack as well as various profiles and applications. It is designed for hostless and host-based operation and supports the Bluetooth Programmable Radio Interface, PCI, and RS-232C interfaces. The BIC2101 is a single-chip protocol processor designed for Bluetooth connectivity and networking applications through a USB or pulse-code-modulation (PCM)/serial port. BrightCom demonstrated an application allowing a pen-type device to send digitized script across freespace to a laptop computer. The application, developed for a strategic partner, does not require any processing power at the receiving device, which can be a computer, cellular telephone, personal digital assistant (PDA), or any electronic device that can run the handwriting-conversion software.

Infineon Technologies (Munich, Germany) brought a host of IC solutions to the Bluetooth Developers Conference, including its Bluemoon I chip set. The chip set consists of two ICs, an RF transceiver, an integrated baseband processor, a link manager, and host-controller interface chip. The RF transceiver integrates a receive IF filter and does not require an external filter to meet Bluetooth specifications. Manufactured with a Si BiCMOS process, the transceiver is housed in a tiny TSSOP38 package. The CMOS baseband controller includes an external Flash-memory interface for rapid prototyping. The chip incorporates a link controller with an integrated PCM interface, UART support for hardware and software handshaking, and integrated program read-only memory (ROM).

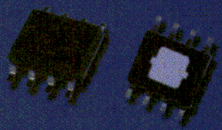
The firm also showcased a high-ef-

emand for high linearity in communication ystems is accelerating.

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

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

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



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ficiency power amplifier (PA) for long-distance (Class 1, 100-m distance) Bluetooth applications. The CBG240 amplifier, which can also be used for 2.4-GHz wireless local-area-network (WLAN) applications, is a two-stage device rated for +23-dBm output power at 1-dB compression from 2.4 to 2.5 GHz and +3.2 VDC. The amplifier also provides control of four output-power settings—+7, +12, +17, and +23 dBm, through analog voltage-control adjustments, allowing Bluetooth devices to be optimized for required range while controlling power consumption. The amplifier features 50-percent typical overall power-added efficiency (PAE) and can operate from a single voltage supply of +2 to +6 VDC. Harmonic suppression is typically better than 40 dB. The heterojunction-bipolar-transistor (HBT) amplifier is manufactured with an indium gallium-arsenide phosphide (InGaP) process. According to Dr. Ewald Pettenpaul, general manager and vice president for the company's Gallium Arsenide business unit, "Our Bluetooth power amplifiers achieve the best RF performance compared to the competition for Class 1 Bluetooth applications, further demonstrating our technological leadership and reinforcing our market position as a leading provider of advanced RF semiconductors for the telecommunications market."

A pioneer in silicon-germanium (SiGe) bipolar and BiCMOS processes, SiGe Microsystems (Ottawa, Ontario, Canada) also brought a Class 1 Bluetooth PA to the Bluetooth Developers Conference—the model PA2423. The tiny amplifier provides +22.7-dBm output power from 2.4 to 2.5 GHz, which translates into +20 dBm at the Bluetooth antenna. It can be supplied in an MSOP8 package for operation at +3.3 VDC where the device achieves 45-percent PAE when operating in Class AB mode (which accounts for the full amplifier chip). The two-stage, low-current amplifier requires only 88-mA current for its rated output power.

Galtronics Corp. (Phoenix, AZ) introduced an innovative Bluetooth antenna, building upon earlier designs that included a half-wave dipole antenna for access points and a half-wave swivel retractable antenna for PC cards.

For those who are curious as to how Bluetooth will fit with WLAN systems, Silicon Wave discussed their partnership with Intersil (Melbourne, FL) to develop ICs for dual-mode Bluetooth and WLAN use. The devices would be used in the construction of a IEEE 802.11b-compliant WLAN radio that could also be switched for Bluetooth use. The availability of these devices would allow both radios to use a common 2.4-GHz antenna and would result in a product that is considerably smaller than the two separate stand-alone systems. According to Greg Williams, CEO and president of Intersil, "We're satisfied that both of these wireless technologies can reside on the same card, giving users the best of both wireless worlds with ease of use, small size, and an affordable price." Dave Lyon, CEO of Silicon Wave, concurs, "By working closely with Intersil, we are able to assure customers and manufacturers of the compatibility of these two dynamic technologies." Silicon Wave is perhaps best known for its Odyssey radio solutions for Bluetooth connectivity, while Intersil is associated with its PRISM WLAN chip sets.

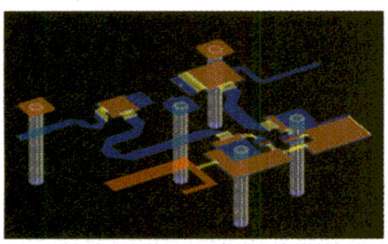
TESTING HARDWARE

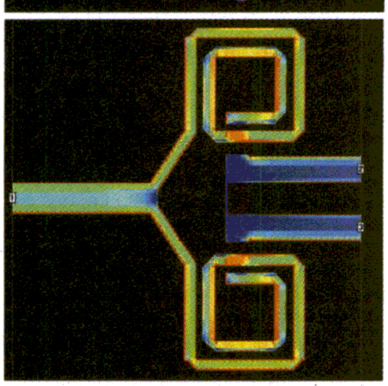
Of course, Bluetooth products can only come to market after they have been tested, and numerous measurement companies were in attendance at the conference with first-generation test systems. For example, Agilent Technologies unveiled their model E1852A Bluetooth Communications Test Set. It performs basic Bluetooth radio testing under the control of a PC. The instrument establishes a link to a Bluetooth device under test (DUT) using standard Bluetooth protocols (see p. 154). It can perform frequency-hopping measurements, check frequency-modulation (FM) deviation, evaluate frequency errors on specified RF bands, perform bit-error-rate (BER) Rx tests on single and multiple timeslots, execute parametric measurements, and make measurements of power over bursts.

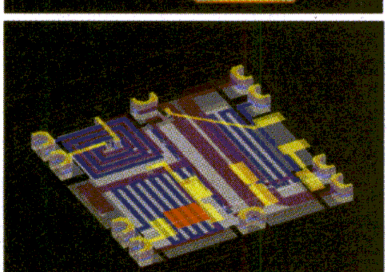
Celerity Digital Broadband Test (Cupertino, CA) offered a peak at their model CS20310B Bluetooth RF testset. The testset provides signal capture across a full 83.5-MHz bandwidth, allowing up to 12,800 sequential hops to be captured in high-speed memory. A broadband downconverter and a high-performance 300-MSamples/s analog-to-digital converter (ADC) are used to capture all of the frequency hops in time, preserving the frequency, modulation, and transient information. The recorder/Rx portion of the testset features –80-dBm sensitivity from 2.4000 to 2.4835 GHz. On the signal-generation side, a precise 300-MSamples/s digital-to-analog converter (DAC) is used to create Bluetooth test signals across the full 80-MHz frequency-hopping bandwidth. The generator delivers 0-dBm output signals with ±1-dB flatness. It includes output attenuation from 0 to 31 dB in 0.5-dB steps.

Computer Access Technology Corp. (Santa Clara, CA) demonstrated their "Merlin's Wand," a new generator for Bluetooth protocol testing. Using its software interface, operators can quickly and easily issue protocol commands and test sequences to analyze or validate designs for compliance to Bluetooth specifications. The instrument is a logical companion to the firm's earlier Merlin Bluetooth Protocol Analyzer which provides advanced event counting and sequencing, comprehensive error detection and analysis, and programmable real-time event triggering and event capture. It connects to a host computer through a USB port.

Representatives from Rohde & Schwarz (Munich, Germany) discussed the company's various measurement solutions for Bluetooth components and systems, including the TS8960/65 test systems for pre-qualification and evaluation of Bluetooth designs. In addition, the company's PTW60 test platform is well-suited for protocol testing according to Bluetooth requirements. The firm also offers a wide range of digitally modulated signal generators and radio-communications test solutions.







Tektronix (Beaverton, OR) displayed their model BPA100 Protocol Analyzer. The instrument, acquired from Digianswer (Nibe, Denmark), a subsidiary of Motorola, is designed to speed and simplify Bluetooth hardware/software integration. It provides packet-data error generation, data decryption, real-time protocol decoding and display, and sophisticated triggering functions. According to Craig Overhage, vice-president for the company's Digital Systems Business Unit, "The BPA100 enables customers to design and build next-generation Bluetooth products by providing a proven solution for device turn-on, stress testing, and interoperability testing, all of which are key to the rapid development of Bluetooth products."

The BPA100 can join and monitor a Bluetooth piconet. In the piconet mode, the BPA100 can generate traffic or inject intentional errors into the piconet to test the capabilities of other devices to stay reliably connected under difficult or stressed conditions. In its independent mode, the BPA100 non-intrusively captures and analyzes data transfers within the piconet.

The BPA100 captures all baseband packets transmitted within a piconet and displays packet payload, status information (such as access errors), and estimated clock and hop frequencies. In addition, the data can be displayed at higher protocol levels, such as Link Management Protocol (LMP), Logical Link Control and Adaptation Protocol (L2CAP), RF communications serial cable emulation based on ETSI TS07.10 (RFCOMM), and Service Discovery Protocol (SDP). With selective filtering and advanced triggering, only data of interest may be logged, simplifying the identification of errors. In free-run display mode, the instrument display updates continuously as new packets are received, allowing the user to observe changes and track messaging in higher protocols. Connection between the protocol analyzer hardware and the monitoring software on the host computer is through USB; data storage is limited only by the size of the user's disk drive. ●●

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(continued from p. 100)

to bias the shunt PIN diode. C159 and C162 are DC blocks. L3, L4, and L8 are RF chokes. With high bias current, the PIN diode will exhibit low resistance, and vice versa. A bias network can be achieved by trial and error on the lab bench. In this particular design, R108, R103, R107, R104, R105, and R106 are chosen to be 61.9, 330, 330, 510, 510, and 1000 Ω, respectively. This particular set of resistances is found to work well to maintain the proper series/shunt-resistance ratio. Thus, good input and output matching is achieved. The RF choke is implemented with 22-nH chip inductor, which has high-enough impedance to block the RF energy. A DC block capacitor of 10 pF has low-enough impedance for passing RF energy at 2.45 GHz. In this particular design, low insertion loss (less than 2 dB) is highly desirable. The RF inductor and DC block are carefully chosen and optimized to minimize the insertion loss at 2.45 GHz. Table 4 lists the parts used in this design.

The π-configured VCA is designed and built for 2.4-to-2.5-GHz unlicensed industrial-scientific-medical (ISM) band. The circuit is built on FR-4 low-cost substrate. With I_{bias} = 26.5 mA, the lowest insertion loss is –2.5 dB. This includes approximately 0.4-to-0.5-dB cable and connector loss. With I_{bias} = 0 mA, the highest insertion loss is –37 dB. The designer should also check the return loss at input and output ports to make sure the VCA is absorptive, not reflective. The return loss is excellent below –20 dB in most cases for this design. The worst-case return loss is still –14 dB, which is good enough for most applications.

DESIGN APPROACHES

Three design approaches, each with its own advantages and disadvantages, are presented here. The important goals in VCA design are: bandwidth, power-handling capacity, dynamic range, port matching, current consumption, space, and ease of design. The π-configured approach is wide bandwidth by nature. It can be designed easily to cover DC to 4 GHz, but it will have more insertion loss at high frequencies. The other two approaches have limited bandwidth due to the quarterwave transformer and hybrid. Since all three approaches use PIN diodes, they all can handle more RF power than their gallium-arsenide (GaAs), FET counterparts. They also have fewer intermodulation (IM) products. From the data result above, it is clear that the resistive-line approach offers the highest dynamic range (greater than 50 dB, compared to approximately 30 dB for the other two approaches). But it requires approximately three times as much space as the other two. The constant-impedance approach uses the least amount of bias current (5.11 mA) to produce 30-dB dynamic range. It can be implemented in many different ways due to the design freedom of the hybrid.

The π-configured approach is the most compact approach. From the ease-of-design perspective, the constant-impedance approach is the easiest one. The resistive-line approach follows as the second-easiest one. It requires many simulations to determine the optimized transmission-line dimension. The π-configured approach requires a trial-and-error approach to get the bias network right. So it will take a while for a good engineer to come up with an optimized bias network. One of the objectives of this article is to present all the trade-offs involved in VCA design. A base-station design engineer might find the resistive-line approach best due to its high dynamic range and good matching, and because space and current consumption are not critical issues. On the other hand, space and current consumption are important to a handset designer, so the handset designer would probably prefer the constant-impedance or π-configured approach. Each approach has its advantages and disadvantages. Hopefully, this tutorial can help engineers choose the appropriate VCA design. ●●

Acknowledgement

The authors thank Mauren Bennett of Agilent Technologies, Peter Shveshkeye, Gerald Hiller, Todd Brown of Alpha Industries, and Chad Blitz of Anaren for their time, assistance, and generous discussions on technical issues.

Optimize high-speed data-converter performance

Analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) are vital elements in many communications circuits. Since communications systems often operate at high frequency, data converters running in these applications require special handling because their accuracy changes significantly when system speeds increase from moderate to fast. Designers must be particularly mindful of the interconnection of these devices to prevent subtle problems that can occur at high speeds.

An application note entitled "How to use High Speed Data Converters" from Analog Devices (Norwood, MA) features a number of tips to ensure good performance in the fast-signal world. Using a question-and-answer format, the four-page note is useful to explain some of the basics that even experienced designers can overlook. As might be expected, most of the things that go wrong at high speeds stem from improper grounding and decoupling of the converters. For example, a converter designed for high speed must have two ground pins, one for analog ground and the other for digital ground. This is because the impedance of a single bond wire for a common ground at high frequency would be sufficiently large to support crosstalk through on-chip stray capacitance between the analog and digital circuitry. Of course, the two grounds must be connected, and this should occur very close to the package with a low impedance connection that is then tied to the system's analog ground. This ground must finally connect to the system's digital ground.

A problem that can be easily overlooked concerns connecting a reference to the converter. Simply connecting the two devices is not advisable because references can introduce noise into the converter. This noise (and its accompanying inaccuracy) will be reflected in the converter's output which is proportional to the reference voltage.

The note is available as a free download from the company's website. **Analog Devices, Inc., Three Technology Way, Norwood, MA 02062; (781) 329-4700, Internet: http://www.analog.com.**

For more information, visit www.mwrf.com

Directional coupler configurations and options explained

Since they are passive components that have been a staple of RF and microwave circuits for decades, directional couplers do not enjoy the same spotlight that shines on the more glamorous microwave integrated-circuit (IC) technology. But as a three-page application note from Merrimac Industries (West Caldwell, NJ) points out, directional couplers can play numerous and important roles in microwave systems, such as sampling and leveling power; measuring and stabilizing frequency; injecting signals; and assisting in power measurements. They are available in a wide range of power-handling sizes, from small surface-mount packages to units that can work up to 600 W continuous or 10 kW peak.

The note, "Directional Couplers, Lumped Element & Stripline, 100 kHz to 65 GHz," introduces designers to the company's line of products, which includes three-port directional couplers, four-port bidirectional couplers, and four-port dual directional couplers. The information is of a general nature, explaining the configuration of line couplers, their packaging, coupling, loss values, and applications that require a certain type of device (for a detailed mathematical explanation of directional-coupler theory including ring and branch types, see "Understand The Basics of Microstrip Directional Couplers," in this issue of *Microwaves & RF*, p. 79).

The note explains the basic theory of line couplers and why a particular type may be more appropriate for a particular application. No coupler can transmit energy without losses, and the note provides a convenient table that shows the coupling value in one column and the coupling loss through the coupler in a second column. Coupling loss is a function of a device's coupling value (3, 6, 10,...30 dB) with the higher losses associated with the lower coupling value. Knowing the coupling loss and a unit's insertion loss, a designer can find the total transmission loss through the main line of a coupler.

A useful list of directional-coupler parameter definitions completes the application note, along with a list of applications in which the devices can serve. The note is available as a free download from the company's website. **Merrimac Industries, 41 Fairfield Pl., West Caldwell, NJ 07006; (973) 575-1300, FAX: (973) 575-0531, Internet: http://www.merrimacind.com.**

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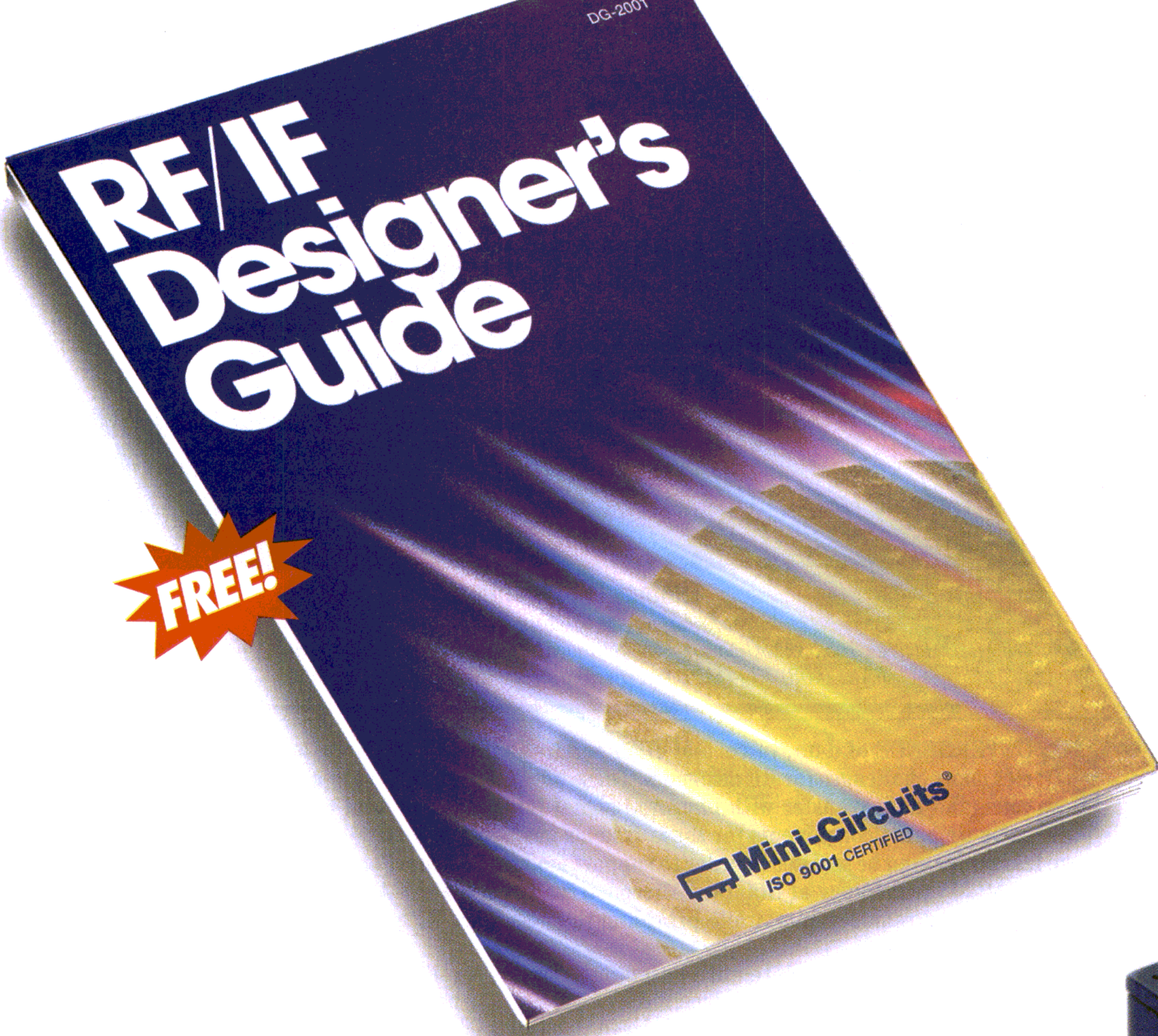

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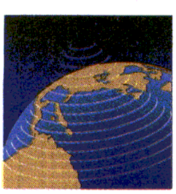

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Transceiver MCMs Fuel 3G Wireless Systems

The use of MCM technology can help cut the cost and power consumption without sacrificing performance in next-generation wireless designs.

Thomas P. Cameron
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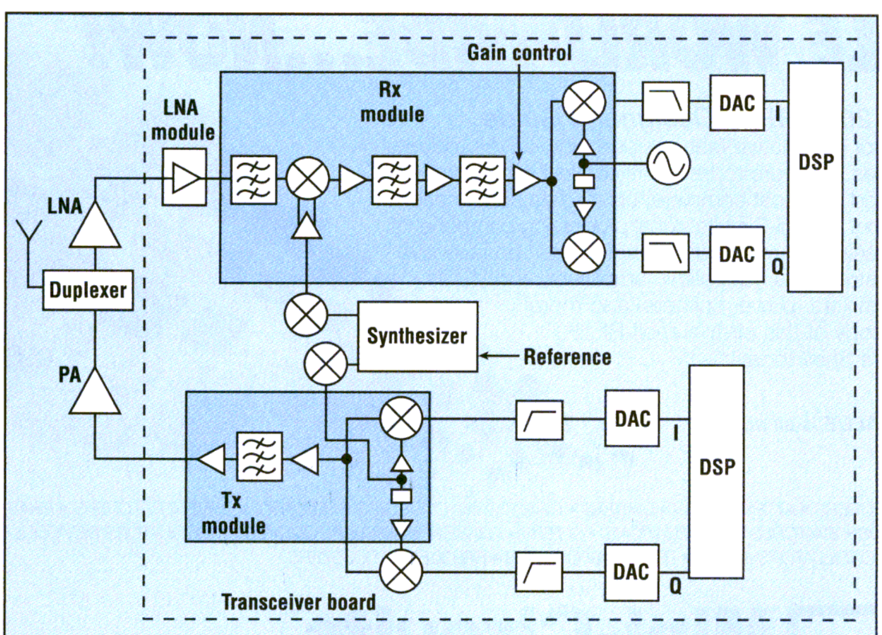
CONVERGENCE of data, voice, and other services within next-generation wireless systems carries many challenges for RF designers. These advanced wireless systems must provide enhanced voice and data transfer with improved signal integrity compared to existing systems. At the same time, the components for these systems must cost less, be available on short notice, consume less power, and be smaller in order to support modern designs. Fortunately, the use of multichip-module (MCM) technology at Stanford Microdevices (Sunnyvale, CA) has made it possible to meet these demanding requirements, while providing the necessary RF performance for third-generation (3G) wireless systems.

Figure 1 shows a radio architecture based on MCMs. The design uses a superheterodyne receiver (Rx) and direct upconversion in the transmit chain. The MCMs are comprised of a transmitter (Tx) module, a low-noise-amplifier (LNA) module, and a Rx module. These MCMs incorporate wideband silicon-germanium (SiGe) and gallium-arsenide (GaAs) RF integrated circuits (RF ICs) that provide design flexibility for many wireless applications.



1. The multicomponent-module (MCM) approach has been used to assemble this WCDMA transceiver for next-generation wireless base stations.

Although the discussion that follows focuses on a wideband code-division-multiple-access (WCDMA) system, the basic configuration can be tailored to other system applications by changing the narrowband components that characterize the specific band of interest. In the case of the Tx and Rx MCMs, this is achieved by changing the surface-acoustic-wave (SAW) filters. In the case of the LNA, the internal matching is modified to optimize the performance for the band of interest. Main-

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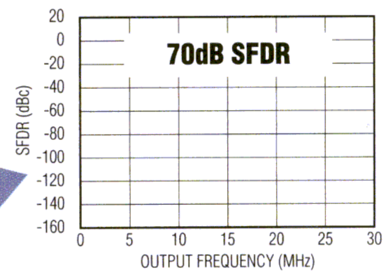

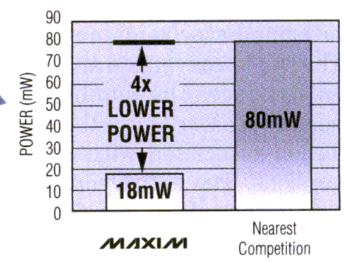

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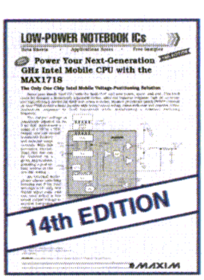
MAX5181/MAX5184	10	1	72	N/A	N/A	I_{OUT}/V_{OUT}
MAX5182/MAX5185	10	2 (Alternate Phase)	70	N/A	N/A	I_{OUT}/V_{OUT}
MAX5186/MAX5189	8	2 (Simultaneous)	58	±1	±0.2	I_{OUT}/V_{OUT}
MAX5187/MAX5190	8	1	60	N/A	N/A	I_{OUT}/V_{OUT}
MAX5188/MAX5191	8	2 (Alternate Phase)	58	N/A	N/A	I_{OUT}/V_{OUT}

Note: Alternate update dual DAC versions available for applications requiring lowest latency.



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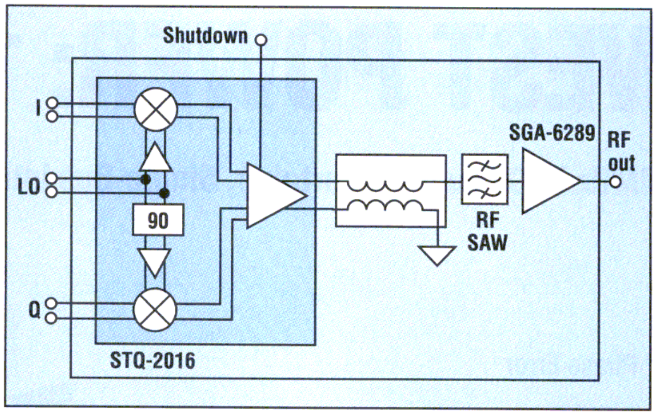
taining a common MCM footprint for different air-access standards enables the use of a common platform for the transceiver card. By using this common platform, a transceiver may be easily transformed to address new and emerging standards with reduced resources, resulting in a shorter design cycle and improved time to market.

Figure 1 highlights the application of the MCMs in a typical transceiver. The transmit chain is based on a direct upconversion architecture which eliminates the need for an intermediate-frequency (IF) filter. The single-conversion architecture not only reduces the number of components, but also reduces the noise degradation associated with multiple conversions. The entire conversion from baseband to RF is performed within the module, requiring only local-oscillator (LO) generation, power conditioning, and miscellaneous passive components to complete the transmit function on the transceiver-card design.



2. This block diagram shows the components used in the STX-3011 WCDMA Tx module.

The Rx chain consists of two MCMs—the LNA and the Rx MCM. The LNA is a 50-Ω module that includes impedance matching and device biasing within the MCM. The Rx MCM incorporates the full downconversion from RF to baseband, including two IF SAW filters and IF gain control.

Figure 2 shows a block diagram of the model STX-3011 WCDMA Tx MCM. The heart of this module is the model STQ-2016 wideband SiGe direct quadrature (Q) modulator. The STQ-2016 modulates the balanced in-phase (I) and Q baseband signals directly onto the RF carrier, eliminating the need for a second conversion stage in the Tx chain. This technique, which is gaining popularity among system designers, reduces cost and size of the Tx chain, and eliminates the noise contribution from the second conversion. This architecture can be implemented only if the modulator has sufficient suppression of the LO and the image signals.

The STQ-2016 was designed with wideband input (baseband and LO) and output (RF) ports for a wide range of systems. The baseband ports have a 3-dB bandwidth exceeding 1 GHz that was measured in a 50-Ω system, while the RF and LO ports address the entire band from 800 to 2500 MHz. The entire modulator design is based on a balanced configuration from baseband to RF to optimize linearity and reject spurious signals. The 50-Ω balanced outputs are converted to a single-ended signal using a low-cost hybrid RF balun between the modulator and the RF SAW filter. The SAW filter has a ladder topology, and provides approximately 25-dB attenuation in the receive band. In the future, as SAW technology advances, it may be possible to replace the filter and balun with a balanced-to-single-ended SAW filter. These filters are currently available at lower frequencies but, at the time of publication, none of these filters were known to be commercially available for the Universal Mobile Telecommunications Services (UMTS) Tx band.

The output stage of the STX-3011 MCM uses a model SGA-6289 wideband SiGe gain block, with usable gain from DC to 5 GHz. The SGA-6289 has an output third-order intercept point (OIP3) of +34 dBm at 2 GHz, and dissi-

Table 1: Summarizing the STX-3011 Tx MCM

Parameter	Units	Minimum	Typical	Maximum	Test conditions
RF and LO frequency	MHz	2110		2170	
Baseband frequency	MHz	DC		1000	In 50-Ω system
LO level	dBm	–8	–5	–2	
Output power (1-dB comp.)	dBm		+12		
Output power	dBm		0		See note (1)
Carrier suppression	dBc		30		(relative to input LO)
Sideband suppression	dBc		40		
Broadband noise floor	dBm		–141		(At 2140 MHz)
Shutdown attenuation	dB		60		
Return loss (RF and LO)	dB		14		
Return loss (RF out)	dB	–12			
Current (+5 VDC)	mA		165		
Operating temperature	°C	–40		+85	

(1) Measured with +1.9-VDC DC bias of 200 kHz, 600 mV peak-to-peak differential drive, and I and Q signals in quadrature.

Table 2: Sizing up the SLX-2043 LNA MCM

Parameter	Units	Minimum	Typical	Maximum	Test conditions
Frequency range	MHz	1700		2200	
Input third-order intercept	dBm		+19		0 dBm per input tone
Output third-order intercept	dBm		+34		0 dBm per input tone
Noise figure	dB		1.2		
Gain	dB		15		
Output pwr. (1-dB comp.)	dBm		+20		
Input VSWR			1.5:1		
Output VSWR			1.5:1		
Supply voltage	VDC		+4		
Current	mA		120		
Operating temperature	°C	–40		85	

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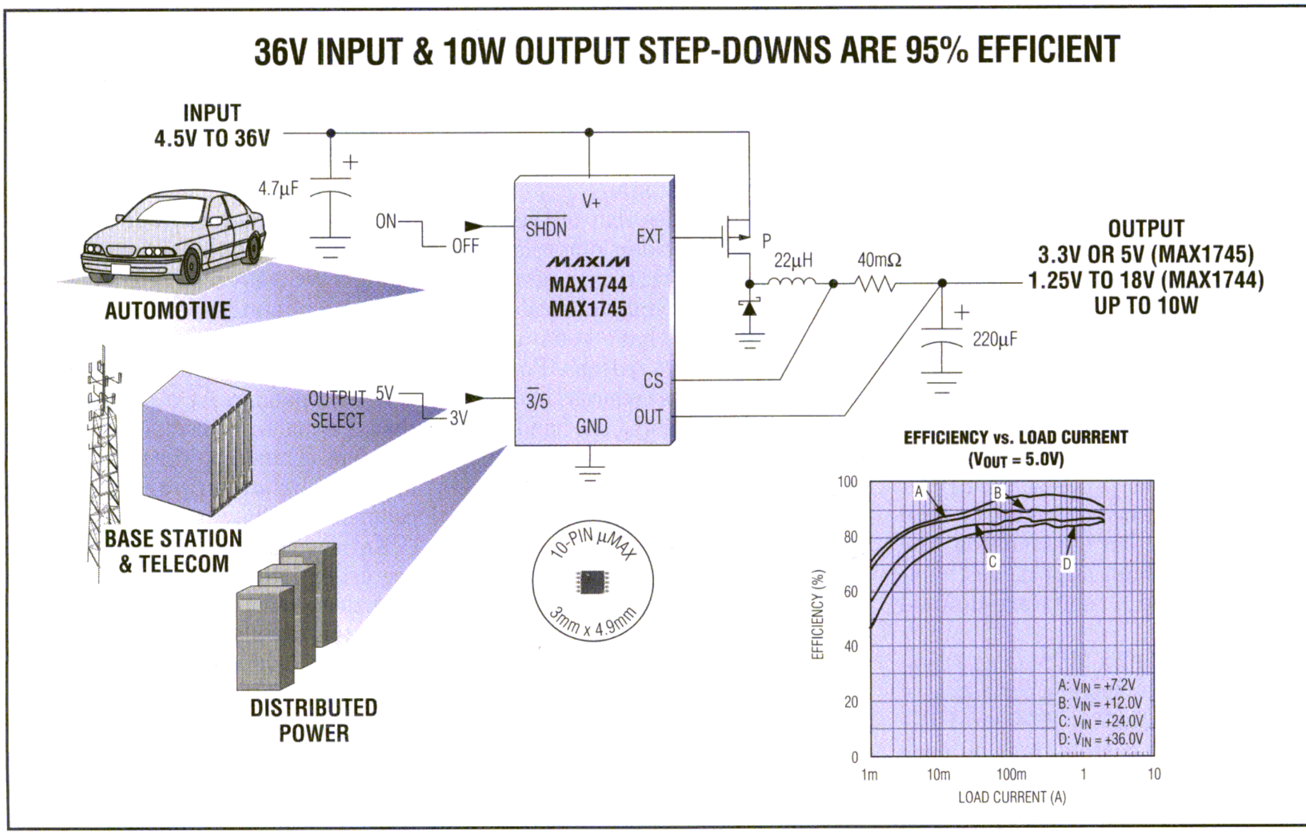

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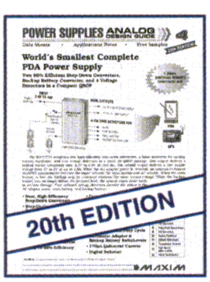

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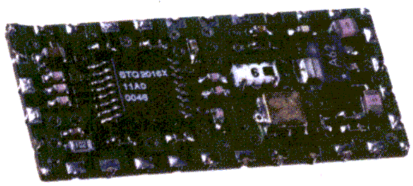


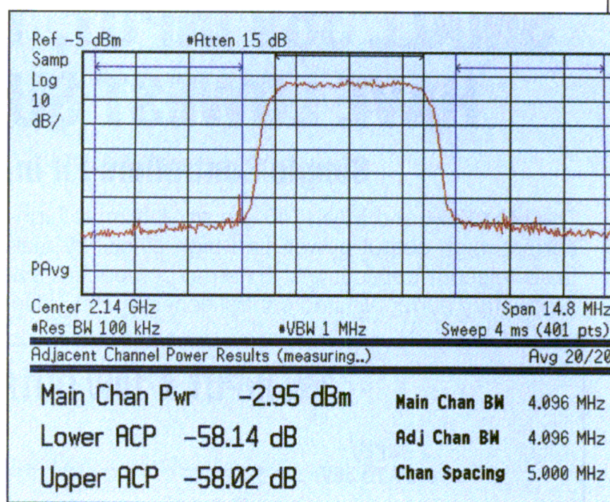
3. The STX-3011 WCDMA Tx module employs low-cost packaging based on the use of FR-4 substrate materials.

pates 300 mW of power when operating with a +4-VDC supply. The wide-band performance of the SiGe ICs enables the application of the Tx module to a number of wireless systems by changing the SAW filter and some passive components. With this MCM approach, a common transceiver motherboard may be used for many wireless-access systems. The module can be easily modified for any RF band, and the channel filtering may be performed in the digital signal processor (DSP). A single DSP can be soft coded or hard coded for a number of standards. The resulting Tx chain approaches what has been called a "software-defined radio."

The STX-3011 Tx MCM (Fig. 3) features low-cost packaging, consisting of a 0.5 × 1.0-in. (1.27 × 2.54-cm) FR-4 substrate with castellations on each side. The castellations are formed by cutting through rows of filled via holes along the perimeter of the module. Manufacturing of the module is based on commonly available surface-mount-assembly (SMA) techniques. This approach provides benefits from the economies of volume and takes advantage of the growing contract manufacturing industry. In addition, this technology provides fast turnaround times, enabling a short design cycle. From a technical standpoint, an FR-4 module has a coefficient of thermal expansion (CTE) that matches that of the FR-4 motherboard, so solder-joint reliability is less of an issue than with other materials, such as ceramic substrates.

Packaged parts have been used in this module for two reasons. First, using packaged parts reduces the cost of the module by avoiding the handling of bare die in the module-assembly process. Second, since hermeticity is required for the SAW filter, this approach eliminates the need for an overall hermetic seal on the module itself. This approach results in a compact design that enables outsource manufacturing simplicity and rapid speed of deployment.

Figure 4 shows the measured WCDMA adjacent-channel rejection for the Tx MCM. The baseband input signals were generated with a model ESG 4437 signal generator from Agilent Technologies (Santa Rosa, CA), using the built-in WCDMA function. A 4.096-MHz chip rate was used with 5-MHz channel spacing. At a power output that is equal to 0 dBm, the measured adjacent-channel power ratio (ACPR) is –58 dBc on upper and lower channels.



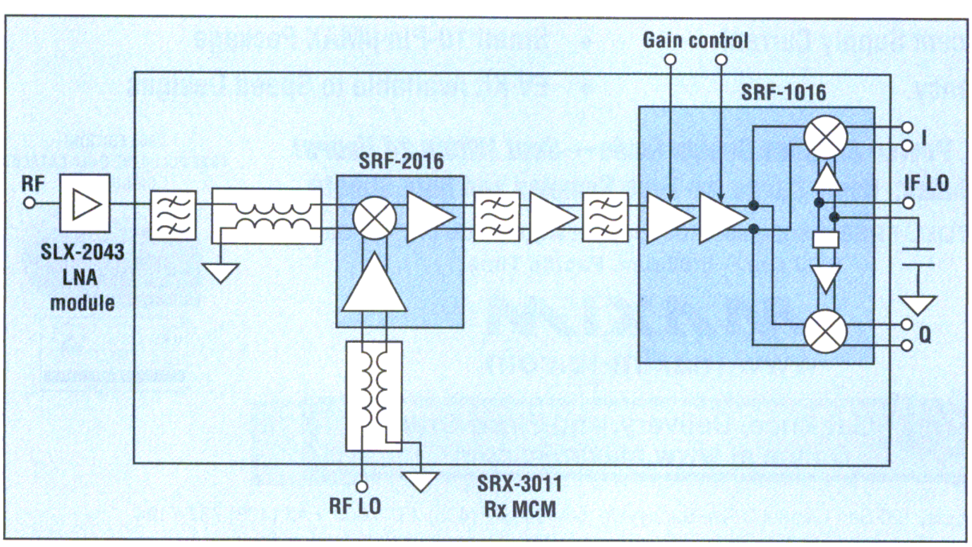
4. The ACPR performance of the STX-3011 Tx module was measured using a WCDMA chip rate of 4.096 MHz and channel spacing of 5 MHz.

Key specifications for the Tx module are listed in Table 1. The module has been designed for an output power of 0 dBm with a peak-to-peak input voltage of 600 mV. The output power at 1-dB compression is +12 dBm. The module has a shutdown feature that provides 60-dB isolation. The shutdown feature is controlled externally by a CMOS signal to the STQ-2016.

One of the most important specifications for a direct-conversion system is the carrier feedthrough. The STQ-2016 has a carrier feedthrough of –40 dBm, but the carrier may be further nulled with a DC offset adjustment. This adjustment has not been included in the present version of the STX-3011, but could be easily added, resulting in a slightly larger footprint.

Figure 5 shows a Rx architecture based on a conventional superheterodyne architecture. It consists of two MCMs, the model SLX-2043 LNA, and the model SRX-3011 Rx MCM. The LNA MCM is a complete "drop-in" module containing the matching circuitry and bias regulation.

Figure 6 shows that the SLX-2043 MCM is packaged



5. This block diagram of the STR-3011 Rx module shows the SLX-2043 LNA and the SRX-3011 receive modules.

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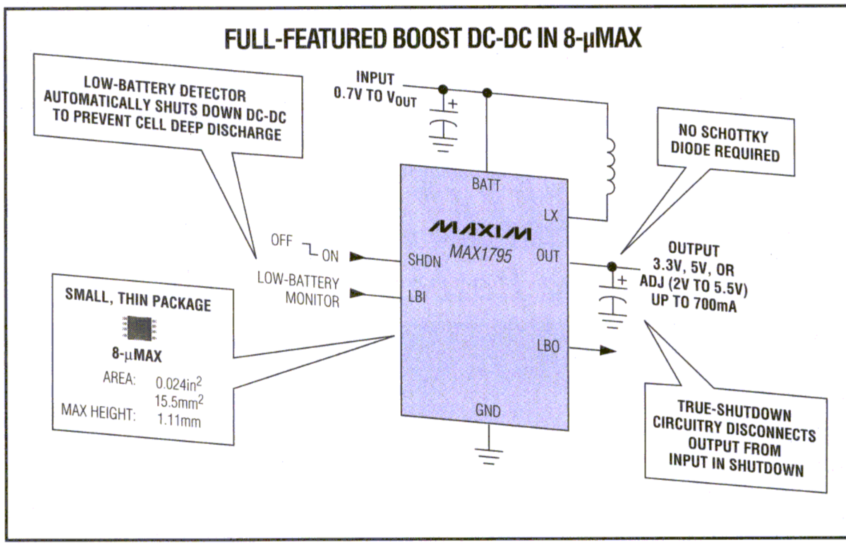

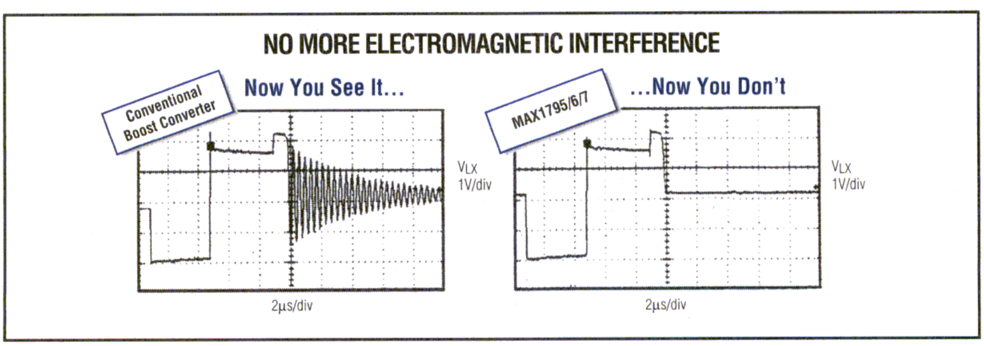

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on a thick-film leadless ceramic substrate measuring 0.3 × 0.4 in. (0.76 × 1.02 cm) It has been optimized to operate from 1700 to 2200 MHz in order to address digital-communications-services (DCS), personal-communications-services (PCS), and UMTS frequency bands. The module is based on pseudomorphic-high-electron-mobility-transistor (PHEMT) technology to achieve low noise figure (1.2 dB), while maintaining the high linearity [an input IP3 (IIP3) of +19 dBm] required for base-station applications. A proprietary technique is employed to simultaneously produce a flat passband response, wideband 50-Ω-matched ports, low noise figure, and good linearity. The SLX-2043 dissipates less than 0.5 W from a single +4.0-VDC supply, and contains built-in bias regulation.

The key specifications for the SLX-2043 are shown in Table 2. The measured IIP3 and noise figure are plotted versus frequency and temperature in Fig. 7. The measured noise figure is very flat over the frequency range of 1700 to 2200 MHz and varies approximately 0.6 dB over the entire temperature range of –40 to +85°C. In the UMTS receive band (1920 to 1960 MHz), the room-temperature noise figure is less than 1 dB, rising to 1.25 dB at +85°C. The measured OIP3 is also minimally impacted over temperature and frequency. In the UMTS band, the OIP3 ranges from +32 dBm at +80°C to +36 dBm at –40°C.

The SMDI SRX-3011 receive module performs full downconversion from RF to balanced I and Q baseband signals. As shown in Fig. 5, the receive module consists of an RF SAW filter, the SRM-2016 active Rx mixer, two IF SAW filters, a balanced amplifier, and the SRF-1016 IF Rx.

The SRX-3011 Rx MCM is shown in Fig. 8. It uses the same packaging approach as the STX-3011 Tx MCM. The SRX-3011 measures approximately 3 × 1 in. (7.62 × 2.54 cm) with much of the printed-circuit-board (PCB) area occupied by the IF SAW filters. For this version, the mechanical layout density of this MCM design was not optimized and further size reduction could be readily achieved. Instead, the layout was optimized for electrical performance. Similar to the STX-3011 Tx MCM, the SRX-3011 Rx MCM is suitable for a surface-mount attachment to the transceiver board.

In the SRX-3011 Rx MCM, the RF signal is processed through an RF SAW filter and converted by the balun from a single-ended to a balanced configuration to drive the RF inputs of the SRM-2016. A balanced architecture is used throughout the entire receive module for improved linearity and reduced spurious responses. The SRM-2016 is a fully integrated SiGe receive mixer. This IC includes the mixer, an LO buffer, and an IF buffer. It has broadband 50-Ω-balanced ports, and has the ability to drive an IF SAW filter without additional buffer circuits. This circuit has been designed to operate from 1700 to 2000 MHz and address

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SPECIFICATION MATRIX

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

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DCS, PCS, and 3G wireless applications. The key target specifications for this MCM are presented in Table 3. The IIP3 of the SRM-2016 active receive mixer is +17 dBm. With gain of 11 dB, the OIP3 is +28. Compared to a passive mixer with 8-dB conversion loss, the active mixer has linearity equivalent to a passive mixer with an IIP3 of +36 dBm, but requires less RF gain preceding the mixer.

The balanced outputs of the SRM-2016 are matched to the balanced WCDMA IF SAW filter. The filter has a 5-MHz bandwidth centered at 190 MHz. By using a balanced IF SAW filter, it is possible to achieve the additional linearity from the mixer without the use of a balun. In addition, increased rejection may be achieved using a balanced SAW filter, as the ground currents in the package are suppressed. The SAW filter has an ultimate rejection of 45 dB, so it was necessary to use two in cascade, as is common in Rx architectures, to achieve high out-of-band suppression. It is necessary to insert an amplifier with good isolation between the SAW filters, to recover the insertion loss of the SAW filters, simplify matching, and to prevent any reflections from traveling between the SAW filters.

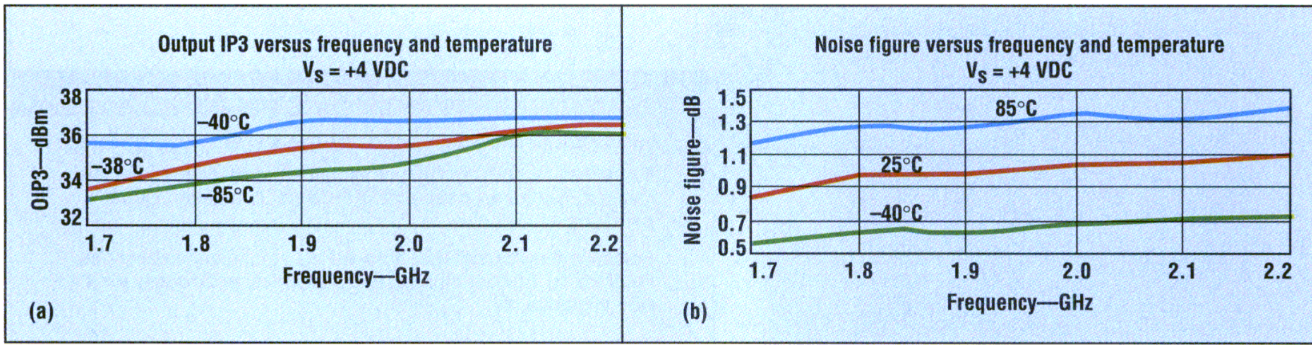
The balanced signal from the second SAW filter feeds into the SRF-1016 IF Rx. The IF signal passes through the gain-control stage which provides –5, +15, or +35 dB of selectable gain through two external pins (GC1 and GC2). The amplified signal is then split

6. The SLX-2043 LNA MCM has been optimized from 1700 to 2200 MHz in order to handle a variety of wireless applications.

evenly between the two mixers for the quadrature demodulation. The balanced I and Q signals are lowpass-filtered on the transceiver before being sampled by the analog-to-digital converter (ADC).

The SRF-1016 may also be configured for an IF sampling architecture by "sticking open" the IF mixer and substituting a DC input for the IF LO. The SRF-1016 has been designed specifically for this purpose—to provide flexibility to the system designer. A baseband sampling system may be converted to an IF sampling system without changing the IF receive strip. In this configuration, the chip provides selectable gain levels of 0, 20, or 40 dB.

The SRF-1016 provides good linearity. In mixing mode, the output power at 1-dB compression is +5 dBm. In IF output mode, the IC features output power at 1-dB compression of +16

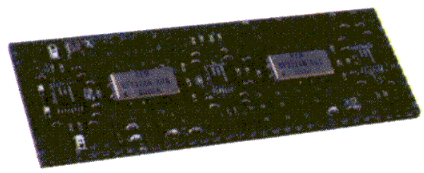


7. The noise figure and OIP3 of the SLX-2043 MCM were measured over frequency and temperature.

dBm. In both configurations, the noise figure for the high gain state is less than 6 dB.

The key specifications for the Rx module are listed in Table 3. The IIP3 is defined by the receive mixer while the output power at 1-dB compression is defined by the IF Rx. The IIP3 is +20 dBm, which is determined by the +17-dBm IP3 of the mixer with the RF SAW in front of it. As mentioned earlier, the real figure of merit is the OIP3 of the mixer, which is +28 dBm because the out-of-band intermodulation distortion (IMD) is stripped off by the IF SAW filters at this point in the chain. The noise figure of the module in the high gain state is 18.5 dB with 3-dB loss from the SAW filter on the front end. The filter adds a 3-dB noise-figure contribution to the Rx's cascaded noise figure. The true figure of merit comes from an analysis of the entire Rx chain. If the LNA is added to the analysis, then the high-gain-state noise figure of the Rx chain becomes 5.5 dB.

The SRX-3011 Rx module performs the entire downconversion that is necessary for a WCDMA system. This MCM may be easily modified for PCS or DCS by changing the SAW filters. By using this combination of the LNA module and the Rx module, the receive chain may be easily customized for several wireless access standards. By using these MCMs, a single transceiver board can serve as a common platform for PCS, DCS, as well as WCDMA systems.



8. In the SRX-3011 Rx module, the RF signal is processed through an RF SAW filter and converted by the balun from a single-ended to a balanced configuration.

In summary, it has been demonstrated that a WCDMA transceiver can be implemented almost entirely using ICs. One possible architecture has been described, although many other variations are possible using the MCM building-block approach. One advantage of this MCM-based philosophy is that it is easy to transform from one architecture to another or from one band to another by changing a MCM. Using multicomponent modules, a transceiver may be quickly applied to many wireless-access standards, without the need for extensive engineering development. The result is higher flexibility and faster time to market. Other benefits include the improvements in first-pass factory yield and reduced rework due to using modules that are 100 percent tested prior to transceiver board assembly. Since the delicate RF circuitry is contained within the MCMs, a lesser-skilled workforce can assemble the transceivers. The module can be assembled using small 0402 components at a contract manufacturer, so the transceiver board assembly line does not need to be fitted with the latest component handlers. Also, the reduced component count of the transceiver board can result in lower factory inventory and overall improved production efficiency.

The MCMs shown here are the first modules from Stanford Microdevices to be developed for the mobile wireless base-station market. These MCMs represent reference designs that can be easily customized to meet the individual needs of a particular system. **Stanford Microdevices, Inc., 522 Almanor Ave., Sunnyvale, CA 94086; (800) 764-6642, (408) 616-5400, FAX: (408) 739-0970, Internet: http://www.stanfordmicro.com.**

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Table 3: The SRX-3011 Rx MCM at a glance

Parameter	Units	Minimum	Typical	Maximum	Test conditions
RF range	MHz	1920		1980	
Input IP3	dBm		+20		
IF center frequency	MHz		190		
IF bandwidth	MHz		5		
Gain	dB		–3/17/37		Set by the gain on SRF-1016 IF Rx RF IC
Output power (1-dB comp.)	dBm		+5		
Noise figure	dB		18.5		High-gain setting on SRF-1016 RF IC
RF LO drive	dBm		0		
IF LO drive	dBm		0		
RF return loss	dB		12		
RF LO return loss	dB		14		
IF LO return loss	dB		20		
Current (at +5 VDC)	mA		350		
Operating temperature	°C	–40		+85	

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BLUETOOTH™ measurements require a special set of capabilities, including frequency-hopping signal generation and analysis. Fortunately, the model CS20310B Bluetooth RF Testset from Celerity Systems (Cupertino, CA) provides the signal-generation and signal-analysis capabilities needed for complete RF characterization of Bluetooth transmitters (Txs) and receivers (Rxs).

The model CS20310B Bluetooth RF Testset provides signal-recording analysis in addition to signal generation. It generates and analyzes signals from 2.40 to 2.4835 GHz, providing a full 83.5-MHz, 1-dB signal-capture bandwidth. The system can generate and capture up to 12,800 sequential frequency hops in high-speed memory. A broadband frequency downconverter and high-performance analog-to-digital converter (ADC) are used in order to capture all frequency-hop information along with their timing information, modulation information, precise frequency information, and transient information. Digital analysis routines are used to process the captured data. In addition, each hop can be demodulated to provide the baseband data that are needed for full protocol analysis (with the help of third-party protocol-analysis software).

The Bluetooth RF testset at a glance

Input/output frequency range	2.40 to 2.4835 GHz
Input/output (1-dB) bandwidth	83.5 MHz
Analyzer passband flatness	±1 dB
Analyzer input sensitivity	–80 dBc
Input attenuation	0 to 31 dB in 0.5-dB steps
Signal output level	0 dBm
Output level flatness	±1 dB
Output attenuation	0 to 31 dB in 0.5-dB steps
Input/output spurious-free dynamic range	50 dB

The testset also provides the capability of generating true Bluetooth signals, using internal pseudorandom-noise (PN) sequences or third-party protocol stacks for the underlying data. Up to 12,800 hops can be stored in internal memory. The stored data are converted to baseband through a precise 30-MSamples/s digital-to-analog converter (DAC). The baseband signals are then converted to the 2.4-GHz Bluetooth band through a high-performance frequency upconverter.

The system offers high-speed memory-storage options from 64 Mb to 2 Gb, with the 12,800-hop storage capacity resulting from the 2-Gb memory. The signal generator section and the recorder/analyzer section achieve amplitude flatness of ±1 dB (see table), and signal levels from the signal generator and to the analyzer can be controlled through precision step attenuation, operating over a range of 0 to 31 dB in 0.5-dB steps.

The signal generator delivers typical output power of 0 dB, while the analyzer provides an input sensitivity of −80 dBc. The spurious-free dynamic range (SFDR) for the analyzer and the signal generator is typically 50 dB (−50 dBc). The VSWR for the analyzer and signal generator is 1.50:1 at 50 Ω.

The Bluetooth testset is based on a modular platform using a 600-MHz Pentium III microprocessor. The system, which operates with Version 4.0 of Windows NT, features 128 Mb of random-access memory (RAM) and a 9-Gb hard-disk drive. It includes 10/100 baseT and U-SCSI interfaces and uses a Matlab-compatible binary data-file format. **Celerity Systems, L3 Communications, 10411 Bubb Rd., Cupertino, CA 95014; (888) 274-5604, (408) 873-1001, FAX: (408) 873-1397, Internet: http://www.csidaq.com.**

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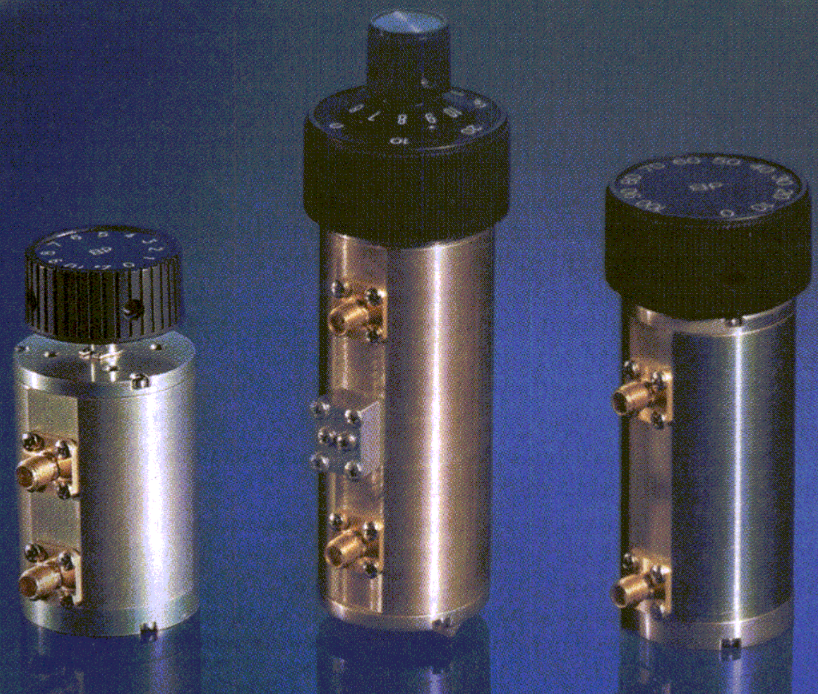

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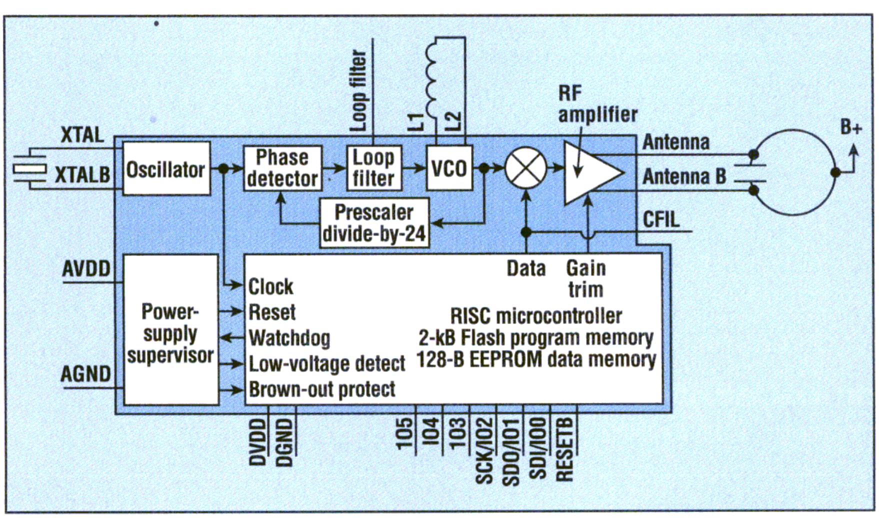
DON KELLER
Senior Editor

WIRELESS applications are constantly driving the demand for high integration, low power consumption, and low cost. But beyond these three demands, many wireless applications, including keyless entry, remote control, short-haul wireless data communications, and remote sensing also require digital control for data encoding, transmission control, and user interfacing. Additionally, nonvolatile memory is often required to retain security or sensor information when the battery runs down. To satisfy the additional requirements of these applications, Atmel Corp. (San Jose, CA) has developed a family of single-chip RF transmitters (Txs) that incorporate an 8-b reduced-instruction-set-computer (RISC) microcontroller (see figure).

Each member of the AT86RF401 family consists of an 8-b microcontroller and a phase-locked-loop (PLL)-based Tx for portable wireless applications in the 250-to-450-MHz range. To reduce component count, two versions of the device are offered with an integrated loop filter optimized for the two most popular RF frequencies in this band. The model AT86RF401U operates at 315 MHz, and the AT86RF401E operates at 434 MHz. For other frequencies in the 250-to-450-MHz band, the company offers the model AT86RF401X, which must be used in conjunction with an external loop filter (usually consisting of three passive external components).



This block diagram shows the AT86RF401's RF Tx, microcontroller, and peripheral components.

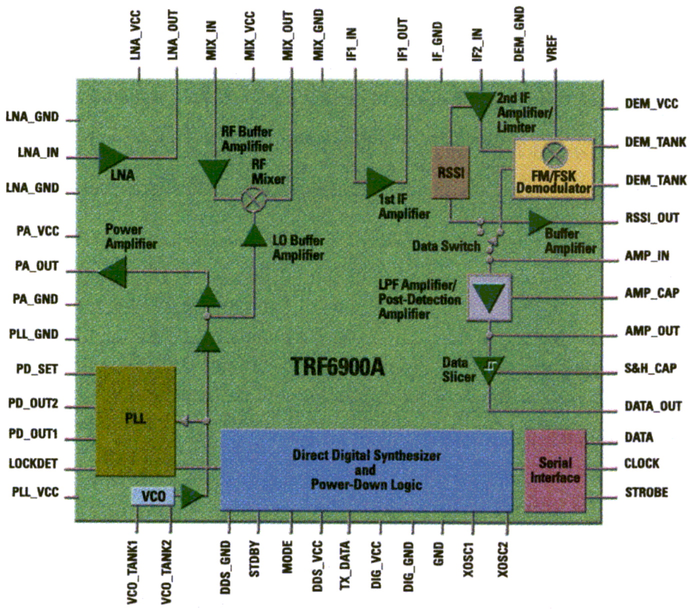
The Tx portion of the chip requires an external crystal or resonator for the reference frequency. This frequency is fed to the chip's phase detector, loop filter, and voltage-controlled oscillator (VCO). The VCO output is looped to the prescaler, divided by 24, and routed back to the phase detector, where it is compared to the reference frequency in standard PLL fashion. The locked VCO output is fed to the chip's RF amplifier.

The microcontroller portion of the chip monitors and controls the RF Tx. It permits software control of output power in 1-dB increments from +1 to +5 dBm into a tuned loop antenna. It also allows the designer to select a preferred encoding method (Manchester, NRZ, PWM, etc.). Data-transmission rates to 20 kb/s can be attained using on/off-keyed (OOK) modulation. With 2 kB of Flash program memory and 128 B of electronically-erasable-programmable-read-only-memory (EEPROM) data memory, designers can update or modify software at any time in the development cycle. The EEPROM data memory also provides space for security parameters, product serial numbers, or other product information. **Atmel Corp., 2325 Orchard Pkwy., San Jose, CA 95131; (408) 441-0311, FAX: (408) 487-2600, Internet: http://www.atmel.com.**

For more information, visit www.mwrf.com

Mixed-Signal RF

Industry's most integrated RF transceiver/transmitter ICs.



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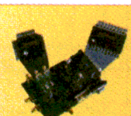
- *No external adjustments required*

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

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

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

48-pin PQFP shown actual size



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

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PRODUCT TECHNOLOGY

Semirigid Cable Assembly

Stainless-Steel Semirigid Cables Handle Hostile Environs

Semirigid cable assemblies employing a stainless-steel outer jacket can withstand vibration and shock levels far beyond standard military specifications.

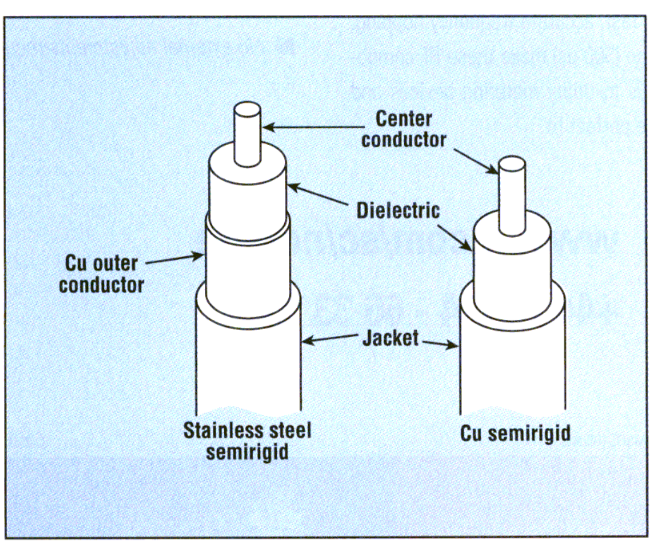
JACK BROWNE
Publisher/Editor

STAINLESS steel can be honed to a fine edge in cutlery, but it can also lend an edge to military-grade semirigid coaxial-cable assemblies. Cable assemblies with an outer jacket of stainless steel manufactured by SSI Cable Corp. (Shelton, WA) offer tensile strength far beyond that of conventional copper (Cu) semirigid cables. The firm offers 304L stainless-steel-jacketed semirigid cables with outside diameters ranging from 0.086 through 0.240 in. (0.218 through 0.638 cm), and with a variety of connector options for applications through 40 GHz.

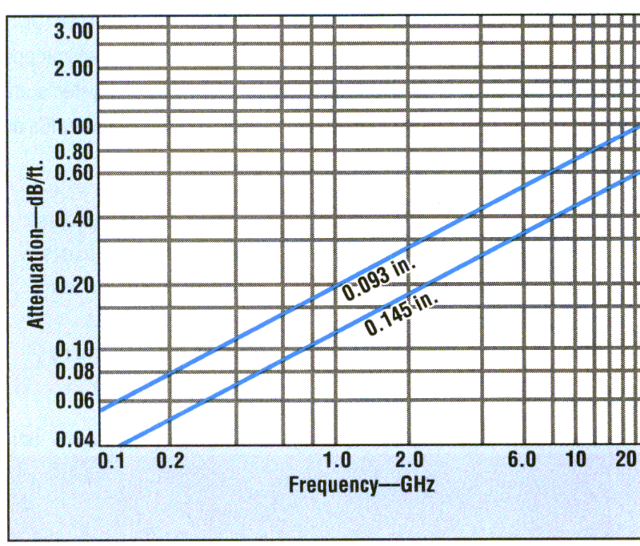
The stainless-steel cable assemblies feature a construction that is somewhat similar to a conventional Cu semirigid cable, with Cu inner and outer conductors sandwiched around a dielectric, but offer enhanced durability through the addition of a stainless-steel jacket around the Cu outer conductor (Fig. 1). The Cu outer conductor provides good conductivity and electromagnetic-interference (EMI) shielding, while the stainless-steel jacket arms the cable assembly with superior mechanical strength. The stainless-steel outer jacket also provides resistance to corrosion in hostile environments.

The stainless-steel cable assemblies, with very low attenuation through 20 GHz (Fig. 2), are highly resistant to metal fatigue. When conventional 0.086-in. (0.218-cm)-diameter Cu semirigid cables with soldered connectors were tested in a sideloading fixture designed to flex the cables ±15 deg. from the connector center conductor, the conventional cable assemblies failed after only 13 flexures. When 0.093-in. (0.236-cm)-diameter stainless-steel cable assemblies with welded connectors were subjected to the same test conditions, they withstood 136 flexures before failing. **SSI Cable Corp., 820 E. Hiawatha Blvd., Shelton, WA 98584; (360) 426-5719, FAX: (360) 426-5912, Internet: http://www.ssicable.com.**

For more information, visit www.mwrf.com



1. The stainless-steel cable assemblies employ an outer jacket of 304L stainless steel for improved reliability.



2. The stainless-steel semirigid cables show low attenuation through 20 GHz.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PRODUCT TECHNOLOGY

Test Set

Simple Instrument Offers Accurate Bluetooth Communications Testing

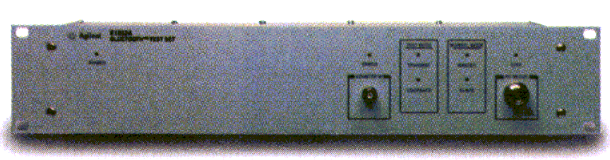
When connected to a Windows-based PC, this rack-mount module is transformed into a flexible measurement system for Bluetooth radio testing.

JACK BROWNE

Publisher/Editor

BLUETOOTH communications systems promise wireless personal interconnections of computers and peripheral devices at 2.4 GHz. Before a plethora of wireless products can be released on the marketplace, however, they must be tested. The model E1852A Bluetooth™ Communications Test Set from Agilent Technologies (Queensferry, Scotland) offers a simple means of performing those measurements under the control of a PC. The instrument executes functional and parametric tests on Bluetooth-enabled devices using simple front-panel connections to evaluate the transmit/receive (T/R) paths of Bluetooth radios.

Bluetooth is a wireless connectivity standard essentially developed by Ericsson and supported by an initial group of developing companies that includes IBM, Intel, Nokia, and Toshiba. The Bluetooth Special Interest Group (SIG) of companies endorsing the standard now numbers more than 2100. The open standard for development of Bluetooth products can be found on the Bluetooth website at http://www.bluetooth.com.



The model E1852A Bluetooth test set can perform all of the basic Rx and Tx tests on a Bluetooth radio using a simple user interface on a PC.

BLUETOOTH BASICS

Bluetooth radios operate across 79 channels from 2.402 to 2.480 GHz using a 1-Mb/s data rate through Gaussian frequency-shift-keying (GFSK) modulation. Devices communicate through time-division-duplex (TDD) techniques where the transmitter (Tx) and receiver (Rx) alternate their transmissions in separate timeslots, one after another. Bluetooth designs employ frequency hopping at rates to 1600 hops/s. As a result, a Bluetooth voltage-controlled oscillator (VCO) must be able to switch across the full frequency range in less than 625 μs.

The model E1852A Bluetooth Communications Test Set (see figure) supports Bluetooth radio testing using a simple interface scheme displayed on a PC. Developed in cooperation with RTX Telecom of Denmark, the test set establishes a link to a Bluetooth device under test (DUT) using standard Bluetooth protocols. It supports the testing of Rxs with or without impairments, such as interference and fading, and testing of Txs for power, frequency, and spectrum occupancy. It can perform frequency-hopping measurements at rates beyond 1600 hops/s. The test set can also evaluate frequency-modulation (FM) deviation, frequency errors on specified RF bands, bit-error-rate (BER) Rx tests on single and multiple timeslots, parametric measurements, and measurements of power over bursts.

The simple-to-use model E1852A test set can perform test-mode and piconet-based measurements (on a single device or within the miniature Bluetooth network known as a piconet, respectively), and uses simple SCPI-like commands for ease of programming and setup. It is shipped with user-interface software that runs on Windows 98 or Windows NT computers and can supply a full measurement summary with pass and fail data. The test set features a remote-command debugging window and a dynamic-link library with debugging messages to speed the development of automated test routines.

For more information on the company's Bluetooth measurement solutions and for a useful application note, "Performing Bluetooth RF Measurements," visit the Agilent website at www.agilent.com. **Agilent Technologies, Inc., Test and Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052.**

For more information, visit www.mwrf.com

Editor's Note: Bluetooth is a trademark owned by Telefonaktiebolaget LM Ericsson, Sweden

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RF IC Addresses Unlicensed 5-GHz Communications

This front-end chip combines a low-noise Rx amplifier, power-transmit amplifier, and a switch for use in the 5-to-6-GHz ISM band.

JACK BROWNE
Publisher/Editor

CONCERN over the operation of 2.4-GHz wireless local-area networks (WLANs) with the expected proliferation of Bluetooth devices at that same frequency has some WLAN developers raising their sights to 5 GHz. One semiconductor supplier that hopes to make that transition a simpler, lower-cost venture is Araftek, Inc. (Fremont, CA), a new firm with a low-cost GaAs RF integrated-circuit (RF IC) chip that is suitable for spread-spectrum communications applications in the unlicensed 5-GHz industrial-scientific-medical (ISM) band.

The 5-to-6-GHz band contains several communications portions of the Unlicensed National Information Infrastructure (UNII) band, including 5.15 to 5.25 GHz, 5.25 to 5.35 GHz, and 5.725 to 5.825 GHz. This unlicensed use of WLAN applications is in contrast to the popular 2.4-GHz ISM band earmarked for WLAN transmissions per IEEE 802.11b standards. However, due to the limited data rates possible at that frequency (approximately 11 Mb/s according to the standard), the fear of spectrum crowding due to the already present microwave ovens and cordless telephones, and the predicted explosion of Bluetooth devices, the 802.11a specification was developed to support high-data-rate WLANs (54 Mb/s) at 5 GHz.

Although suitable for a variety of wireless applications at 5 GHz, including remote monitoring and portable data terminals, the AR7501A is especially well-suited to HyperLAN and other high-data-rate WLANs at that frequency. The AR7501A provides all of the RF front-end functions required for half-duplex communications. It combines a power amplifier (PA) for transmit functions, a low-noise amplifier (LNA) for receive functions, and a transmit/receive (T/R) switch for control of the transmit and receive modes.

The PA section provides better than +21-dBm typical 1-dB compression output power at 5.85 GHz and +23.5-dBm typical output power at 5.15 GHz. Typical gain is 18 dB from 5.15 to 5.85 GHz, with a typical gain flatness of ±1 dB. The transmit amplifier incorporates a power-detection output which delivers +1.2 VDC at an output level of +23 dBm. The output power can be controlled electronically over a range of approximately +11 to +23 dBm. The PA circuitry draws approximately 308 mA from a +5-VDC supply.

The LNA section achieves 21-dB typical small-signal gain with typical gain flatness of ±1 dB from 5 to 6 GHz. The output power is typically +3.5 dBm at 5.15 GHz while the noise figure is typically 3.5 dB with a maximum of 4.5 dB across the operating band. The LNA requires 36-mA typical current at +5 VDC. It achieves input return loss of 8 dB and an output return loss of 12 dB, both with partial external impedance matching.

Finally, the time-domain-duplex (TDD) T/R switch operates through a complementary-metal-oxide-semiconductor (CMOS)-logic-compatible control pin using high and low logic levels of nominally +5 VDC (a minimum of +2.4 VDC) and 0 VDC (a maximum of +0.7 VDC). The switch, which draws approximately 1-mA input current, achieves a switching speed of better than 5 μs. The isolation between the transmit and receive paths is typically 13 dB, while the receive and transmit path insertion losses are typically 2.3 dB or less in either the transmit (high logic) or receive (low logic) states. The bias current is approximately 5.5 mA at +5 VDC, with a current draw of only 0.3 μA in the power-down mode.

The AR7501A is housed in a compact 28-pin quad small-outline package (QSOP) suitable for applications where space is limited, such as in the Personal Computer Memory Card International Association (PCMCIA) cards commonly used to add WLAN capabilities to a laptop computer. A power-down mode can be added to the AR7501A by adding an external switch in series with the drain-voltage supply line. **Araftek, Inc., 40990 Encyclopedia Circle, Fremont, CA 94538; (510) 580-2501, FAX: (510) 580-2508, Internet: http://www.araftek.com.**

For more information, visit www.mwrf.com

Software-Based Monitoring System Checks Digital Carriers

This versatile and simple-to-operate carrier-monitoring testset can be used to evaluate the health of satellite and terrestrial communications systems.

Mike Bush

Managing Director

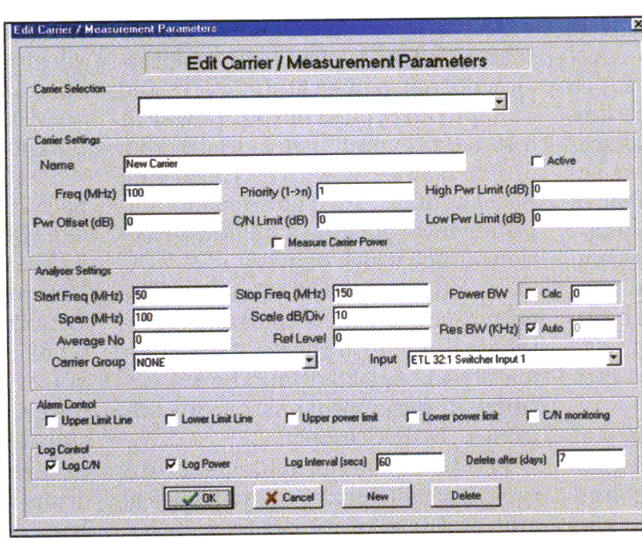
ETL Systems, Unit 4, Foley Trading Estate, Hereford HR1 2SF, United Kingdom; (44) 1432-370078, FAX: (44) 1432-278833, e-mail: mab@etlsystems.com, Internet: http://www.etlsystems.com.

CARRIER monitoring is essential to the successful operation of a satellite-communications system. By using software-based carrier-monitoring systems such as those developed by ETL Systems (Hereford, United Kingdom), carriers for satellite systems, as well as analog and digital terrestrial broadcast and communications systems, can be continuously monitored for weak or failing signals. Monitoring carriers when they first arrive in the equipment hall from a communication system's antennas and low-noise block downconverters (LNBs) provides a first line of defense and warning against failing signals and systems.

The software-based carrier-monitoring system developed by ETL Systems allows digitally-modulated carriers to be monitored and alarmed from 1 MHz to 26 GHz. In the case of satellite-communications carriers at L-band (850 to 2150 MHz), such as those in the ASTRA system, multiple carriers can appear from one LNB source, and this system is likely to feature several of these LNB sources. The carrier-monitoring system copes with multiple sources through an RF switch, which selects the source to be monitored and subsequently feeds the output of the selected LNB to a spectrum analyzer.

The flexible software used in the carrier-monitoring system can also be used to monitor reverse-path cable-television (CATV) signals from 1 to 100 MHz, even though the hardware architecture used to do this is somewhat different than the hardware employed for monitoring satellite or terrestrial microwave-communications systems.

For monitoring satellite carriers, the test system employs a model E4402B spectrum analyzer from Agilent Technologies (Santa Rosa, CA), a personal computer (PC), and an RF switch. Depending on the number of signals to be monitored, the RF switch may range from a small eight-way unit to a 32-way or larger switch. Other carriers, such as 70-MHz and television-broadcast signals, can be monitored at the same time that satellite carrier monitoring is being performed. The PC, which is used for instrument control and signal analysis, displays exactly what is received by the spectrum analyzer. Up to three carrier parameters can be monitored at any one time.



1.The "Edit Carrier/Measurement Parameters" screen of the carrier-monitoring-system software intuitively steps an operator through the settings needed for effective carrier-frequency and power measurements with a spectrum analyzer.

An operator using the carrier-monitoring system first sets up a carrier profile. The software provides the facility to set up a mask or performance template against which a selected carrier can be analyzed. The mask consists of an outer limit line and an inner limit line. Dragging points with the computer mouse will set up limits by positioning lines. Subsequently, any increase or decrease of carrier profile will cause an alarm. In addition, the system measures and displays the power levels of digital carriers and the facility exists to key in upper and lower alarm limits.

The system also measures the carrier plus noise to noise ratio [(C + N)/N]. The option exists to select a programmable number of scans in order to optimize the measurement. Subsequently, an alarm-threshold value can be selected. Full-fault reporting is available, and graphic information such as carrier-to-noise plots can be printed.

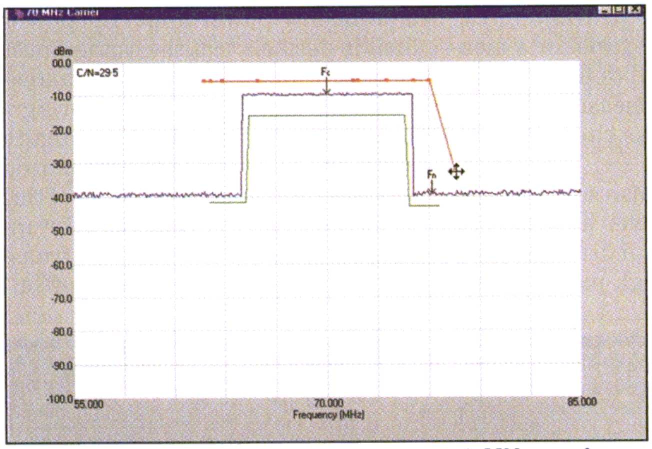
SOFTWARE SPECIFICS

When the software is first run, it opens the "Carrier Status," "Alarm Status," and then the "Event Log" windows. The windows may be positioned and sized as required. The configuration of these windows is saved when the operator exits the program.

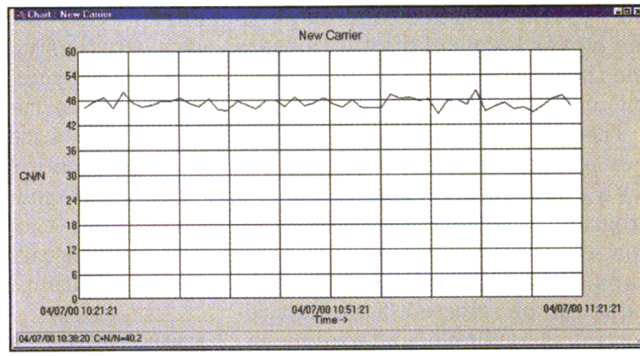
It is necessary to define the input as a first step; the software will then require the operator to define a carrier using the table found in the "Edit Carrier/Measurement Parameters" screen (Fig. 1). The screen allows operators to name a new carrier (using the carrier selection box) or to select or edit an existing carrier name. As with all file systems, the name selected for a particular carrier should be meaningful, since this name will be used in the event log to report any changes in the carrier's status. The "Active" box enables or disables the monitoring function for the selected carrier. Carriers are identified by their frequency (in megahertz).

When the system is monitoring a large number of carriers, it may take several minutes in order to measure all of the carriers. It may be desirable to measure some carriers more frequently than others. This can be achieved by setting a priority for each carrier. The lower the priority number is, the more often the carrier is measured. For example, if a carrier is set to priority one, then the carrier will be measured during every complete measurement cycle. If the carrier is set to a priority of two, it will be measured every two measurement cycles. A value of 100 means that the carrier will be measured every 100 measurement cycles. Obviously, the time for a measurement cycle will depend on the number of carriers measured during the cycle, as well as the measurement parameters.

Operators must also set the high-power limit (the power limit in decibels that the carrier must exceed before generating a high-power alarm) and the low-power limit (the power limit in decibels that the carrier must be below, before generating a low-power alarm) prior to monitoring a carrier. The "power offset" is a figure in dB and is added to the measured carrier power. One application of this would be to provide an offset for antenna gain and feeder loss in a transmit system. With the correct offset,



2. This demonstration screen shows a 70-MHz carrier with markers indicating the carrier center frequency (Fc) and the noise level frequency (Fn).



3. This is a typical plot of captured (C + N)/N carrier data, which can be displayed on the PC screen or printed out for archival purposes.

the displayed power would be in effective radiated power (ERP) or effective isotropic radiated power (EIRP). The carrier-to-noise limit control establishes the limit for the carrier-to-noise level below which an alarm will be sounded. The "Measure Carrier Power" function is typically used with transmit carriers to measure the carrier power.

A number of settings on the "Edit Carrier/Measurement Parameters" screen are devoted to the control of the spectrum analyzer. The start and stop frequencies, span, scale, and reference level use the software to adjust those settings on the connected instrument. It should be noted that changing some parameters will have an effect on others. For example, assume that a carrier at 70 MHz is to be monitored with a bandwidth of 40 MHz. This can be achieved by setting the frequency to 70 MHz and the span to 40 MHz, or by setting the start frequency to 50 MHz with the stop frequency set at 90 MHz.

For the resolution bandwidth, if an

operator checks the "Auto" box, the spectrum analyzer's default resolution-bandwidth setting will be used. If not checked, the user is free to enter a resolution bandwidth. Note that many spectrum analyzers offer only a limited range of values for the resolution bandwidth.

For the power-bandwidth ("Power BW") setting, it is necessary to know the bandwidth that a carrier occupies (in order to calculate the power of the modulated carrier). If the "Calc" box is checked next to the "Power BW" selection, the software will instruct the analyzer to measure the power bandwidth. If the "Calc" box is not checked, the user can enter a power bandwidth (in megahertz). If the "Calc" option is selected and the carrier is defined as part of a carrier group, the application will calculate the bandwidth from the trace data. If the carrier is not part of a group, the spectrum analyzer is instructed to measure the bandwidth. This provides better accuracy, but requires the analyzer to perform an extra sweep and, therefore, takes longer to complete.

The averages setting ("Average No") allows an operator to enter the number of averages from 1 to n and sets the number of spectrum-analyzer sweeps that are taken before the resulting data is read by the application. When monitoring noisy signals, for example, averaging will be needed to achieve accurate C/N and power measurements. Caution must be used when choosing this value, as each sweep may take a second or more to complete. Additional controls support the selection of a carrier group, the selection of an RF input source, and the enabling or disabling of alarms for various test parameters, such as lower limit lines and upper limit lines.

To demonstrate the carrier-monitoring system in use, Fig. 2 shows a 70-MHz carrier with the lower mask positioned inside the carrier envelope and the upper mask in the process of being moved into position. The "drag points" are clearly shown with the right-hand point positioning in progress. The markers showing Fc and Fn indicate the adjustable carrier center frequency and noise-level frequencies, respectively. The top left-hand corner of the display shows the (C + N)/N value, which can be plotted as a function of time (Fig. 3) for archival purposes.

The bottom section of the "Edit Carrier/Measurement Parameters" screen is for the data-log control of the measured C/N and carrier-power levels. This section contains four controls. The two check boxes "Log C/N" and "Log Power" turn the data logging of the associated measurements on and off. The "Log Interval" control sets the maximum rate (in seconds) that the data are logged. It should be noted that this is a maximum figure and that the actual logging rate depends on how often the carrier is measured. For example, if the logging interval was set to 1 s but a complete measurement cycle was to take 20 s, the data would be logged every 20 s (each time that the carrier is measured). If the logging interval was set to 60 s, the carrier would still be measured every 20 s, but a snapshot of the C/N and power will only be stored every 60 s. Data logging of this type can build up a large amount of data. Eventually, the PC would run out of memory and disk-storage space. To prevent this, the software includes a "Delete After (days)" field that allows the user to specify the maximum age of the data on the system. Data older than this value are automatically deleted.

Selecting "OK" will save the data, "CANCEL" exits the program without saving, "NEW" saves the current data and clears the form for the definition of a new carrier, and "DELETE" erases the carrier from the data base. The user is warned before any information is deleted.

The carrier-monitoring software operates effectively to 26 GHz, dictated only by the upper frequency limits of the spectrum analyzer that are selected for use with the system. The software is easy to use and requires minimal training. It is flexible and can be used with most software packages and with a wide range of hardware in order to address a variety of carrier-monitoring requirements. The system is inexpensive compared to many existing products and is therefore not only suitable for large installations, but also smaller ones that have previously been unable to justify the cost of a monitoring system.

ETL Systems has been supplying solutions for satellite earth stations since 1989, more recently adding products aimed at CATV head-end requirements. In addition to the carrier-monitoring system, the company supplies a variety of solutions for communications applications, notably at L-band. The firm is well-known for its L-band matrices, such as a distributive 32 × 32 matrix in a six-space rack-mount configuration. In addition, several amplifiers provide signal boosts for satellite-communications systems through 2150 MHz. Model 2500 is a high-band unit with dual amplifiers, each with 28-dB maximum gain from 500 to 2150 MHz. The gain is adjustable in 0.5-dB steps. The amplifier, which handles input signals to +5 dBm without damage, achieves maximum output power of +15 dBm at 1-dB compression. For low-band applications, the model 2501 provides performance that is similar to that of the model 2500, but with better noise figure (5 dB) and a frequency range spanning 10 to 1000 MHz. The firm's model 2502 amplifier is an eight-port L-band distribution amplifier that has a frequency range of 850 to 2050 MHz. It has a 20-dB gain-control range, 33-dB gain at 950 MHz, and 38-dB gain at 2050 MHz.

ETL Systems also supplies multichannel L-band monitors, which consist of a rack-mount controller and 16 receiver (Rx) modules. These support real-time monitoring of L-band digital channels. The monitors detect present signals in the form of a demodulator lock. The monitors are also useful for monitoring signal levels and bit-error rates (BERs), and provide adjustable threshold levels for setting alarms. **ETL Systems, Unit 4, Foley Trading Estate, Hereford HR1 2SF, United Kingdom; (44) (0) 1432 370078, FAX: (44) (0) 1432 278833, e-mail: mab@etlsystems.com, Internet: http://www.etlsystems.com.**

For more information, visit www.mwrf.com

Linear LNAs Boast Miniscule Noise Figures At 2 GHz

A pair of LNAs has been developed for 2-GHz applications using silicon BiCMOS without germanium.

Keng Leong Fong and David Szmyd

Application Engineers

Philips Semiconductors, 811 E. Arques Ave., Sunnyvale, CA 94088; (408) 474-7202, FAX: (408) 474-7212, e-mail: fong@ieee.org.

SILICON (Si) bipolar complementary metal-oxide semiconductor (BiCMOS) still has room for improvement, as demonstrated by a pair of low-noise amplifiers (LNAs) designed and developed by Philips Semiconductors (Sunnyvale, CA). Fabricated with the firm's QUBiC4 0.25-μm Si BiCMOS process, these amplifiers do not require the additional germanium (Ge) doping (as in SiGe) to achieve noise figures of 1.1 dB or less at 2 GHz. With performance that rivals that of gallium arsenide (GaAs) and SiGe LNAs, one of the designs exhibits a noise figure of 0.99 dB and third-order intercept of +5 dBm at 2 GHz while using only 4-mA current, while the other amplifier features a noise figure of 1.1 dB and third-order intercept of +9 dBm with 6-mA current.

The rapid growth of wireless communication systems has increased the demand for high-linearity and low-noise RF amplifiers. As the first active circuit in a wireless receiver (Rx), the LNA should have low noise figure and high gain to increase the sensitivity of the Rx. Furthermore, high linearity is desirable to increase the selectivity of the Rx without using expensive RF filters in front of the LNA. Although much attention has been focused on the performance of new technologies using SiGe semiconductor processes to achieve low amplifier noise figures, what follows is a report on two amplifiers fabricated with conventional Si wafers, albeit using a high-performance BiCMOS semiconductor process.

The block diagram (see figure) shows the circuit topology of the LNAs. Transistor Q_1 and inductance L_e form the transconductance stage of the LNA. Inductive degeneration is used to increase the linearity of the LNA. Transconductance stages with inductive degeneration have lower noise figures than those with resistive degeneration, since the degeneration inductor (apart from its loss resistance) does not introduce an additional noise source. It has been shown that the transconductance stages using inductive degeneration are more linear (higher third-order intercept performance) than those using resistive degeneration with the same current and transconductance.[1]

To reduce the noise contribution from transistor Q_1, a large device (using many parallel emitter fingers) with small base resistance (less than 3 Ω) is used. However, the device size should not be so large that the base-collector capacitance would decrease the reverse isolation, power gain, and stability of the LNA. Resistor R_b is used to bias the base of transistor Q_1 and to isolate the bias circuitry from the input of the transconductance stage. Resistor R_b is typically designed to have large resistance in order to reduce the noise contribution from the bias circuitry and to avoid significant loading on the RF input port, which would increase the noise figure.

Capacitor C_1 serves as the DC-blocking capacitor. Together with inductor L_t, it forms the input-matching network which is optimized for minimum noise-figure (constrained by an S_{11} requirement of less than –10 dB).[2] A low-frequency trap, formed by capacitor C_t, is added to the input of the LNA to improve the third-

The two BiCMOS LNAs at a glance

Performance parameters	LNA_1	LNA_2
Total supply current (mA)	4	6
Power gain (dB)	16.7	14.2
Noise figure (dB)	0.99	1.1
Input third-order intercept (dBm)	5	9
S_{11} (dB)	–11	–20
S_{22} (dB)	–15	–13
S_{12} (dB)	–21	–19.5

order intercept performance.[3] The trap network has low impedance at low frequency due to the large capacitance of C_t and the small inductance of L_t. At RF, inductor L_t becomes part of the input-matching network. Capacitor C_3 and inductor L_3 form the output-matching network to transform the impedance at the collector of transistor Q_1 to match that of the load resistor (not shown in the figure).

Two 2-GHz LNAs have been implemented in Philips Semiconductors' QUBiC4 0.25-μm BiCMOS process (a process which is still under development).[4] The bipolar negative-positive-negative (NPN) transistors (without Ge) used in the designs have peak

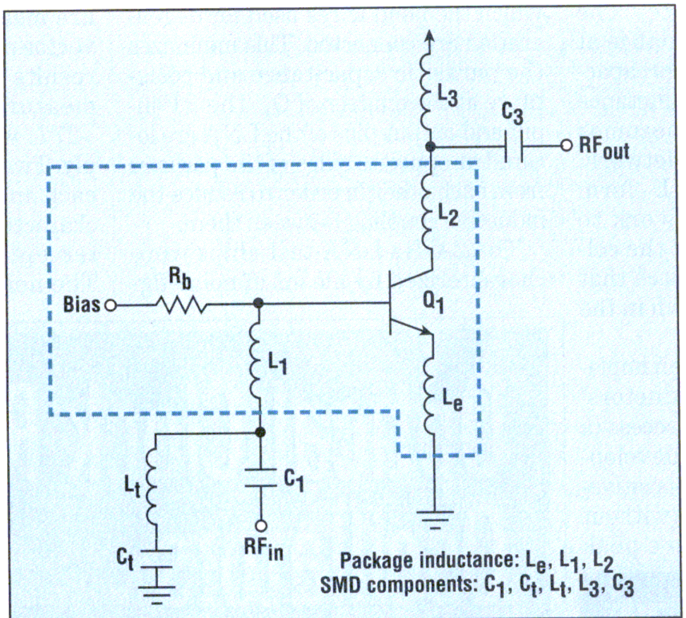
THE RESULTS SHOW THAT PURE Si BIPOLAR DEVICES (WITHOUT USING Ge) CAN ACHIEVE BETTER PERFORMANCE THAN SiGe DEVICES IF THEY ARE PROPERLY OPTIMIZED.

transition frequency (f_T) and maximum frequency of oscillation (f_{MAX}) of 34 GHz and 88 GHz, respectively. The double-poly NPN transistors use an L-shaped inside spacer (between the emitter and base) which creates sub-lithographic emitter openings and produces high performance. Shallow trench isolation (STI) is used to reduce base-collector capacitance and thus improve f_{MAX} performance. Deep-trench isolation is used to isolate NPN collectors and to reduce the collector-substrate capacitance.

The LNAs are housed in low-cost plastic thin-shrink small-outline packages (TSSOPs). To obtain the lowest noise figure, one design (LNA_1) uses two package pins for emitter degeneration and 4 mA of bias current. To obtain higher third-order-intercept performance, the other design (LNA_2) uses only one package pin (higher inductance) for emitter degeneration and 6 mA of bias current (see table). Transistor Q_1 is placed close to the bonding pads to which the bond wires used for degeneration are connected. This minimizes the parasitic capacitance and resistance at the emitter of Q_1. The RF input and output pins of the LNA are located at opposite sides of the package from each other in order to reduce the inductive coupling between them.

The 2-GHz LNA test chips were characterized by means of noise-figure measurement equipment and a vector network analyzer (VNA). The results are shown in the table. The measurements were performed at +27°C with a +2.5-VDC power supply. Two RF input signals of –30 dBm each and 1 MHz apart were used to characterize the input third-order intercept performance of the LNAs. The noise figures reported are directly read from an Agilent Technologies (Santa Rosa, CA) noise-figure meter, and they include the power loss from off-chip low-cost surface-mount devices (SMDs) and BMC connectors. If the power loss from the external components were removed, the intrinsic noise figure of LNA_1 would be less than 0.9 dB.

In summary, two 2-GHz high-linearity ultra LNAs have been implemented and characterized. The noise and linearity performance results show that Si bipolar devices can achieve performance similar to GaAs devices at lower cost. The results show that pure Si bipolar devices (without using Ge) can achieve better performance than SiGe devices if they are properly optimized (such as the devices in Philips' QUBiC4 BiCMOS process).



The block diagram shows the circuit topology of the LNAs.

The advantage of using well-established Si BiCMOS technology, for one thing, is the reliability data available for the more mature process. Much is yet to be learned about SiGe devices under various bias conditions and operating environments compared to Si BiCMOS. **Philips Semiconductors, 811 E. Arques Ave., Sunnyvale, CA 94088; (800) 447-3762, (408) 991-2000, FAX: (408) 991-2311, Internet: http://www.semiconductors.philips.com.**

For more information, visit www.mwrf.com

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BOOKMARK

Ultra-Wideband Radar Technology

James D. Taylor, Editor

Ultra-Wideband Radar Technology is a collection of topics from technical sources. It is intended to provide engineers and managers with a practical technical theory about ultra-wideband (UWB) radar systems, including transmitters (Txs), receivers (Rxs), and applications.

Traditional radars use a modulated continuous-wave (CW) source for transmission. Target returns are processed by Rxs with relatively narrow bandwidths. UWB radar systems operate with signals that have a bandwidth of greater than 25 percent of the center frequency. Since many UWB circuits operate with short-duration signals, the steady-state condition is never realized. This requires analyzing the system in the time domain and observing transient conditions, as opposed to analyzing the steady-state frequency response that characterizes traditional radar systems. In order to understand the special conditions related to UWB radar systems, this text provides the reader with a thorough introduction to UWB radar principles and applications.

Chapter 1 discusses UWB radars and differences from common narrowband radars. Topics include how UWB signals will produce effects not encountered in conventional low-resolution radars, the information content of UWB sources and signal-waveform changes during detection and ranging processes, and how UWB waveform and antenna characteristics mutually affect each other.

Feature detection is the subject of Chapter 2. Topics cover conventional methods for optimal detection of radar signals, correlation processing, and optimal detectors for UWB signals. Other subjects include inter-period correlation processing (IPCP), signal processing after IPCP, and moving targets.

Chapter 3 presents a correlation concept for identifying UWB radar targets. Issues include target signature, target recognition, correlation coefficient algorithms, pulse compression, and target-signature variation with orientation.

Chapter 4 examines the theoretical issues in UWB Rx design. Subjects include frequency-domain-channelized Rxs, time-domain-channelized Rxs, the Battelle UWB Rx, concepts of digitizing and recording monopulse impulse signals, and pulse compression. Other topics include signal correlation and signal-to-noise-ratio (SNR) improvement, pulse-compression theory, pulse-compression SNR analysis, phase-coded waveforms, and known barker codes. Other topics include pseudorandom sequences pseudorandom-noise

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(PN) codes, polyphase codes, as well as Welty and Golay codes. Pulse-compression digital signal processing (DSP), trade-offs between analog and digital processing, and time- and frequency-domain correlation processing are discussed.

Chapter 5 discusses compression of wideband returns from overspread targets. Subjects include radar-imaging principles, range Doppler radar imaging, binary-phase codes, and frequency-coded signals. Micropower impulse radar is the subject of chapter 6. Issues include a background review of impulse radar, a micropower-impulse-radar (MIR) system, a MIR motion detector, and MIR applications.

Chapter 7 presents UWB technology for intelligent transportation systems (ITS). Topics include ITS requirements, components and application areas, multiple-access communications, and range finding. Other issues include interference rejection, spectrum issues, and vehicle-sensing and identification applications.

Chapter 8 reviews the design, performance and applications of a coherent UWB random-noise radar system. Included is a radar-system description with block diagrams, the theory of random-noise polarimetry and proof-of-concept experimental and field-test results.

Chapter 9 discusses power semiconductor devices for generation of nanosecond and sub-nanosecond pulses. Circuit-engineering topics include step-recovery diodes, thyristor and drift step-recovery-diode circuits, Sub-nanosecond and picosecond devices and circuits, and bipolar and field-effect transistors (FETs), the effects of fast switching in silicon (Si)-diode structures, and the effects of circuit parameters.

Chapter 10 introduces the reader to Fourier series-based waveform generation and UWB radar signal processing. Issues discussed include the generation of uncoded and coded waveforms, velocity processing, and UWB radar-system configuration and signal processing.

Chapter 11 analyzes a high-resolution step-frequency radar system. Topics include the step-frequency radar block diagram and waveform generation, target return modeling, moving-target detection in clutter, and two-dimensional (2D) imaging.

A coherent all-radio band-system very-high-frequency (VHF) synthetic aperture radar and other UWB radar-systems demonstration results are the subject of chapters 12 and 13. Topics include a description of the VHF system and physical configuration with block diagrams, test results, and foliage-penetrating radar and target detection results from the US Army Research Laboratory. **(2001, 424 pp., hardback, ISBN: 0-8493-4267-8, $99.95.) CRC Press LLC, 2000 NW Blvd., Boca Raton, Fl. 33431; (800) 272-7737 FAX: (800) 374-3401, Internet: http://www.crcpress.com.**

Antenna remains dry in high-wind conditions

A second-generation 5.6-m Ka-band antenna has a dual-reflector Gregorian optics system coupled with close-tolerance manufacturing techniques for accurate surface contour, and closely controlled pattern characteristics. A rain deviator ensures that the feed window remains dry in high-wind conditions. The low-backlash mount construction provides 125-mph (200-km/hr) wind survival and accounts for low values of beam-radial pointing errors during tracking modes. Applications include high-density data, mobile voice-communications networks, and television-broadcast video distribution. **Andrew Corp., 10500 W. 153rd St., Orland Park, IL 60462; (708) 349-3300, Internet: http://www.andrew.com.**

VCXO spans 25.92 to 622.08 MHz

A wideband voltage-controlled crystal oscillator (VCXO) for Synchronous Optical Network/synchronous-digital-hierarchy (SONET/SDH) applications offers a frequency range of 25.92 to 622.08 MHz. With a frequency that can be extended to 900 MHz, the pull is ±2000 to ±5000 PPM. Output is +10 dBm into 50 Ω and temperature stability is ±50 PPM from –40 to +85°C. Linearity is ±5 percent. **KS Electronics LLC, 16406 N. Cave Creek Rd., No. 5, Phoenix, AZ 85032-2919; (602) 971-3301, FAX: (602) 867-7250, Internet: http://www.kselectronics.com.**

Antennas target wireless data applications

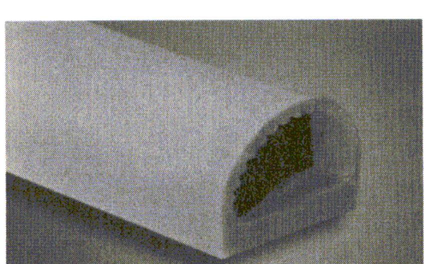
The Datenna™ family is a series of wireless broadband antennas designed specifically for wireless data and voice applications in the 2.1-to-5.8-GHz range. Polarization options include horizontal, vertical, +45/–45 deg., or horizontal/vertical models. Models with optimized bandwidth include industrial scientific medical (ISM), multipoint distribution system (MDS), multichannel MDS (MMDS), Unlicensed National Information Infrastructure (UNII), and dual band, as well as 3.4-to-3.6-GHz wireless-local-loop (WLL) applications. The family includes four directional-log periodic models, eight directional panel models, two directional diversity polarization models, and three omni models. The antennas are equipped with standard pole-mount hardware and will accommodate optional azimuth swivel wall-mount and mechanical downtilt kits for simultaneous tilt and swivel. **Decibel Products, Inc., 8635 Stemmons Freeway, Dallas, TX 75247; (800) 676-5342, (214) 634-8502, Internet: http://www.decibelproducts.com.**

Rx suits narrowband LMDS applications

The model MM25-6LNA is an integrated receiver (Rx) consisting of a low-noise amplifier (LNA), mixer, and local-oscillator (LO) doubler amplifier. The RF range is 20 to 30 GHz, while the LO frequency range is 10 to 15 GHz at –4 to 0 dBm. The intermediate-frequency (IF) range is DC to 5 GHz. With a single-sideband (SSB) noise figure (NF) and 3.0 dB typical to 3.5 dB maximum, the RF-to-IF gain is 20 dB typical and DC bias is +8 to +12 VDC at 200 mA maximum. This Rx can be used for narrowband local multichannel distribution system (LMDS) or for full-band multichannel radiometer applications. **Spacek Labs, Inc., 212 E. Gutierrez St., Santa Barbara, CA 93101; (805) 564-4404, FAX: (805) 966-3249.**

Gaskets reduce low deflection forces

Various standard hollow profile ultra-Vanshield RF-interference/electromagnetic-interference (RFI/EMI) shielding gaskets are available with special inner-surface features. These designs maintain dimensional stability under compression while reducing the low deflection forces of hollow shapes to lower levels. The dual elastomer styles have highly conductive outer surfaces co-extruded over a resilient metal-free inner core with more than 100-dB attenuation up to 1 GHz. **Vanguard Products Corp., 87 Newtown Rd., Danbury, CT 06810; (203) 744-7265, FAX: (203) 798-2351, e-mail: vanguard@worldnet.att.net, Internet: http://www.vanguardproducts.com.**



Antenna designed for harsh weather

A geosynchronous-operational-environment-satellite/maritime-satellite (GOES/MARISAT) prime-focus antenna feed is intended for use in a reflector with a force/deflection (F/D) ratio of 0.36 to 0.38. This weatherized, electronically heated and self-contained feed system is designed for use in harsh weather environments. The system operates over a temperature range of –79 to +50°C. GOES transmitter (Tx) frequency range is from 2024.1 to 20.34.1 MHz, while the MARISATE Tx frequency range is from 1638.5 to 1642.5 MHz. The receiver (Rx) frequency range is from 1682.1 to 1694.2 MHz and the MARISAT Rx frequency range is from 1537.0 to 1541.5 MHz. **Seavey Engineering Associates, Inc., 28 Riverside Dr., Pembroke, MA 02359; (781) 829-4740, FAX: (781) 829-4590, Internet: http://www.seaveyantenna.com.**

Diplexer screens PCS signals

The model W1807FL personal-communications-services (PCS) filter, nine-element diplexer is designed to be intermodulation distortion (IMD) free. Standard dual +37-dBm input signals produce <–140 dBc of IMD. Covering full PCS bands with <1.2-dB insertion loss, band center receiver/transmitter (Rx/Tx) isolation is >90 dB. With a return loss of >–16 dB, the power capability is >50 W. **Wireless Technologies Corp., 1009 Shaver St., Springdale, AR 72762; (877) 420-7983, (501) 750-1046, FAX: (501) 750-4657, e-mail: wireless@ipa.net, Internet: http://www.duplexers.com.**

For more information, visit www.mwrf.com

Joint boasts 200-W transmitted power

The model AM75RJ is a brass-constructed in-line rotary waveguide joint designed for use on rotating dish antennas in satellite-communications uplink and earth-station applications. The device can handle transmitted power in excess of 200 W and is precision engineered to ensure a typical maximum insertion loss of 0.2 dB. It is centered for a transmit frequency range of 14.0 to 14.5 GHz (Ku-band) and has a maximum VSWR of 1.5:1. The device uses UBR120-type flanges. **Advanced Microtek Ltd., Intec 4.1 Wade Rd., Bassingstoke Hants RG24 8NE, United Kingdom; 01256 355771, FAX: 01256 355118, e-mail: sales@linkmicrotek.co.uk, Internet: http://www.linkmicrotek.co.uk.**

OCXO features ±50-PPB frequency stability

The QEO SC 17 is an oven-controlled crystal oscillator (OCXO) boasting an overall frequency stability of ±50 PPB, including variation with a temperature range from –20 to +70°C, supply voltage, load, retrace, and first-year aging. It features G-sensitivity up to 1 PPB/G. The device is capable of either +3.3- or +5.0-VDC operation and a tuning range of ±2 PPM for 0 to +4 VDC with a +5.0-VDC power supply and ±0.25 PPM for 0 to +2.5 VDC with a +3.3-VDC power supply. Warmup time for the device is 5 min., after which the device is within ±50 PPB of nominal frequency. Applications include code-division-multiple-access (CDMA), wireless-CDMA (WCDMA), and Global System for Mobile Communications (GSM) base stations, switch platforms, and third-generation (3G) base stations for the IMT-2000 and Universal Mobile Telecommunications Systems (UMTS) cellular systems. **Temex Electronics, Inc., 3030 W. Deer Valley Rd., Phoenix, AZ 85027; (623) 780-1995, FAX: (623) 780-9622, Internet: http://www.temex-components.com.**

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Plotter boasts 7.937-μm resolution

The Protomat™ C100/HF is a circuit-board plotter that extends the speed and safety of mechanical printed-circuit-board (PCB) prototyping to surface-sensitive materials and substrates used in high-frequency applications. Offering a 340 × 200-mm work area and 7.937-μm resolution, the reproducibility precision is ±0.005 mm. Register hole system precision is ±0.02 mm, a three-phase motor is adjustable from 10,000 to 100,000 RPM, and power consumption is 200 VAC. The package measures 420 × 330 × 565 mm. **LPKF Laser & Electronics, 6180 SW Arctic Dr., Beaverton, OR 97005; (316) 831-9696, FAX: (316) 831-9692, Internet: http://www.lpkfcadcam.com.**

Coupler spans 1 to 18 GHz

The model 1831 90-deg. hybrid coupler operates from 1 to 18 GHz. With a coupling of 3 dB, amplitude imbalance is ±10 deg. maximum and isolation is 17 dB minimum. VSWR is 1.35 maximum while insertion loss is 2 dB maximum. Power rating is 20 W average and 3 kW peak. **Krytar, 1929 Anvilwood Court, Sunnyvale, CA 94089; (408) 734-5999, FAX: (408) 734-3017, Internet: http://www.krytar.com.**

Oscillators work to 52 MHz

The EV series of ceramic surface-mount oscillators is available in +3.3- or +5.0-VDC models with a frequency range spanning 1.02 to 52 MHz. Features include an absolute pull range (APR) up to 100 PPM, tri-state function, commercial or industrial temperature ranges, and linearity up to 10 percent. Applications include digital subscriber lines (DSLs), cable modems, and asynchronous transfer mode/Synchronous Optical Network/synchronous digital hierarchy (ATM/SONET/SDH). **Ecliptek Corp., 3545 Cadillac Avenue, Costa Mesa, CA 92626-1401; (800) ECLIPTEK, (714) 433-1200, FAX: (714) 433-1234, e-mail: sales@ecliptek.com, Internet: http://www.ecliptek.com.**

Software targets active-filter synthesis

Filter Free is personal-computer (PC) design software that creates filters based on a designer's design requirements. It features synthesis capability up to second-order filters. The software features an active-filter design capability that supports two Thomas biquad topologies, as well as positive- and negative-gain single-amplifier biquads. All active filters may be resistance-scaled by the user. Filter Free supports seven filter types in lowpass, highpass, and bandpass forms. **Nuhertz Technologies LLC, 1810 W. Northern Avenue, Suite A-9 No. 175, Phoenix, AZ 85021-5211; (602) 216-2682, FAX: (602) 216-1613, Internet: http://www.nuhertz.com.**

DAI operates to 60°C

The model 50289-DAI is a distribution-antenna interface (DAI) for frequency bands from the frequency-modulation (FM) broadcast range of 88 to 108 MHz to the personal-communications-services (PCS) range of 1800 to 2000 MHz. The DAI's operating temperature is –30 to 60°C and this interface enables multiple communication devices for radiating systems. The DAI is 100 percent passive and is equipped with transmission-line filters and type-N connector ports. The unit offers the user the capability of providing multiple services, including all municipal operations on a single antenna system with the ability to add bands as the system grows. The DAI features a maintenance-friendly modular construction in a rugged, field-proven NEMA-4 environmental enclosure. **Aerocomm, 464 Hudson Terrace, Englewood Cliffs, NJ 07632; (201) 227-0066, FAX: (201) 227-0067.**

PA ranges 20 to 150 MHz

The model BHE27157-500 is a very-high-frequency (VHF) radio booster that operates over the 20-to-150-MHz frequency range with 500-W minimum output power. This ruggedized power amplifier (PA) is powered from vehicular +22- to +32-VDC power and can operate over the –20 to +55°C temperature range with 100-percent condensing humidity. Output power is measured and controlled remotely, as are the amplitude-modulation (AM) and frequency-modulation (FM) automatic-level controls (ALC). The unit is housed in a 12.25 × 19.00 × 26.00-in. (31.12 × 48.26 × 66.04-cm) package. **Comtech PST, 105 Baylis Rd., Melville, NY 11747; (631) 777-8900, FAX: (631) 777-8877.**

Synthesizers feature +2.7- to +5.5-VDC supply

The ADF421x series of dual phase-locked-loop (PLL) synthesizers consists of the ADF4210 (operating from 550 MHz to 1.2 GHz), the ADF4211 (operating from 550 MHz to 2.0 GHz), the ADF4212 (operating from 900 MHz to 2.7 GHz), and the ADF4213 (operating from 900 MHz to 3.0 GHz). The synthesizers enable state-of-the-art local oscillators (LOs) for the upconversion and downconversion of RF signals in frequency and timing circuits. Performance exceeds 92 dBc/Hz at 900 MHz and 200-kHz channel spacing with a charge-pump voltage that operates to +6 VDC while the synthesizer operates at +3 VDC. **Analog Devices, 3 Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; (781) 329-4700, FAX: (781) 329-1241.**

Rxs cover 260 to 470 MHz

The second generation (2G) of the LC-series receiver (Rx) modules provides a complete solution for the wireless transfer of serial, control, and command information over distances of more than 300 ft. when paired with an LC-series transmitter (Tx). The modules operate in the 260-to-470-MHz band and interface to virtually any data source, including microcontrollers and decoder chips. **Linx Technologies, Inc., 575 SE Ashley Place, Grants Pass, OR 97526; (800) 736-6677, Internet: http://www.linxtechnologies.com.**

For more information, visit
www.mwrf.com

Amplifiers target fixed wireless applications

The SGL-0163 and SGL-0263 are silicon-germanium (SiGe) heterojunction-bipolar-transistor(HBT) monolithic-microwave-integrated-circuit (MMIC) amplifiers offering low-noise, high-input intercept-point products aimed at applications in second-generation/third-generation (2G/3G) wireless infrastructure and fixed wireless applications. The SGL family is optimized for the 800-to-1000-MHz and 1900-to-2400-MHz communication bands. The SGL-0163 has a noise figure of 1.2 dB; +5-dBm input third-order intercept point (IP3), and small-signal gain of 16 dB. The SGL-0263 has a noise figure of 1.3 dB; +6-dBm input IP3 and signal gain of 15 dB. P1dB compressed output power can be improved 5 dB in both products by increasing the input voltage from +3 to +4 VDC and current from 11 to 25 mA. **Stanford Microdevices, Inc., 522 Almanor Ave., Sunnyvale, CA 94086; (408) 616-5400, FAX: (408) 739-0970, e-mail: info@stanfordmicro.com.**

Epoxy boasts low shrinkage upon cure

The EP30 is a two-component epoxy adhesive for high-performance bonding applications. The adhesive develops physical-strength properties even when cured at ambient temperatures. Cure can be accelerated through the use of moderate heat. The epoxy boasts good chemical resisitance, dimensional stability, hardness, and optical clarity. Electrical insulation properties remain desirable even upon prolonged exposure to moisture. The volume resistivity exceeds 10^{15} Ω-cm and the dielectic constant measure <3.5. The epoxy adheres to substrates including metals, ceramics, glass, and plastic. Typically lap-shear strength exceeds 3000 psi for aluminum-to-alumninum (Al-to-Al) bonds and is not affected by exposure to adverse environmental conditions. Shrinkage upon cure is low. The epoxy is especially suited for assemblies where only very-thin bond lines are dictated by design considerations. **Master Bond, Inc., 154 Hobart St., Hackensack, NJ 07601; (201) 343-8983, FAX: (201) 343-2132, Internet: http://www.MasterBond.com.**

Detector spans 2 to 18 GHz

The model TD-30T-218-FC-HS is a miniature threshold detector. The threshold detector features hybrid microwave-integrated-circuit (MIC)/monolithic-MIC (MMIC) technology that operates over the full 2-to-18-GHz frequency range. This high-speed device boasts a response time of <100 ns and a minimum dynamic range of –10 to –20 dBm (with –20 to +5 dBm typical). The device features external threshold adjustment and a VSWR of <3.0:1, as well as removable SMA female connectors. It uses a single supply of +12 VDC at 100-mA maximum current. **Planar Monolithics Industries, 7311-G Grove Rd., Frederick, MD 21704; (301) 662-4700, FAX: (301) 662-4938, e-mail: amcp misales@aol.com, Internet: http://www.amwave.com.**

Attenuator operates from 8 to 18 GHz

A current-controlled, nonlinearized, absorptive, analog attenuator typically operates over the 8-to-18-GHz octave band. The model CVAN-8018-60-SP with Options 002 and 10F is optimized for 9.5 to 10.0 GHz. The VSWR is 2.0:1 and the RF operating input power is +20 dBm with a survival rating of +30 dBm. The rise time is 100 ns maximum and the fall time is 20 ns maximum. The unit is housed in a 2.0 × 1.8 × 0.5-in. (5.08 × 4.57 × 1.27-cm) package. **American Microwave Corp., 7311-G Grove Rd., Frederick, MD 21704; (301) 662-4700, FAX: (301) 662-4938, e-mail: amcpmisales@aol.com, Internet:http://www.amwave.com.**

Modem works from –40 to +85°C

The model 560MM-TW modem module is designed for use with any embedded system application. The modem operates in the –40 to +85°C extreme temperature range. The modem is self-contained and features an onboard modem controller as well as a data pump that provides system engineers with the flexibility of being able to add modem functionality into system products with minimal resources. Standard features include 56-kb/s data speed, 14.4-kb/s fax, voice recording and playback, digital-line protection, along with dual-tone-multifrequency (DTMF) decoding. Optional features include two-wire leased-line and dial-up support, as well as simultaneous voice and data (SVD) on one telephone line. **Radicom Research, Inc., 679 E. Brokaw Rd., San Jose, CA 95112; (408) 392-9688, FAX: (408) 392-9689, Internet: http://www.radi.com.**

Synthesizer provides 0.7-Hz fequency resolution

The model STEL-9941 is a high-performance, single- channel S-band synthesizer. Output power is 0 dBm ±1.5 dB. The unit has an operating temperature of 0 to 70°C. The device combines direct digital synthesis (DDS) with microwave mix/divide circuits to boast advanced performance specifications, including a frequency resolution of 0.7 Hz, switching speed of 150 ns, and high spectral purity. Standard models operate from 1.6 to 2.8 GHz. Due to its modular design, however, several performance options are available up to 18 GHz with limited effect on lead times. These generic modules are attached to a common base plate with blind mate connectors. Readjustment is not necessary when changing modules, enabling maintenance and logistics processes. The internal oscillator is free running or phase locks to an external 10-MHz reference. **ITT Industries, Microwave Systems, 59 Technology Dr., Lowell, MA 01851; (978) 441-0200, FAX: (978) 453-6299, e-mail: mwsystems@itt.com, Internet: http://www.ittmicrowave.com.**

For more information, visit www.mwrf.com

Tool kits

Tool kits and test equipment are discussed in a 300-page catalog. Hand, power, and specialty tools; wire and cable; soldering equipment; computer and local-area-network (LAN) products; telecom test equipment; workstations; and shop supplies are presented. Storage and handling equipment, lighting and optical products, and field accessories are offered. **Jensen Tools, Inc.;** *(800) 426-1194, (602) 453-3169, FAX: (800) 366-9662, (602) 438-1690, e-mail: jensen@stanleyworks.com, Internet: http://www.jensentools.com.*

Dielectric resonators

A 92-page catalog focuses on dielectric resonators, coaxial resonators, and ceramic filters. Coaxial inductors and coaxial resonator kits are highlighted, along with ceramic filter packaging. Applications and design solutions software are discussed. **Trans-Tech;** *(301) 695-9400, FAX: (301) 695-7065, e-mail: transtech@alphaind.com, Internet: http://www.trans-techinc.com.*

Signal conditioning

A front-end, personal-computer (PC)-based signal-conditioning platform is the subject of a 64-page booklet. The booklet is a collection of customer solutions spanning diverse industries and applications, including research and development (R&D), aerospace, electronics, and semiconductors. Applications range from durability testing to production test, quality control, environmental monitoring, industrial control, and automated test. **National Instruments;** *(800) 258-7022, FAX: (512) 683-9300, e-mail: info@ni.com, Internet: http://www.ni.com.*

Signal recovery

Signal recovery products are covered in a 128-page catalog. Preamplifiers, lock-in amplifiers, transient recorders, digital delay generators, AC voltmeters, and supporting software are offered. Applications include spectroscopy and light measurement, materials characterization, electrochemistry, electronics, engineering, semiconductor studies, and medical research. **PerkinElmer Instruments;** *+44 (0) 118 977 3003, FAX: +44 (0) 118 977 3493, Internet: http://www.signalrecovery.com.*

Resistance testers

Clamp-on ground-resistance testers are the subject of a brochure. Specifications include resolution, measurement range, and accuracy. Applications, features, and ordering information are provided. **Chauvin Arnoux, Inc.;** *(800) 343-1391, (617) 451-0227, FAX: (617) 423-2952, Internet: http://www.aemc.com.*

TETRA standard

A primer examines Terrestrial Trunked Radio (TETRA), which is an international digital radio standard defined by the European Telecommunications Standards Institute (ETSI). The benefits of TETRA over conventional professional-mobile-radio/public-access-mobile-radio (PMR/PAMR) standards for mobile radio systems used in public-safety applications are described. TETRA's specifications and the basic test requirements of TETRA transmitters (Txs) and receivers (Rxs) are explored. **IFR;** *(800) 835-2352, (316) 522-4981, e-mail: info@ifrsys.com, Internet: http://www.ifrsys.com.*

Power dividers

Components are overviewed in a 152-page catalog. Power dividers; directional couplers; high-power dual directional couplers; diode detectors; directional detectors; waveguide couplers; 90- and 180-deg. hybrids; waveguide adapters; coaxial terminations; low-, medium-, and high-powered waveguide terminations; and coaxial attenuators are covered. Continuously variable attenuators, interdigital and bandpass filters, 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 detailed. Product specifications and mechanical outlines are included. Custom designs are available. **Microwave Communications Laboratories, Inc.** *(800) 333-6254, (727) 344-6254, FAX: (727) 381-6116.*

Packaging solutions

Plated-copper (Cu)-on-thick-film (PCTF™) technology is the subject of a six-page brochure. An explanation of the technology is provided, along with discussions of the technology's benefits and solutions. The company's manufacturing capabilities are also included. **Remtec;** *(781) 762-9191, FAX: (781) 762-9777, e-mail: sales@remtec.com, Internet: http://www.remtec.com.*

Logic analyzers

Test, measurement, and monitoring products are the focus of a 757-page catalog. Oscilloscopes, logic analyzers, logic scopes, spectrum analyzers, network analyzers, power meters, signal generators, electromagnetic/RF-interference (EMI/RFI) solutions, wireless communication testsets, optical-network products, broadband-transmission test products, protocol analyzers, mixed-signal sources, logic sources, benchtop products, semiconductor testers, probes, and carts are offered. Video products, such as waveform monitors, generators, measurement sets, audio tests, picture-quality analysis systems, and video-network monitoring are featured. Product specifications are included. **Tektronix, Inc.;** *(800) 426-2200, Internet: http://www.tektronix.com.*

DC blocks

Cables and connectors are available from a 169-page catalog. Adapters, attenuators, circulators, coaxial cables and connectors, DC blocks, detectors, and directional couplers are listed. Isolators, limiters, phase trimmers, power dividers, shorts, switches, terminators, and waveguide-to-coax adapters are featured. **Pasternack Enterprises;** *(949) 261-1920, FAX: (949) 261-7451, e-mail: sales@pasternack.com, Internet: http://www.pasternack.com.*

For more information, visit www.mwrf.com

Network tester

A 15-page brochure examines applications of the ANT-20 advanced network tester in Synchronous Optical Network (SONET) networks up to the OC-192 hierarchy level. The brochure offers elegant solutions to typical test problems using the ANT-20. Network optimization work is also covered. **Wavetek Wandel Goltermann Eningen GmbH & Co.;** *+49 7121 86-1616, FAX: +49 7121 86-1333, e-mail: info@acterna.com, Internet: http://www.acterna.com.*

Power supplies

A 47-page catalog presents switching power supplies and DC-to-DC converters for worldwide applications. Ultraminiature, open-frame, enclosed, industrial rail-mount, external, wall-mount, as well as high-density board-mount switching power supplies are offered, along with high-performance DC-to-DC converter products. Specifications are provided. A part-number index is included. **Astrodyne;** *(800) 823-8082, (508) 823-8181, Internet: http://www.astrodyune.com.*

Pulse generators

An 18-page catalog features test equipment from a variety of manufacturers. Pulse generators, logic analyzers, plotters, meters, RF signal generators, inductance-capacitance-resistance (LCR) analyzers, spectrum analyzers, precision sources, oscilloscopes, frequency counters, impedance analyzers, network analyzers, power supplies, audio analyzers, semiconductors, and signal generators are offered. Telecommunications, TV and video, data-communications, RF measurement, and data-acquisition (DAQ) equipment are also available. **Test Equipment Connection Corp.;** *(800) 615-8378, (407) 804-1780, FAX: (800) 819-TEST, (407) 804-1277, Internet: http://www.testequipmentconnection.com.*

Chip resistors

High-power resistive products for microwave and RF applications are the focus of a catalog. Surface-mount-device (SMD), chip, flanged, and flangeless resistors, terminators, and attenuators are offered. Custom products are also discussed. Application notes and a millimeter-conversion table are included. **American Technical Ceramics;** *(631) 622-4700, FAX: (631) 622-4748, e-mail: sales@atceramics.com, Internet: http://www.atceramics.com.*

Telecommunications

A 132-page communications catalog focuses on the telecommunications-service industry. Cable, telephone and electrical test equipment, and service aids are presented. **Jensen Tools, Inc.;** *(800) 426-1194, (602) 453-3169, FAX: (800) 366-9662, (602) 438-1690, e-mail: jensen@stanleyworks.com, Internet: http://www.jensentel.com.*

Test equipment

Test equipment is the subject of a 55-page product catalog. New equipment offerings include oscilloscopes, arbitrary function generators, probes, DC power supplies, waveform generators, data-acquisition (DAQ) equipment, pulse generators, spectrum and network analyzers, as well as cable. Reconditioned equipment offerings feature power supplies, spectrum analyzers above and below 1 GHz, RF measurement equipment, RF signal sources, signal generators, audio analyzers, counters, logic analyzers, plotters, oscilloscopes, and meters. **TestEquity, Inc.;** *(800) 529-3457, FAX: (800) 272-4FAX, Internet: http://www.testequity.com.*

Cable assemblies

Application notes for the models UFA147B and UFA210B Uti-FLEX® flexible microwave cable assemblies focus on the assemblies' amplitude and phase stability versus temperature ranging from –50 to 100°C. The notes outline the cables' percentage change in insertion loss at various temperatures as well as phase stability. **MICRO-COAX;** *(800) 223-2629, (610) 495-0110, FAX: (610) 495-6656, Internet: http://www.micro-coax.com.*

Connectors and cable

A 280-page catalog features components and assemblies for a variety of applicatons. Connectors, cable, integrated-circuit (IC) sockets, semiconductors, transistors, diodes, rectifiers, crystals, oscillators, inductors, coils, filters, capacitors, and resistors are specified. Potentiometers, thermistors, switches, relays, wire, cable, test equipment, batteries, fuses, transformers, and power supplies are also included. **Digi-Key Corp.;** *(800) 344-4539, (218) 681-6674, FAX: (218) 681-3380, Internet: http://www.digikey.com.*

Interconnect solutions

A source book is a guide to expose product designers and engineers to many proven interconnect concepts for the design of application-specific solutions. The 100-page book is divided into sections that focus on multi-cycle test connectors, product connectors, board-to-board connectors and interfaces, and high-performance test sockets. Each solution includes a description of the design challenge, a description of the solution, and a review of the results. The last section of the guide discusses facets of spring-contact probe technology, including terminology, coaxial and RF principles, lab test results, and data on electrical performance. **Synergetix;** *(913) 342-0404, FAX: (913) 342-6623, e-mail: info@synergetixnet.com, Internet: http://www.synergetixnet.com.*

Printed-circuit boards

A 96-page printed-circuit-board (PCB) hardware catalog discusses a product line consisting of retainers, injectors, extractors, and conduction-cooled products. Collected performance data evaluate and recommend product lines for clamping force, retention force, shock and vibration, thermal resistance, materials, and finishes. Calculations and test results are included to help engineers select the appropriate PCB hardware for design needs. **APW Electronic Solutions;** *(858) 375-2323, FAX: (858) 679-4555.*

For more information, visit www.mwrf.com

EMI shielding

A 230-page engineering handbook presents electromagnetic-interference (EMI) shielding. Cost-effective solutions for major applications, contract manufacturing, and supply-chain management are presented. Shielding solutions for wireless communications, gaskets, conductive compounds, engineered laminates, and grounding products are discussed. **Chomerics;** *(781) 935-4850, FAX: (781) 935-4318, Internet: http:// www.chomerics.com.*

Plated copper on thick film

A catalog describes the plated-copper-on-thick-film (PCTF) proprietary manufacturing process. The technology combines patterned copper (Cu)-plated images with air-fireable thick films on ceramics for the manufacture of metallized substrates, chip carriers, and packages. The catalog shows how PCTF technology provides cost-effective microelectronic packaging solutions for telecommunications, sensors, and wireless and fiber-optic data-transfer devices. **Remtec, Inc.;** *(781) 762-9191, FAX: (781) 762-9977, e-mail: sales@ remtec.com, Internet: http:// www.remtec.com.*

LDO regulators

Low-dropout (LDO) regulators are the subject of an 11-page brochure. Dual 1-A and 2-A, low-power MSOP-8, along with high-current LDOs are covered. Fast-transient-response 5-A and 3-A, dual-output, SOT-23, low-power 500-mA and 750-mA, p-channel metal-oxide-semiconductor (PMOS) 1-mA, and low-current models are also offered. A section of application reports is included. **Texas Instruments, Inc.;** *(800) 477-8921 ext. 4337, Internet: http:// www.ti.com/sc/sineon.*

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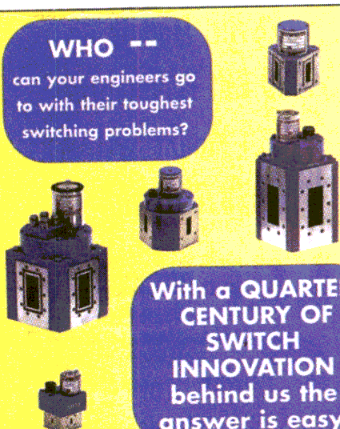

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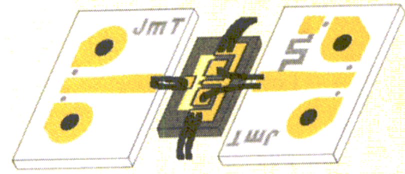

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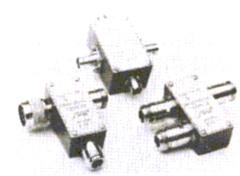

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LOOKING BACK

February 1988 brought the introduction of a line of gallium-arsenide (GaAs) monolithic-microwave-integrated-circuit (MMIC) oscillators from Pacific Monolithics (Sunnyvale, CA). The line included tunable voltage-controlled oscillators (VCOs) capable of operation from 1 to 6 GHz and dielectric resonator oscillators (DROs) at custom frequencies from 0.7 to 18 GHz.

Microwaves & RF March Editorial Preview

Issue Theme: Wireless Technology

News

The Wireless/Portable Conference & Exhibition (February 12-16, 2001) has blossomed into one of the premier events for designers of wireless and portable devices and systems. If you cannot make it to the show, the next best thing is to catch Microwaves & RF's extensive wrapup.

Design Features

Contributed articles in March will cover a wide range of frequencies, from RF concerns about Global System for Mobile Communications (GSM) systems to measurement issues at frequencies past 90 GHz. Authors from Agilent Technologies (Santa Rosa, CA) offer methods for manufacturing on-wafer measurements of nonplanar RF diodes, while authors from Maxim Integrated Products (Sunnyvale, CA) review the basics of scattering (S)-parameters.

Product Technology

March's Product Technology section will feature a first look at the lowest-cost, highest-output power-amplifier (PA) integrated circuit (IC) yet available for IEEE 802.11b wireless local-area networks (WLANs) operating at 2.4 GHz and 11 Mb/s. Additional articles will unveil a complete chip set for the higher-data-rate version of WLANs, IEEE 802.11a for 54-Mb/s applications at 5 GHz, and an instrument that combines a microwave frequency counter, microwave power meter, and voltmeter under one roof.