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FOR DESIGNERS AT HIGHER FREQUENCIES

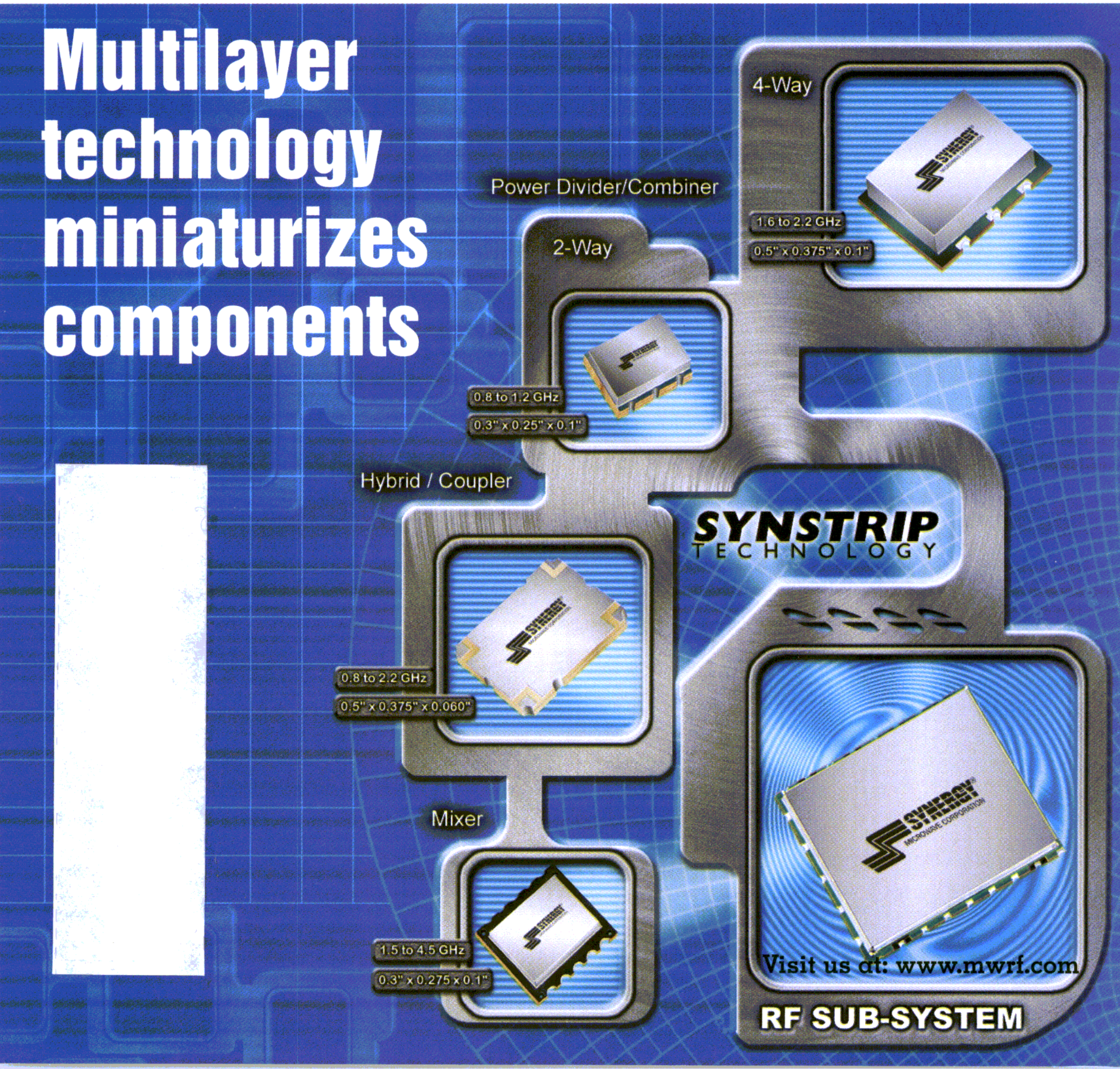
Microwaves & RF

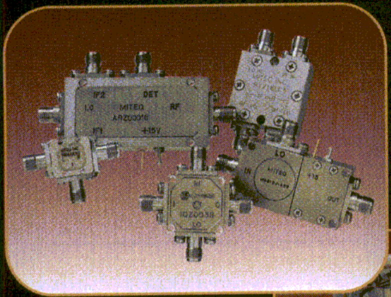
Military Electronics Issue

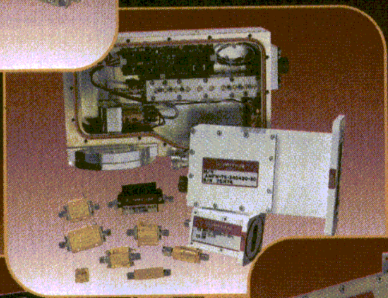
NEWS
Surveying the needs of military electronics

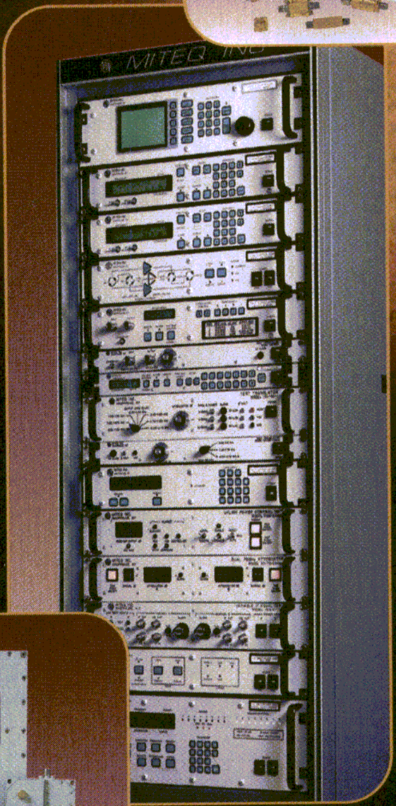
DESIGN FEATURE
Extend the limits of oscillator analysis

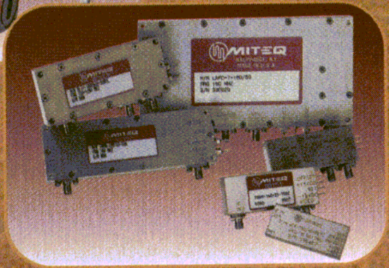
PRODUCT TECHNOLOGY
VXI-based synthesizers add wideband modulation

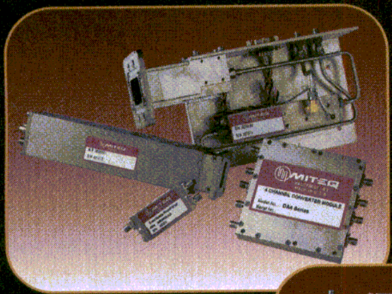




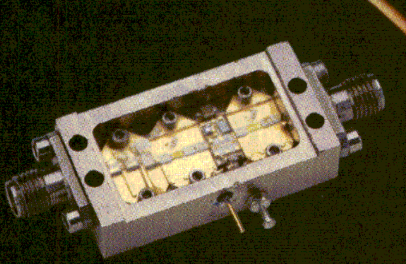








AMPLIFIERS for every application

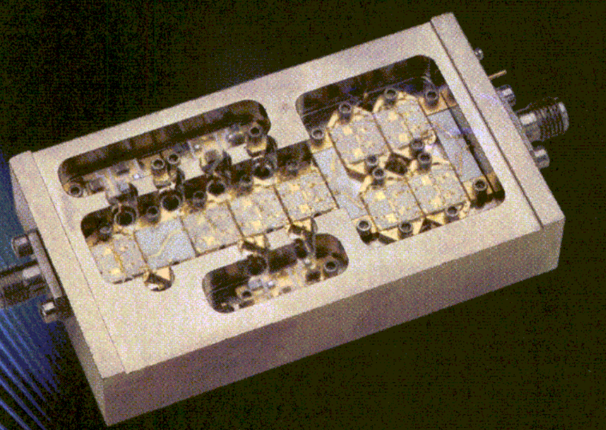


ULTRA BROAD BAND

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA018-203	0.5-18.0	20	5.0	2.5	7	17	2.0:1	250
JCA018-204	0.5-18.0	25	4.0	2.5	10	20	2.0:1	300
JCA218-506	2.0-18.0	35	5.0	2.5	15	25	2.0:1	400
JCA218-507	2.0-18.0	35	5.0	2.5	18	28	2.0:1	450
JCA218-407	2.0-18.0	30	5.0	2.5	21	31	2.0:1	500

MULTI OCTAVE AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA04-403	0.5-4.0	27	5.0	1.5	17	27	2.0:1	550
JCA08-417	0.5-8.0	32	4.5	1.5	17	27	2.0:1	550
JCA28-305	2.0-8.0	22	5.0	1.0	20	30	2.0:1	550
JCA212-603	2.0-12.0	32	5.0	3.0	14	24	2.0:1	550
JCA618-406	6.0-18.0	20	6.0	2.0	25	35	2.0:1	600
JCA618-507	6.0-18.0	25	6.0	2.0	27	37	2.0:1	800

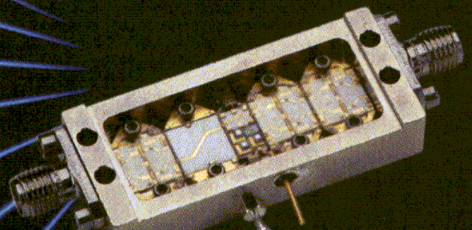


MEDIUM POWER AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-P01	1.35-1.85	35	4.0	1.0	33	41	2.0:1	1000
JCA34-P02	3.1-3.5	40	4.5	1.0	37	45	2.0:1	2200
JCA56-P01	5.9-6.4	30	5.0	1.0	34	42	2.0:1	1200
JCA812-P03	8.0-12.0	40	5.0	1.5	33	40	2.0:1	1700
JCA1218-P02	12.0-18.0	22	4.0	2.0	25	35	2.0:1	700

LOW NOISE OCTAVE BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-3001	1.0-2.0	40	0.8	1.0	10	20	2.0:1	200
JCA24-3001	2.0-4.0	32	1.2	1.0	10	20	2.0:1	200
JCA48-3001	4.0-8.0	40	1.3	1.0	10	20	2.0:1	200
JCA812-3001	8.0-12.0	32	1.8	1.0	10	20	2.0:1	200
JCA1218-800	12.0-18.0	45	2.0	1.0	10	20	2.0:1	250



NARROW BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-1000	1.2-1.6	25	0.75	0.5	10	20	2.0:1	80
JCA23-302	2.2-2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7-4.2	30	1.0	0.5	10	20	2.0:1	90
JCA56-401	5.4-5.9	40	1.0	0.5	10	20	2.0:1	120
JCA78-300	7.25-7.75	27	1.2	0.5	13	23	2.0:1	120
JCA910-3000	9.0-9.5	25	1.2	0.5	13	23	1.5:1	150
JCA910-3001	9.5-10.0	25	1.2	0.5	13	23	1.5:1	150
JCA1112-3000	11.7-12.2	27	1.1	0.5	13	23	1.5:1	150
JCA1213-3001	12.2-12.7	25	1.1	0.5	10	20	2.0:1	200
JCA1415-3001	14.4-15.4	35	1.4	1.0	14	24	2.0:1	200
JCA1819-3001	18.1-18.6	25	1.8	0.5	10	20	2.0:1	200
JCA2021-3001	20.2-21.2	25	2.0	0.5	10	20	2.0:1	200

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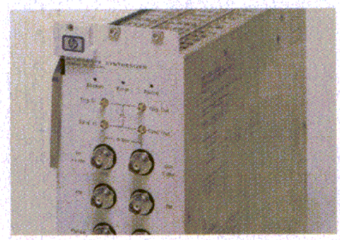

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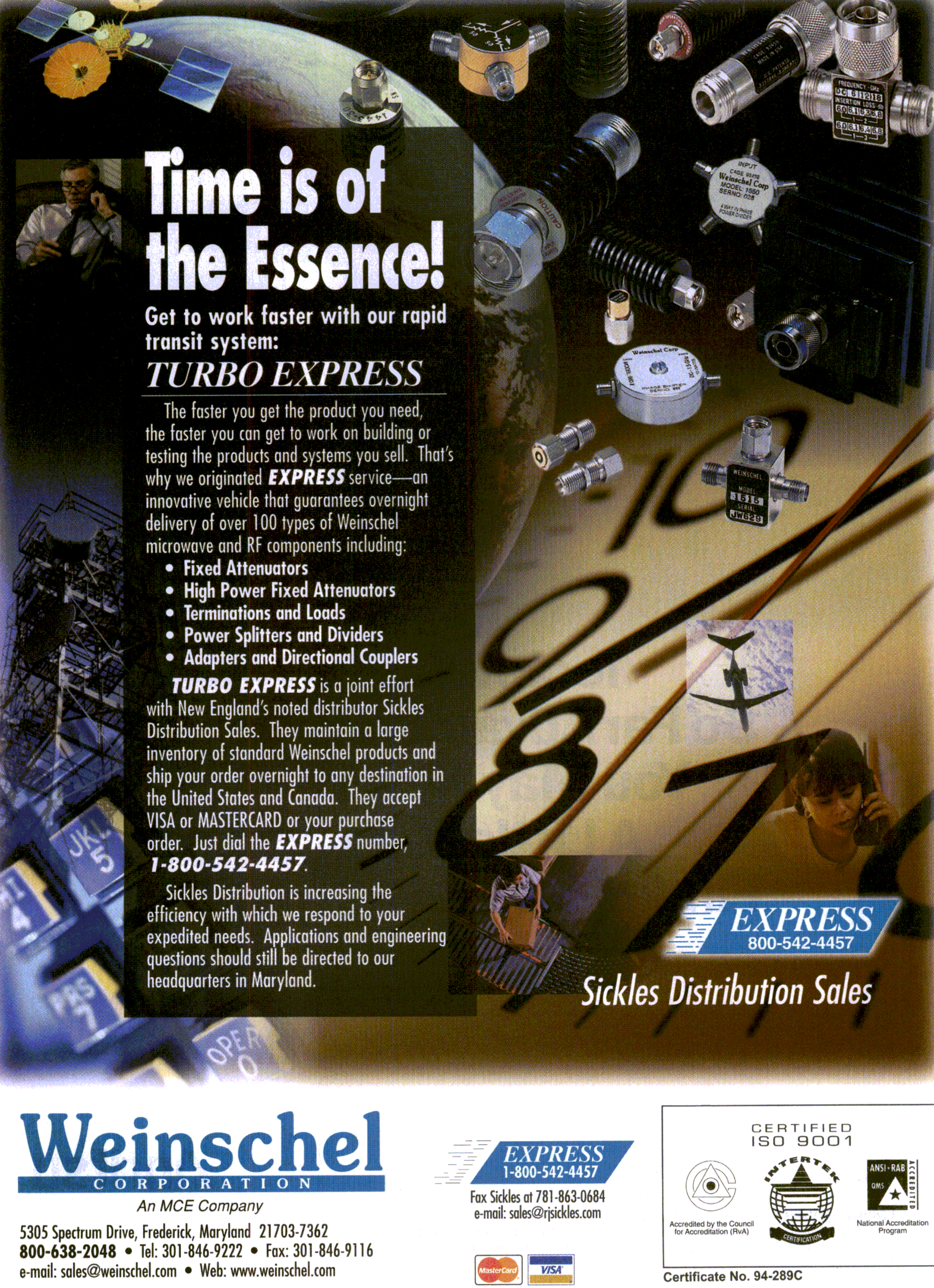

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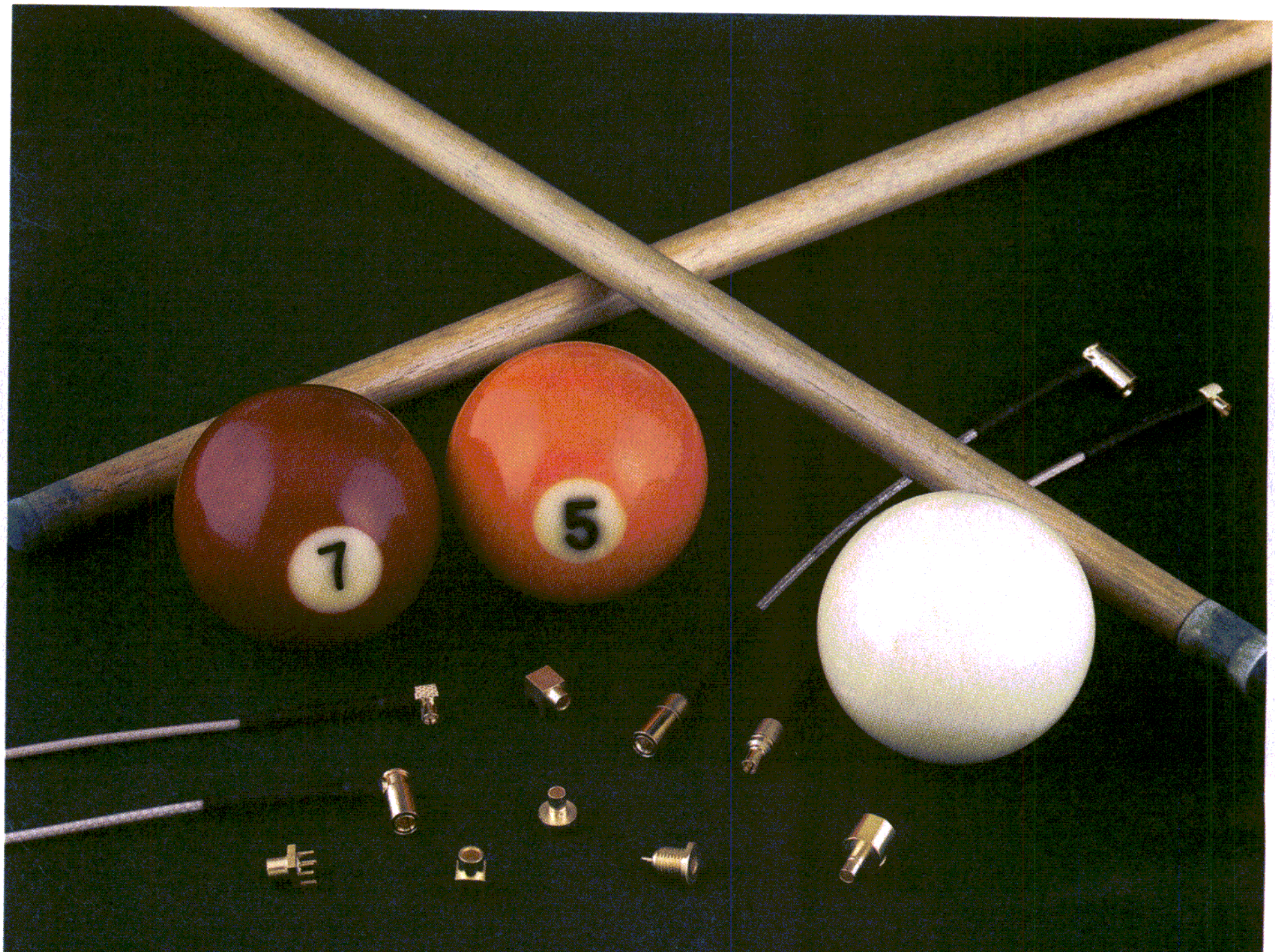

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BIOMEDICAL ISSUES

To the editor:

Regarding Dr. Kumar's letter that appeared in April's Feedback (p. 13), concerning my February article (p. 105) "Studying Biomedical Issues Of High-Frequency Radiation," I wanted to note that the list of references had been chosen primarily for their tutorial value and that I had deliberately avoided using recent controversial papers in the wireless area. Interested readers can find my report on cellphone-related biomedical issues in the AP-S Turnstile column (*IEEE Antennas and Propagation Magazine*, Vol. 41, December 1999, pp. 98-99).

Also, it may be noted that in a letter to the editor in the February 2000 issue of the *IEEE AP-S Magazine* that Dr. J.M. Osepchuk cautioned readers about "'Electrophobia,' currently focused toward wireless base stations, and exploitation of Electrophobia by peddlers of shielding devices..."

Rajeev Bansal
Professor
Dept. of Electrical and Computer Engineering
University of Connecticut
Storrs, CT

TRANSISTOR WEBSITE

To the editor:

I have read April's editorial (p. 17) and feel that our website should be of interest to your readers and is worthwhile reviewing. The address is: http://www.gaascode.com.

For 12 years, GaAs Code has specialized in using device physics as the basis of practical software tools and services for those using, building, and designing microwave circuits around GaAs FETs and HEMTs. For the last two years, we have manufactured and sold a pulsed-measurement instrument which measures the dynamic current-voltage characteristics that a device will follow under RF conditions. The dynamic I(V) characteristics are almost always different from the static (or DC) measured characteristics for all device types that the instrument measures—heterojunction bipolar transistors (HBTs), silicon (Si) bipolar transistors, high-electron mobility transistors (HEMTs), field-effect transistors (FETs), and diodes.

We have also found Pete Conrad's website reviews absorbing and helpful—and a quick way to see what is out there on the congested web.

James Bridge
GaAs Code

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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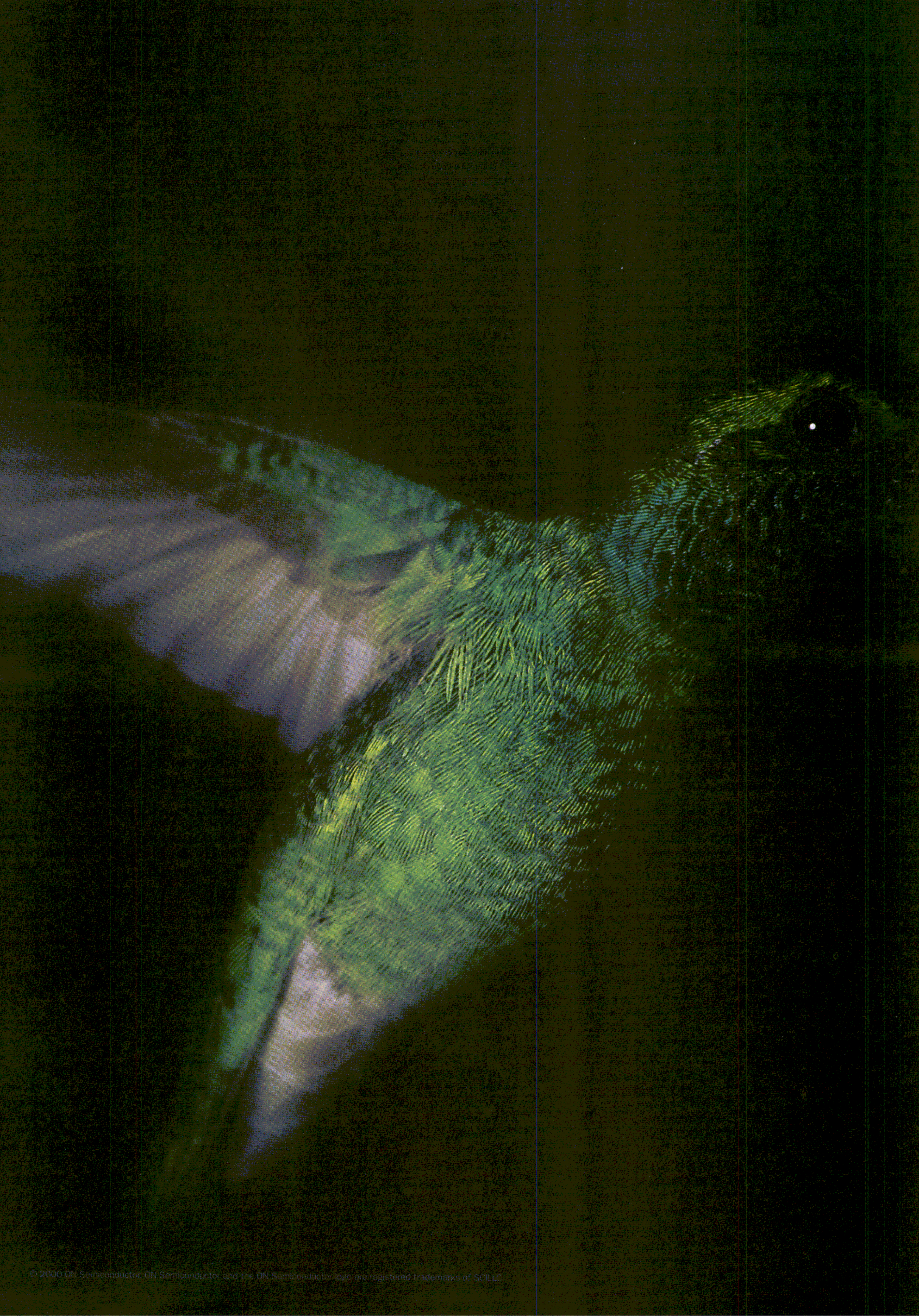

ORGANIZING A SHOW FOR THE MILITARY

Military electronics is the focus of this issue. Military electronics was once the mainstay of this industry, until the spread of wireless and general commercial opportunities began in the late 1980s. In the wake of the "gold rush" toward commercial customers, military systems developers have often been left behind. But government defense spending has stabilized, and the military electronics economy is fairly healthy for those high-frequency-electronics firms that chose to remain in this area.

Typically, as privately held high-frequency firms prepare their Initial Public Offerings (IPOs) by highlighting their commercial business, they tend to downplay revenues from military sources. Ironically, it has been the military applications, such as electronic-warfare (EW), electronic-countermeasures (ECM), and radar systems, which have traditionally driven the state of the art in electronics. The spread-spectrum technology, which is now commonplace in cordless telephones and wireless local-area networks (WLANs), was developed originally for secure battlefield communications.

Traditionally, military budgets have funded the research and development of advanced electronics technologies, with many of these technologies eventually filtering to the consumer level. But with the growth and lure of global communications markets, many of the former suppliers of military electronics have shifted their business plans away from the military and more toward commercial and consumer customers. Military system designers have made tremendous strides in adapting commercial-off-the-shelf (COTS) hardware to their designs, but COTS components do not fill all military design needs.

With ever-expanding commercial business, military customers must compete with commercial customers for the hardware, software, and test equipment they need to upgrade current systems and develop new systems. And they have few dedicated trade shows to learn about new technologies and solutions. Until now.

The Military Electronics Show is scheduled for November 7-9, 2000 in the Ronald Reagan Center (Washington, DC). Sponsored by *Microwaves & RF*, this show is for design engineers concerned with military-grade components and systems. It is not about COTS and it is not another wireless show. It is meant to provide a single venue where engineers can learn more about the technologies and products that impact their military and aerospace designs, from jammer amplifiers to radar-warning receivers.

The Military Electronics Show will present technical sessions on all levels of military component and system design, including software simulation and test techniques, and will offer an exhibition area for manufacturers to showcase their latest hardware, software, and test equipment. If you'd like to get involved as a technical presenter or as an exhibitor, drop me a note at jbrowne@penton.com.

Military designers have been ignored for more than a decade. It's time someone paid attention to them.

Jack Browne

Publisher/Editor

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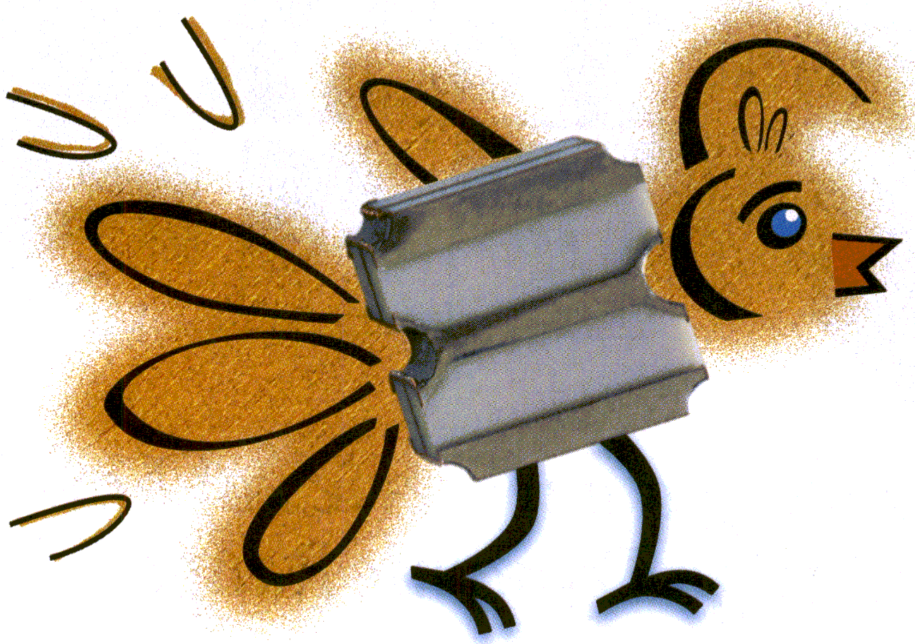

TVS Solution Prevents ESD Failures On 10/100-Mb/s Ethernet LANs

NEWBURY PARK, CA—Semtech Corp. announced that it has leveraged its proprietary EPD TVS™ technology to produce the first transient-voltage-suppression (TVS) integrated circuit (IC) designed specifically to prevent failures from static discharges when connecting local-area-network (LAN) cables to routers, hubs, bridges, and NIC cards.

The SR2.8 TVS array protects high-speed-data interfaces from electrostatic discharge (ESD) to the IEC 1000-4-2, Level 4 standard. The SR2.8 incorporates four surge-rated, low-capacitance steering diodes and a TVS diode in a single package. Operating at only +2.8 VDC, the SR2.8 array configuration allows the user to protect two high-speed-data or transmission lines simultaneously.

"High-speed LANs—especially those carrying low-voltage RGB signals—are especially vulnerable to latch-up from static discharge, particularly cable-discharge effect (CDE), which occurs when you move cables during installation or re-routing," says Tom Dugan, Semtech's marketing director of protection products. "Developed with our EPD TVS advantage, the SR2.8's superior electrical characteristics prevents the resulting latch-up or destruction of delicate sub-5-V complementary-metal-oxide-semiconductor (CMOS) line transceivers in a way that other manufacturers have been unable to attain."

Delays In Wire Line Broadband Boost Wireless Broadband Market

OYSTER BAY, NY—The arrival of broadband technologies to the wireless neighborhood has been delayed by problematic rollouts, raising the value of the wireless broadband market, according to new findings from Allied Business Intelligence, Inc. (ABI). The limitations of conventional wired broadband technologies have become evident. Line congestion and slow deployments of digital subscriber line (DSL) and cable modems have proven to be constant hurdles faced by many service providers, consultants, and their customers.

Broadband fixed WLL technologies subscribers, world market, 2000 to 2005

Year	Subscribers (millions)
2000	0.2
2001	0.9
2002	2.0
2003	3.9
2004	6.2
2005	9.4
CAAG	113 percent

As a result, service providers are turning to wireless technologies. These technologies include local-multipoint-distribution-system (LMDS), multichannel-multipoint-distribution-system (MMDS), and personal-communications-services (PCS) systems operating in the various industrial-scientific-medical (ISM) bands (900 MHz, 2.4, 5.1, and 5.8 GHz). These technologies are expected to gain more than nine million broadband subscribers by 2005 (see table), according to a recent ABI research report, "LMDS, MMDS, and ISM 2000: Global Markets and Trends for Fixed Wireless Broadband."

"These wireless systems will be used to provide fiber and high-speed copper equivalents to otherwise underserved customers," states ABI senior analyst Andy Fuertes.

MMDS, including the 3.4-to-3.7-GHz worldwide standard for fixed wireless access, is expected to lead the market with 70-percent share in 2005, largely in the residential and small-office, home-office (SOHO) markets. LMDS will continue to make inroads into the market for high-value customers, accounting for 60 percent of subscriber revenues in 2005.

LMDS will continue to make inroads into the market for high-value customers, accounting for 60 percent of subscriber revenues in 2005. Traditional wire-line and wireless carriers will join small ISPs in using a collection of bands (largely unlicensed) and technologies to address dark spots in their coverage areas.

California Law Enforcement Benefits From WAN Technology

ORANGE, CA—Global Pacific Wireless Internet, a division of Worldwide Wireless Networks, Inc. (WWWN), has been selected by the city of Garden Grove and its police department to construct a wireless broadband network connecting its police substations. WWWN's integrated wireless Internet network will deliver aerial high-speed wide-area-network (WAN) connectivity to the Garden Grove Police Department's 10 police substations. These substations are strategically located throughout the city to act as support stations in areas that need extra patrol and police presence. The Garden Grove Police Department chose WWWN's wireless network and its system to serve as its primary wireless WAN connection and Internet backbone connectivity because the system enables any Garden Grove Police Department employee to access all police records and data that are available at the main police-station computer and can rapidly transfer that information wirelessly to the substations.

WWWN's wireless WAN and its system can be rapidly deployed and relocated for wireless remote-access applications. The WAN's performance and reliability will quickly enable the Garden Grove Police Department to access various state and federal records in virtually seconds, cutting down on valuable response time.

Lead Is Eliminated From BGA Packages

LEXINGTON, MA—STMicroelectronics has announced the successful development of lead-free ball-grid-array (BGA) and micro-BGA packages. The new packages, where conventional tin/lead (SnPb) solder balls are replaced by a tin/silver/copper (SnAgCu) alloy, were developed within the ECOPACK® program that ST has been pursuing as part of its commitment to achieve total environmental neutrality.

Lead is widely used throughout the economics industry and, in particular, has always been a critical component of the solder used for printed-circuit-board (PCB) assembly. For the same reason, it is also widely used in semiconductor packaging—for coating the leads of through-hole packages, for die attach of power packages, and for the balls of BGA packages. In fact, the conventional BGA packages currently in production have a lead content up to 15 percent, the highest of any semiconductor package.

"Lead has always been extensively used in the electronics industry and its elimination poses major challenges to semiconductor manufacturers. However, ST is fully committed to finding alternatives to toxic metals, even when current international regulations allow their continued use, and the development of lead-free BGA packages is an important milestone," says Carlo Cognetti, ST's corporate package development and engineering director.

Class Of Reduced SAR Embedded Antennas Introduced

CANNES, FRANCE—As handsets get smaller, meeting the specific-absorption-rate (SAR) requirements will present a challenging dilemma for wireless handset designers. How will tomorrow's antenna technology significantly reduce SAR while improving effective radiated power (ERP)? The answer may lie in a family of reduced SAR embedded antennas that was recently introduced by RangeStar Wireless.

RangeStar's reduced SAR embedded antenna is specifically designed to provide wireless design manufacturers with a solution to meet current European and Federal Communications Commission (FCC) SAR requirements—one that does not depend on shielding or power reduction. RangeStar has worked for the past several years to develop this class of internal antennas that significantly reduces SAR, which allows original equipment manufacturers (OEMs) to increase power in order to improve ERP.

"The impact of the reduced SAR embedded antenna is increased performance and maximum ERP," says David McCartney, executive vice president of RangeStar. "RangeStar's embedded antenna allows wireless designers to fully maximize output while meeting the requirements of the FCC and other international guidelines."

Weighing in at only 2 g (nominal), the antenna offers a gain of 1 to 2 dBi while operating in the 800-to-1900-MHz bands. The internal antenna can provide a 4-dB front-to-back ratio that relates to an average SAR measurement of 1.5 W/kg. In addition, the reduced SAR embedded antenna provides the unique ability to be mounted over components on the printed-circuit board (PCB) [i.e., the duplexer].

Market Demands Increase For InGaP HBTs And PHEMTs

SOMERSET, NJ—EMCORE Corp.'s Electronic Materials Division (E2M) recently announced the completion of the first phase of expansion at its fabrication facility to meet increased market demand for its indium-gallium-phosphide (InGaP) heterojunction-bipolar-transistor (HBT) and pseudomorphic-high-electron-mobility-transistor (PHEMT) products used in wireless and fiber-optic communication devices. The additional 2000 sq. ft. of fabrication space will accommodate up to six additional high-throughput TurboDisk® epitaxial wafer platforms and support expansion of the division's characterization capabilities. The first phase of expansion nearly doubles production capacity for 4- and 6-in. (10.16- and 15.24-cm) wafers. EMCORE also has launched a second phase of expansion that will again double production capacity for these products.

"Recent orders for both PHEMT and HBT epitaxial materials for wireless have resulted in a 300-percent increase in E2M's six-month backlog since the beginning of FY00," says Reuben Richards, president and CEO of EMCORE. "We are currently shipping both 4-in. and 6-in. InGaP HBTs and PHEMTs to our wireless customers for power amplifiers for GSM (Global System for Mobile Communications), TDMA (time-division-multiple-access), and CDMA (code-division-multiple-access) multiband wireless handsets and to our fiber-optic customers for high-speed digital components for OC-48 and OC-192 fiber-optic communication."

"We are seeing rapid growth in the demand for both 4-in. and 6-in. InGaP HBT wafers , as designers and manufacturers have realized the performance and reliability advantages of InGaP HBTs compared to conventional AlGaAs HBTs," says Craig Farley, vice president of E2M. "Recent high-volume orders for PHEMT wafers from major wireless component manufacturers have demonstrated that MOCVD (metal-organic-chemical vapor deposition) epitaxial material is superior to MBE for both HBT and PHEMT applications."

Declining Investment In Research And Development Alerts Defense Industry

WASHINGTON, DC—The Aerospace Industries Association (AIA) continues to be alarmed as the Defense Department chips away at its investment in research and development (R&D). The FY 2001 budget proposes a half billion dollar decrease in RDT&E funding from the FY 2000 budget. After adjusting for inflation, FY 2001 RDT&E is at the lowest level in 18 years. AIA has proposed a plan to increase investment in aerospace R&D over five years. AIA's plan calls for a $2 billion increase in Defense Department funding of aerospace RDT&E in FY 2001.

The Defense Department's long-term research budget is even more alarming. The FY 2001 budget proposal would further reduce RDT&E investments in Fiscal Years 2002 to 2005. This steady decline in research investment is likely to have a negative effect on the quality of equipment provided to America's men and women in uniform. Strong investment in R&D is critical to national security, economic well being, and international competitiveness.

High-Speed Internet Access For Public Places Introduced

NEW ORLEANS, LA—Lucent Technologies recently announced the ORINOCO high-speed wireless Internet-access and networking system. Building upon Lucent's WaveLAN wireless local-area network (WLAN) for business and enterprise, the ORINOCO family now adds new home-networking products as well as products that are designed to provide secure, high-speed Internet access in public hot spots such as universities, office complexes, and airports.

Whether for home, office, or travel, all of these systems use the same ORINOCO personal-computer (PC) radio card. Formerly known as the WaveLAN PC card, the ORINOCO PC card provides high-speed wireless networking and secure Internet access for laptop and desktop computers, as well as a wide range of mobile computing devices. The ORINOCO system also includes various access points that act as base stations for the wireless users and provides a high-speed connection to the Internet.

Based upon the industry standard IEEE 802.11 (Wi-Fi)-compliant technology, ORINOCO provides 11-Mb/s speed over the unlicensed 2.4-GHz spectrum, with ranges up to 1200 ft. The Lucent Technologies ORINOCO PC card fits into almost any laptop or mobile computing device and is compatible with other 802.11-compliant systems, including the popular Apple AirPort™ system.

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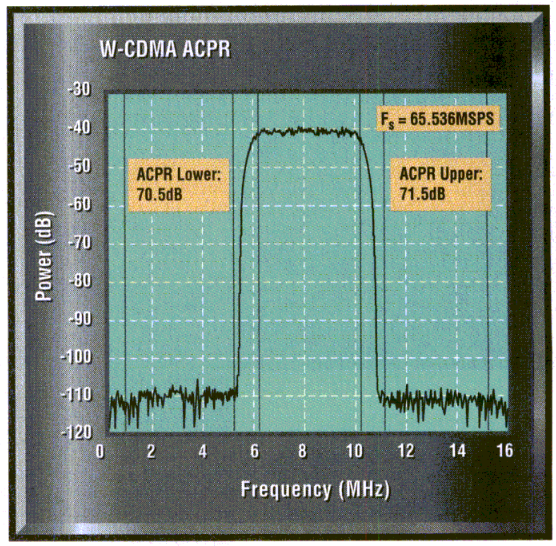

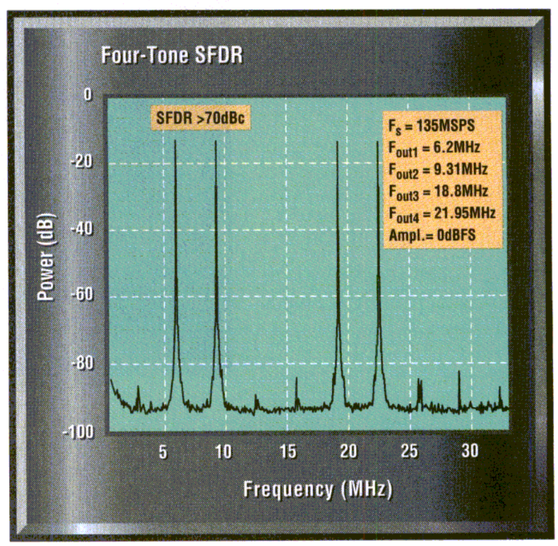

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CIRCLE NO. 293

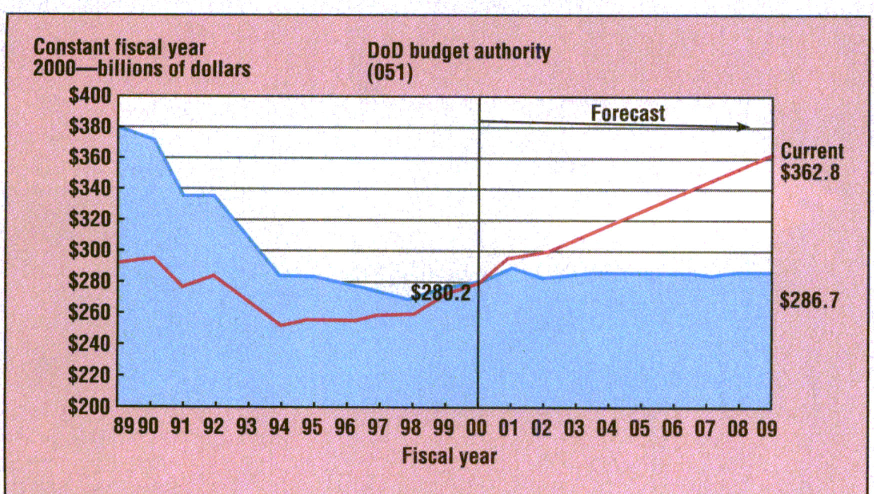
Defense planners must walk a fine line to cut costs, keep forces ready, and maintain the high quality that has characterized military systems over the years.

Defense Spending Choices Force A Balancing Act

GENE HEFTMAN

Senior Editor

FEW issues of federal government spending evoke more public debate than the amount of money requested by the military each year to defend the national interests of the US. Between now and 2010, approximately $270 to $300 billion of taxpayers' money (in constant Year-2000 dollars) will be spent each year to maintain US defense forces at a high state of readiness. But to maintain that state, the country must, in the words of the 35th Annual 10 YR Defense Electronics Forecast (1999) of the Government Electronics and Information Technology Association (GEIA), "address the affordability challenges of being the world's only remaining superpower." Until very recently, it was doubtful that sufficient political and economic will existed to spend the money necessary to upgrade and modernize the military as defense budgets plummeted during the 1990s (Fig. 1). However, budget surpluses from a booming economy over the next few years could keep appropriations on an even keel and allow the military to restore some of the fighting capability that reduced spending has diminished over the years (note the virtually constant expenditure level in constant dollars from 2000 to 2009 in the GEIA's budget forecasts in Fig. 1).



1. After a decade of decline, the US military budget will rise slightly (in constant dollars) over the next decade according to the latest forecast of the GEIA.

Given this slight uptick in spending, it is not clear how much the increase will restore military capability. The reason is that a host of variables and complex scenarios make the shape of tomorrow's armed forces and how it is equipped highly unpredictable (see "Electronics Are A Secret Weapon In The Military Budget," *Microwaves & RF*, June 1999, p. 27, and "Military Retrenchment Spells Electronics Growth," *Microwaves & RF*, June 1998, p. 37.) In the GEIA's view, the spending cuts on equipment of the last decade have created a giant shortfall from what is needed to maintain a modern military force (see table). However, the Forecast concedes that "Post-Cold War Force structure reductions . . . have reduced current requirements from those of the 1974-1993 period." On the other hand, the Forecast refers to a recent Congressional Budget Office (CBO) study that found that planned rates of procurement are still far short of the levels required to modernize the armed forces. The third column of the table lists the annual purchases necessary to sustain today's forces, assuming a broad number of variables, equipment lifetimes, and other assumptions. In light of current and projected budgets shown in Fig. 1, it is doubtful that the monies available will be able to satisfy the ambitious purchase schedule laid out by the GEIA.

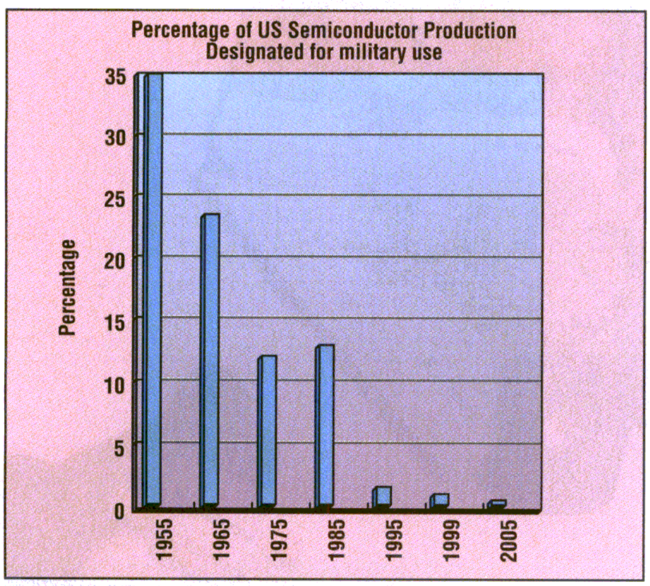
To be sure, modernization and improved equipment are necessary to keep the US as the world's number one military superpower. The question is the affordability issue. How

Deferring equipment replacement has created an aging force

	Average annual purchases			Annual purchases needed to sustain today's forces*
	1974 to 1993	1994 to 1999	2000 to 2005	
Tanks, artillery, and other armored vehicles	1485	24	28	623 to 872
Helicopters	124	44	30	155 to 263
Fighter/attack aircraft	308	44	72	174 to 232
Other aircraft	38	10	17	45 to 59
Ships	17	7	8	8 to 10

*Range of annual purchases needed reflects effect of different assumptions on length of service lives.

much is the US willing to spend to maintain supremacy? The short answer is not as much as the military is used to. This means that military systems must not only meet the high-performance and reliability standards of the past, but must do so on skimpier budgets. As far back as 1983, the government thought it had the answer with the Commercial-Off-The Shelf (COTS) initiative, but in the year 2000 it is still not clear how the program can keep the US armed forces on the cutting edge.



2. The nation's semiconductor manufacturing resources devoted exclusively to military devices are declining rapidly, as shown in this bar graph from *Revolution in Miniature,* by Braun & McDonald.

On its face, using commercial components where possible in place of those made specifically for the military at much higher cost is a logical method for reducing the cost of defense equipment and systems. Moreover, the armed services get the benefit of the latest commercial technology, which is constantly improving by virtue of the competitive forces of the marketplace driving companies to outdo one another in the race for profits and business success. The reality is far more complex for the simple reason that defense spending is not what it used to be, and manufacturers have more lucrative opportunities in commercial markets.

"Defense contractors expect to buy low volumes at commercial prices," says Peter Milliken, Product Line Manager of Semiconductor Products and Services at UTMC Microelectronic Systems (Colorado Springs, CO), a supplier of semicustom and standard VLSI integrated circuits (ICs) to aerospace and defense markets. "They also want access to advanced semiconductor technologies like systems-on-a-chip (SOC), but the intellectual property (IP) to do that has been pretty pricey," he adds. A chip manufacturer cannot afford an up front cost of approximately a half-million dollars for a potential volume of 100 or even 1000 pieces. And the government does not want to absorb a royalty for a device that is not a guaranteed success. In short, the government wants advanced technology but the cost and accessibility issues are proving difficult to resolve.

Another example of the price/volume dilemma experienced by Milliken is the plastic packaging issue. Surface-mount plastic packaging is desirable in some space-vehicle applications to reduce the weight of large pin-count IC packages and reduce board-space requirements, but the volumes needed by defense contractors run only approximately 1000 pieces over five years. But assembly manufacturers who do plastic packaging require anywhere from 2500 to 10,000 pieces to make the job profitable, effectively cutting off that option. Since ceramic-package lot sizes are economic in 250-piece lots, the company is forced to use that technique.

"The whole goal of the Dr. Perry mandate (Dr. William Perry was Secretary of Defense in 1994 when the COTS rules went into effect) is to use commercial products in military applications where you can," says Tom Terlizzi, Vice President and General manager of Aeroflex Circuit Technology (Plainview, NY). "Instead of military specifications for an integrated circuit, a performance specification is used. Rather than specifying the part to the finest detail, it is left up to the manufacturer to do what he best knows how to do," he adds. But such COTS programs have met with mixed results. Some specifications have been too relaxed, while others are not stringent enough. A commercial part cannot simply be used in a military application, according to Terlizzi. "You must know the device physics and where it can be used", he states. With

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Product Number	Frequency Mhz	POUT Watts	Gain dB	Supply Voltage	Package Number	Internal Matching
To 1.0 GHz – GOLDMOS FET						
PTF 10136	1000	6	18.0	28	20244	N
PTF 10147	1000	10	15.0	26	20244	N
PTF 10137	1000	12	13.0	28	20244	N
PTF 10007	1000	35	12.0	28	20222	N
PTF 10052	1000	35	12.0	28	20235	N
PTF 10015	1000	50	12.0	28	20235	N
PTF 10031	1000	50	12.0	28	20222	N
PTF 10139*	1000	60	12.0	28	20235	N
PTF 10138*	1000	60	12.0	28	20222	N
PTF 10009	1000	85	12.0	28	20230	N
PTF 10049	470–860	85	12.0	32	20240	I
PTF 10159	470–860	120	12.0	32/28	20240	I
PTF 10019	860–900	70	13.0	28	20237	I
PTF 10133	860–900	85	13.0	28	20237	I
PTF 10100	860–900	165	12.0	28	20250	I
PTF 10162	860–960	18	14.0	26	20222	N
PTF 10036	860–960	85	11.0	28	20240	I
PTF 10160*	860–960	85	15.0	26	20248	I/O
PTF 10020	860–960	125	11.0	28	20240	I
PTF 10149	921–960	70	15.0	26	20252	I
1.0–2.2 GHz – GOLDMOS FET						
PTF 10111	1500	6	15.0	28	20222	N
PTF 10107	2000	5	11.0	26	20244	N
PTF 10135	2000	5	11.0	26	20249	N
PTF 10041*	2000	12	10.0	26	20249	N
PTF 10053	2000	12	10.0	26	20244	N
PTF 10021	1400–1600	30	11.0	28	20237	I/O
PTF 10125	1400–1600	135	11.5	28	20250	I/O
PTF 10045	1600–1650	30	10.0	28	20222	N
PTF 10112	1800–2000	60	11.0	28	20248	I/O
PTF 10153*	1800–2000	60	12.5	28	20248	I/O
PTF 10120	1800–2000	120	10.0	28	20250	I/O
PTF 10043	1900–2000	12	11.0	26	20222	I
PTF 10035	1900–2000	30	11.0	28	20237	I/O
PTF 10123*	2100–2200	5	11.0	28	20244	N
PTF 10119	2100–2200	12	10.0	28	20222	I
PTF 10048	2100–2200	30	10.0	28	20237	I/O
PTF 10122	2100–2200	50	10.0	28	20248	I/O
PTF 10134*	2100–2200	100	10.0	28	20250	I/O

Note: An "*" next to the product part number indicates the specifications are preliminary and subject to change without notice. Please contact your sales representative for further product information. Complete product information is available on our Website at: **www.ericsson.com/rfpower.**

Packages are not to scale.


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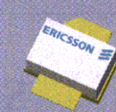
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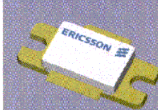
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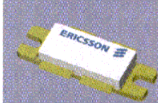
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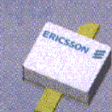
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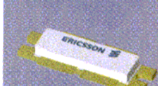
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military budgets shrinking and commercial business growing, it is becoming difficult to get commercial chipmakers to build products for the military.

An example of what spending cutbacks and COTS have wrought is illustrated in Fig. 2. This bar graph shows the percentage of US semiconductor production devoted to defense systems, and projects what lies ahead over the next five years. Over a span of half a century, the percentage fell from 35 percent in 1955 to near zero by the year 2005. This is at the core of present and future semiconductor procurement problems for military hardware. Unless military requirements align themselves with the types of devices produced for commercial systems, obtaining the necessary electronics for advanced systems will be difficult.

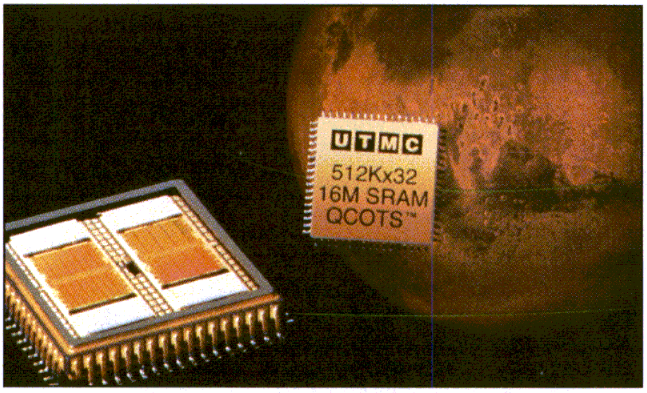
STANDARDIZING IS KEY

Among suppliers of components and equipment to the defense industry, there is broad consensus that the military must use more COTS-type ICs, including the use of standard products wherever possible. Such is the case even for contractors whose sole business is military. One way to accomplish this, according to Dave Martell, Director of Business Development for Microwave Products at Zeta-IDT (San Jose, CA), a supplier of RF power products and systems to the Department of Defense, is the use of a standardizing technique called platforming. "Say you're building seven different types of radar and you need a synthesizer," he says, "Maybe there is a way to use one 'Brand X' synthesizer for all seven types. Then you can go out and get a quotation for a higher volume of parts and get the benefits of economies of scale." Today, the military is using more standard parts than ever, and the idea of non-recurring-engineering (NRE) charges is frowned upon.

The same sentiment is echoed by Carl Fisher, Manager of Business Development at MPD Technologies, Inc. (Hauppauge, NY), a manufacturer of high-power solid-state amplifiers for the aerospace and defense industry. Many of the company's military products are built to specification and are unique. Still, Fisher says, "Standard power modules are at the heart of our amplifier systems. The power modules that we build apply to a high-frequency system, whether it's 1 kW or 10 kW; we use the same modules in each product." And these modules are designed to be upgradeable as technology evolves. As an example, they are using laterally-diffused-metal-oxide-semiconductor (LDMOS) power devices wherever possible, but the next generation of power semiconductors could be the highly touted but as yet unproven silicon-carbide (SiC) technology. So the modules must be designed to accept SiC devices when it becomes a viable technology.

Test-equipment manufacturers are following the lead of semiconductor- and equipment-makers when it comes to employing COTS principles and standardized components. The Aerospace, Defense, and Broadband Communications Group of Agilent Technologies (Palo Alto, CA) is a major advocate of the COTS concept when it comes to the automatic test equipment (ATE) required for military hardware. Rick Pearson, general manager of the group, claims that one way to do that is "to leverage from the commercial market using the best possible solutions from the communications world." Even when building custom test equipment to spec that uses standard off-the-shelf test equipment, Pearson says that "To meet customer requirements we can modify some of the software and downloadable firmware. But to make hardware modifications, the market must be large enough to justify those changes."

The fact is, test-equipment makers and defense contractors alike are trying to get away from the mil-spec and custom-systems approach and use as much COTS as possible in test systems. Doing so would reduce test-equipment costs, permit open industry standards, and take advantage of the latest advances in technology. The biggest stumbling block is the Test Program Set (TPS), which is the software that directs the instruments performing the tests. This is the high-cost item in the test gear and Agilent, together with other manufacturers, is devising methods to permit new instruments to be plugged into a test set without affecting the TPS, which would yield large cost savings when instruments must be changed. The concept is called test-asset interchangeability, and its purpose is to allow a particular test asset (instrument) to be replaced with an alternative of sufficient capability, but of a different design or from



3. Four 4-Mb memory devices are housed in this multichip-module (MCM) SRAM from UTMC Microelectronic Systems. Designed for space and military systems, such packaging saves space and weight in satellite systems.

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PMBTH10	SOT23	25	40	400	0.6	1-20						
PMBTH81	SOT23	20	40	400	0.6	1-20						
BFS17W	SOT323	15	50	300	1.6	2-20	4.5		500			
BFR92AT	SC-75*	15	25	300	5	3-30	2	14	1000	3	8	2000
BFT92W	SOT323	15	35	300	4	3-30	2.5	17	500	3	11	1000
BFR93AT	SC-75*	12	35	300	5	5-40	1.5	13	1000	2.1	8	2000
BFQ67T	SC-75*	10	50	300	8	3-30	1.3	13	1000	2.2	8	2000
PBR941	SOT23	10	50	360	8	3-30	1.4	15	1000	2	9.5	2000
PRF947	SOT323	10	50	250	8	3-30	1.5	16	1000	2.1	10	2000
PRF949	SC-75*	10	50	150	8	3-30	1.5	16	1000	2.1	10	2000
PRF957	SOT323	10	100	270	8	5-50	1.3	15	1000	1.8	9.2	2000
BFR505T	SC-75*	15	18	150	9	1-10	1.2	17	900	1.9	10	2000
BFR620T	SC-75*	15	70	300	9	3-30	1.1	15	900	1.9	9	2000
BFC520	SOT353	8	70	1000	9	3-30	1.3	31	900	1.5	19	2000
BFE520	SOT353	8	70	100	9	3-30	1.2	17	900	1.9	10	2000
BFM520	SOT363	8	70	100	9	3-30	1.1	15	900	1.9	9	2000
BFG520W/X	SOT343	15	70	500	9	3-30	1.6	17	900	1.8	11	2000
BFG540W/X	SOT343	15	120	500	9	10-60	1.9	16	900	2.1	10	2000
BFG11W/X	SOT343	8	500	760	9	50-150					7	1900
BFG403W	SOT343R	4.5	3.6	16	17	5-5	1	20	900	1.6	22	2000
BFG410W	SOT343R	4.5	12	54	22	2-15	.9		900	1.2	22	2000
BFG425W	SOT343R	4.5	30	135	22	3-30	.8		900	1.2	20	2000
BFG480W	SOT343R	4.5	250	360	18	30-150	1.2		900	1.8	16	2000
BFG21W	SOT343R	4.5	200	600	18	50-250					12	1900

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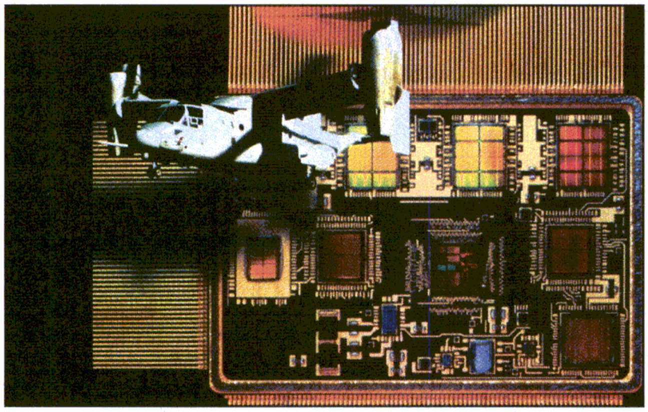
a different manufacturer without affecting the TPS. To accommodate interchangeability, Agilent has developed a measurement subsystems architecture (MSA). Under MSA, asset-control modules permit obsolete instruments to be replaced with newer modules while still providing the same answers as the original instrument.

CONQUERING OBSOLESCENCE

Military systems are designed to have long lifetimes, often for 10 years or more. Today's commercial equipment generally lasts for only a few years as business tries to keep consumers buying with new bells and whistles to keep the cash registers ringing. While consumer products require a constant influx of new technology—semiconductor and otherwise—military products must have a steady flow of devices that will be available for the life of the system. But given the reductions in military spending over the past decade, it is virtually impossible for IC manufacturers to continue to supply and stock 10-year old devices when commercial markets are so much more lucrative. Thus, electronic defense systems need some means of continuing to function as the circuits that drive them become obsolete.

The armed forces understand the problem, which is one of the reasons for the COTS initiative. Moreover, it is necessary for military hardware to incorporate the latest technology for maximum effectiveness. One of the techniques being used by chip makers to avoid obsolescence and keep within the spirit of COTS is the multichip module (MCM), a hybrid type of IC that takes advantage of advanced technology by packaging complex functions in a single IC package using multiple



4. A high-performance system such as this 64-b superscaler microprocessor with cache memory from Aeroflex Circuit Technology can be packaged in an MCM for defense electronics systems. This packaging technique meets military needs for a COTS IC that incorporates the latest in processor technology.

chips. At Analog Devices (Greensboro, NC), Bob Barfield, product marketing manager for the Multichip Products Business Unit states that "We're trying to look across multiple organizations, multiple customers, and multiple programs to define somewhat generic functions. These can be things such as direct IF conversion, analog-to-digital converters (ADCs) and others, and they would be released as standard products, hence a COTS product. The idea is to promote that functionality to gain widespread acceptance among users, which is in tune with what COTS is trying to do."

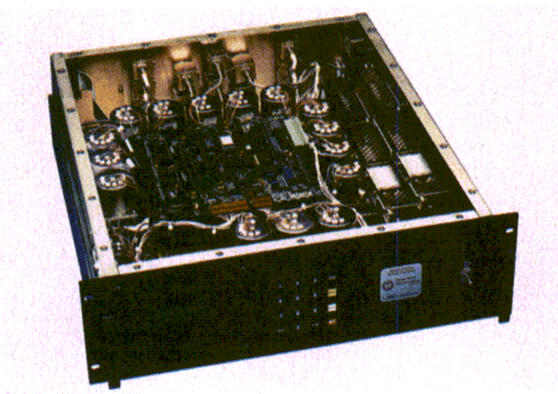
The company offers several grades of these functions including one that is fully tested across the full military temperature range to guarantee the performance. But for applications that do not require such stringent testing—called ruggedized industrial grade—less screening is performed, resulting in a less-expensive part. Whatever the grade, however, all devices are produced on the same manufacturing line. One of the benefits of the MCM approach for military applications is that a package can be designed with a specific functionality and pinout arrangement. As semiconductor technology improves, the devices inside the package can be upgraded with advanced versions but the functionality and pinout remain the same. This allows military hardware to be upgraded with the latest technology without necessitating changes to the original design.

An example of the MCM approach is a 16-Mb static random access memory (SRAM) from UTMC Microelectronic Systems for use in satellite applications (Fig. 3). The device packages four 4-Mb memory die using both sides of the substrate in a 68-lead ceramic flatpack, which increase packaging density and conserves space and weight. The company claims that this type of module is less than half the size and weight of four individual SRAMs, and offers lower cost/bit. It is also a radiation hardened (rad-hard) part rated for a total-dose exposure of up to 30 krds(Si) and can be shielded up to 100 krad(Si) for operation in geosynchronous orbits.

MCM technology is featured in a MIPS microprocessor package that contains a 64-b superscaler processor chip together with 2 MB of embedded cache memory from Aeroflex Circuit Technology (Fig. 4). The package is a 280-lead ceramic flatpack aimed at military and high-reliability markets. The processor is a high-speed type that can issue one integer and one floating-point instruction per cycle. This device represents the goal of MCM technology—to provide advanced semiconductors, to increase equipment life span by continuously upgrading performance in a small footprint, and to provide an orderly migration path for future products by upgrading with new devices as they become available.●●

Coaxial switch matrix supports 100 outputs

The model 2201 coaxial, bidirectional, normally open-switch matrix is configured with one input and can have up to 100 outputs. It operates from DC to 18 GHz and is ideal for use in automatic test equipment (ATE), environmental/laboratory test equipment, and programmable patch panels and interconnects. The matrix has a switching speed of 50 ms and an impedance of 50 Ω. It includes a solid-state controller with a front-panel liquid-crystal-display (LCD) screen and a keypad for manual override and RS-232, RS-422, and IEEE-488 general-purpose-interface-bus (GPIB) remote interfaces. The bidirectional open-switch matrix operates at temperatures from 0 to +50°C and is enclosed in a 5.5 × 19 × 20-in. (13.97 × 48.26 × 50.80-cm) rack-mountable housing. Options include rack slides. **Dow-Key Microwave Corp., 4822 McGrath St., Ventura, CA 93003-7718; (805) 650-0260, FAX: (805) 650-1734, Internet: http://www.dowkey.com.**



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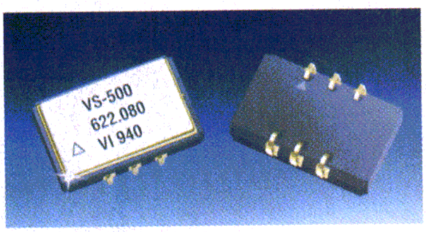


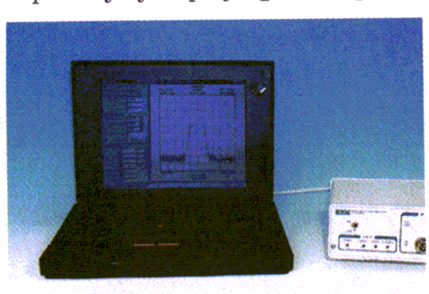
SAW-based VCO offers low jitter

Model VS-500 standing-acoustic-wave (SAW)-stabilized, voltage-controlled oscillator (VCO) operates at the fundamental frequency of its internal SAW filter. It boasts high stability and high quality factor (Q) for low phase jitter over a wide operating temperature range. The VCO is available at operating frequencies from 155 MHz to 1 GHz and is ideal for clock smoothing and frequency translation in telecommunications applications. Typical jitter is 3 ps for the 622.08-MHz version and 6 ps for the 155-MHz version. The VCO has complementary outputs with emitter-coupled-logic (ECL) and positive-emitter-coupled-logic (PECL) levels. The oscillator is housed in a hermetically sealed, J-lead, surface-mount package. **Vectron, International, 166 Glover Ave., Norwalk, CT 06856-5160; (203) 853-4433, FAX: (203) 849-1423, Internet: http://www.vectron.com.**

CIRCLE NO. 59 or visit www.mwrf.com

Software boosts spectrum analyzer's capabilities

The model PA2500 personal-computer (PC)-based spectrum analyzer spans 100 kHz to 2500 MHz and includes software that provides sophisticated capabilities and facilitates analysis. In conjunction with a notebook computer, the Windows™-compatible software provides several automatic features, including markers, spectrum memories, max hold, peak search, and signal track. The software can display multiple spectrums, each with its own settings. It can also take advantage of the Windows multi-tasking capability by displaying the output of several PA2500 analyzers simultaneously. **DKD Instruments, 750 Amber Way, Nipomo, CA 93444; (805) 929-2285, FAX: (805) 929-5983, Internet: http://www.dkdinst.com.**



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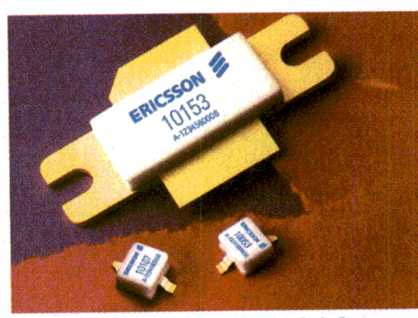
Power transistors serve base stations

Three RF power transistors operate from 1.8 to 2.0 GHz for use in base stations serving Global System for Mobile Communications (GSM)-800, digital Advanced Mobile Phone Service (D-AMPS), and enhanced data for global evolution (EDGE). Model PTF10107 can deliver 5 W of RF power, model PTF10053 provides 12 W of output power, and model PTF10153 yields 60 W. The GOLDMOS transistors exhibit 33.5-dB gain, which is typically 3 dB higher than their bipolar counterparts. Return loss for the PTF10107 is −27 dB at 1.975 GHz. The PTF10107 and PTF10053 measure 4 × 5 mm, and the PTF10153 measures 20 × 34 mm, including flanges. **Ericsson Components, 715 North Glenville Dr., Richardson, TX 75081; (877) 374-2642, FAX: (972) 583-5005, Internet: http://www.ericsson.com.**



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AT&T Rides The Roller Coaster

Before AT&T's initial public offering (IPO) of stock in its wireless phone unit in late April, the biggest US IPO belonged to United Parcel Service, Inc. (UPS), when it raised $5.5 billion last year. AT&T easily eclipsed that mark by taking in $10.62 billion on sales of 360 million shares at $29.50 each. The shares represent 16 percent of the company's wireless group, giving it a market capitalization of $68.15 billion. They will trade as a "tracking" stock on the New York Stock Exchange (NYSE) under the symbol AWE (a tracking stock provides investors with an economic interest but not an ownership stake in the company).

Although the wireless unit runs the third-largest wireless network in the US with 12.2 million subscribers and had revenues of $7.6 billion last year, it reported a net loss of $400 million. This occurs at a time when wireless communications is expanding rapidly, and robust growth is forecast for cell-phone use.

The number of wireless phone users grew by 16.8 million last year, the biggest single-year gain on record. But building the wireless infrastructure is costly. AT&T spent $2.4 billion last year on system build out and plans to invest another $4.1 billion this year. Fortunately, the wireless unit will receive approximately $7 billion from the IPO to support this growth while the remaining $3.6 billion will go to AT&T.

The euphoria of the IPO, however, was short lived. Within a few days, AT&T posted an earnings drop for the first quarter of 2000, despite the fact that wireless services revenues rose by 40 percent, to $2.1 billion from $1.5 billion in 1999. The company announced quarterly earnings that met analyst's expectations, but also said that revenue growth for the full year would be approximately 9 percent less than last year's. The latter statement sent the wrong message to Wall Street as AT&T shares fell 14 percent (or $7) to close at $41.94 on May 2. This was the biggest one-day decline in the stock since the crash of 1987. As of this writing, the stock was still headed downward, closing at $38.44. Meanwhile, AWE continued to hold its own, closing at $30.31 on the same day.

In addition to projecting a drop in earnings for the year, the company has business and technical concerns that could spell trouble in the future. Up to 6200 jobs may be cut by 2001 to offset high marketing expenses and lower long-distance rates. And its time-division-multiple-access (TDMA) air-interface wireless technology is not compatible with competing technologies such as wideband code-division multiple access (WCDMA), the standard that many believe will dominate the field in third-generation (3G) wireless technology.••

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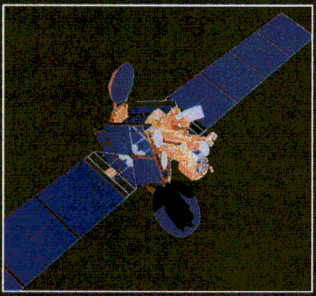

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where our interconnects have more than *ten years* of *space heritage*. Outstanding *thermal stability* over wide temperature spans and *low outgas* materials. Special products to meet demanding *PIM* specifications.

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for needs ranging from high power to high density. *Flexible* and *semi-rigid* products to withstand the severe conditions of shipboard, airborne or ground-based operations. A low-density PTFE dielectric *reduces attenuation* by up to 30% over conventional materials.

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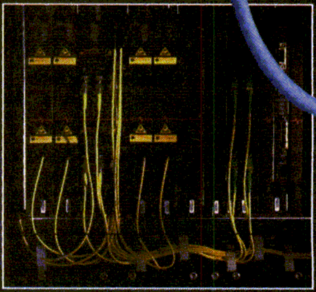
Radar...

systems, including phased array. Products and processes optimize *phase tracking* over frequency and temperature. *Miniature* products with *blindmate* connector interfaces such as GPO™ and GPPO™ allow increased packing density.



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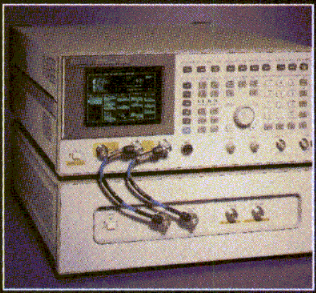
systems and test gear. Our *microwave* products provide *clear signal* transmission even as SONET rates exceed 10 Gb/sec; our *optical* products provide the same *transparent performance* outside the electrical world.

Wireless...

systems. The *outstanding thermal stability* of our semi-rigid products eliminates dielectric expansion during automated soldering processes.



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CIRCLE NO. 217

Contracts

EMS Technologies, Inc.—Has announced a second order from P-Com, Inc. to supply antennas for P-Com's point-to-multipoint (PMP) wireless telecommunications network. P-Com's fixed wireless networks connect a central hub to several "points" over a shared wireless spectrum.

Motorola, Inc.—Has announced the signing of a further expansion contract with Etisalat worth more than $16 million. Work will start immediately in the northern United Arab Emirates to deploy Motorola Network Solutions Sector (NSS) market-leading Horizonsystems infrastructure solutions to provide additional coverage and capacity on a macrocellular (wide-area) and microcellular (high-density defined area) basis.

COMSAT Corp.—Under the terms of a contract with a maximum value of $111.9 million over a five-year period, COMSAT Mobile Communications (CMC) will provide the US Navy with global satellite service over the Inmarsat system for high-speed data, voice, and multimedia communications.

Lucent Technologies and KMW—Have reached a general purchase agreement in high-technology components for IMT-2000.

Giga-tronics, Inc.—Revealed that its Instruments Division has received an order in excess of $2.3 million for its three-slot VXI microwave synthesizer. The order came through Midoriya Electric Co. Ltd., Instruments Division's distributor in Tokyo, Japan, and is for ultimate delivery to Advantest Corp. for use in automatic test systems.

Communications and Power Industries Holding Corp.-Microwave Power Products Division (CPI-MPP)—Announced that it has awarded a contract for the production of 29 dual-pulsed traveling-wave-tube (TWT) assemblies by ITT Industries' Avionics Division. This award is a follow-on to an earlier contract received in 1998.

Sanders—Signed a 42-month, $4.2 million US Government contract to develop an adaptive scan scheduler that will increase the likelihood of identifying and surviving a broad range of guided missile threats.

Spectrum Signal Processing, Inc.—Announced a contract with Analog Devices, Inc. (ADI) to develop math libraries for ADI's TigerSHARC® digital-signal-processing (DSP) architecture. The TigerSHARC math libraries consist of math functions, real and complex vector functions, matrix functions, filters, Fast Fourier transforms (FFTs), and a variety of statistical functions.

REMEC, Inc.—Has entered into a production agreement expected to result in approximately $27 million in sales of base-station products to a major mobile telecommunications-network equipment manufacturer.

Fresh Starts

SCC Communications Corp.—Has expanded its Wireless Phase I and Phase II service offerings with 9-1-1Connect.SM Whenever a subscriber to a contracted wireless carrier calls 911, SCC will ensure that critical information is immediately routed to the appropriate public-safety answering point (PSAP) through SignalSoft's leading-edge W911 and Location Manager software applications.

RangeStar Wireless, Inc. and Molded Interconnect Device (MID), LLC—Announced that they have entered into a strategic manufacturing agreement. The alliance brings together RangeStar's embedded (internal) antenna design and integration with MID, LLC injection-molded plastic and selected metallized applications.

dBm, LLC—Has finalized an agreement to purchase the satellite test-equipment line from Telecom Analysis Systems of Eatontown, NJ.

Simplex Solutions, Inc.—Announced the acquisition of Snaketech, a developer of integrated-circuit (IC) verification technology used in system-on-a-chip (SOC) design.

UltraRF—Announced the appointment of Sangus as a manufacturer's representative to cover Sweden, Norway, Denmark, and Finland.

Agilent Technologies, Inc.—Signed an agreement to acquire the Optical Technology Center (OTC) from Telecom Italia's central research laboratory, CSELT. Agilent will acquire 50 OTC research employees and modern facilities in Turin, Italy, including advanced laboratory equipment and the research center's patent portfolio.

Vitesse Semiconductor Corp.—Agreed to acquire all of the equity interests of Orologic, Inc. for $450 million in common stock. Orologic is a fabless semiconductor company that develops high-performance system-on-a-chip (SOC) solutions that enables data-packet processing at OC-48 and OC-192 rates.

Alpha Industries, Inc.—Has signed a definitive agreement to acquire privately held Network Device, Inc. of Sunnyvale, CA. Network Device provides advanced technology gallium-arsenide (GaAs) integrated-circuit (IC) design and fabrication, especially heterojunction bipolar transistor (HBT), to the growing markets for wireless telephones and other wireless technologies.

Remtec, Inc.—Has acquired Tecmark Plating Services, and equipped the 13,000-sq.-ft. facility with state-of-the-art electrolytic and autocatalytic plating lines. The expanded facility is also supported by an on-site analytic laboratory and X-ray system for advanced quality control and research-and-development (R&D) activity. Designed specifically for plating of ceramic boards and crystals, the enhanced facility now offers improved cycle times and a production capability of 50,000 melalized ceramic panels per month.

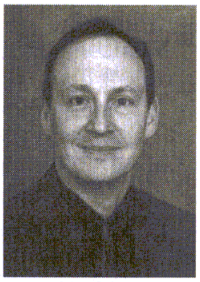
SignalSoft Corp.—Has acquired BFound.com, a Victoria, British Colombia-based company experienced in mobile-asset tracking on the Internet. The acquisition allows SignalSoft to immediately offer a variety of asset-tracking services to wireless markets worldwide.

Mobilocity, Inc.—Announced its official operational launch and the opening of its New York City headquarters. Mobilocity's website is http://www.mobilocity.net.

Harris Corp.—Samuel D. Wyman III to president and general manager of the Microwave Communications Division; formerly general manager of Digital Microwave Corp.'s Seattle, WA operations. Also, Daniel R. Pearson to president and general manager of the Communications Products Division (CPD); formerly vice president and general manager of strategic management and business development for the Government Communications Systems Division (GCSD).

RangeStar Wireless—John Harris to chairman, president, and CEO; formerly senior vice president of Uniden America.

Barry Industries, Inc.—Michael J. Gregory to vice president of manufacturing; formerly in charge of the MRP and ISO9000 programs. James K. Wood to director of marketing; formerly held senior marketing positions with several Canadian manufacturers.



GREGORY

WOOD

Alpha Industries, Inc.—Tom Leonard to chairman of the board of directors; formerly president and chief executive officer. Also, David Aldrich to president, CEO, and membership on the board of directors; formerly president and chief operating officer.

Hirose Electric (USA), Inc.—Rocco J. Melchione to vice president of sales and marketing of the Americas; formerly sales and marketing manager.

Quad Systems Corp.—Ted Shonek to chief executive officer; will continue to serve as president.

Richardson Electronics—Kevin C. Oakley to vice president and general manager of the Medical Systems Group; formerly senior vice president at Infimed, Inc.

CTS Corp.—Donald R. Schroeder to vice president of business development and chief technology officer; formerly vice president of sales and marketing.

Interconnect Devices, Inc. (IDI)—Anne Bush to the position of central regional sales manager; formerly inside account manager. Also, Jay Preister to product specialist; formerly employed in circuitry testing with Lucent Technologies.

Lawrence Behr Associates, Inc.—Will Daugherty to director of product marketing; formerly director of marketing at Seaward International, Inc.

Unitek Miyachi Corp.—Mark Rodighiero to vice president of the Laser and Systems Division; formerly vice president of engineering.

CPI Satcom Division—Robert Blanchfield to director of materials; formerly director of materials at ARGOSYSTEMS, Inc.

Leitch Technology Corp.—Margaret Craig to president of Leitch, Inc.; formerly president of Snell & Wilcox's US operation.

CMP Media/Miller Freeman—Mike Buetow to editor in chief of *PC FAB* magazine; formerly communications director for IPC.

Filtronic Solid State—Tally Costa to national director of sales and marketing for semiconductor products; formerly regional sales manager for Richardson Electronics.

COSTA

TIERNEY

Kanthal Globar—Brian Tierney to divisional manager of the Niagra Falls, NY facility; formerly manager of quality and engineering for the Niagra Falls, NY facility.

Seiko Instruments USA, Inc. Fiber Optics Group—Mark Kim to senior production manager; formerly operational manager with Xylan.

Short Courses

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e-mail: conted@gatech.edu
Internet: http://www.conted.gatech.edu

Microwave Antenna Measurements Short Course
June 20-23 (Northridge, CA)
California State University, Northridge
Northridge, CA 91330-8295
Shirley Lang, Program Administrator
(818) 677-2146, FAX: (818) 677-5982
e-mail: shirley.lang@csun.edu
Internet:
http://www.ecs.csun.edu/~crs/mam

Digital Communications Engineering
July 4-5 (Oxford, England)
University of Oxford
Department of Continuing Education
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e-mail: dee.broquard@conted.ox.ac.uk

Digital Transceiver Design
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Synthetic Aperture Radar Technology and Applications
July 17-21 (Ann Arbor, MI)
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Center for Professional Development
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Ann Arbor, MI 48109-2092
(734) 647-7200, FAX: (734) 647-7182
Internet: http://www.cpd.engin.umich.edu.

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Internet: http://www.conted.gatech.edu

Meetings

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e-mail: esc@cmp.com
Internet:
http://www.embedded.com/summer

2000 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting
July 16-21 (Doubletree Hotel, Salt Lake City, UT)
IEEE Antennas and Propagation Society and the 2000 International Union of Radio Science
Magdy F. Iskander, General Chair
University of Utah
(801) 581-6944
e-mail: iskander@ee.utah.edu
Internet:
http://www.ext.usu.edu/confer/aps2000

2000 International Conference on Subsurface Sensing Technologies and Applications (SSTA 2000)
July 30-August 4 (San Diego, CA)
Texas A&M University
Department of Electrical Engineering
Cam Nguyen
(409) 845-7469, FAX: (409) 845-6259
e-mail: cam@ee.tamu.edu
Internet: http://ee.tamu.edu/subsurface-sensing-conference

NIWeek2000—The Worldwide Conference on Measurement and Automation
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2000 IEEE International Symposium On Electromagnetic Compatibility
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2000 IEEE Bipolar/BiCMOS Circuits and Technology Meeting
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Janis Jopke, Conference Manager
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Application Profile

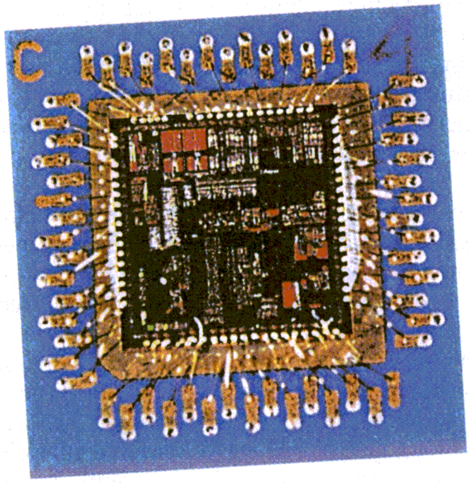
How to make Cell Phones Smaller and Lighter? BGA with Integrated Components using DuPont Green Tape™.

National Semiconductor is a leader in applying the LTCC advantages of high-density interconnect capability, ability to integrate passive components and functions, and low-loss performance. In a recent design, National chose to combine its advanced ICs for wireless communications with Green Tape™, DuPont's brand of LTCC tape dielectric material, to provide optimum performance in the smallest possible package.

Challenge: Decreased Size and Cost, Improved Performance for Wireless Devices

Portable wireless applications have quickly become the main driver for smaller, more cost-effective packaging and interconnects. For example, in the last few years, cell phones have evolved into lightweight, palm-size devices with a host of new functions. Their weight has decreased by a factor of 10, and the wholesale selling price by 75 percent.

OEM designers are now learning that integrating IC and package design to take advantage of the



unique properties of Low Temperature Co-fired Ceramic (LTCC) technology can yield decreased size and improved performance in wireless devices.

Solution: Green Tape™ LTCC Allows for High I/O Counts in Chip Scale Package

National's newest chipsets use Green Tape™ packaging capabilities to provide a chip scale package that can accommodate the high I/O counts of a highly integrated RF analog front end using micro BGA (ball grid array) technology. The current package, only 9 x 9 mm, can provide 81 I/Os in a micro BGA array, plus topside pads for wirebonding that interconnects to the BGA pads on the backside. The high number of I/Os allows for multiple grounds to improve RF performance, while the embedded multilayer structure contains 14 RF bypass capacitors constructed using a combination of high-K and low-K dielectrics.

The performance of the frequency synthesizer function can be enhanced through the use of an embedded VCO resonator that provides a high Q, and therefore lower phase noise, than that available using a VCO resonator located on the silicon.

This approach, co-designing the silicon and LTCC elements to achieve optimized size and performance, demonstrates the use of co-integration for wireless applications requiring smaller package size and higher performance at the lowest possible cost.

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

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Shorting-post analysis aids patch-antenna design

Microstrip patch antennas (MPAs) are promising candidates for miniaturized mobile-communication handsets. A method for reducing the lateral dimensions of an MPA consists of loading the antenna with one or several shorting posts, which are metallic vias connecting the patch to the ground plane. A via's position and dimensions are a way to reduce the resonant frequency of an MPA, which in turn, affects the MPA's dimensions. Until now, only experimental and simulation information has been available for dealing with vias. Recently, however, Rebekka Porath of Philips Research Laboratories (Aachen, Germany) developed a full analytical theory for calculating the full spectrum of resonant frequencies of a shorting-post MPA. Specifically, the zero mode of an unloaded MPA plays a central role in reducing the operating frequency of a shorting-post device. The theory permits complete calculation of all relevant antenna parameters and can be extended to multiple shorting posts. See "Theory of Miniaturized Shorting-Post Microstrip Antennas," *IEEE Transactions on Antennas and Propagation*, January 2000, Vol. 48, No. 1, p. 41.

Smart antennas bolster broadband wireless-access networks

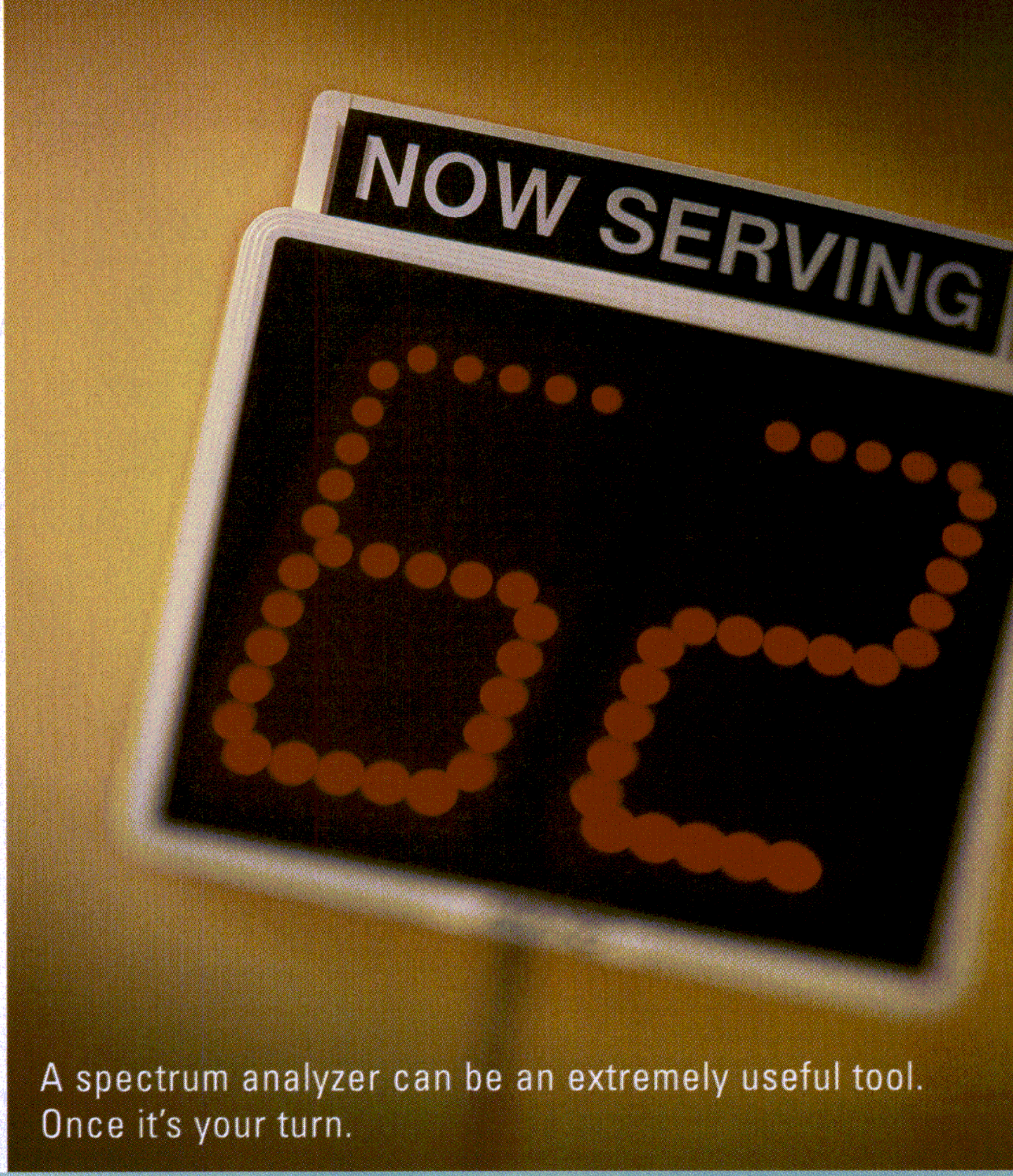
A significant market opportunity exists for providing fixed broadband wireless access (BWA) to residential, business, and small-office, home-office (SOHO) locations. Successful BWA systems need to be scalable, have high spectrum efficiency and high bit rates, and be easy to deploy at the infrastructure and subscriber ends. According to Khurram Sheikh of Sprint Advanced Technology Laboratories (Burlingame, CA), David Gesbert of Gigabit Wireless, Inc. (Mountain View, CA) *et. al.*, smart-antenna (SA) technology offers important leverages to enable such features. The authors provide an overview of the various BWA architectures and the challenges facing each. Next, they cover SA technology and the best applications for BWA architectures. These include array gain, diversity gain, co-channel interference reduction, angle reuse [space-division multiple access (SDMA)], spatial multiplexing, and channel estimation. The authors contend that a multiple-antenna system can increase spectrum efficiency by three to 10 times, while also enhancing other desirable features. See "Smart Antennas for Broadband Wireless Access Networks," *IEEE Communications Magazine*, November 1999, Vol. 37, No. 11, p. 100.

Shield plastic parts to prevent interference

The increased use of plastic housings in computers and telecommunications equipment requires shielding techniques to protect the sensitive electronics inside the cases from external interference (EMI). This is accomplished through the use of conductive coatings applied to the plastic substrate. Determining the proper coating involves many factors according to Brian C. Jackson of Enthone-OMI UK (Woking, UK) and Thomas W. Bleeks of Enthone-OMI, Inc. (West Haven, CT). First, they explain the key issues that determine the performance of a conductive coating when applied to plastic—adhesion, conductivity, durability, cost, appearance, and others. Then, a number of different methods for applying the coating are explained such as electroless, electroplated, conductive paint, and vacuum metallizing. Each method has its pros and cons, but overall, electroless coating provides the best shielding performance. Another key factor in shielding is the package mechanical design, since EMI leakage between mating joints and surfaces is the primary reason that shielding effectiveness is reduced. See "Performance Characteristics of Conductive Coatings for EMI Control," *Interference Technology Engineers' Master (ITEM), The International Journal of EMC*, 1999 edition, p. 125.

Measure ADC noise by cross correlation

A problem in characterizing high-speed, medium-resolution analog-to-digital converters (ADCs) is obtaining accurate measurements of time-varying noise with traditional test setups. Some low-noise ADCs exceed the test capabilities of laboratories, so Giovanni Chiorboli and Massimo Fontanili of the Dipartmento di Ingegneria dell'Informazione, University of Parma (Parma, Italy) devised a new technique to increase the measurement accuracy of time-varying noise. It is a dual-channel method (using two similar ADCs) based on the noise measurement of the distribution function of the cross-correlated noise between the two channels. The cross correlation between the two channels is used to estimate the noise of the test setup. This is what differentiates the author's method from all others; the contribution of the test setup can be distinguished from the effective ADC noise, and it is not effected by quantization noise and converter nonlinearities. See "Cross-Correlation Noise Measurement in A/D Converters," *IEEE Transactions on Instrumentation and Measurement*, December 1999, Vol. 48, No. 6, p. 1282.



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CIRCLE NO. 390

Advancing The Analysis Of Microwave Oscillators

This return to the virtual-ground-based transmission analysis method for resonators and oscillators explores how to obtain the correct loop-transmission parameters.

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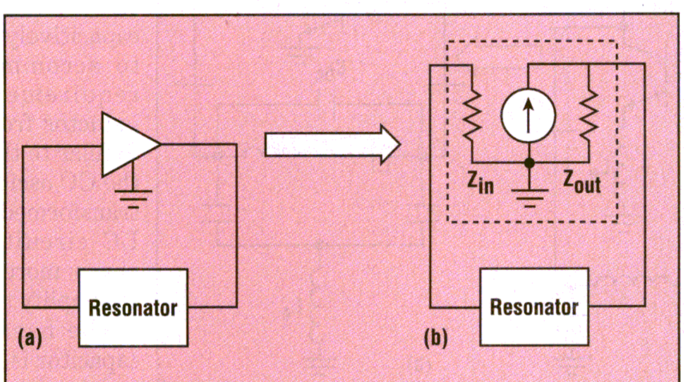
ANALYSIS of microwave oscillators requires imagination. Oscillator phenomena are often vaguely described by traditional approaches, such as the negative-resistance method. But a technique called transmission analysis with a virtual ground, where an oscillator is characterized as a feedback loop composed of amplifier and resonator sections, can provide much-needed insights into oscillator behavior.

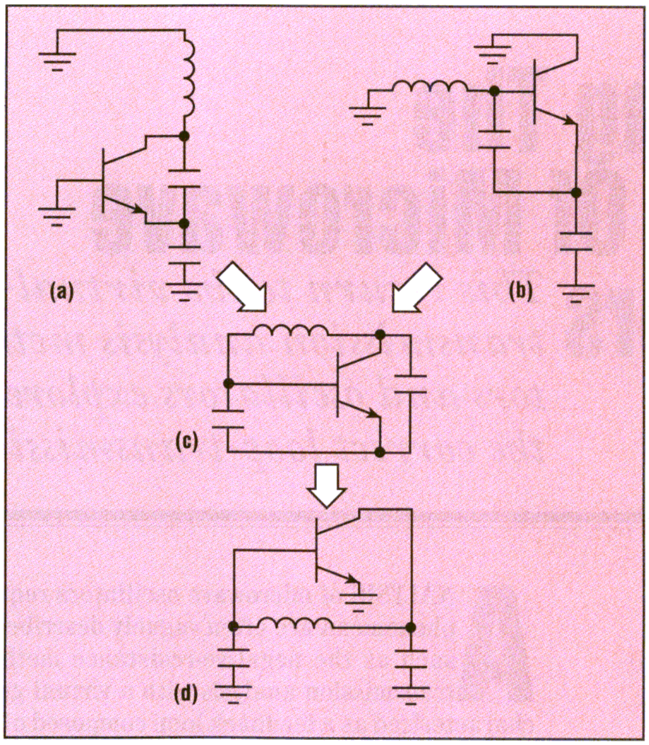
Oscillator-transmission analysis with a virtual ground can provide a clear view of oscillator mechanics.[1] When examining an oscillator, it is often not obvious what the input signal is, where it is, or how it is being amplified. In cases where signal routing appears confused, the task of defining an oscillator's transmittance parameters becomes nearly impossible. But by using a virtual ground as a reference point for an oscillator circuit, it is often possible to bring order to chaos. By properly isolating the amplifying device in an oscillator circuit, the reference point can generally be found (Fig. 1).

The active device in Fig. 1b is shown as the source, although it is initially unidentified. The noise across input impedance Z_{in} is magnified by the controlled source (the active device) and channeled back through the resonator when in proper phase. This source may be difficult to detect in actual circuits, even when the ground or reference point is fixed. But regardless of how an engineer chooses the ground point, even when it is made as large as the entire bottom metal coating of a printed-circuit board (PCB), it may not account for the problem of isolating the noise source. When analyzing an oscillator, a particular layout should not be a constraint, but rather a circuit should be examined in terms of how the noise "sees" the circuit. In order to do this, the virtual-ground analysis approach is essential. To illustrate this, several basic oscillator topologies with bipolar junction transistors (BJTs) will be examined.



1. By isolating the active device in an oscillator circuit (a), a reference point for analysis (b) can usually be found.

An old joke among desperate design engineers is that when an oscillator is needed, the best approach is to design an amplifier, and when an amplifier is needed, design an oscillator. The two most popular oscillator configurations (Figs. 2a and b) were discovered in just this way, as unstable amplifiers based on transistor common-base and collector (emitter-follower) circuits, respectively. The inductive-capacitive (LC) components show what is needed to worsen an amplifier or improve an oscillator. All bias components are neglected in these cases since they would only complicate the transformations. The output circuits are also of secondary concern and should be omitted when basic topologies are compared. When taking the point of view of the noise, it cannot be readily discerned in either topology, unless the topologies are redrawn as Fig. 2c or even Fig. 2d.

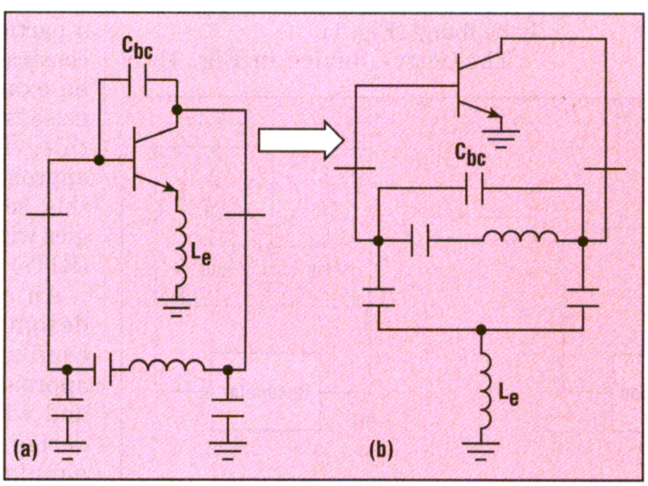


2. The basic oscillator topologies include (a) common-base (CB), (b) common-collector (CC), and (c) common-emitter (CE) types, which can be redrawn into a common configuration (d) for analysis.

The circuits of Figs. 2a, 2b, and 2c represent the three main oscillator families, although in essence they are the same, since noise acts within and upon them in the same way. The differences in their layouts only disguise the similarities of the circuits. The basic oscillators are made more dissimilar with different output signal topologies and additional resonator components. Any names for special oscillators have not been used in this article to avoid any ambiguities in the analysis of these basic oscillator types. For the sake of this analysis, reducing a design to a common-base (CB), common collector (CC), or common-emitter (CE) topology based on a BJT active device will be attempted. The next step will be to determine how power is coupled out of the oscillator circuitry and what (if any) special frequency-stability components are used.

The CB oscillator (Fig. 2a) typically channels output signals through capacitive coupling from the collector, with the DC supply provided through the inductor. Although the load for this source is typically 50 Ω, the coupling capacitance and the inductance can be used to transform the load and to channel power out of the oscillator more effectively. In redrawing Fig. 2a to Fig. 2d, the load and the coupling capacitance are placed in parallel with the inductor in order to analyze the complex resonator in isolation to determine the actual resonator loss and frequency.

This basic oscillator is often designed with a surface-acoustic-wave (SAW) or crystal resonator in the base for high-frequency stability. Although the base electrode is no longer at ground, the circuit is still identified as a CB configuration because the additional stabilizing circuits (no matter how effective and expensive) are considered secondary in this analysis. The oscillator will usually work without these stabilizing elements since they act mostly as high-Q series LC tanks which do not disturb the phase conditions established by the main LC resonator. Any analysis should proceed at first without these high-Q resonators, including only their effective series resistances. This analysis approach will facilitate the initial oscillator design, with the SAW or crystal resonator included subsequently for superior selectivity without a change in the gain margin or in the phase balance.

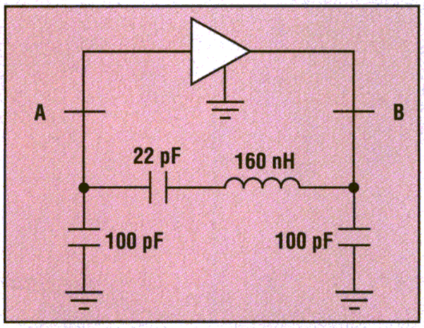


3. This basic oscillator with shunt-capacitance coupled series resonator helps to visualize the path of noise.

The CC oscillator configuration (Fig. 2b) usually couples output signals from the collector, although for analysis purposes this should no longer be thought of as a common-collector topology. It is convenient to form the load with a transistor, thus creating a complex amplifier.[1] In transforming the basic CC configuration to that of Fig. 2d, the load is in series with the collector, effectively increasing its output impedance. As with the CB case, the load is capacitively coupled in order to accommodate the DC requirements using the inductor from the collector. Similar to the previous case, the CC oscillator load can be transformed with this simple LC circuit to couple out power more effectively (and to simplify the analysis).

The base-emitter (BE) capacitor is frequently omitted in this configuration, especially at high frequencies, since the transistor's internal base-to-emitter capacitance is generally sufficient. Furthermore, omitting the BE capacitor corresponds well with low-transistor phase shifts at microwave frequencies as well as the desired transistor-impedance transformation.[1] In order to fulfill the DC requirements, a capacitor is needed in series with the inductor of Fig. 2b. By balancing the value of this capacitor with the value of the inductor, high-frequency stability can be obtained. In this way, an effective LC resonator is achieved: the shunt-capacitance coupled series resonator.[1]

The CE oscillator is often used with a feedback loop. For example, a two-port SAW resonator can replace the LC components shown in Fig. 2d, arranged in series with microstrip lines or with an inductor to achieve the required phase conditions. It should be noted, however, that Fig. 2d was intentionally drawn differently than Figs. 2a or b. The LC elements of Fig. 2d were grouped

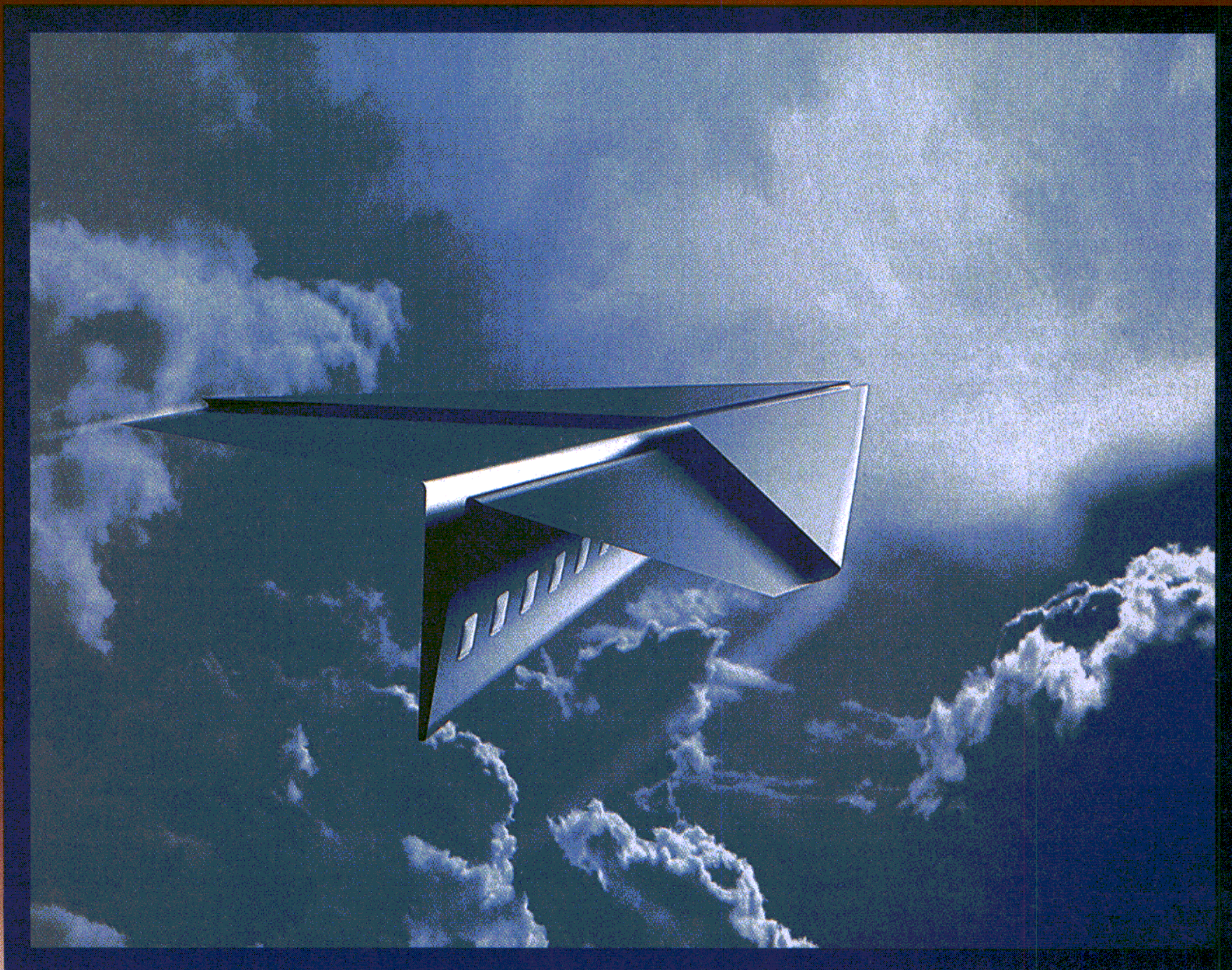


4. This example shows a basic oscillator stabilizing loop at 100 MHz.

together and separated from the transistor to highlight the feedback loop, with the active device shown to resemble the ideal controlled source of Fig. 1. The natural feedback loop shows how noise circulates in the oscillator, and it must be set off to understand the noise mechanisms and to find the proper transmittance.

The natural feedback loop shows how the noise circulates in the oscillator and this is needed to set off in order to understand the action and find the right transmittance. Although the topologies of Figs. 2a and b are often useful, they do not clearly illustrate the mechanics of the oscillator, and should be transformed to the equivalent form of Fig. 2d. This can be performed in two steps: by first removing the actual ground into a single node, and second by inserting the virtual ground at the active device noise, which is common to the controlling and controlled branches, in this case the emitter.[1]

Before determining the loop transmittance, it is necessary to account for the non-ideal characteristics of the source. The undesired transmission or bilateral action of the transistor shows as a nonzero S_{12} value for the device. At low frequencies, this reverse transmission can often be neglected, but at higher frequencies, it becomes more critical. The main source of the problem has to do with the base-collector capacitance of the device. To some degree, this capacitance is included when designing an



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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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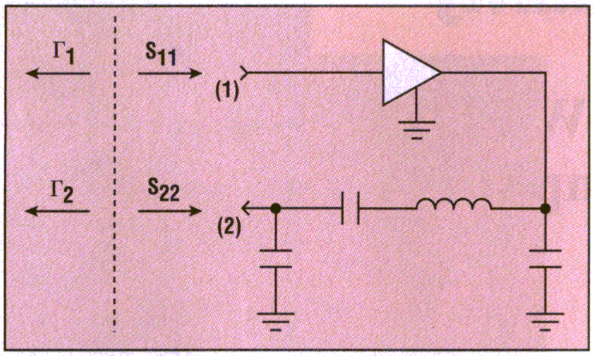
oscillator based on forward-transmission magnitude and angle. Looking for an essential solution, it may be useful to take the noise viewpoint once more. To visualize this situation, Fig. 3 shows a basic oscillator with shunt-capacitance coupled series resonator. The internal BC capacitance is set off here as well as the series (internal and external) parasitic inductance in the emitter. Although the transistor's physical capacitances are rather complex, they will be examined here only in the linear terms of small-signal S-parameters.



5. This is a description of two possible open-loop analysis settings in terms of reflection coefficient.

In an analysis of noise, the base-collector capacitor, C_{BC}, together with the intentionally added resonator, makes the task somewhat more complex. The solution involves taking the parasitic feedback into account. A concern is the parasitic feedback inductance in the emitter, which can be accounted for by inserting the virtual ground at the true emitter electrode, even within the internal circuitry of the transistor (for analysis purposes).

Removing the effects of feedback in the noise path can isolate the single feedback loop and the real resonator. To do this, the modified transistor S-parameters must be calculated, for example, by inserting the appropriate negative values of C and L to cancel the base-collector capacitance and emitter inductance in the analysis. In practice, it is possible to minimize the effects of S_{12} for microwave transistors from –20 to –40 dB by compensating for the base-collector capacitance in this matter, with even greater efficiency achieved by canceling the emitter inductance. Once the real feedback loop is isolated, it is possible to proceed with the true transmission analysis.

For a nearly ideal oscillator such as that of Fig. 3, this type of analysis may appear simple, with two appropriate analysis points clearly shown. Yet, unlike an amplifier, the source- and load-terminating impedances in an oscillator cannot always be a simple 50 Ω. By applying low-frequency voltage analysis some years back,[4] this analysis was initiated for oscillators in order to find the proper source and load terminating impedances. In order to extend this

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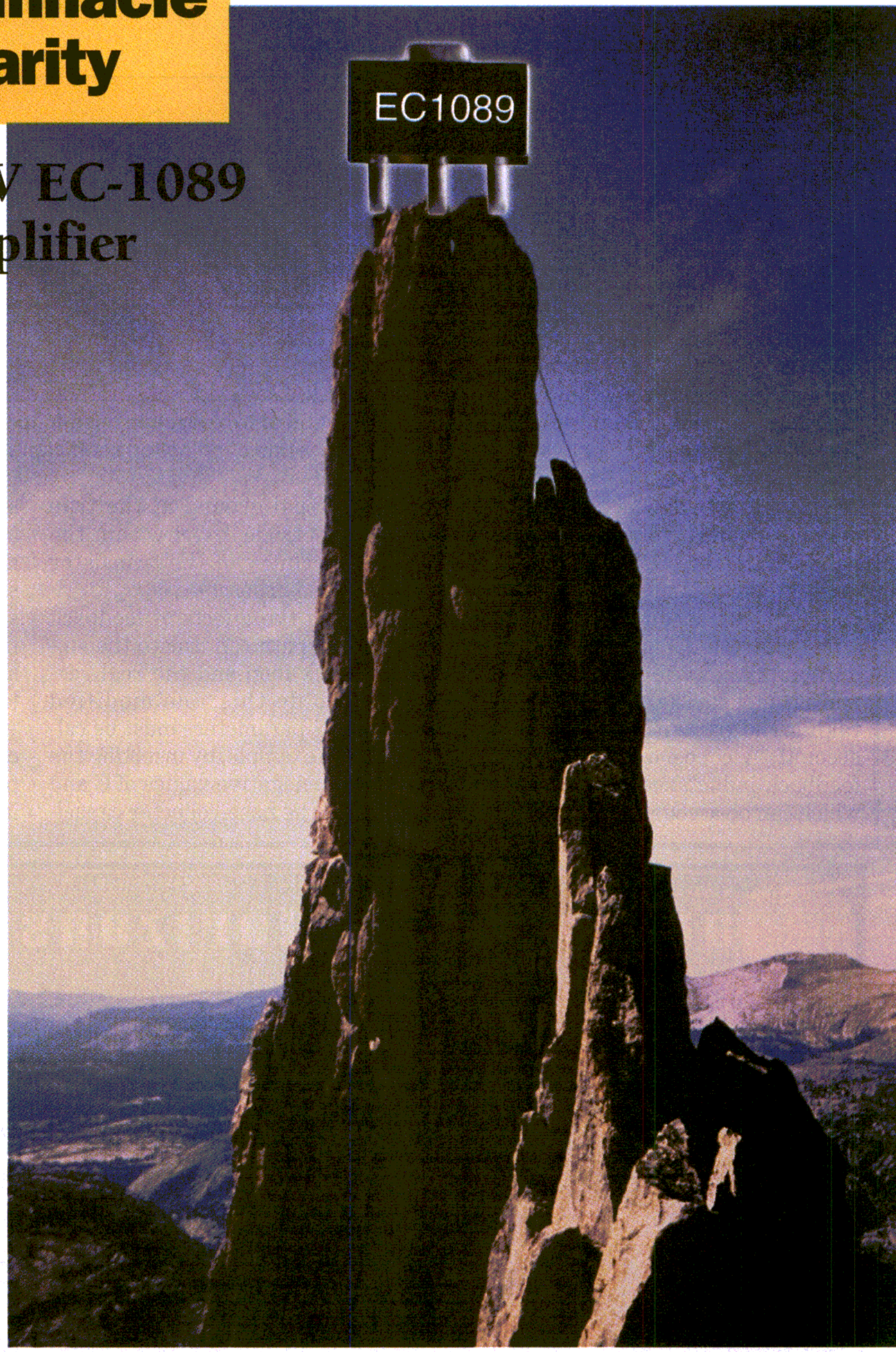

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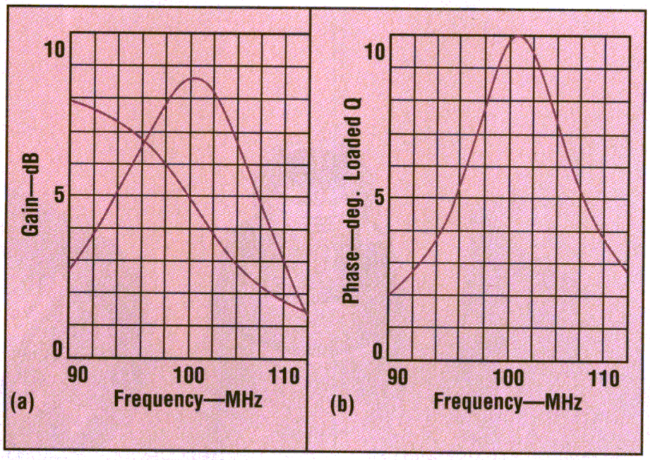
analysis to a general form with S-parameters, a basic oscillator feedback loop example may help (Fig. 4).

The shunt-C coupled series LC resonator for this example was calculated according to the procedure given in reference 1—for a center frequency (f_0) of 100 MHz, a loaded quality factor (Q_L) of 10, and a characteristic system impedance (Z_0) of 50 Ω. The resultant phase shift is approximately –140 deg. and the loss for a practical inductor Q_0 of 100 amounts to 0.8 dB. For analysis purposes, this will be assumed as an ideal gain element in Fig. 4, matched to the resonator, where S_{11}, S_{12}, and S_{22} = 0; Z_0 = 50 Ω; S_{21} = 3; and the phase shift = 140 deg.

With these assumptions, the amplifier is unilateral, otherwise the circuit would have an additional feedback loop that could not be visualized explicitly. Looking for an appropriate oscillator-loop transmittance, it is necessary to differentiate between an absolute feedback loop by applying the virtual-ground concept to the external transistor circuitry and, if needed, to the internal feedback loop as described earlier. Finding a "break" point for the loop is critical to the analysis.



6. Exemplary 50-Ω-based transmittance and loaded Q for the oscillator open loop as in Fig. 5 with resonator values provided in Fig. 4 are shown.

Assuming an ideal amplifier with 50-Ω input and output ports, one would expect that the loop could be broken at either point A or B. Unfortunately, a real 50-Ω impedance is rarely achieved, and a return loss of 20 dB is probably an accurate value in terms of analysis, with a return loss of 10 dB as quite tolerable for achieving reasonable precision in predicting the transmittance. Furthermore, if a particular transistor impedance is significantly reactive, it could be artificially excluded from the transistor and included within the resonator (for analysis purposes) for good separation between the active and reactive parts of the loop.

Some transistors may present very-high imped-

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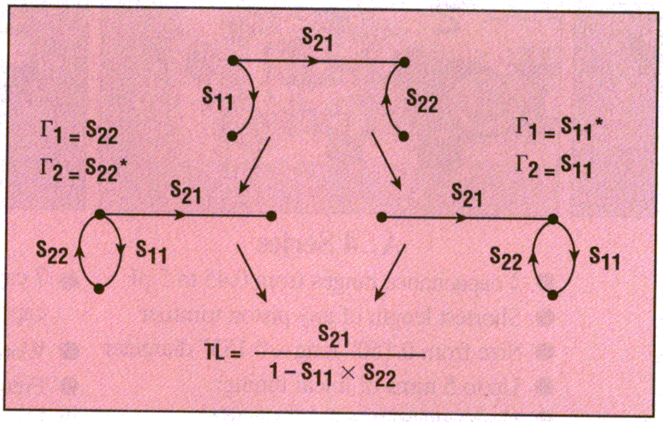
ances, resulting in high losses and mismatches in the loop. In order to break apart sections of a loop or oscillator design for analysis, a simple rule of thumb is to make the breaks in a way so that the sections or blocks show the same impedances after the break as before it. Assuming the ideal 50-Ω amplifier of Fig. 4 and breaking the loop at its input (point A), an analysis would proceed with an excitation from the source impedance Z_S at the amplifier input with the resonator loaded by load impedance Z_L. Setting Z_L is simple, since it must equal the amplifier input impedance of 50 Ω. But setting Z_L is not straightforward, since it represents the complex impedance of one side of the resonator. But modern circuit simulators, such as Genesys 7 from Eagleware (Stone Mountain, GA), support analysis with complex impedances as well as impedances described in S-parameter files. In this way, the resonator, with a transistor at its input, can be analyzed as a one-port S-parameter file (resonator.s1p) that can then be applied as the input impedance for analysis of the loop. The results may seem flawed, with cancellation of transmission just at the middle of the passband, but the approach can lead to the proper solution.



7. The loop transmittance can be derived graphically by application of analysis impedances conditions to a two port representing the disconnected oscillator loop.

Breaking the loop should preserve a single impedance interaction. Terminating one broken end with the impedance of the second end should accomplish the preservation of a single impedance interaction with the use of its own conjugate impedance. The rule for terminating broken loops is "one load, one match."

This could be applicable in a twofold manner for a particular loop point, either by loading the output and matching the input or loading the input and matching the output. In general, it should be also valid in any condition and any loop point. To verify this, the example can be used to check the postulates. The two analysis possibilities can be described from

Fig. 5:

$$\begin{cases}\Gamma_1 = S_{11}^* \\ \Gamma_2 = S_{11}\end{cases} \qquad (1a)$$

$$\begin{cases}\Gamma_1 = S_{22} \\ \Gamma_2 = S_{22}^*\end{cases} \qquad (1b)$$

With the ideal amplifier of Fig. 5, the first possibility reduces to a simple 50-Ω termination analysis. Taking the exemplary values, it is possible to achieve the characteristics of Fig. 6 for this ideal circuitry.

Similarly, if the amplifier exhibits any pure resistance at its input then, according to the postulate just listed, it can be taken as a source/load-analysis termination. This second possibility is not so apparent, however. It requires the use of a one-port S-parameter file (resonator.s1p) mentioned earlier to set the excitation impedance function and similarly (but using conjugate values) to set the load impedance function. The conjugate file can be created from the derived resonator.s1p file by inverting all angle signs (with the help of a text editor). The files are then applied analysis impedances to obtain the transmittance results similar to a 50-Ω analysis.

To examine this approach further for a complex-impedance amplifier, but with the same loop, a design trick can be used. The 100-pF capacitor at point A can be divided into two 50-pF capacitors in parallel, with one attached to the transistor and the other isolated. This can then be seen as a new break for point A in the loop. The twofold analysis that was presented before is then applied to this new configuration (a circuit simulator with the capability of setting the port impedances as complex variables would be useful), providing the same results as earlier. The same approach at point B will provide similar results.

A point in the loop is still needed for the transmittance analysis, but between the series capacitor and the inductor. Ideally, conjugate impedance files could be found for this break point, applied as complex-analysis impedances that would yield the results similar to the analysis of Fig. 6. And the real effort would be placed on performing the calculations rather than on the analysis settings.

The question was asked earlier: How is it possible to break the oscillator loop and then terminate it in microwave S-parameter analysis, to obtain the right transmittance? One approach is to perform the analysis (or measurement) with any analysis impedance (such as 50 Ω, and then calculate the desired transmittance. Any S-parameters derived with the standard setting should be sufficient to calculate the desired characteristics. What is desired is to find the function of loop transmittance, TL (S_{21}, S_{11}, S_{22}).

A complete derivation with detailed transformation would be too long here, but it can be briefly described. The first step is to find a general expression for a two-port transmittance with generalized source/load impedances. Next, by inserting the analysis impedance conditions of eqs. 1a or 1b into that expression, the desired final function can be obtained. To accomplish the first step, the impedance Z-matrix can be advantageous as independent from external impedances. The useful relationships are gathered in references 5 and 6.

The task can be outlined as follows: take the initial S-parameters (analyzed or measured) with a standard impedance ($Z_0 = 50\ \Omega$), determine the Z-parameters normalized initially to Z_0, renormalize them to general impedances, and achieve the actual $S|_2|$ upon the renormalized Z-parameters. The important point in the procedure is the normalization itself. Usually when transforming network parameters, the Z-parameters are normalized as Z_{ii}/Z_0. When the input/output characteristic impedances Z_1, Z_2 are unequal yet real, then normalization should take place as Z_{11}/Z_1, $Z_{21}/\sqrt{Z_1} \times Z_2$, Z_{22}/Z_2.

Now, it is a matter of dealing with a completely general situation, that is, generalized S-parameters, with arbitrary reference impedances. Normalization of Z-parameters should now be referenced to real parts of these impedances, that is Z_{11}/R_1, $Z_{21}/\sqrt{R_1} \times R_2$, Z_{22}/R_2 where:

$R_1 = \mathrm{Re}(Z_1)$, and

$R_2 = \mathrm{Re}(Z_2)$

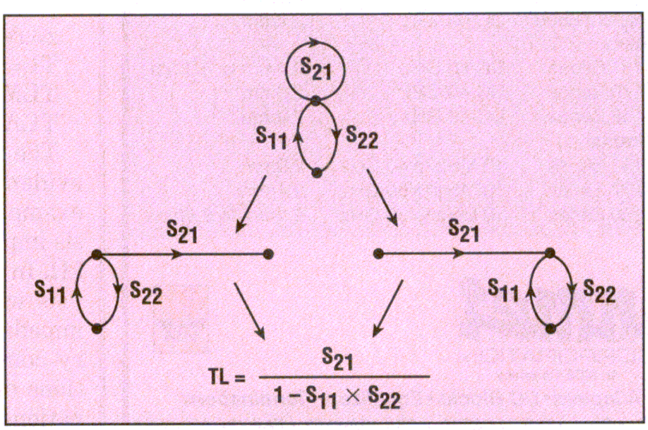
After all transformation and simplification, the required expression can be described as:

$$S_{21}' = S_{21} \cdot \sqrt{r_1 \cdot r_2} \cdot \frac{(1-\Gamma_1)\cdot(1-\Gamma_2)}{(1-S_{11}\cdot\Gamma_1)\cdot(1-S_{22}\cdot\Gamma_2)} \qquad (2a)$$

where:

all variables that are referred to standard, initial reference impedances Z are usually assumed to be 50 Ω. Even when the S-parameters are from analysis or measurement within a 50-Ω system, the new arbitrary reference impedances Z_1 and Z_2 are described by the relevant reflection coefficients Γ_1 and Γ_2. Describing them in terms of reflection coefficients is designed in order to simplify equations, yet Γ_1 and Γ_2 alone are not sufficient here and their parts: $r_1 = \mathrm{Re}(Z_1)/Z_0$ and $r_2 = \mathrm{Re}(Z_2)/Z_0$ must appear independently as a result of normalization to $\mathrm{Re}(Z_1)$ and $\mathrm{Re}(Z_2)$.

Equation 2a can be checked with the aid of a circuit simulator, analyzing a known two-port network within the arbitrary reference impedances and comparing the results with those computed from eq. 2a. It is useful to describe two simplified versions of the expression with eq. 2b used



8. This flow graph represents an oscillator loop and its two disconnection variances.

for real (although not equal) reference impedances Z_1 and Z_2:

$$S_{21}' = S_{21} \cdot \frac{\sqrt{(1-\Gamma_1^2)\cdot(1-\Gamma_2^2)}}{(1-S_{11}\cdot\Gamma_1)\cdot(1-S_{22}\cdot\Gamma_2)} \quad (2b)$$

The second version (eq. 2c) is for real and equal reference impedances Z different from the initial Z_0:

$$S_{21}' = S_{21} \cdot \frac{1-\Gamma^2}{(1-S_{11}\cdot\Gamma)\cdot(1-S_{22}\cdot\Gamma)} \quad (2c)$$

It is now time to substitute the impedance-analysis conditions 1a and 1b into general expression 2a to obtain the required loop transmittance TL. From the assumptions, using either of the expressions should reduce to the same form. Although complicated in appearance, the substitutions yield the simple form:

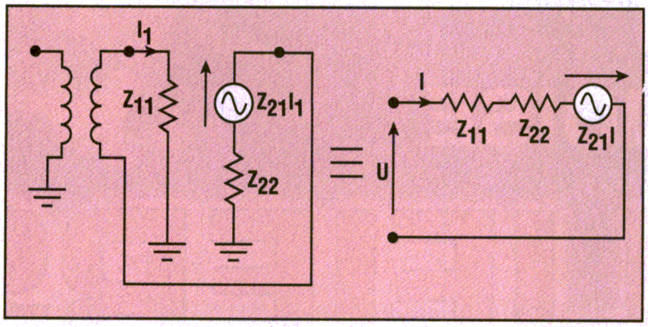
$$TL = \frac{S_{21}}{1-S_{11}\cdot S_{22}} \quad (3)$$

This function can be readily implemented in a modern circuit simulator to find the true loop transmittance without any requirement for special reference impedances. This has been successfully accomplished within Genesys 7, which now includes post-processing capabilities, achieving the same results as obtained earlier with the termination-impedance settings.

The script needed in Genesys 7 for the transmittance derived with post-processing is:

```
using linear1.sch1
x=.rect[s21]
y=.rect[s11]
z=.rect[s22]
TL=x/(1-y*z)
TLM=db20(TL)
TLA=ang(TL)
```

The usefulness of this approach is evident when applied to a difficult example,[2] where the required analysis impedance was approximately 10 kΩ. In attempting an open-loop analysis with this type of termination impedance, results are unsatisfactory compared to individual simulations of transistor/resonator combinations. This is because the C_{BC} and C_{BE} capacitances (which are fractions of a picofarad), manifest themselves with serious effects at these high impedances. However, their effects are only felt in the analysis since, in the actual circuitry, they have negligible effects due to larger shunt resonator capacitances.



9. This illustration shows the negative impedance analysis within the oscillator loop represented in terms of Z-parameters.

Taking the loop transmittance (TL) as the analysis goal preserves the real impedance interaction, showing reasonable results despite the non-unilateral transistor. This non-unilateral characteristic means that the TL depends slightly on the analysis impedance chosen, although variations are acceptable in practice. For the most precise analysis, single feedback should be achieved first, as described earlier, by extracting the unilateral gain element and transferring its internal feedback into the resonator.

The earlier symbolic derivations could be somewhat complex to follow in full detail. But the task at hand can be somewhat simplified through the use of a flow-graph technique.[5,6] Figure 7 shows a graphic representation of an open loop as a unilateral S-parameter two-port network with the two analysis impedance conditions applied as seen in eq. 3.

Note that at the end where the conjugate impedance is attached, there is no reflected wave (ideal impedance matching), so no arrows are marked. Obtaining the transmittances of the two resultant simple graphs is straightforward according to universal flow-graph rules. As Fig. 8 shows, there are two possible ways to disconnect the loop graph, at the beginning or at the end of the S_{21} arrow. The two ways lead to one general loop-transmittance expression.

The loop-transmittance expression was expressed in S-parameters and normal in microwaves. Z-parameters were only used to facilitate derivation. Nevertheless, it is also possible to express the TL function in terms of impedances, yielding the even simpler form:

$$TL = \frac{Z_{21}}{Z_{11} + Z_{22}} \tag{4}$$

This description, just quotient of transimpedance to the sum of input/output impedances, compares with common "negative resistance" analyses. They are usually obtained in any oscillator branch, providing some insight as to where and if the circuitry is expected to oscillate. But what is their relation to the true loop transmittance? An ideal circuit similar to that in Fig. 9 will be used here to receive a general explanation.

$$Z = \frac{U}{I} = \frac{I \cdot Z_{11} + I \cdot Z_{22} - Z_{21} \cdot I}{I}$$
$$= Z_{11} + Z_{22} - Z_{21} \tag{5}$$

Let the loop be represented as one Z-parameter two-port network with an ideal transformer inserted to represent the impedance function within the loop. The resultant Z function is derived along with the transformation. Comparing this result to eq. 4, a similarity can be seen since both generally have transimpedance and input/output impedances. The difference is in the operator, with division in contrast to subtraction. Transmittance provides the required loop description in terms of gain, corresponding directly to the practical oscillator parameter gain margin, usually maintained above 5 dB.●●

References

1. Stan Alechno, "Analysis Method Characterizes Microwave Oscillators," *Microwaves & RF*, November 1997 to February 1998.
2. Stan Alechno, "The Virtual Ground in Oscillator Design—A Practical Example," *Applied Microwave & Wireless*, July 1999.
3. Stan Alechno, "Microwave Switched VCO With Microstrip Branch Resonator—The Virtual Ground In Practice," October 1999.
4. Stan Alechno, "Analysis of the Cascode Crystal Oscillator," *RF Design*, May 1997.
5. "S-Parameter Techniques for Faster, More Accurate Network Design," Hewlett-Packard Application Note 95-1.
6. "S-Parameter Design," Hewlett-Packard Application Note 154.

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.

CIRCLE NO. 302

Refining CDMA Mobile-Phone Power Control

A versatile RF chip set provides the performance to maintain power control for maximum capacity in CDMA wireless communications systems.

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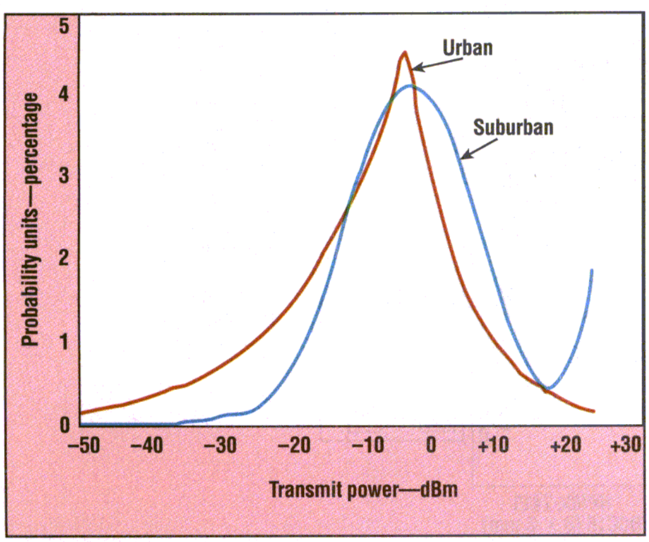
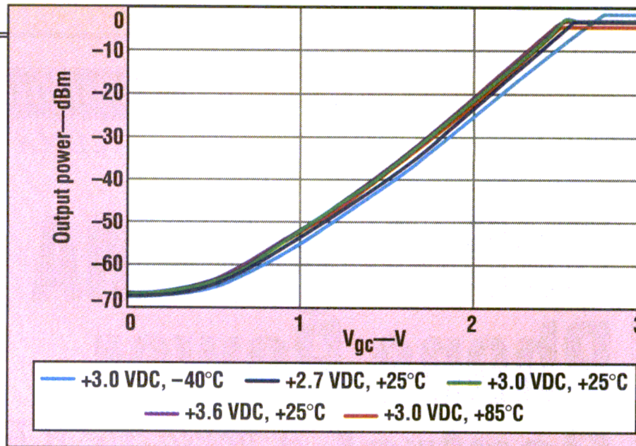
CAPACITY in a code-division-multiple-access (CDMA) system is determined not only by the total number of users on a particular channel and a particular cell, but also by the power received by the base station from each user's handset. Thus, it is important to have handsets transmit at the lowest possible power to optimize CDMA capacity.

To achieve the lowest possible handset transmit power, CDMA systems implement a very tight power control and take advantage of the natural low rate of voice activity in normal speech, reducing the transmission rate when voice activity is low and, hence, lowering the average transmit power. The base station establishes a very tight closed-loop control of the output power of each handset, commanding it to increase or decrease its power by 1 dB every 1.25 ms. As a handset station traverses a cell, its output power will be decreased when it approaches the base station, and it will be increased as it gets farther away from the center of the cell. Figure 1 shows typical statistical profiles for the handset transmit power generated from actual field-test data from deployed CDMA units, for urban and suburban topographies.[1] It is clear that the average transmit power of the handset (+10.6 dBm suburban, +5.4 dBm urban) is significantly lower than the maximum.



1. This plot shows the probability distribution of mobile-station transmit power in a CDMA system.

Using adaptive bias techniques in the RF section of a handset, closed-loop operation delivers the required linearity at high output power with enough "headroom" to support a reasonable manufacturing margin, while simultaneously exhibiting low current consumption at average transmit power to provide enhanced standby and talk-time performance. The current consumption at high output power is important because it challenges the thermal design of the handset. Figure 1 illustrates the probability that the handset spends little time transmitting at the maximum output power and, hence, the current consumption at that point has only a minor influence on talk time. Therefore, the real figure of merit for CDMA mobile phones should be the statistical-average current consumption (I_μ), which is the current consumption integrated over the user's statistical profile. In fact, the industry-standard method of measuring talk time consists of continuously sweeping the output power of the handset from –50 to +23 dBm according to the statistical profiles shown in Fig. 1.[1]



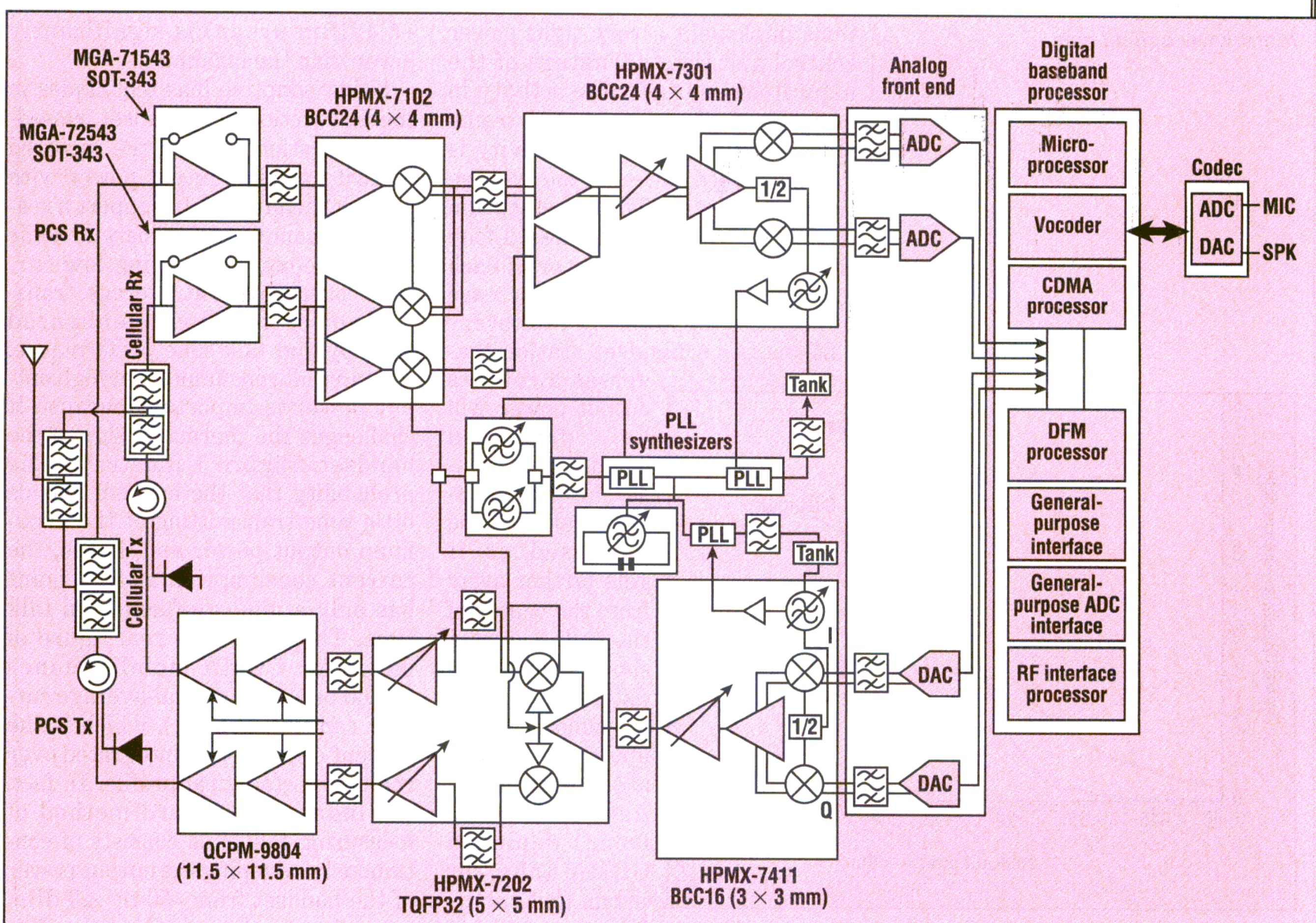
3. These measurements show the output power versus gain control over temperature and bias variations for the modulator/amplifier IC.

Figure 2 shows the block diagram of a tri-mode RF chip set from Agilent Technologies (Newark, CA). The transmit chain consists of three elements: a modulator/variable-gain-amplifier (VGA) intermediate-frequency (IF) chip, an upconverter/RF VGA chip, and an impedance-matched power-amplifier (PA) module. The receive chain comprises two low-noise amplifiers (LNAs) with bypass-switch integrated circuits (ICs), a downconverter chip, and an IF VGA/demodulator chip.

TRANSMIT GAIN CONTROL

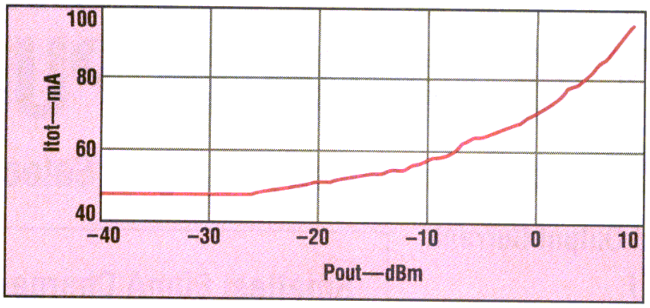
The modulator/VGA IC (model HPMX-7411) contains a quadrature modulator, a variable-gain IF amplifier, a negative-resistance cell to generate the local-oscillator (LO) signal, and a voltage-controlled-oscillator (VCO) buffer amplifier. For CDMA applications, the differential in-phase (I) and quadrature (Q) signals are received from the baseband processor and applied directly to the input of the mixers. The on-chip negative-resistance cell with an external tank network tuned to two times the frequency of the LO ($2f_{LO}$) operates as a VCO, feeding a broadband divide-by-two circuit that drives the I and Q mixers in quadrature. The modulated signal is then applied to the VGA. For frequency-modulation (FM) applications, the FM is directly applied to the tank of the VCO at twice the modulation frequency. The signal goes through the divide-by-two circuit, and is applied to the mixers. The I and Q mixers are latched to permit the FM signal to pass into and through the VGA without frequency conversion. The complete signal path, including the negative-resistance cell, employs differential circuitry to provide high common-mode noise suppression. The broadband quadrature divide-by-two circuit is implemented using a toggle flip-flop topology. The modulator can also operate with an injected LO signal.

Figure 3 shows the measured performance at the output of the VGA. At the typical 130 MHz IF, the IC consumes 30 mA from a +3-VDC sup-



2. This block diagram illustrates a tri-mode RF chip set from Agilent Technologies for CDMA and AMPS applications.

ply and delivers –2 dBm into an 800-Ω effective differential load with an adjacent-channel power ratio (ACPR) of –62 dBc/30-kHz signal separation. The modulator has unadjusted carrier and sideband suppression of 30 dB with an injected LO power of –10 dBm. The VGA provides 60 dB of linear gain control with a control voltage of +0.3 to +2.5 VDC. At full gain, the output noise power is –138 dBm/Hz.



4. The total current consumption versus output power for the upconverter/driver IC is plotted for an ACPR of –55 dBc/30 kHz.

The upconverter/VGA (model HPMX-7202) contains three separate transmit chains that are enabled through band-select and mode-select digital controls: CDMA at 1900 MHz, CDMA at 800 MHz, and Advanced Mobile Phone Service (AMPS). The CDMA chains consist of a double-balanced upconverter mixer and an RF VGA with adaptive bias. As the gain in the driver is reduced—and, hence, the output power decreases—the current consumption is reduced. The AMPS chain consists of a double-balanced mixer and a fixed-gain driver. LO buffers are included in all chains.[2]

Figure 4 shows the measured total current consumption for the upconverter/driver RF ICs versus output power for a constant ACPR of –55 dBc/30 kHz (this ACPR was selected arbitrarily). By integrating the current consumption (Fig. 4) over the probability distribution function of the handset (Fig. 1), a statistical average-current consumption of only 56 mA is obtained (suburban model). This illustrates the advantage of using adaptive-bias techniques in CDMA mobile phones. The upconverter/driver consumes I_μ = 56 mA and delivers +9 dBm of output power with an ACPR of –55 dBc at 30 kHz. In AMPS mode, the RF IC consumes 43 mA and delivers +8-dBm output power.

The PA module (model QCPM-9804) is a fully matched two-stage dual-band tri-mode amplifier housed in an 11.5 × 11.5-mm printed-circuit assembly. It consists of four separate ICs—one driver and one output-stage IC for each band. As in the upconverter/driver RF IC, dynamic bias techniques are used to achieve a low statistical average-current consumption. The current consumption of the PA can be adjusted by varying a control voltage. Figure 5 shows the performance of the PA when it operates with a very simple two-state current control adjustment. An ACPR of –47 dBc/30 kHz is achieved at the highest output power and it improves markedly as the power decreases. The PA operates in the high-state mode at high output power, and is switched to the low-state mode at some transition power in order to save current. By integrating the current consumption of each element in the transmit chain over the probability distribution function of the handset, the chip set achieves an I_μ of 280 mA for the complete transmit chain, from I-Q mixer input to the antenna.

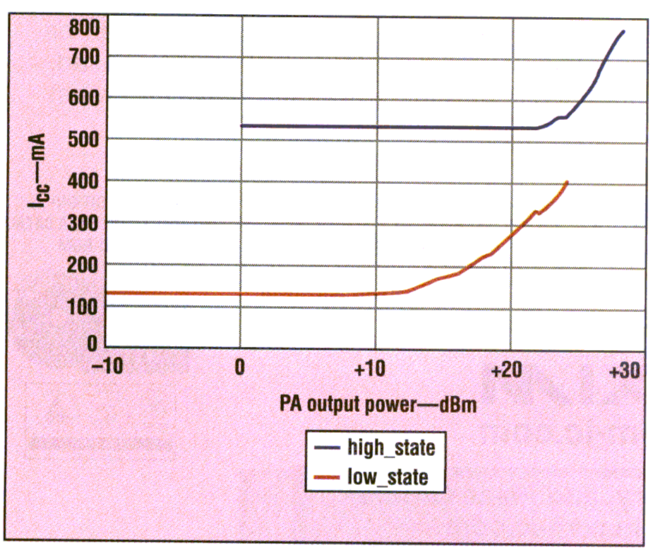
The probability distribution functions of the handset transmit power shown in Fig. 1 also apply to the receive power, since the open-loop power control of a CDMA phone dictates a known relation between the receive and transmit power: The transmit power (P_T) is given by:

$$P_T = -73 - P_R \text{ dBm}$$

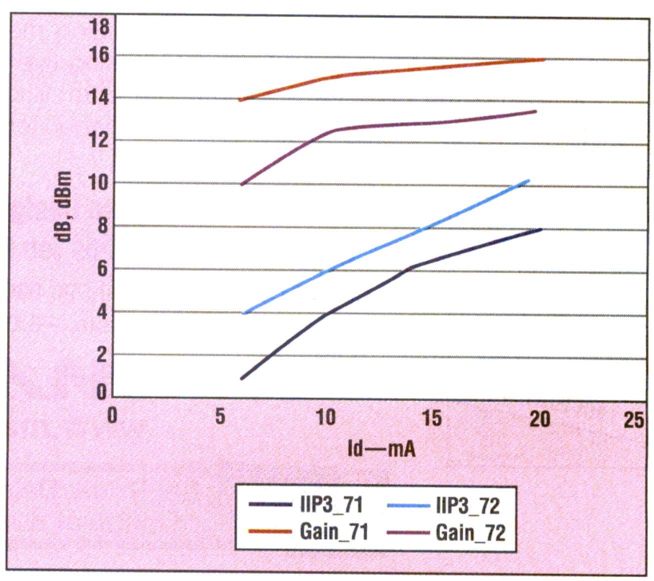
where:

P_R = the receiver power (in dBm).

Note that a value of –76 dBm would be substituted for the person-



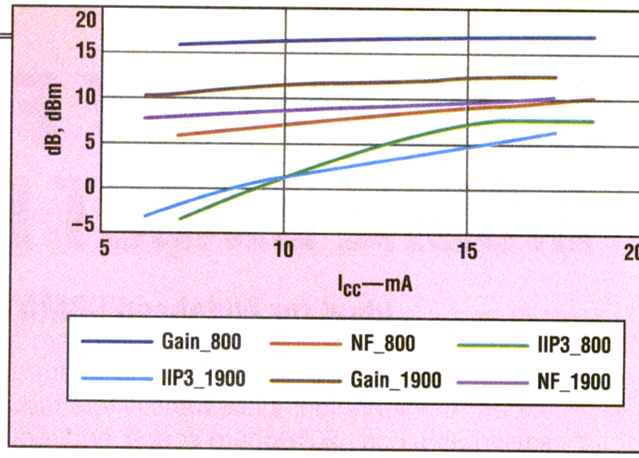
5. The power-amplifier current consumption versus output power is plotted for operation with a two-state current control adjustment.



6. These measurements show gain and input third-order intercept point versus current for the receiver LNA ICs.

al-communications-services (PCS) band.

The basic concept for the receive chain is to provide variable current consumption in the RF components so that high linearity at high current can be achieved when needed, while operating the receive chain at low current consumption the majority of the time. Models MGA-71543 and MGA-72543 ICs each contain an LNA with a bypass switch. These devices have two main features. First, the current consumption is 0 mA when the part is in bypass mode. Second, the linearity and current consumption when the part is in LNA mode can be adjusted externally. The gain and noise figure of the receiver components in the chip set were designed so that the LNA is statistically in the bypass mode, drawing zero current the majority of the time.



7. These measurements show gain, noise figure, and input third-order intercept point versus current for the PCS and CDMA mixers.

Figure 6 shows the measured gain and input third-order intercept point versus device current for the LNA. The MGA-71543 and MGA-72543 have typical noise figures of 1.3 and 1.5 dB, respectively. As an example of the advantage provided by the dynamic bias of the LNA, the MGA-72543 delivers an input third-order intercept point (IIP3) of +10 dBm at 20 mA. If the LNA is switched to bypass mode when the received power is –80 dBm (24 dB above the minimum required), the statistical average-current consumption of the LNA is only 6 mA (suburban model).

The HPMX-7102 contains three single-balanced mixers that are enabled through band-select and mode-select digital controls: one for 1900 MHz CDMA, one for 800 MHz CDMA, and one for AMPS. The current/linearity of all mixers is variable through a voltage-controlled pin. Figure 7 shows the gain, noise figure, and IIP3 versus current for the PCS and cellular CDMA mixers.●●

References

1. Stage 4 system performance tests, CDMA Development Group, April 1998.

2. K. Carter *et al.*, "A CDMA/FM Upconverter And Variable-Gain Driver Amplifier Integrated Circuit," *Symposium Digest, 1999 IEEE RFIC Symposium*, 1999, pp. 81-84.

For further reading

H. Morkner, M. Frank, and S. Yajima, "A Miniature PHEMT Switched-LNA For 800 MHz To 8 GHz Handset Applications," *Symposium Digest, 1999 IEEE RFIC Symposium*, 1999, pp. 109-112.

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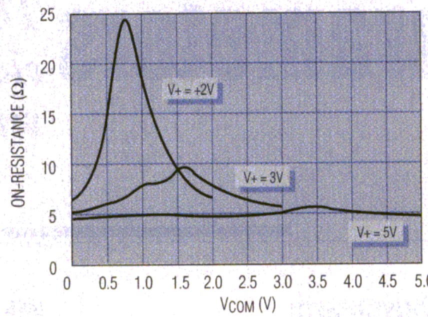
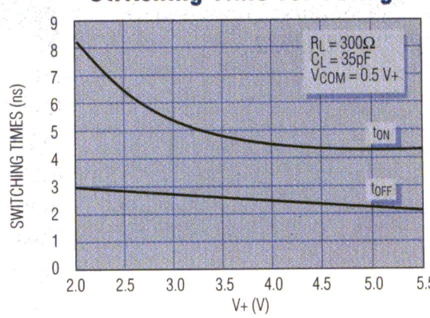
On-Resistance vs. V_{COM}



Switching Time vs. Voltage



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PART	FUNCTION	SWITCH STATES		R_{ON} (Ω max)	R_{ON} MATCH/FLATNESS (Ω max)	SWITCHING TIMES (ns)		INDUSTRY-STANDARD PINOUT
		NO	NC			t_{ON}	t_{OFF}	
MAX4614	Quad SPST	4	—	10	1	12	10	74HC4066/ MAX4610
MAX4615	Quad SPST	—	4	10	1	12	10	MAX4611
MAX4616	Quad SPST	2	2	10	1	12	10	—

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CIRCLE NO. 244

Accurately Compute PLL Active-Filter Parameters

This method optimizes active-filter elements and is readily implemented with a simple computer algorithm.

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ACCURATE circuit and subsystem simulation continues to challenge high-frequency engineers, who are being increasingly forced to address time-to-market concerns. In a previous article[1], an analysis approach was developed to achieve precise calculation and optimization of the element values for passive lowpass filters used in phase-locked-loop (PLL) current-charge pumps. In this article, an analysis of active fourth-order lowpass filters is performed. By implementing this analysis approach with a computer algorithm, fast and exact synthesis is achieved—eliminating the trial and error often involved in the design of these filter circuits. Two kinds of phase detectors are discussed: the voltage type and the current-charge-pump type.

Figure 1 shows a common PLL circuit. The sensitivity of the voltage-type phase detector is given by:

$$K_p(in\ V/rad) = V_{cc}/2/\pi \text{ or } V_{cc}/4/\pi \quad (1)$$

depending on the type of phase detector used.

The sensitivity of the voltage-controlled oscillator (VCO) is:

$$K_o(in\ rad/sec/V) = 2\pi K_v = 2\pi\,\Delta F/\Delta V \quad (2)$$

The divider ratio is N. The PLL filter uses an operational amplifier and is shown in Fig. 2. The following time constants are defined:

$$T_1 = R_1C_1 \quad (3a)$$

$$T_2 = R_2(C_1 + C_2) \quad (3b)$$

$$T_3 = R_2C_2 \quad (3c)$$

$$T_4 = R_3C_3 \quad (3d)$$

After some calculations, the transfer function of the loop filter can be found by:

$$F(s) = -(1 + sT_2)/sT_1/(1 + sT_3)/(1 + sT_4) \quad (4)$$

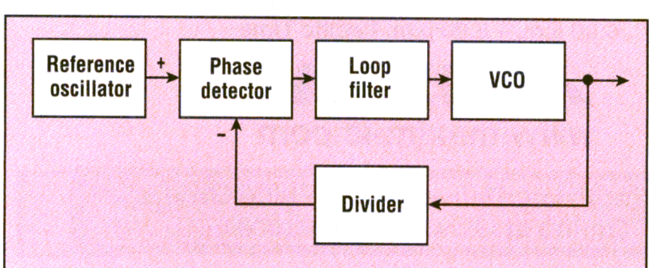
The open-loop gain of the PLL is:

$$A(s) = -K_pK_oF(s)/s/N \quad (5)$$

The minus sign is chosen to maintain a negative feedback loop as the operational amplifier is reversing the signal. Substituting s = jΩ,

$$A(j\omega) = -K_pK_o(1 + j\omega T_2)/(1 + j\omega T_3)/(1 + j\omega T_4)/(N\omega^2T_1) \quad (6)$$

And the open-loop phase is:



1. This simple block diagram represents the basic structure of a PLL.

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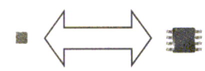

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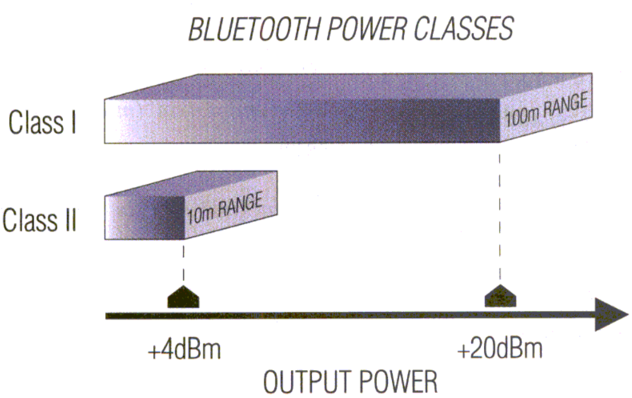

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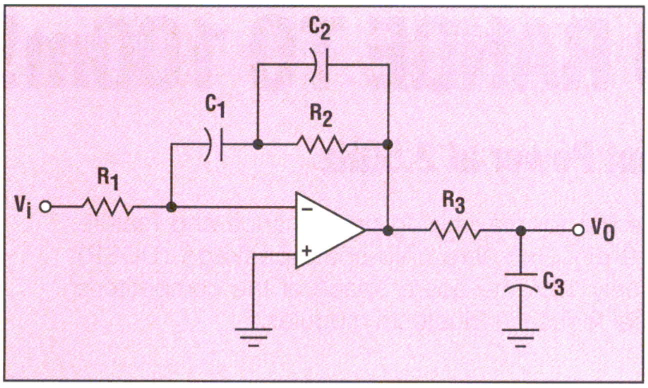
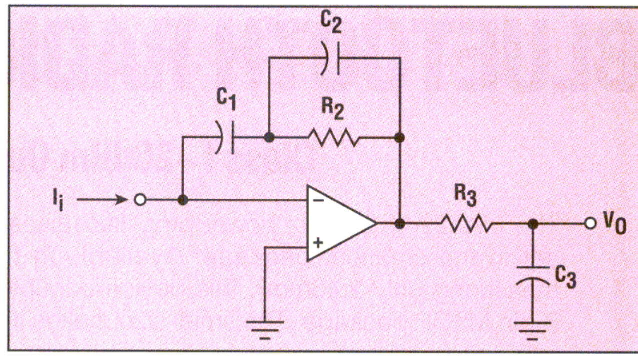


2. This schematic shows a fourth-order active PLL filter.



3. This schematic shows a fourth-order charge-pump PLL filter.

$$\varphi = \pi + tan^{-1}(\omega T_2) - tan^{-1}(\omega T_3)$$
$$-tan^{-1}(\omega T_4) \quad (7)$$

The parameter ω_0 is defined as the angular frequency that maintains:

$$|A(j\omega_0)| = 1 \quad (7a)$$

The following phase values are also defined:

$$\alpha = tan^{-1}(\omega_0 T_2) \quad (8a)$$

$$\beta = tan^{-1}(\omega_0 T_3) \quad (8b)$$

$$\gamma = tan^{-1}(\omega_0 T_4) \quad (8c)$$

And the phase margin, ϕ, is defined as:

$$\phi = \varphi - \pi = \alpha - \beta - \gamma \quad (9)$$

The function $\phi(\omega)$ has a maximum point. If this point is set at ω_0, then the phase margin will be minimal at that point. This is equivalent to the requirement that the derivative of $\phi(\omega)$ is zero at ω_0, that is:

$$d\varphi / d\omega|_{\omega=\omega 0} = 0 \quad (10)$$

Using eq. 7,

$$d\varphi / d\omega|_{\omega=\omega 0} = T_2 / [1 + (\omega_0 T_2)^2]$$
$$-T_3 / [1 + (\omega_0 T_3)^2] -$$
$$T_4 / [1 + (\omega_0 T_4)^2] = 0 \quad (11)$$

By multiplying by φ_0 and using eq. 8:

$$tan(\alpha) / [1 + tan^2(\alpha)]$$
$$-tan(\gamma) / [1 + tan^2(\gamma)] = tan(\beta) /$$
$$[1 + tan^2(\beta)]$$

Using the identity:

$$tan(x) / [1 + tan^2(x)] =$$
$$sin(2x) / 2$$

$$sin(2\alpha) - sin(2\gamma) = sin(2\beta) \quad (12)$$

From eq. 9:

$$\beta = \alpha - (\phi + \gamma)$$

Defining m = $(\pi + \gamma)$ and substituting back into eq. 12 yields:

$$sin(2\alpha) - sin(2\gamma) =$$
$$sin[2\alpha - 2m]$$

$$sin(2\alpha) - sin(2\gamma) =$$
$$sin(2\alpha)\ cos(2m) -$$
$$cos(2\alpha)\ sin(2m)$$

Defining, for convenience, x = sin (2α), and using the identity cos = $(1 - sin^2)^{0.5}$ yields:

$$x[1 - cos(2m)] - sin(2\gamma) =$$
$$-sin(2m)\ sqrt[1 - x^2]$$

Squaring leads to:

$$x^2[1 + cos^2(2m) - 2cos(2m)] +$$
$$sin^2(2\gamma) - 2x\ sin(2\gamma)[1 - cos(2m)] =$$
$$sin^2(2m)[1 - x^2]$$

$$x^2[2(1 - cos(2m))] - 2x\ sin(2\gamma)$$
$$[1 - cos(2m)] + sin^2$$
$$(2\gamma) - sin^2(2m) = 0$$

And using the identities:

$$2sin^2(m) = 1 - cos(2m)\ and - sin^2$$
$$(2m) = 4sin^2(m)cos^2(m)$$

then:

$$x^2[4sin^2(m)] - 4x\ sin(2\gamma)sin^2(m) +$$
$$sin^2(2\gamma) - 4sin^2(m)cos^2(m)$$

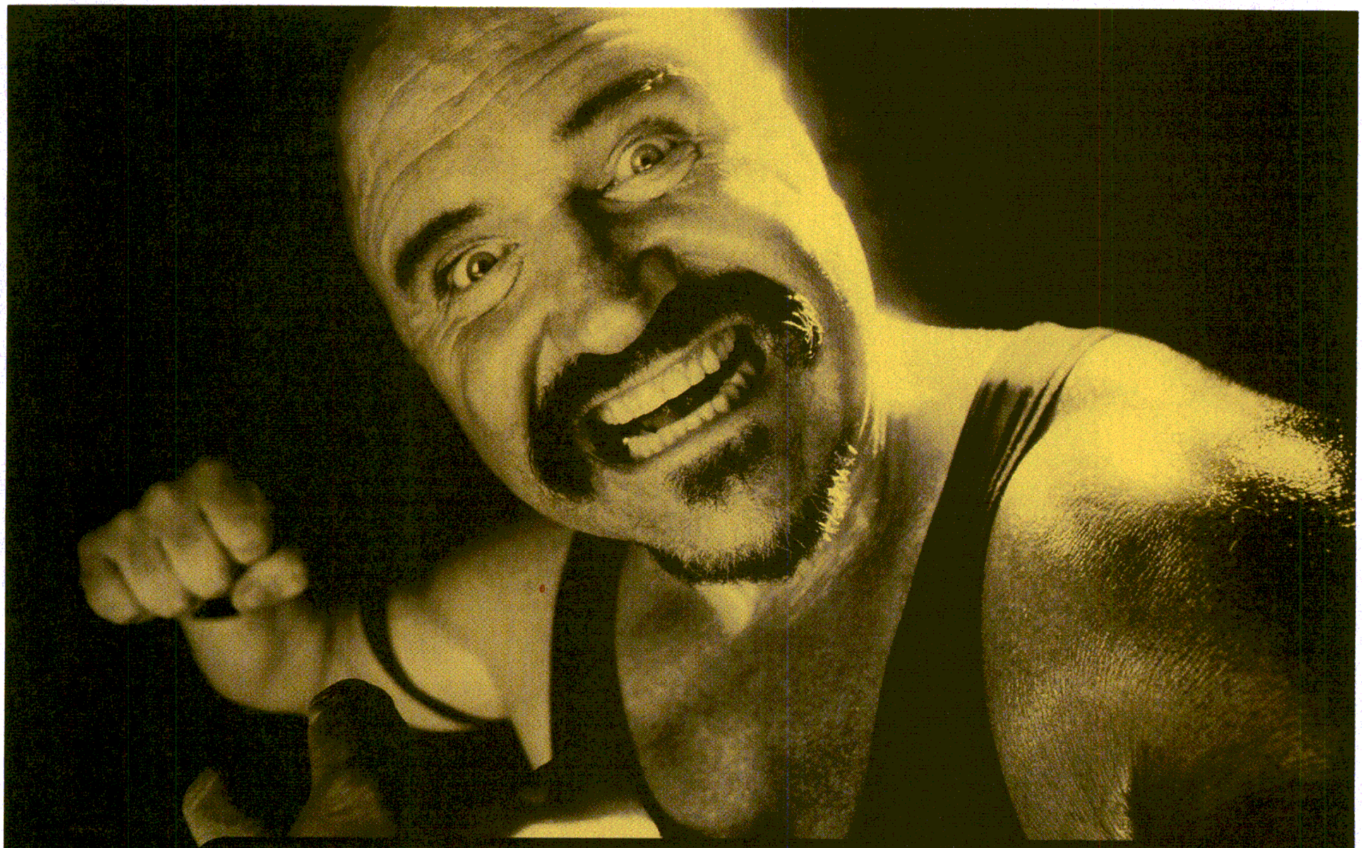
$$x^2 - x\ sin(2\gamma) + sin^2(2\gamma) /$$
$$[4sin^2(m)] - cos^2(m) = 0 \quad (13)$$

Solution of this quadratic equation provides:

$$x = 0.5\ sin(2\gamma) + sqrt\{0.25sin^2(2\gamma) +$$
$$cos^2(m) - sin^2(2\gamma) / [4sin^2(m)]\}$$

Results of example 1

Pole f_4	Pole f_3	Zero f_2	Gain margin	Closed-loop attenuation (dB) at 1 kHz	at 10 kHz	at 100 kHz
527.451	527.451	43.542	19.3	33.54	91.59	151.56
1000	349.4366	43.1074	21.4	32.82	89.54	149.49
10000	249.8609	41.6560	38.6	32.19	75.11	132.14
100000	242.2475	41.4455	58.4	32.36	72.36	115.33
∞	241.4214	41.4214	∞	32.38	72.35	112.35



$$= 0.5\ sin(2\gamma) + sqrt\{0.25sin^2(2\gamma)$$
$$[1 - 1/sin^2(m)] + \cos^2(m)\}$$

$$= 0.5\ sin(2\gamma) + sqrt\{0.25sin^2(2\gamma)$$
$$[-cos^2(m)/sin^2(m)] + cos^2(m)\}$$

$$= 0.5\ sin(2\gamma) + cos(m)sqrt$$
$$\{1 - [sin^2(2\gamma)/2/sin(m)]^2\}$$

Substituting back the value of m provides:

$$x = 0.5\ sin(2\gamma) + cos(\phi + \gamma)\ sqrt$$
$$\{1 - [sin^2(2\gamma)/2/sin(\phi + \gamma)]^2\} \quad (14)$$

Since x = sin (2α) and the sine has the same sign in the first two quadrants, it is impossible to differentiate between them (For example: for α = 15 or 75, x = sin (30) = sin (150) = 0.5).

To overcome this problem, use the tangent that has different signs. Using the identity:

$$tan\ (\alpha)/[1 + tan^2(\alpha)]$$
$$= 0.5sin\ (2\alpha) = x/2$$

gives:

$$tan^2(\alpha) - [2/x]tan(\alpha) + 1 = 0$$

then:

$$tan(\alpha) = 1/x + sqrt[1/x^2 - 1] \quad (15)$$

From eq. 9,

$$\beta = \alpha - \phi - \gamma \qquad (16)$$

And from eq. 8,

$$\omega_0 T_3 = tan(\beta) \qquad (17)$$

From eq. 6, evaluate the absolute value of A(jφ) at φ_0:

$$|A(j\omega_0)| = 1 = [K_p K_o/(N\omega_0{}^2 T_1)]$$
$$sqrt\{(1 + (\omega_0 T_2)^2)/(1 + (\omega_0 T_3)^2)/$$
$$(1 + (\omega_0 T_4)^2)\}$$

Using eq. 8:

$$T_1 = [K_p K_o/(N\omega_0{}^2)]$$
$$sqrt\{(1 + tan^2(\alpha))/(1 + tan^2(\beta))/$$
$$(1 + tan^2(\gamma))\}$$

And using the identity:

$$sqrt\ (1 + tan^2(x)) = |1/cos(x)|$$

$$T_1 = [K_p K_o/(N\omega_0{}^2)]$$
$$abs\{\cos(\beta)\cos(\gamma)\cos(\alpha)\} \quad (18)$$

Defining f_2 as the frequency of the zero and f_3 and f_4 as the frequencies of the of poles of the open-loop gain, then:

$$T_2 = 1/(2\pi f_2);$$
$$T_3 = 1/(2\pi f_3);$$
$$T_4 = 1/(2\pi f_4); \qquad (19)$$

And using $\varphi_0 = 2\pi fp\ _0p$ and eq. 8:

$$\alpha = tan^{-1}(f_0/f_2) \qquad (20a)$$
$$\beta = tan^{-1}(f_0/f_3) \qquad (20b)$$
$$\gamma = tan^{-1}(f_0/f_4) \qquad (20c)$$

For the PLL design, the known parameters are phase-detector sensitivity K_p, VCO sensitivity K_0, and divider ratio N. The selected parameters are loop angular frequency φ_0, phase margin ϕ, and f_4, which is the frequency of the pole of R_3 and C_3.

To realize the PLL calculation:

1. Calculate γ from eq. 20.
2. Calculate x from eq. 14.
3. Calculate tan (α) from eq. 15 and derive α.
4. Derive f_2 from eq. 20. $F_2 = f_0 / \tan(\alpha)$.
5. Calculate β from eq. 16.
6. Derive f_3 from eq. 20. $f_3 = f_0 / \tan(\beta)$.
7. Calculate T_1 from eq. 18.
8. Calculate T_2, T_3, and T_4 from eq. 19.
9. Choose C_3. Derive R_3 from eq. 3. $R_3 = T_4 / C_3$.
10. Choose C_1. Derive R_1 from eq. 3. $R_1 = T_1 / C_1$.
11. Calculate R_2 and C_2 from eq. 3.
$R_2 = (T_2 - T_3) / C_1$
$C_2 = T_3 / R_2$.

The current flowing into the operational amplifier in Fig. 2 is V_{CC} / R_1. The sensitivity of the voltage-phase detector is $K_p = V_{CC} / 2 / \pi$. The sensitivity of the current charge-pump phase detector is $K_d = I / 2 / \pi$. It means that $K_p = K_d / R_1$. If arbitrarily one selects $R_1 = 1$, K_d can be substituted for K_p in the equations, especially in eq. 18, to get the design for the current charge-pump phase detector using Fig. 3. Step 10 of the design summary has to be changed. C_1 is no longer selectable. From eq. 3, it can be seen that $C_1 = T_1$.

A PLL design is required with the following parameters:

1. The phase detector used is a current charge pump type with a current of 1 mA.
2. Phase-detector sensitivity (in A/rad) = $10^{-3}/2/\pi$.
3. VCO sensitivity (in MHz/V) = 4.
4. K_0 (in rad/sec/V) = $8\pi10^6$.
5. Divider ratio = 10^5.
6. Loop filter required f_0 = 100 Hz.
7. Phase margin = 45 deg.
8. Different frequencies, f_4, for the pole have been chosen.

The results are shown in the table. Analysis of the closed-loop gain was performed by a computer-aided-engineering (CAE) program.[2]

The maximum attenuation results from choosing a multiple pole ($f_4 = f_3$). The results are shown in line one in the table. In line two, f_4 was chosen as $10f_0$, with only a small decrease in attenuation. Lines three and four are for f_4 = 100 f_0 and 1000 f_0, respectively. In line five, the pole of f_4 is eliminated. The loop is a regular third-order loop. With f_4 = 1000, eq. 18 yields $T_1 = 0.2448\ \mu s$ and $C_1 = 0.2448\ \mu F$. From eq. 19, $T_2 = 3692.058\ \mu s$, $T_3 = 455.462\ \mu s$, and $T_4 = 159.155\ \mu s$. C_3 is selected as $0.1\ \mu_m$. And from eq. 3, $R_3 = 1591$, $R_2 = 13218$, and $C_2 = 0.03445\ \mu F$.

A simulation using the program in ref. 3 produced results identical to those shown in the table.●●

References

1. D. Rosemarin, "Accurately Compute PLL Charge-Pump Filter Parameters," *Microwaves & RF*, February 1999, pp. 89-94.
2. E.L. Unruh, *Linear Phase-Locked-Loop Control System Analysis*, Artech House, 1991.
3. D. Rosemarin, "Technique Provides Simple Analysis of PLL Functions," *Microwaves & RF*, November 1993, pp. 89-91.

For further reading

U. Rohde, *Digital PLL Frequency Synthesizers: Theory and Design*, Prentice-Hall, 1983.

Model And Build A Ku-Band DRO

Ku-Band DRO, Part 2

One key to designing a high-performance dielectric resonator oscillator (DRO) lies in accurately modeling the electrical effects of the resonator.

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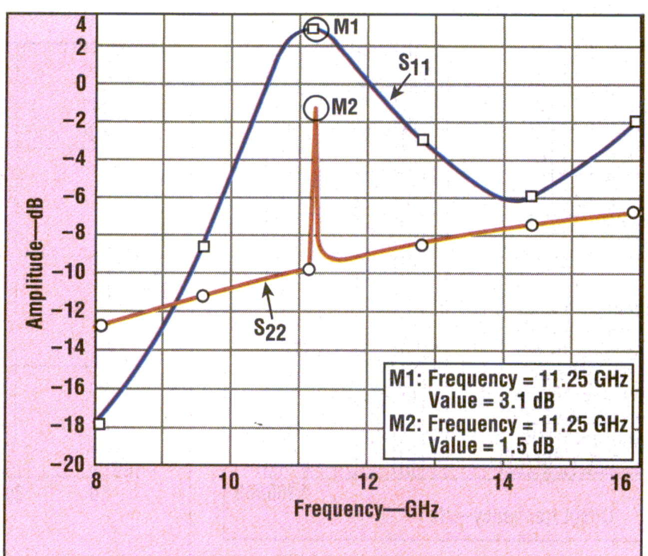
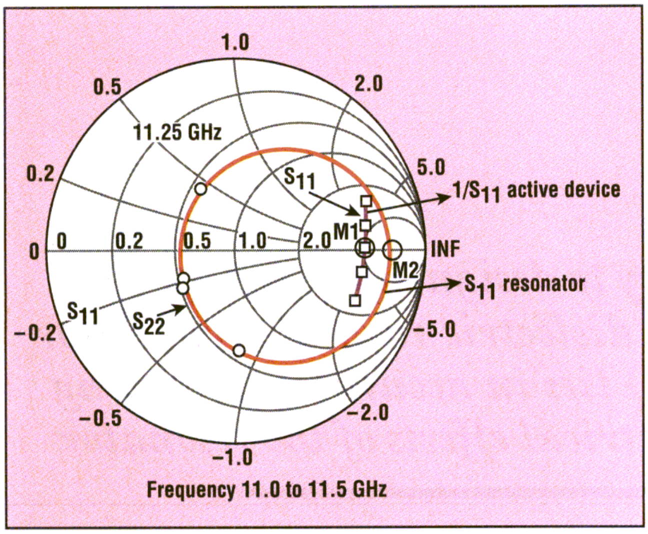
LAST month, the basics of dielectric resonator oscillators (DROs) were reviewed, along with the role of nonlinear simulation in the design of a low-noise DRO. Design theory outlined techniques for achieving good frequency stability as well as a target phase-noise specification at the design frequency of 11.25 GHz. The conclusion of this two-part article shows how to model the dielectric resonator (DR) and how to translate this design theory into the construction of a practical DRO.

Linear simulation, using the Touchstone formatted S-parameter files (*.s2p), can help create a first-approximation DRO design. Although an oscillator is essentially a saturated (nonlinear) circuit under steady-state operation, a linear simulation will provide a good initial circuit layout before fine-tuning the design in a nonlinear simulator. For both simulations, considerable care must be taken to account for the many component and circuit-board parasitic elements in the simulation. At Ku-band, parasitic elements of 0.5 nH can amount to an impedance of 40 Ω. Therefore, an accurate simulation resulting in a minimum of board tuning in the laboratory can only be achieved through careful modeling of all components used by the design, including:

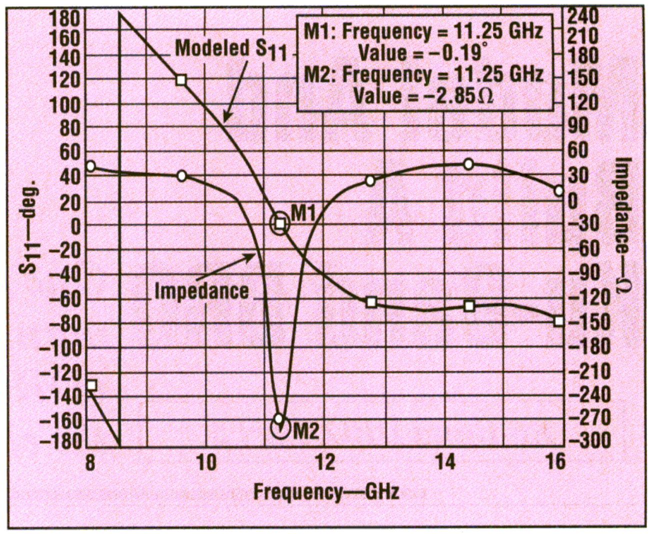
1. Using models for the 0603 resistors and capacitors that include parasitic elements. Most manufacturers of such components now provide an accurate high-frequency model.
2. Carefully modeling transmission lines (lengths and widths), especially in regard to impedance steps, crosses, and open stubs with capacitive effects.
3. Using an accurate model of the board characteristics including loss-tangent effects and



4. Linear circuit simulation was used to determine the S_{11} and S_{22} transmission losses from the FET and DR.



5. Linear circuit simulation was used to determine the S_{11} and S_{22} reflection coefficients from the FET and DR.



6. The linear circuit simulator was used to predict the negative resistance of the NE72218 MESFET device.

metal-deposition thickness.

4. Utilizing via holes and via pads instead of perfect grounds where appropriate.

The resonator is modeled as a parallel resistor-inductor-capacitor (RLC) circuit with values of L and C adjusted to provide the proper resonant frequency (11.25 GHz) and Q factor.

The resonant frequency is:

$$f_0 = 1/2\pi^{0.5}$$

with L and C being the equivalent model inductive and capacitive elements of the resonator.

The Q is defined as:

$Q_0 = (2\pi)$[(maximum energy stored)/(energy dissipated per cycle)]

For simulation purposes, Q_0 can be shown as:

$$Q_0 = (\omega_0/2)(d\phi/d\omega)$$

where:

ω_0 = the resonant frequency (= $2\pi f_0$), and

ϕ = the phase of the resonator impedance.

For a parallel resonator at resonance:

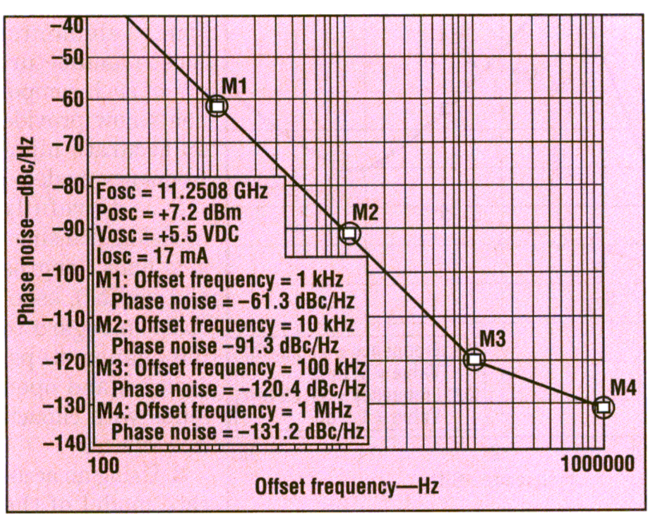
$$Q_0 = R/L\omega_0$$

because:

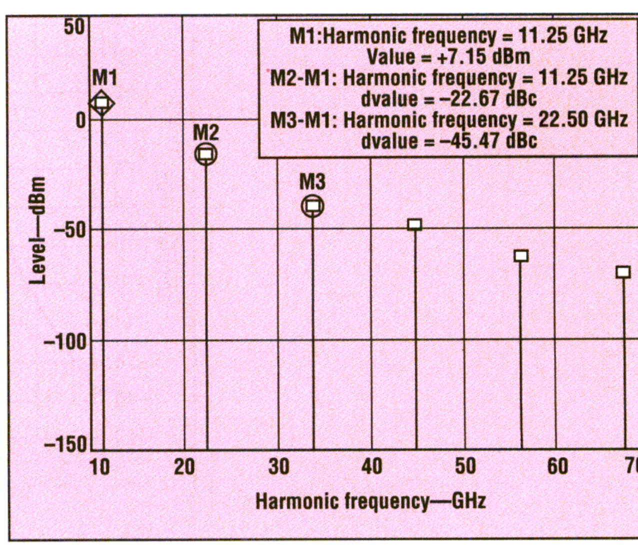
$$d\phi/d\omega = 2R/L$$

at resonance.

Therefore, the value of R defines the DR's unloaded Q. As the frequency selectiveness of the resonator increases, its phase noise decreases. Also, off resonance, this derivative diminishes, causing the Q to decrease. Such a resonator model is also provided by Trans-Tech through their program DR. In the model, the DR is then coupled to the 50-Ω transmission line through a transformer where the ratio (n) simulates the coupling coefficient (β) (at distance d). When β (or n) is

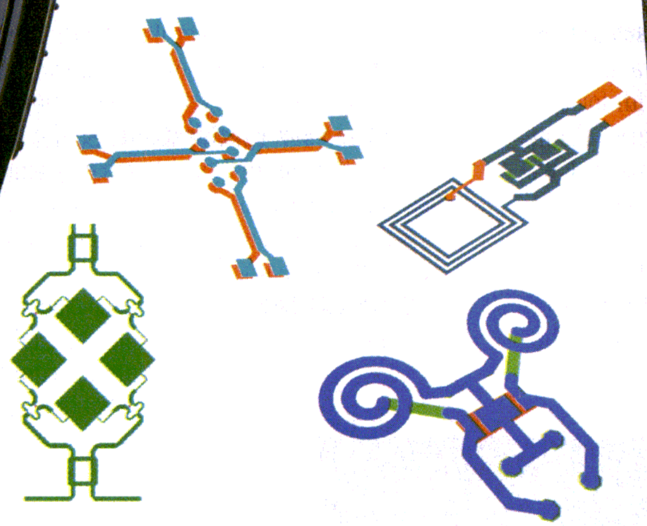


7. The nonlinear circuit simulator was used to model the phase noise of the 11.25-GHz dielectric resonator oscillator.



8. The nonlinear circuit simulator was also able to model the harmonic levels expected from the DRO.

CLR



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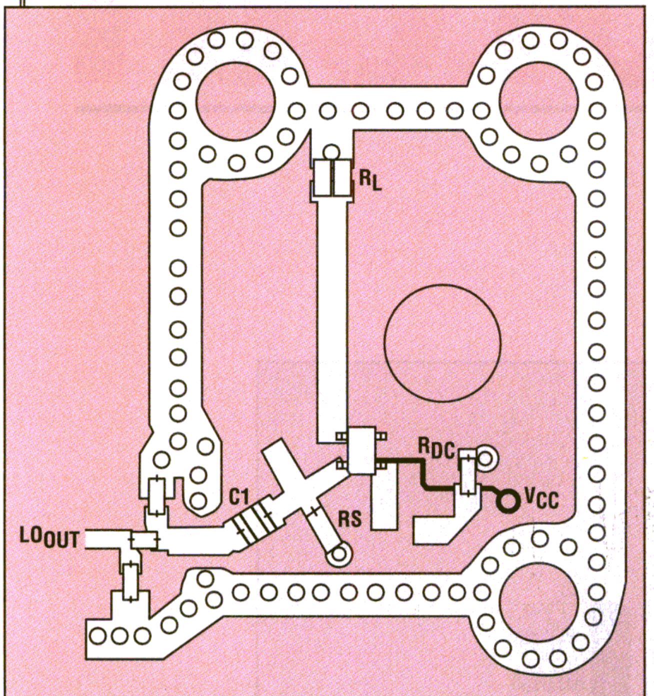


9. The following circuit layout was used to assemble the DRO.

adjusted, the increased or decreased coupling is characterized by the insertion loss of the bandstop filter as seen in Fig. 4. This coupling coefficient will eventually be fine-tuned in the nonlinear simulation to minimize phase noise while keeping an appropriate output power, but initially should be set so that the filter's insertion loss is less than the reflection gain provided by the active device on the gate port (–1.5 dB versus +3.1 dB in Fig. 4) Figure 5 also shows the coupled DR's reflection coefficient in the DR plane of reference in a Smith chart to be compared to the FETs' reflection coefficient.

Once the DR is modeled (in terms of the parallel RLC network), physical placement of the puck on the board needs to be simulated. This is achieved through a transformer where transform-ratio n defines the amount of coupling and through a 50-Ω transmission line which introduces the desired amount of phase and adjusts the loop phase. The first location approximation will be performed under small-signal conditions. However, as the device saturates and its S-parameters change accordingly, a refinement will be conducted for best output power and phase-noise performance during the nonlinear simulation.

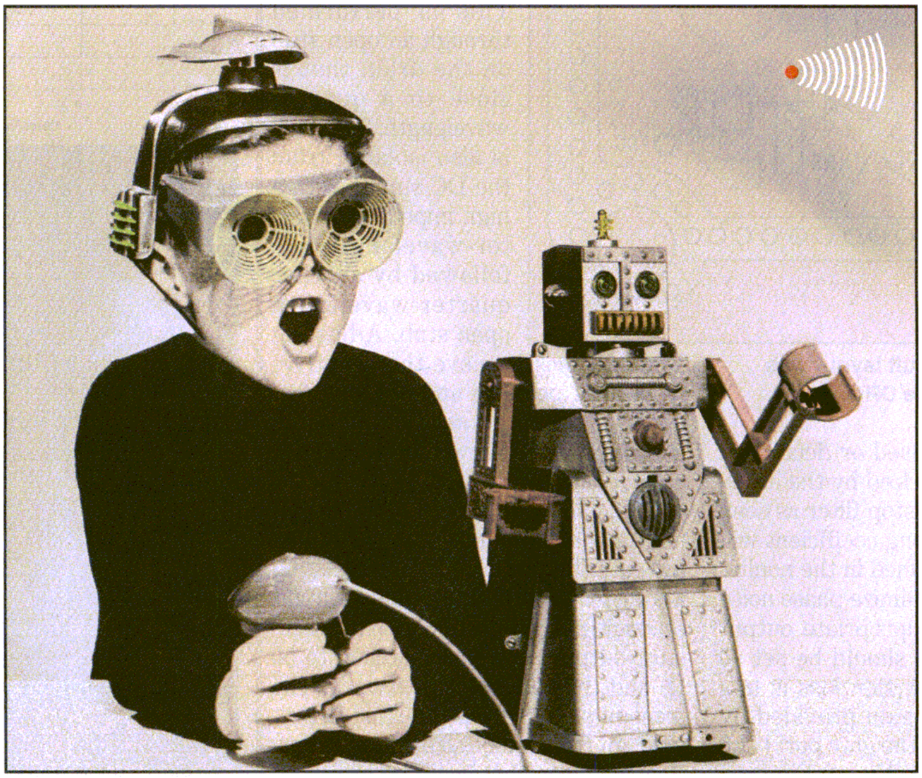
From the negative-resistance amplifier section, it is known that the common-drain amplifier should be set so that:

- Its drain will be AC shorted at the frequency of interest, providing the required feedback to unstabilize the FET. This is performed through an open stub on the drain that is close to a quarter wavelength. The stub is also isolated from the DC supply with a high impedance quarter-wavelength line followed by another quarter-wavelength open stub. Adjusting TL8 will mostly move the negative-resistance peak up and down in frequency. Its length was adjusted so that the maximum negative resistance occurred at 11.25 GHz (Fig. 6).
- The source reactance will define the amount of negative resistance at the gate. This is achieved by adjusting a transmission line in the linear-circuit schematic in conjunction with the oscillator-output network (matched to 50 Ω) and the self-biasing network. The transmission line was adjusted to provide approximately +3 dB gate-reflection coefficient but could be increased to provide a higher return gain. However, too much return gain could provide unwanted spurious oscillation due to the non-perfect return loss of the 50-Ω load shorting the gate beyond the DR's placement. A short open stub models the FET's second source pin.
- It will provide a negative resistance on the gate port and a good output match into 50 Ω.
- The phase delay of the transmission line must be set to 0 deg. so that the first condition is respected and a steady-state oscillation occurs.

For a better understanding of the simulation, designers should consider the parameter $1/S_{11}$ of the active device, since $\Gamma_{in} \times \Gamma_R \pm 1$ is of interest, as well as making sure that $\Gamma_{in} > (1/\Gamma_R)$

(continued on p. 164)

TECHNOLOGY



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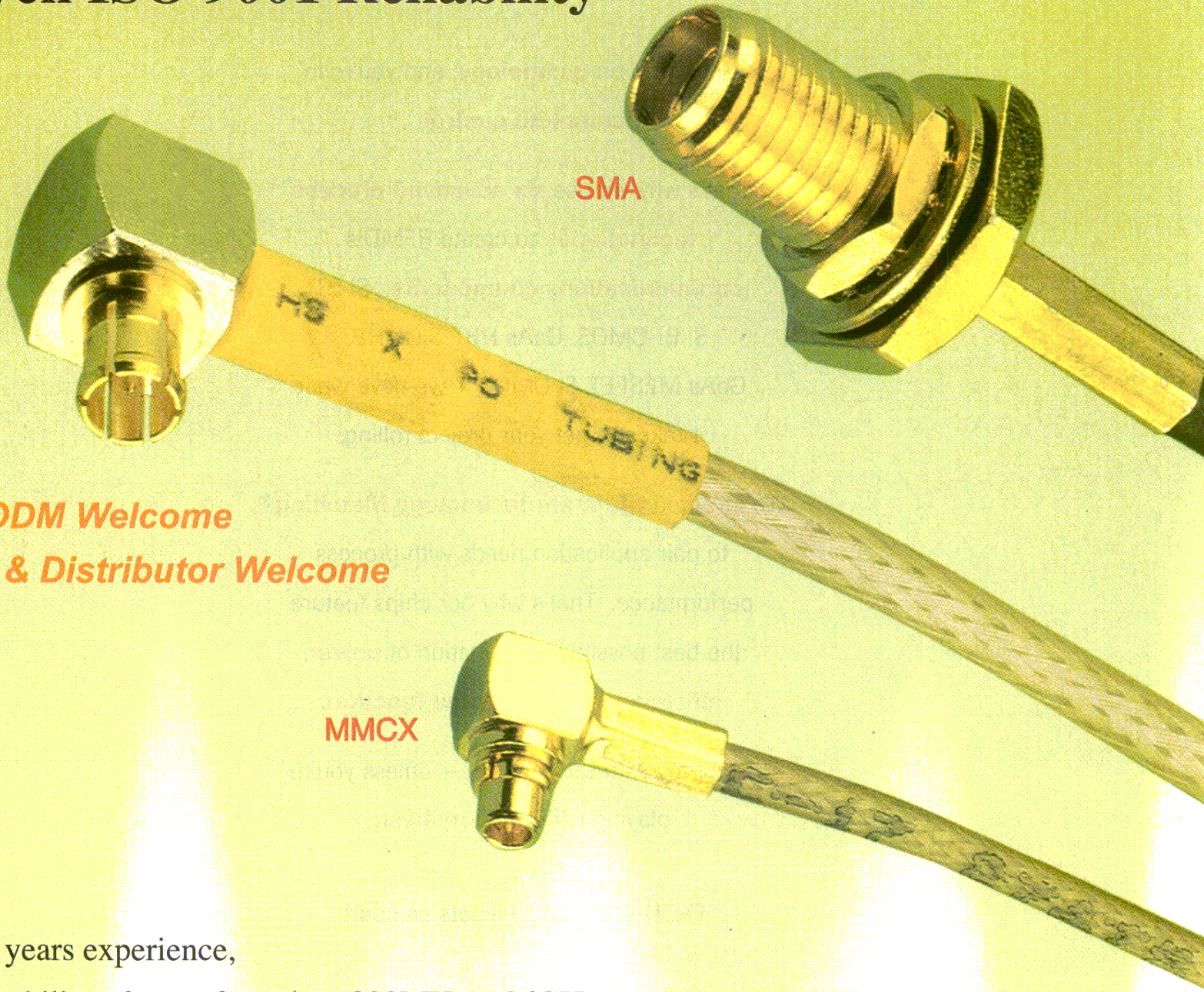

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Couplers Shrink HF/VHF/UHF Designs

A novel approach to designing directional couplers delivers highly integrated solutions with excellent broadband coupling flatness.

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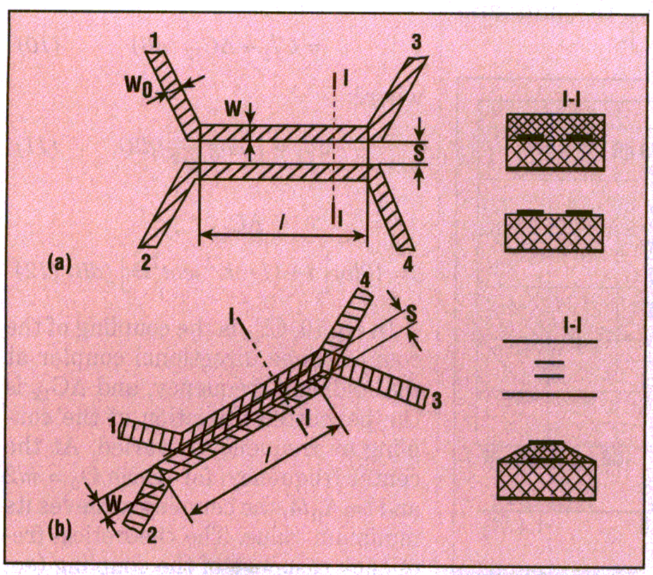
MINIATURE coupled-line directional couplers are indispensable components in most wireless and avionics systems, and can be found in other RF systems as well. Unfortunately, the classical quarter-wavelength directional coupler designed to operate in the very-high-frequency (VHF) and ultra-high-frequency (UHF) ranges has large dimensions that make it difficult to apply to miniaturized RF devices. However, a new type of coupled-line directional coupler described in this article offers a viable alternative for miniature-RF applications.

One of the most useful coupler structures is the four-port network formed by two coupled lines positioned close enough to each other to share electric and magnetic fields (Fig. 1). This coupled-line directional coupler is a completely symmetric (axes of symmetry XX and YY) four-port network (Fig. 2a). Analysis and synthesis of this coupler can be achieved through the mirror-reflection method.[1,2] The coupler can be represented by independent even and odd modes. In the even mode (Fig. 2b), currents in both lines are equal and co-directional. In the odd mode (Fig. 2c), currents are equal and opposite. The final currents are obtained by superpositioning the two modes.



1. This is a diagram of an edge-coupled-line coupler (a). This is a diagram of a broadside-coupled-line coupler (b).

According to the mirror-reflection method, homogeneous coupled lines are calculated with characteristic impedances Z_{0e} (even mode) and Z_{0o} (odd mode). It should be noted here that Z_{0e} is not equal to Z_{0o} because partial capacitances between the lines are different for even and odd modes. Perfect matching of a coupled-line directional coupler occurs when:[2]

$$Z_{0e}Z_{0o} = 1 \qquad (1)$$

where:

$Z_{0e} = z_{0e}/z_0$, and

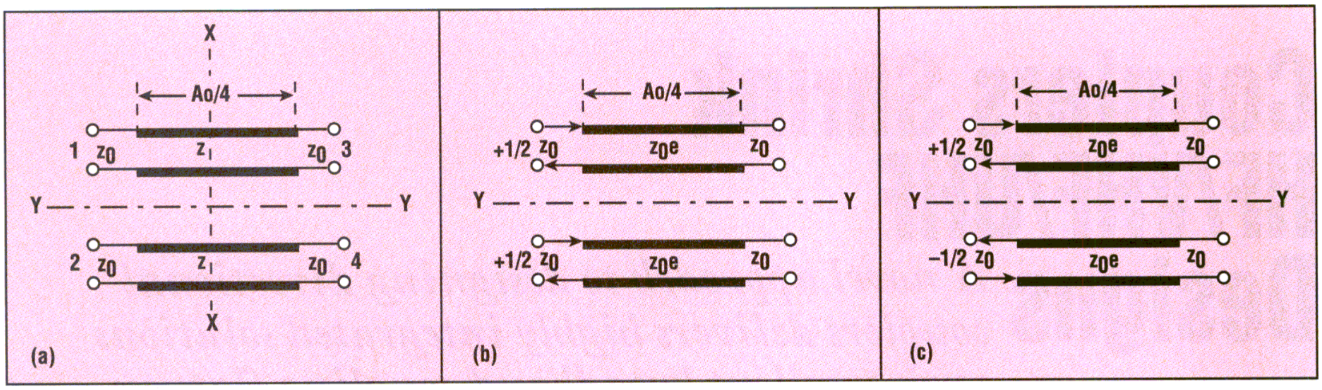
$Z_{0o} = z_{0o}/z_0$ are normalized characteristic impedances.

Note that eq. 1 does not depend on frequency or the length of the coupled lines. The scattering matrix of the ideally matched coupler can be derived from:[2]

$$[S] = \begin{bmatrix} 0 & S_{12} & S_{13} & 0 \\ S_{12} & 0 & 0 & S_{13} \\ S_{13} & 0 & 0 & S_{12} \\ 0 & S_{13} & S_{12} & 0 \end{bmatrix} \qquad (2)$$

where:

$$S_{12} = \frac{i(Z_{0e} - Z_{0o})sin\Theta}{2cos\Theta + i(Z_{0e} + Z_{0o})sin\Theta} \qquad (3)$$



2. These diagrams show the equivalent four-port network of a coupled-line directional coupler (a), the equivalent circuit for even mode (b), and the equivalent circuit for odd mode (c).

$$S_{13} = \frac{2}{2\cos\Theta + i(Z_{0e} + Z_{0o})\sin\Theta} \qquad (4)$$

where:

$\Theta = 2\pi l/\Lambda$ = the electrical length of the coupled lines, and

Λ = the guide wavelength.

The quadrature phase difference between output ports 2 and 3 is evidenced by multiple "i" by which eq. 3 differs from eq. 4:

$$\arg\frac{S_{13}}{S_{12}} = \pi / 2 \qquad (5)$$

Quadrature eq. 5 between output signals does not depend on frequency. For fixed frequency, quadrature does not depend on the length of the coupled lines.

A signal propagating from port 1 to port 3 on one transmission line produces a coupled signal in the opposite direction—from port 4 to port 2—on the other transmission line. For this reason, this coupler is known as a contradictional or backward-wave coupler.

The coupled-line coupler offers ideal matching and isolation that are independent of frequency and coupled-line length (see eq. 2), but the coupling and insertion losses (see eqs. 3 and 4) change with frequency and with coupled-line length. The maximum signal in the coupled port 2 occurs when the length of coupling structure is $\Lambda_0/4$.

where:

Λ_0 = the midband guide wavelength in the coupled lines.

This wavelength depends on the parameters of the transmission lines, the permittivity of the substrate, and the center frequency f_0.

The module of coupling (voltage-coupling factor) for the midband operating frequency is:

$$K = |S_{12}|_0 = \frac{Z_{0e} - Z_{0o}}{Z_{0e} + Z_{0o}} \qquad (6)$$

Equation 6 can be rearranged to provide:

$$Z_{0e} = \sqrt{\frac{1+K}{1-K}},\ Z_{0o} = \sqrt{\frac{1-K}{1+K}} \qquad (7)$$

Using eq. 7), eqs. 3 and 4 can be rewritten in the following form:

$$|S_{12}|^2 = \frac{K^2\sin^2\Theta}{1-K^2\cos^2\Theta} \qquad (8)$$

$$|S_{13}|^2 = \frac{1-K^2}{1-K^2\cos^2\Theta} \qquad (9)$$

From eq. 8, the frequency characteristics of the coupling are:

$$C_{12} = 10\log \frac{1}{|S_{12}|^2}$$

$$= 10\log\frac{1}{K^2}[1+(1-K^2)\cot^2\Theta]$$

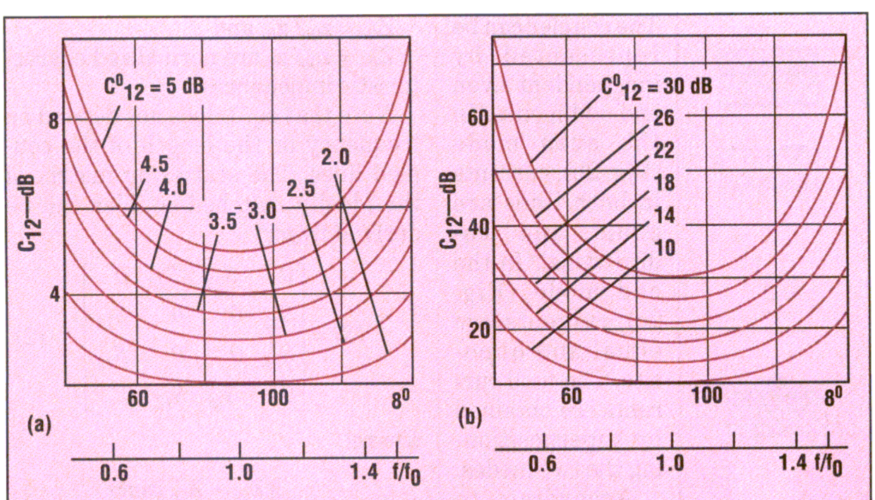
$$= C_{12}^0 + \Delta C_{12}\ (dB) \qquad (10)$$

where:

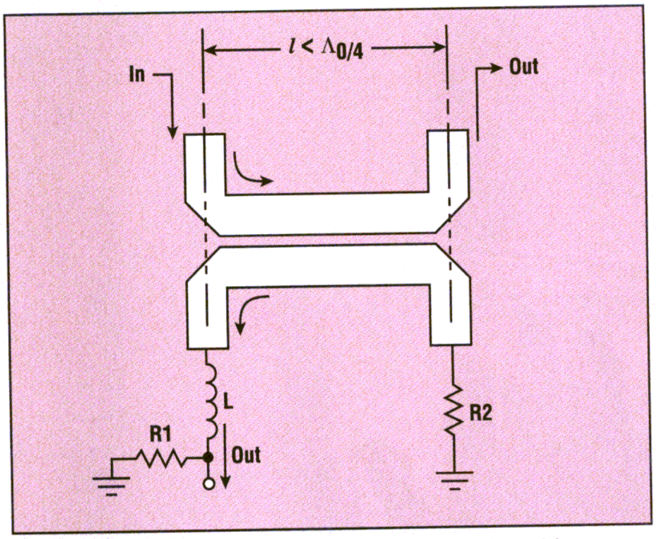
$$C_{12}^0 = 10\log\frac{1}{K^2}(dB) \qquad (11)$$

$$\Delta C_{12} = 10\log\lfloor 1+(1-K^2)\cot^2\Theta \rfloor\ (dB) \qquad (12)$$

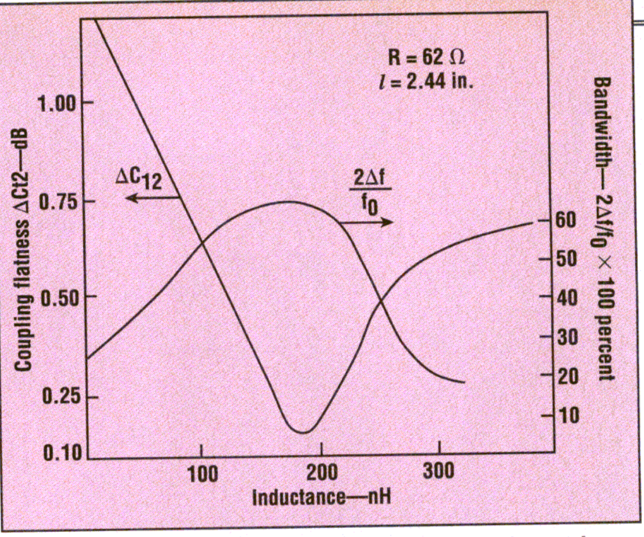
In eq. 10, C^0_{12} is the coupling of the coupled lines directional coupler at the midband frequency, and ΔC_{12} is the permitted deviation of the coupling as frequency is varied. At the center frequency, for which $\Theta_0 = \pi/2$ and $l = \Lambda_0/4$, the coupling achieves its minimum value. The theoretical frequency response of the coupling (eq. 10) is shown in Fig. 3 for tight and weak coupling.



3. Coupling versus electrical length and relative frequency for the coupled-line couplers with tight (a) and weak (b) coupling can be seen.



4. A miniature coupled-line directional coupler with compensation network can be seen.



5. Experimental characteristics of a 127-MHz microstrip directional coupler having coupled-line length l = 2.44 in. (6.20 cm) and shunt resistor R_1 = 62 Ω are shown. The relationship between inductance L and coupling flatness ΔC_{12} can be seen. The relationship between inductance L and bandwidth $2\Delta f/f_0 100$ percent for a coupling flatness of 0.1 dB is also shown.

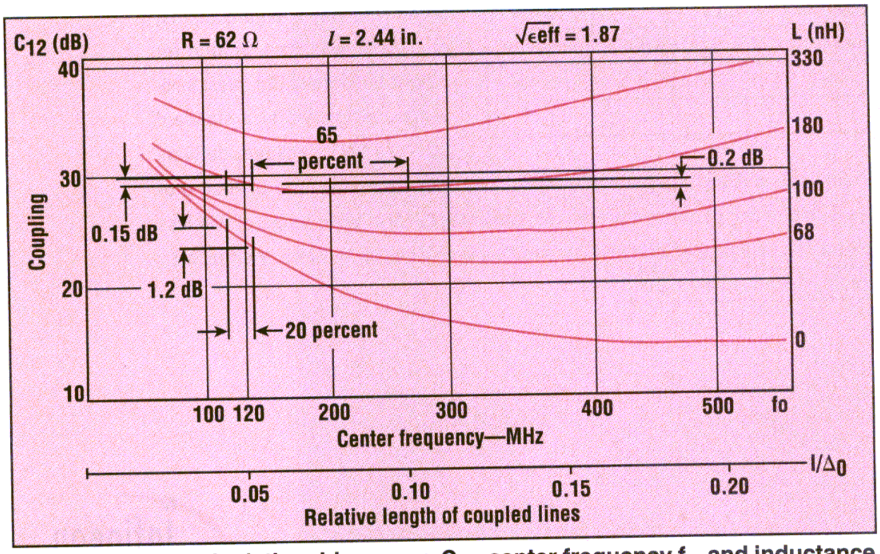
In the VHF and UHF range, the classic directional coupler with a coupled-line length of $\Lambda_0/4$ has large dimensions, which makes it difficult to build. Figure 4 shows a new microminiature directional coupler[3] comprised of two coupled lines that have a very short geometric length (less than $\Lambda_0/4$). This length depends on several requirements, including midband frequency, insertion loss, coupling, matching, and directivity.

The main problem of the short coupled-line coupler is that its degree of coupling varies with frequency (Fig. 3). A special compensation circuit is used to diminish this effect. The secondary line output is electrically connected with series inductor L and shunt resistor R_1 (Fig. 4). The other end of the secondary line is terminated with resistor R_2, where the value is equal to the impedance of the secondary line. The inductance value depends on the coupling flatness, midband frequency, and coupling value. The value of the shunt resistor R_1 depends on the impedance of the secondary line and inductance value.

Figure 5 illustrates the experimental relationship between inductance and coupling flatness ΔC_{12} for a frequency of 127 MHz and a bandwidth of 20 percent, and the relationship between inductance and bandwidth for a coupling line having a length of 2.44 in. (6.20 cm) and a shunt resistor $R_1 = 62\Omega$. Figure 6 illustrates the experimental relationship between coupling, the center frequency (or relative length of coupled lines l/Λ_0), and inductance for the same directional coupler.

Experiments have shown that for 20-percent bandwidth, the present microstrip directional coupler with L = 180 nH, R_1 = 62 Ω, f_0 = 127 MHz has a coupling flatness of ±0.05 dB, a directivity of more than 23 dB, an insertion loss of less than 0.15 dB, a VSWR of less than 1.15, and length l = 0.05 Λ_0 (five times less than a traditional directional coupler with l = Λ_0 /4). Tuning of the midband frequency (f_0) and coupling (C°_{12}) is realized by varying the inductance.

Unlike traditional $\Lambda_0/4$ directional couplers, the present coupler provides miniature dimensions in HF, VHF, and UHF bands. The level of integration of the coupler is approximately five times higher than in other well-known devices. The coupling flatness in an equally wide band is four times better than in a coupler without the compensation circuit. Tuning of the coupling and the midband frequency can be provided simply by varying the inductance value L.●●



6. An experimental relationship among C_{12}, center frequency f_0, and inductance L is seen here.

References

1. J. Reed and G. Wheeler, "A Method Of Analysis Of Symmetrical Four-Port Networks," *IRE Transactions Microwave Theory Techniques*, Vol. MTT-4, October 1956, pp. 246-252.
2. L. Maloratsky and L. Yavich, *Design And Calculation Of Microwave Elements On Strip-Line*, Soviet Radio, Moscow, 1972.
3. L. Maloratsky and J. Ide, *Miniature Directional Coupler*, Patent USA #5, 424, 694, June 13, 1995.

EM-Based Models Improve Circuit Simulators

This new modeling approach uses full-wave analysis tools to obtain accurate models and operates at high speed to perform numerical techniques.

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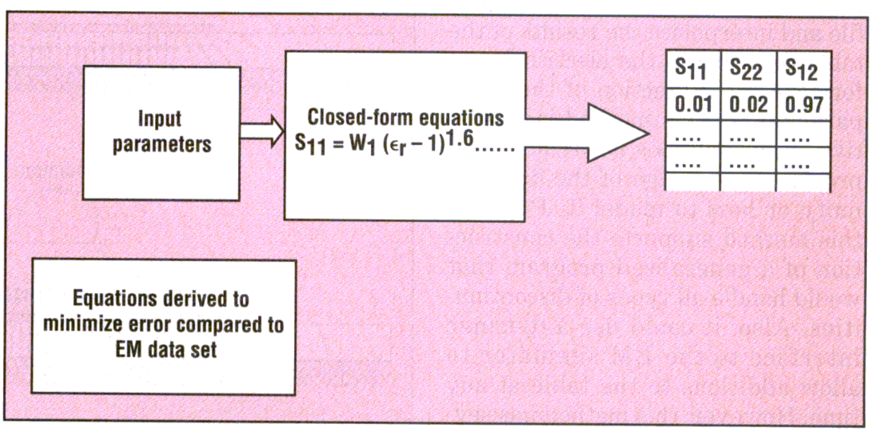
SOPHISTICATED software programs that model the RF electrical characteristics of individual components and overall systems are the cornerstone of modern high-frequency design. These programs have introduced several numerical techniques that improve design performance and manufacturing yield, but the techniques require the program to simulate the behavior of each component thousands—if not millions—of times. Modeling shortcuts have been devised to minimize simulation time, but they lose accuracy as frequency increases.

This article addresses a modeling approach that uses full-wave analysis tools to obtain accurate electrical discontinuity models while operating at speeds that are sufficient to perform numerical techniques such as optimization and design centering. The article presents a general discussion of the steps required to realize this type of system, and concludes with a sample implementation of this system as it models a microstrip lowpass filter circuit. The purpose of this article is to introduce this technique within a commercially available microwave computer-aided-design (CAD) package.

One impractical but obvious approach to creating electromagnetic (EM)-based models (Fig. 1) is to combine a circuit simulator with an EM simulator to automatically perform simulations of discontinuities based on the given input parameters. Unfortunately, this method is not computationally efficient enough to support tuning, optimization, or yield analysis of complex circuits. Despite the practical limitations, this method does have several significant advan-

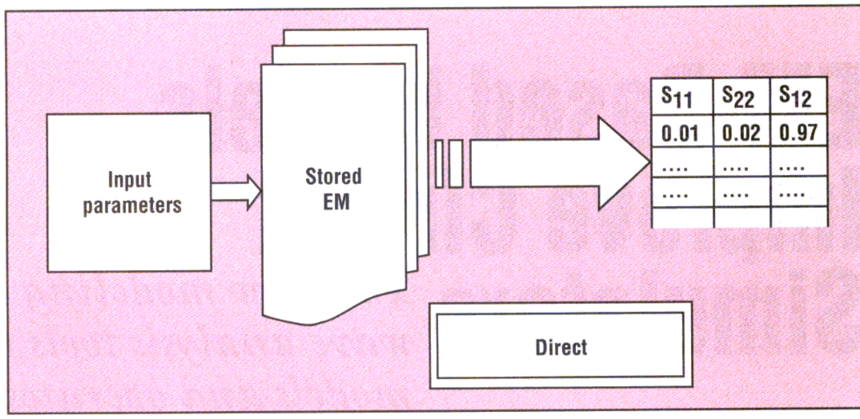


1. Closed-form equations are designed to minimize error when compared to EM simulations.

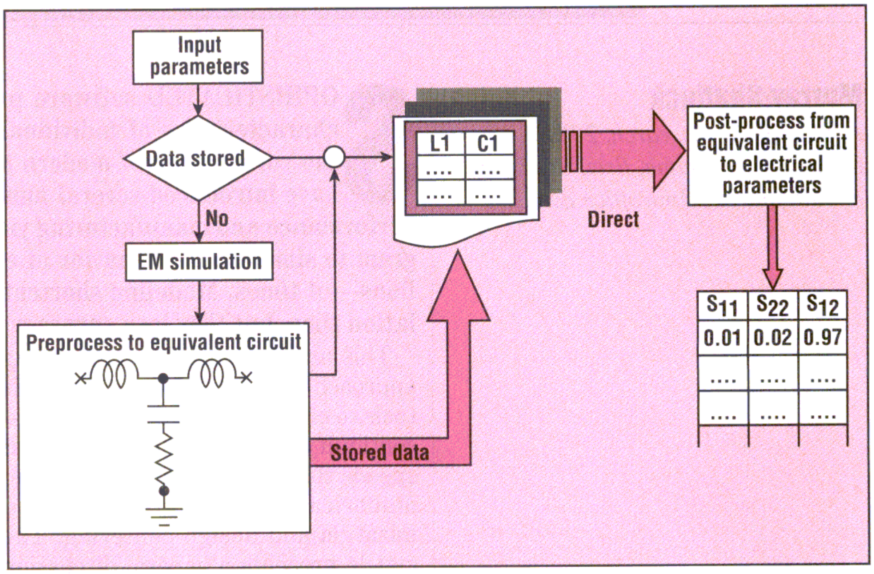
tages that drastically improve the design process for the user. First, the accuracy of the model is equivalent to the accuracy of the underlying EM simulation engine. Second, automatic generation of EM structures can save considerable time and eliminate human error. Lastly, the dynamic range of the discontinuity model can be improved to take into account a wider variety of dielectric materials and impedances than closed-form equations.

An alternative approach (Fig. 2) stems from the classical method of model development. Closed-form equations from an analytically solvable problem similar to the problem at hand are derived by mapping the input parameters into this closed-form solution. Based on a large amount of data, this mapping is modified to minimize error between measurements (EM simulations in this case) and the output of the model. Since the end result of this method is a closed-form equation, it results in a computationally efficient implementation that is ideal for the high number of evaluations required by the circuit simulator. In theory, this method of model generation has numerous advantages and would be the perfect solution, except for one drawback: it is a non-systematic approach of model development. Each model must be addressed individually, and the accuracy and quality of the model strongly depends on the developer's ability to choose suitable equations to map the input parameters.

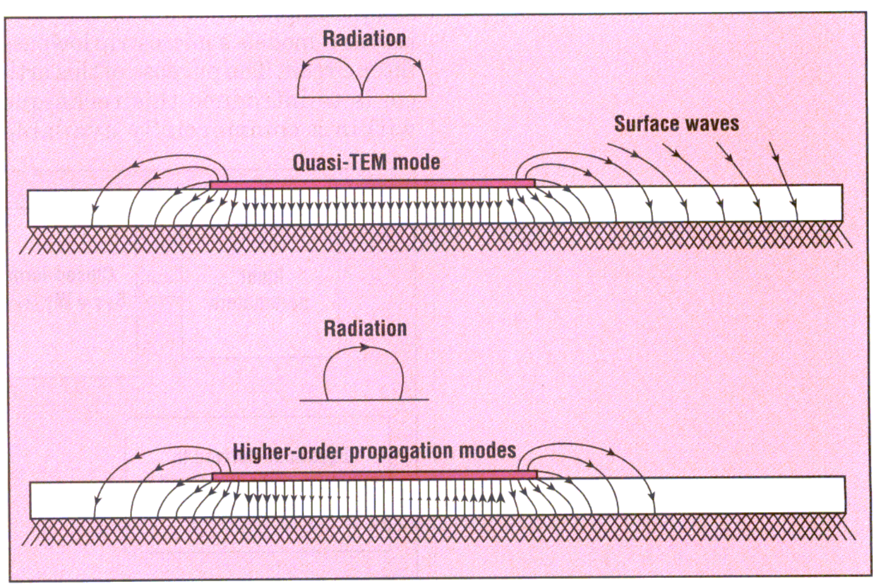
Yet another possibility is to store the results of the EM simulations in a file and interpolate the results of the table to estimate the electrical performance as a function of the input parameters. This method is attractive because it does not require any previous knowledge of the discontinuity or how to model it. Further, this method supports the construction of a generalized program that would handle all types of discontinuities. Also, it could use a dynamic interface to the EM simulator to allow additions to the table at any time. However, this method has several major problems that complicate its application. The composite electri-



2. This diagram shows a parameterized model using direct interpolation of stored EM simulations.



3. This is a flow chart of the proposed EM-based discontinuity parameterized model.



4. This diagram shows a portion of the possible propagating modes on a microstrip line.

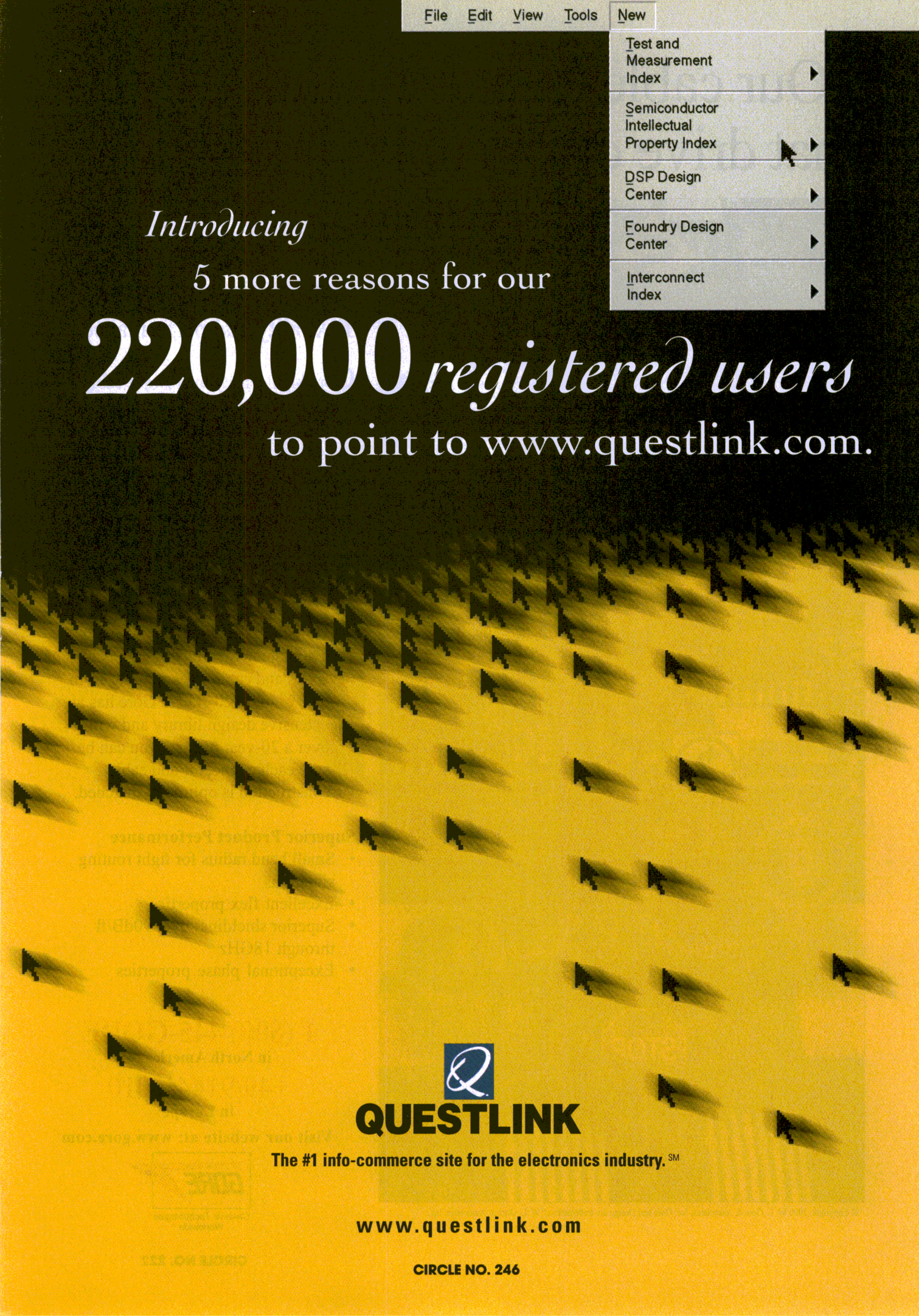
cal parameters can have quickly varying characteristics with the potential for step changes in parameters (for example S-parameter phase, or Y-parameters going to infinity). Interpolation across these types of discontinuities in the data can result in gross errors at these locations, which forces sampling of the input parameters on a finer interval. Finally, the amount of computer memory required to store the interpolation samples could quickly become unrealistic. This problem expands exponentially as the number and range of the input parameters are increased.

The approach used within Microwave Office's EM-based discontinuity models is a derivative of the last technique, which overcomes the disadvantages while retaining a systematic approach to the modeling process. In this approach (Fig. 3), the EM-simulated data are first preprocessed, resulting in the component values of a passive equivalent circuit. After correctly determining a suitable equivalent circuit, the resulting component values are noted to behave relatively benignly as a function of the input parameters and without discontinuous steps in value. The interpolation is then performed on these sampled component values and the resulting equivalent circuit is used to evaluate the electrical parameters of the circuit.

This approach allows the data to be sampled at a coarser interval, thus minimizing the number of EM simulations and the amount of computer memory required for a particular simulation. In addition, this approach provides some physical interpretation of the ongoing changes as a function of the input parameters, supporting a better grasp of the problem. Another benefit of this type of modeling is that it always can be constrained so that the resulting output electrical parameters are representative of a causal system that conserves energy. In the interpolation of S-parameters, for example, it is possible and highly likely that the resulting system will create energy at some interpolation points. This is especially true when the modeling of lossless discontinuities as an interpolation error creates loss on one side while creating gain on the other side. Processing the problem as an equivalent circuit eliminates this problem. Further, if loss is to be included in the model, resistive terms can be added to the model.

One must control the size of the data base by limiting the range of the input parameters. The allowable range of the independent input parameters and the sample frequency determine the quantity of data within the filled interpolation data base. In the case of the selected interpolation model, the required sampling for a particular error tolerance depends on the complexity of the interpolation method and the local stability of the function being interpolated. Selection of input-variable ranges should be studied in the context of several frames of reference. First, one must look at the parameter as seen by the end user and consider what he or she considers to be a reasonable range. Secondly, one must take a close look at the capabilities of the EM simulator and determine over what range reliable data can be obtained using an automated-collection process. Finally, one should look at the physical properties of the discontinuity to determine the limits of single-mode propagation.

Single-mode propagation is usually the limiting factor and often occurs at input-variable values that are lower than the user desires. However, once multimode propagation is reached, the entire modeling system, as proposed, begins to introduce significant errors. If one of the transmission lines constructing the discontinuity supports more than one propagating mode, the circuit simulator will inaccurately predict the circuit interactions because it does not support multimode propagation within the other models. To support this system, the EM simulator would be required to determine the generalized scattering matrix of the discontinuity, separating each mode into an effective electrical port. Further, the circuit simulator would have to support multimode excitation of all models. Beyond the guided modes of a conductor, one must also investigate the alternate modes of propagation such as radiation and the excitation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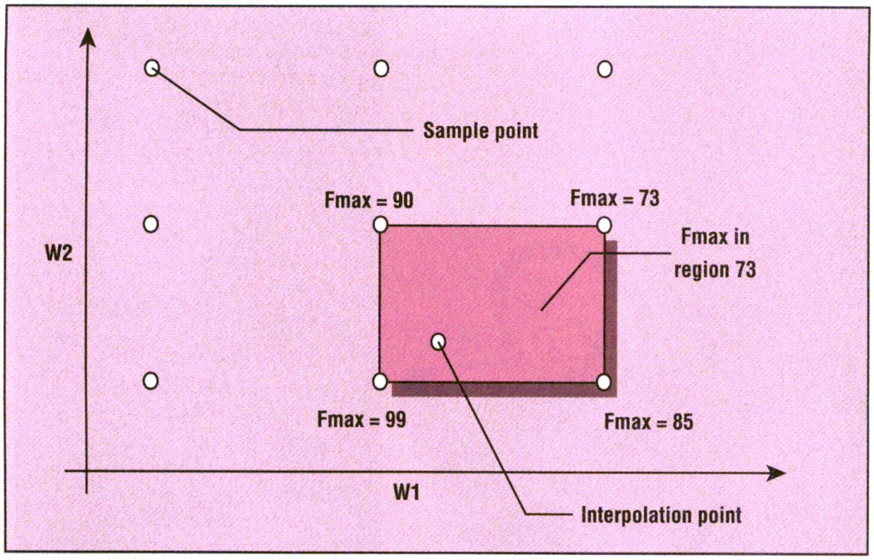
of dielectric-waveguide modes or surface waves. Figure 4 depicts a portion of the possible propagating modes on a microstrip line. Depending on the type of EM simulator used, excitation of these modes can result in significant errors in the electrical parameters, thus propagating errors into the model. As multimode guided propagation is approached, the electrical parameters begin to behave violently, significantly varying from the desired response of the junction. All of this indicates that the upper limit of the input variables should be set before this occurs. Although this often disappoints the user, implementation of such a limit is in his or her best interest and will result in better designs.

For a particular set of discontinuity dimensions, excitation of these undesired modes is typically a function of frequency. Thus, choosing the upper frequency limit is in direct conflict with selecting the ranges of the dimensional parameters. If the finite frequency limit is set for a particular substrate, the conflict between frequency, dimensions, and the user's desires is not resolved. Consider a microstrip step example. If a user is working at 70 GHz on 100 μm GaAs, the width limitation for this discontinuity, based on elimination of higher order modes, may be 100 μm. However, a different user working at 20 GHz on the same substrate should not have that same limitation.

In an attempt to resolve this problem, the author takes the following approach, illustrated in a two-dimensional sense in Fig. 5. For each EM simulation and at a particular set of dimensions, estimates of the onset of higher-order modes and limitations due to the EM simulator are obtained. The limitation with lowest frequency is then reduced by a certain percentage to avoid problems at its onset. EM simulation then proceeds to this frequency limit, and the frequency limit is stored within the interpolation table. Upon interpolation of the electrical parameters, the lowest frequency limit of all points used in the interpolation determines the upper frequency limit within that space. Since these limits are dynamic and require significant calculations, a



5. This graphic shows a method of determining the upper frequency limit within an interpolation cell.

system of warning the user of the changing limit is required.

A complete system of EM-based discontinuities using the described system has been implemented in microstrip. This system uses a three-dimensional (3D), planar, full-wave EM simulator incorporating the spectral-domain method of moments (MOMs). The system has also been interfaced to the Microwave Office 2000 simulation environment through the user-accessible modeling interface. To test the models, a user would ask, "What type of difference will these EM-based discontinuity models have on a real-world circuit with multiple discontinuities?" To test this, a simple lowpass filter circuit with a cutoff frequency of 5.5 GHz was designed in 30-mil microstrip with Er = 2.94. The filter design consists of multiple microstrip discontinuities, including MTEEs, MSTEPs, MBENDS, and MOPENS. The circuit was modeled with the closed-form and EM-based models. Figures 6 and 7 show a layout and photograph of the lowpass filter.

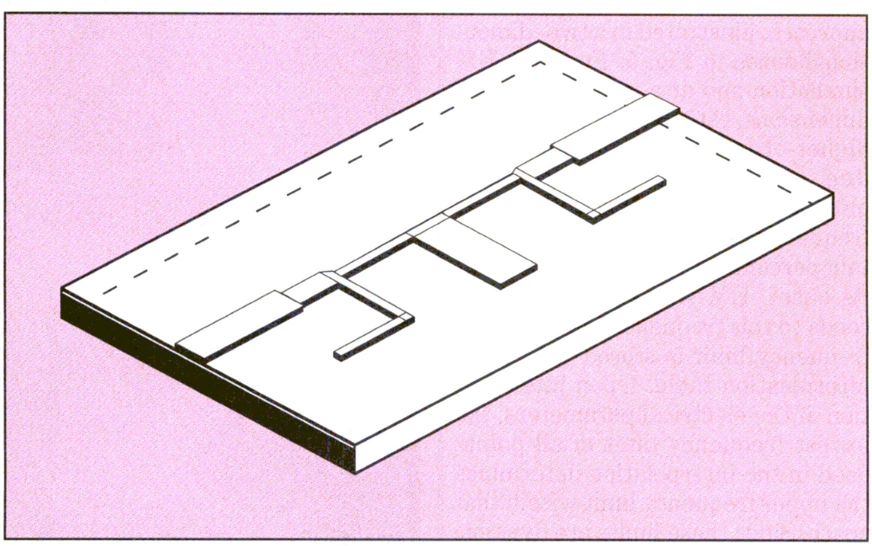
It should be noted that this circuit was designed to operate at frequencies where the closed-form models have degraded. Due to the fabrication materials and processes available, tests were conducted on 30-mil substrates with a relative dielectric constant of 2.94 at frequencies up to 10.5 GHz. While not an extremely high frequency, the scale of the discontinuities tested supports multimode propagation at 13 GHz on the widest lines. If one were to scale these tests to a 10-mil substrate, test frequencies of 31.5 GHz would be required. Using a 100-μm substrate, test frequencies would exceed 80 GHz.

The fabrication and test processes can introduce errors that cause the measurement to differ from the simulations. These include calibration errors, variations in the dielectric constant of the substrate, and dimensional variations in the etching process. Calibrations were made at the end of the SMA connectors on a vector network analyzer (VNA), but the transitions from coax to microstrip were not removed. Further errors should be expected from the effects of inter-element coupling and radiation.

Figure 8 includes a rectangular plot of the circuit simulations and filter measurements. The use of the EM-based models significantly improves the accuracy of the simulation in the passband of the filter. In fact, the discrepancies between the measurement and the circuit simulation could easily be explained by the uncalibrated coax-to-microstrip transition. In the stopband, however, the measurement shows some significant variations from both circuit simulations. This is especially true near the transmission nulls that are caused by the two open-circuited stubs. It is in these regions, where high currents are present on the shunt stubs, that radiation and cou-

Parameter tolerances for yield analysis

Parameter	Nominal value	Tolerance	Distribution
ϵ_r	2.94	2 percent	Uniform
H	30 mil	±1 mil	Uniform
Etch	0	±1 mil	Uniform



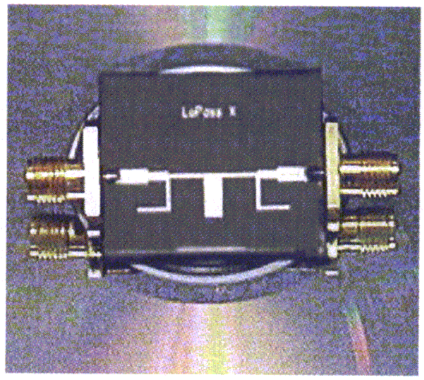
6. This is the layout of the prototype lowpass filter.

pling between the circuits are highest. A full-wave EM simulation of the filter has shown these effects, verifying that conclusion.

With improved confidence in the circuit simulations using the EM-based models, one can harness the Monte Carlo analysis available within Microwave Office to evaluate the sensitivity of the design to fabrication tolerances. Figure 8 also shows the statistical variation in the scattering parameters using the EM-based models. Three input parameters were assigned the tolerances shown in the table.

The variable "etch" refers to the fabrication process that is used to pattern the conductor. The line widths and lengths are modified through equations in the circuit simulator to reflect the appropriate changes in an over- or under-etched condition.

Yield analysis shows that the stopband is not extremely sensitive to manufacturing tolerances. Therefore, one would expect that, even with the coupling and radiation effects predicted by the full-wave simulation, these effects are relatively immune to fabrication tolerance. The passband, on the other hand, experiences some dramatic changes with the specified tolerances. From this point, one could perform various other analyses available within Microwave Office to improve the design. Examples include performance optimization to improve the nominal response, or design centering to optimize the yield for a particular set of manufacturing tolerances. It is in this regime that the EM-based models show their advantage over full-wave EM simulation, and result in an improved design.



7. This is a photograph of the prototype lowpass filter.

It has also been shown that the EM-based discontinuity models offer significant improvements in the accuracy of circuit simulations. With this new accuracy, one can have increased confidence in the numerical optimizations and yield analysis performed within the circuit simulator. The benefits of EM-based discontinuity models within the Microwave Office simulation environment are clear from this example. However, the EM-based discontinuity models will not replace the usefulness of the EM simulator to evaluate the effects of radiation and inter-element coupling. Ultimately, it is the intelligent application of multiple

IS-95 CDMA and cdma2000

Vijay K. Garg

IS-95 CDMA and cdma2000 covers two of the key standards for modern digital wireless communications systems: Interim Standard 95 (IS-95) code-division multiple access (CDMA) and cdma2000. The text provides guidelines for parameters of a CDMA network and outlines a migration path for CDMA to third-generation (3G) CDMA systems.

The book's opening chapter introduces the reader to the major attributes of CDMA and access technologies that are used for cellular personal communications services.

The second chapter reviews the different types of spread-spectrum (SS) systems currently employed in modern communications systems.

Chapter 3 discusses the digital voice-encoding systems for CDMA and wideband CDMA.

Chapter 4 discusses the concepts of diversity reception where multiple signals are combined to improve system signal-to-noise ratio (SNR).

Chapter 5 covers the functional entities of the wireless network and the interfaces between them.

Chapter 6 presents a high-level description of the IS-95 CDMA air interface.

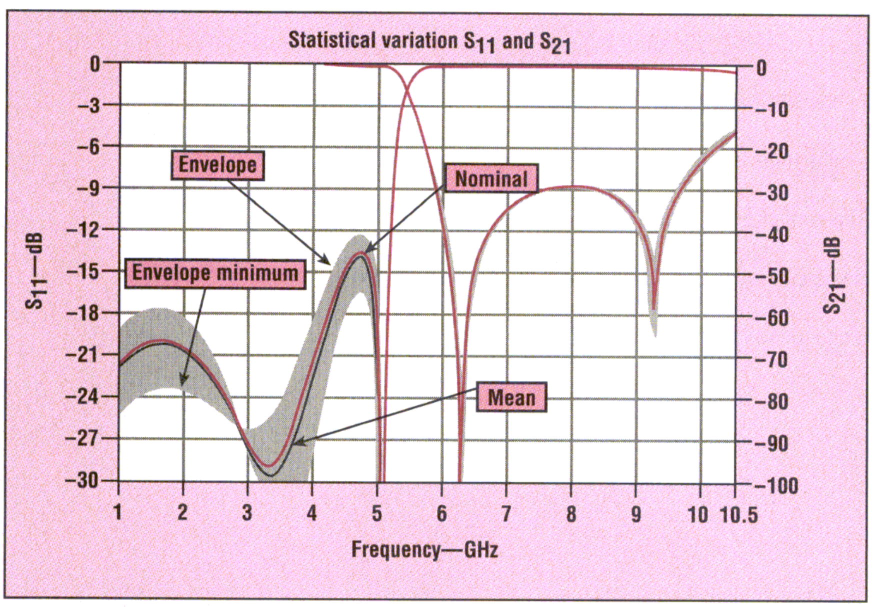
Chapter 7 covers how to introduce a CDMA carrier in an existing Advanced Mobile Phone Service (AMPS) or time-division-multiple-access (TDMA) system.

Chapter 8 discusses the IS-95 call-processing states that a mobile station goes through in getting to a traffic channel while Chapter 9 reviews the layering concept protocols for IS-95 CDMA.

Chapters 10 and 11 cover soft handoff and power control and the parameters used to identify a mobile station.

Chapter 12 presents the basic guidelines for engineering a CDMA system including propagation models, link budgets, and link capacity. Chapter 13 reviews the procedures for calculating the capacity of a CDMA system.

Chapter 14 reviews standards for data services supported by CDMA cellular PCS systems presenting highlights of the Telecommunications Industry Association (TIA) IS-99, TIA IS-637, and TIA IS-657 standards while Chapter 15 is dedicated to a review of cdma2000 radio-transmission technology (RTT) that uses CDMA to satisfy the needs of #G wireless communication systems. (2000, 423 pp., hardcover, $75.00, ISBN: 0-13-087112-5.) **Prentice Hall PTR, One Lake St., Upper Saddle River, NJ 07458; (800) 382-3419, FAX: (201) 236-7141, Internet: http://www.phptr.com.**



8. This is a rectangular plot of the circuit simulations and filter measurements.

simulation methods that result in the best-performing designs and the fastest time to market.

For further reading

Fang Wang, Vijaya K. Devabhaktuni, and Q.J. Zhang, "A Hierarchical Neural Network Approach To the Development of Library of Neural Models for Microwave Design," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 46, No. 12, December 1998, pp. 2391-2403.

P.M. Watson, K.C. Gupta, and R.I. Mahajan, "Development of Knowledge Based Artificial Neural Network Models for Microwave Components," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 46, No. 5, May 1998.

John W. Bandler, Mostafa A. Ismail, Jose Ernesto Rayas-Sanchez, Qi-Jun Zhang, "Neuromodeling of Microwave Circuits Exploiting Space-Mapping Technology," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 47, No. 12, December 1999, pp. 2417-2427.

Norbert H.L. Koster and Rolf H. Jansen, "The Microstrip Step Discontinuity: A Revised Description," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-34, No. 2, February 1986, pp. 213-223.

Akifumi Nakatani, Stephen A. Maas, and Jesse Castaneda, "Modeling of High Frequency MMIC Passive Components," *IEEE MTT-S Digest 1989*, pp. 1139-1142.

Brian Easter, "The Equivalent Circuit of Some Microstrip Discontinuities," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-23, No. 8, August 1975, pp. 655-660.

Mohamad D. Abouzahra, "On the Radiation from Microstrip Discontinuities," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-29, No. 7, July 1981, pp. 666-668.

Peter Benedek and Peter Silvester, "Equivalent Capacitances for Microstrip Gaps and Steps," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-20, No. 11, November 1972, pp. 729-733.

Peter Silvester and Peter Benedek, "Equivalent Capacitances of Microstrip Open Circuits," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-20, No. 8, August 1972, pp. 511-516.

Peter Silvester and Peter Benedek, "Microstrip Discontinuity Capacitances for Right-Angle Bends, T Junctions, and Crossings," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-21, No. 5, May 1973, pp. 341-346.

Alistair F. Thomson and Anand Gopinath, "Calculation of Microstrip Discontinuity Inductances," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-23, No. 8, August 1975, pp. 648-654.

M. Kirschning, R.H. Jansen, and N.H.L. Koster, "Measurement and Computer-Aided Modeling of Microstrip Discontinuities By An Improved Resonator Method," *IEEE MTT-S International Microwave Symposium Digest*, May 31-June 3, 1983, pp. 495-497.

Brian C. Wadell, *Transmission Line Design Handbook*, Artech House, Boston, MA, 1991, pp. 289-330.

K.C. Gupta, Ramesh Garg, Inder Bahl, and Prakash Bhartia, *Microstrip Lines and Slotlines*, Artech House, Boston, MA, 1996, pp. 179-200 and pp. 255-263.

K.C. Gupta, Ramesh Garg, and Rakesh Chadha, *Computer-Aided Design of Microwave Circuits*, Artech House, Boston, MA, 1981, pp. 189-197.

Douglas C. Montgomery, *Design and Analysis of Experiments*, John Wiley & Sons, New York, 1997.

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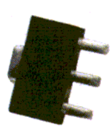

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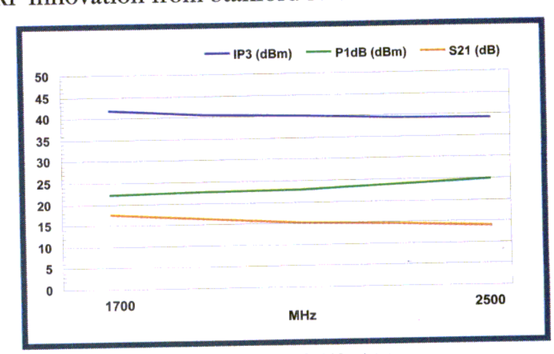

Typical device performance. Bias =5V @ 110mA typ.

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CIRCLE NO. 207

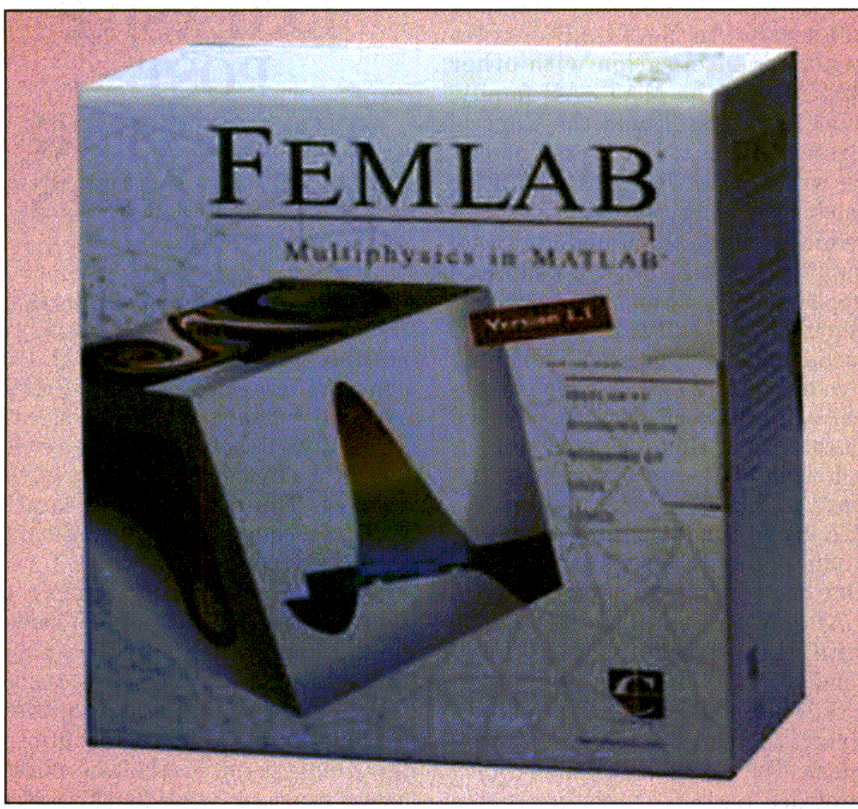
Software Simplifies Physical Modeling

This tool enables users to solve problems in chemical and electrical engineering, structural mechanics, and multidisciplined areas using partial differential equations.

PARTIAL DIFFERENTIAL EQUATIONS (PDEs) ARE THE mathematical foundations for a host of important areas in engineering and physics. Electromagnetics, structural mechanics, fluid dynamics and heat transfer are a few examples of areas that are described with PDEs. FEMLAB from COMSOL, Inc., (Burlington, MA) simplifies the application of PDEs to these complex problems, using the well-established finite-element method of analysis.

FEMLAB (see figure) was designed for PDE-based multiphysics modeling, simulation, parametric analysis, and optimal design on a desktop personal computer (PC) or Unix workstation. The program is shipped with a large library of predefined models for chemical, electrical, and mechanical engineering.

The equation-based foundation of



FEMLAB *is a powerful problem-solving program based on the use of partial differential equations within the MATLAB environment.*

Software Simplifies Physical Modeling

the software enables simulation in an extremely broad range of scientific and engineering fields. Some of the application areas include electromagnetics, fluid dynamics, structural mechanics, heat transfer, chemical reactions, semiconductor simulation, and wave propagation. Each mode is based on its particular PDE model. In a physics mode, the desired model can be set up without any explicit formulation of the underlying PDE. The multiphysics capabilities of the program make it possible to combine any set of physics modes and equation-based modes, providing full freedom in modeling. Model libraries include acoustics, chemical engineering, electromagnetic (EM), and equation-based along with fluid dynamics, geophysics and heat transfer. Other libraries include semiconductor device models, structural mechanics, and wave-propagation models.

FEMLAB is designed to run on top of MATLAB from The Mathworks, Inc. (Natick, MA). The close connection to MATLAB enables seamless integration with other products in the MATLAB family, such as Simulink and the Control System Toolbox. For users unfamiliar with MATLAB and its application modules, the basic program is a high-level mathematical modeling tool supported with a host of dedicated applications programs. For example, Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Models developed in FEMLAB can be saved as MATLAB functions for parametric studies or iterative design purposes. One can export models to the MATLAB environment for incorporation with other products in the MATLAB family.

For modeling, Simulink provides a graphical block-diagram environment. The Control System Toolbox provides functions specialized to control engineering, and is a collection of algorithms, which implements common control-system design, analysis, and modeling techniques. By combining FEMLAB with Simulink or the Control System Toolbox, it is possible to use highly accurate models of physical phenomena in the simulations or systems design.

The FEMLAB software allows operators to seamlessly move between an equation-based interface and the physics applications, where models are built using properties that are tailored for the specific application area. Any combination of physics applications and equation-based applications are supported, thereby providing the freedom of multiple modeling approaches. By using the interface between FEMLAB and Simulink, it is a simple matter to explore these accurate physics models in a dynamic simulation environment. The result is an accurate model of a complex multidisciplinary physics system.

THE FEMLAB PROGRAM IN COMBINATION WITH MATLAB PROVIDES EXTENSIVE POST-PROCESSING CAPABILITIES.

The FEMLAB program brings the power of numerical analysis into multiphysics applications through an interactive interface. Many models can be built through the physical quantities involved, rather than the equations describing them. Users can model intense nonlinear-coupled multiphysics applications with ease. There is no inherent limitation on simultaneous simulation of many physical phenomena. The program's solvers handle the conversion to equations and their solution in a fully automated way. Users create models through a graphical user interface (GUI) or by writing custom MATLAB, C, or Fortran code.

The FEMLAB program in combination with MATLAB provides extensive post-processing capabilities. Several solutions can be visualized at the same time using colored surfaces, contours, lines, streamlines, height, and vector field plots. One can save and load models developed in the GUI either as binary code in a model MAT file or as a MATLAB M-code in an M-file.

The FEMLAB application program interface (API) allows users to write MATLAB functions and methods to create customized GUI components for specific applications. The programs large model library contains completed models from different application areas. The models can be used to acquaint one with the programs operation and serve as a starting point for building new models.

The hard-copy documentation furnished with the program is excellent with many examples and tutorials. Included are a users guide and introduction, a reference guide, structural-mechanics guide, an application-interface guide, and a model- library manual. Also included are an automatic-control manual for heat experiments and a computational-electromagnetics manual.

The PC version of the program requires a computer with Windows 95, Windows 98, Windows NT 4.0, or Windows 2000, MATLAB Version 5.3, a minimum of 16-b color graphics capability, and a minimum of 128 MB of random-access memory (RAM). P&A: $2995 single-user license Windows. **COMSOL, Inc., 8 NE Executive Park, Suite 310 Burlington, MA 01803; (781) 273-3322, FAX: (781) 273-6603, e-mail: info@comsol.com, Internet: http://www.comsol.com, http://www.femlab.com.**

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ALAN ("PETE") CONRAD
Special Projects Editor

CD-ROM Contains Powerful Analysis Tools

This free collection of software tools includes a capacitor modeling software program and a multilayer circuit-design program based on low-temperature-cofired-ceramic (LTCC) foundry services.

CAPACITOR MODELING TOOLS CAN EXPEDITE THE design process for selecting the right capacitor to suit a particular circuit. Version 3 of CapCad is such a tool, and it is offered free of charge as part of a complementary compact-disc-read-only-memory (CD-ROM) software and data collection from Dielectric Laboratories (Cazenovia, NY).

The handy capacitor program determines SPICE parameters and models S_{21} parameters, S_{11} parameters, Z-parameters, Y-parameters, quality factor (Q), or equivalent capacitance for single and multilayer capacitors. Modeling can be performed over temperature or frequency and the results can be saved and exported in standard SPICE (S2P)-file format.

The main toolbar in the CapCad Version 3 contains 11 buttons that provide direct selection of the menu items. The first button will open an existing S2P data file for viewing. The remaining buttons provide the user with a choice of seven capacitor types and a bias-filter-network design. Capacitor types include the company's DiCap, T-Cap, Border Cap, and Gap Cap models, along with many multilayer capacitors. In addition, a miniature RF blocking network and a broadband DC block are available for modeling purposes.

All of the capacitor selection windows allow users to specify selected parameters for a capacitor to be modeled. These include size, voltage rating, material, capacitance, tolerance, and termination impedance. A parameter can be changed by selecting the desired parameter type with a mouse click or by using the tab key, and then selecting a value from the drop-down list. Changing the associated section of a part number will also change a parameter.

Graphics plots are available for all of the components through the device plot window. The window defines the device for those parameters that are plotted with a choice of rectangular or Smith chart. Any two devices can be plotted for comparison. When two devices are selected, two device plot windows are visible. Device parameter data can be plotted over a frequency range at a fixed temperature or over a temperature range at a fixed frequency.

The CD-ROM offers DiPak™ Design Kit, a component model library that interfaces with the Series IV computer-aided-engineering (CAE) design suite from Agilent Technologies (Santa Rosa, CA). These models, with the CAE program, allow operators to design multilayer circuits based on low-temperature-cofired-ceramic (LTCC) foundry services. The DiPak Design Kit contains five libraries of simulation models, layout macros, design-rule-checking functions, schematic symbols, and palette bitmap files. P&A: free. **Dielectric Laboratories, Inc., 2777 Rte. 20 East, Cazenovia, NY 13035; (315) 655-8710, FAX: (315) 655-8179, Internet: http://www.dukabs.com.**

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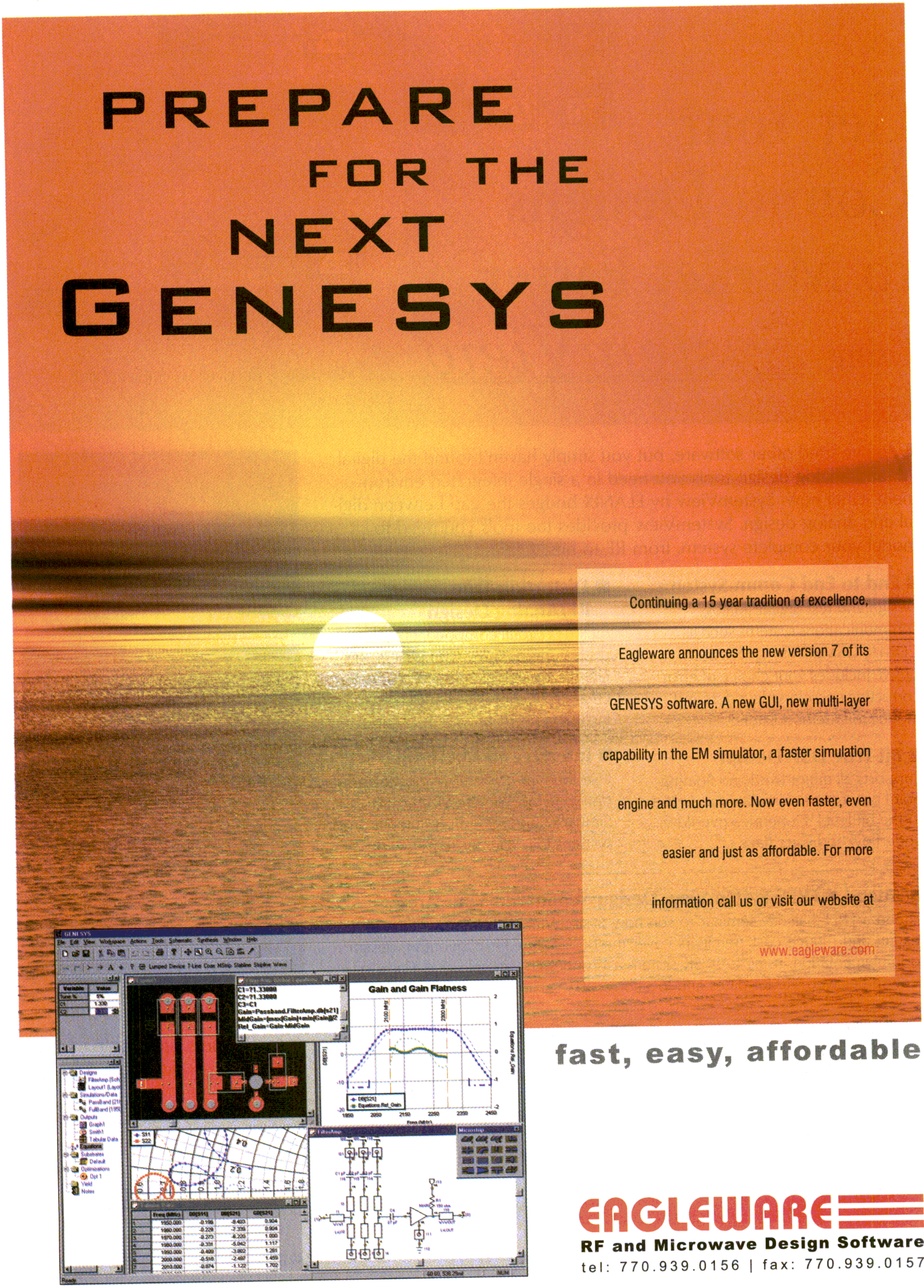

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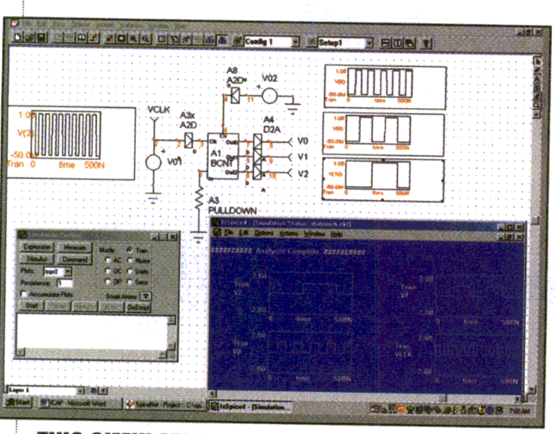
SPICE Program Sweetened With Features

The latest version of this full-featured SPICE package offers more than 14,000 models and a host of new features, including parameter sweeps and real-time waveform displays.

ANALOG AND DIGITAL DESIGNERS HAVE LONG agreed upon one thing: SPICE is a powerful simulation tool for both types of circuits. SPICE, which is an acronym for simulation program with integrated-circuit (IC) analysis, can be used for frequency- and time-domain analysis of mixed analog and digital circuits and systems. The latest version of IsSpice4 from Intusoft (San Pedro, CA) carries on the tradition of the original Berkeley SPICE program by remaining compatible with standard SPICE files and engines, such as the XSPICE simulator from Georgia Tech (Atlanta, GA). IsSpice4 is bundled with SpiceNet, a schematic-entry program that manages multiple-circuit configurations, and IntuScope, a programmable waveform viewer. The programs, along with more than 14,000 models, are integrated into a seamless package with the help of ActiveX technology from Microsoft.

More than 1000 new models have been added to the latest version of the software, including more than 50 new primitive digital elements, such as flip-flops and state machines and a new binary counter (see figure). The program also includes a 12-state logic simulator for simulation of full mixed-signal analog/digital circuits.



THIS SIMULATION SCREEN *shows a binary counter.*

Borrowing from the open-architecture XSPICE software, IsSpice4 incorporates new modeling options, including tools using a nonproprietary analog hardware-description language (HDL) based on C language. Similar to traditional SPICE models, the XDL models based on XSPICE (and now IsSpice4) are created with C subroutines. Code describing a model's behavior is linked to the simulator through an external file (Windows DLL) rather than being bound within the executable program. This allows new models to be added, and old models changed externally, without having to recompile IsSpice4.

The IsSpice4 simulator uses the Microsoft ActiveX technology to provide an automation interface allowing the simulator to be controlled with external scripts as well as the internal scripts implemented in Berkeley SPICE3. Intusoft is the only commercial SPICE vendor that implements and extends the script language introduced with Berkeley SPICE3. This allows IsSpice4 to make and record sophisticated measurements of circuit performance. The measurements include rise time, gain margin, or propagation delay. These automatic measurements are set up and made available to the user through the SpiceNet schematic package.

The simulator itself works by formulating the Kirchoff-current-law (KCL) equations, summing the cur-

SPICE Program Sweetened With Features

rents at each node in a network, and setting the result equal to a constant. This admittance matrix is modified in SPICE3 to set the independent voltage sources and in XSPICE to contain state variables. The matrix itself is referred to as a modified-nodal-admittance (MNA) matrix. For DC and operating-point analysis, the MNA matrix solution is iterated, and the new MNA values are recomputed for each iteration until a stable result is achieved. Certain circuits, such as flip-flops, can cause the simulator to oscillate between stable solutions. When this happens, the simulator uses certain heuristic techniques to stabilize itself.

For transient solutions, it is necessary to linearize a circuit about its nonlinear operating point at each time point. The dynamic circuit changes with time are accounted for by iterating the solution until the error estimate at the next time point is less than a preset amount. IsSpice4 uses several techniques to reduce the computational load, including forward prediction of the states and node voltages for the next time step and bypassing of the matrix-load operation for parts that have little or no change in their inputs.

AC analysis is considerably simpler. Once the operating point is established, a small-signal equivalent circuit is created and a single matrix solution is performed for each frequency. Since no iterations are required, the solution is exact, other than for errors created by the finite computer word length. AC analysis is therefore more precise and faster than transient analysis.

IsSpice4 is designed to work with SpiceMod, a SPICE modeling spreadsheet to create an unlimited number of SPICE models from a manufacturer's data sheets. SpiceMod produces accurate models that can be used with any Berkeley SPICE compatible program. SpiceMod is also integrated with ICAP/4, Intusoft's analog and mixed-signal circuit-design system. The models and subcircuits created in SpiceMod can be immediately used in SpiceNet schematic diagrams and IsSpice4 circuit simulations. The software documentation is excellent with easy-to-follow instructions and examples. P&A: $2984 and up; stock. **Intusoft, P.O. Box 710, San Pedro, CA 90733-0710; (310) 833-0710, FAX: (310) 833-9658, e-mail: info@intusoft.com, Internet: http://www.intusoft.com.**

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ALAN ("PETE") CONRAD
Special Projects Editor

System-Design Tool Augments Model Libraries

The latest edition of a powerful system-level software tool includes new communications function libraries along with contributions from numerous partners.

MILITARY AND COMMERCIAL SYSTEM DESIGNERS have found a useful tool in SystemView from Elanix (Westlake Village, CA). Since its introduction in 1991, this computer-aided-engineering (CAE) package for the personal computer (PC) has been used to model the behavior and performance of major systems. Now, the latest version of the package (Version 4.5) adds an advanced communications library to help designers of next-generation systems.

SystemView (see figure) incorporates functions and model libraries that allow users to design and develop advanced systems based on analog, RF, digital, and logic functions. Designs can include custom or predefined signal sources, external data files, or even real-time data. SystemView can readily model any of the advanced modulation formats used in modern communications systems, including frequency-shift-keying (FSK) modulation, quadrature-phase-shift-keying (QPSK) modulation, quadrature amplitude modulation (QAM), time-division-multiple-access (TDMA) schemes, and code-division-multiple-access (CDMA) schemes.

Version 4.5 of SystemView adds functions useful to engineers involved in CDMA system design, including a new Walsh code generator, encoder, and decoder. Plus/minus limit parameters have also been added to all opamp circuits, and an inductive-capacitive (LC) lowpass-filter model allows operators to design elliptical filters.

SystemView now contains the Real Time DSP Architect (RTDA), a software module which links with the Code Composer Studio development environment from Texas Instruments (Dallas, TX). This development environment and the RTDA include support for the TMS320C54x family of digital signal processors (DSPs), including the TMS320C59 and 5410 evaluation boards.

SystemView 4.5 includes integration with design tools from Xpedion Design Systems (Santa Clara, CA). Release 4.5 also includes new third-generation (3G) wireless design software developed in partnership with EnTegra Ltd.

This release of the software also includes a powerful digital-subscriber-line (DSL) analysis tool. The DSL software library enables developers of asymmetric DSL (ADSL), Second Generation High Data Rate DSL (HDSL-2), and related copper (Cu)-pair modems to easily test their designs. **Elanix, Inc., 5655 Lindero Canyon Rd., Westlake Village, CA 91362; (800) 535-2649, FAX: (818) 597-1427, e-mail: elanix@elanix.com, Internet: http://www.elanix.com.**

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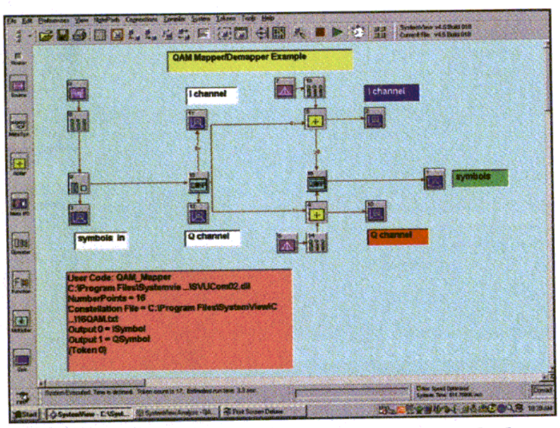

A TYPICAL DESIGN SCREEN *in SystemView includes symbolic tokens to represent various component and system functions and sources.*

ALAN ("PETE") CONRAD
Special Projects Editor

Math Program Adds Functions, Toolboxes

This widely used mathematical modeling program has added useful new functions as well as some optional toolboxes for communications systems and components.

MATHEMATICS IS THE BASIS FOR MOST HIGH-FREQuency analyses. It is also the basis for a software tool widely used by high-frequency design engineers, MATLAB from The MathWorks (Natick, MA). The latest version of this program offers an improved user interface, a number of enhancements, and several new optional toolboxes.

The latest version of MATLAB offers new features for enhanced support for integer data types. The program features reduced storage requirements and a new plot editor for interactive modification of figure properties and plot annotation. It also offers support for the new NASA standard Hierarchical Data Format-Earth Observing System (HDF-EOS) code. The program includes gateways to grid, point, and swath objects, support for reading and writing Portable Network Graphics (PNG) images, a suite of visualization functions for volumetric data, differential-equation solvers for mass matrices, a revamped, browser-based M-file profiler, and the capability to generate summary reports in HTML format.

MATLAB includes hundreds of functions for data analysis and visualization, numeric and symbolic computation, engineering and scientific, graphics, modeling, simulation, prototyping, programming, application development, and graphical-user-interface (GUI) design. Combined with the optional toolbox, Simulink, the program provides users with an interactive tool for modeling, simulating, and analyzing dynamic systems.

Simulink is also the host for additional toolboxes. These additional toolboxes include a quantized-filtering toolbox and a signal-processing toolbox. The former provides extensible design, analysis, and prototyping tools for fixed-point and custom precision floating-point filters used in digital-signal-processing (DSP) applications. It supports the simulation and bit-true analysis of these filters with a wide range of precision. In addition, a code-division-multiple-access (CDMA) reference blockset is available for Simulink. It contains a collection of Simulink blocks for creating and simulating the CDMA IS-95A standard systems for wireless communications.

A graphical event-driven simulation with stateflow capability allows an operator to graphically model event-driven behavior within Simulink. Stateflow simplifies the simulation of protocols, synchronization loops, and control-logic signals that activate the time-driven datapath components of complex signal-processing and communications systems. Other toolboxes are available for control design and analysis as well as additional signal and image processing. P&A: $1900 (MATLAB basic); stock. **The MathWorks, Inc., 3 Apple Hill Dr., Natick, MA 01760-2098; (508) 647-7000, FAX: (508) 647-7101, Internet: http://www.mathworks.com.**

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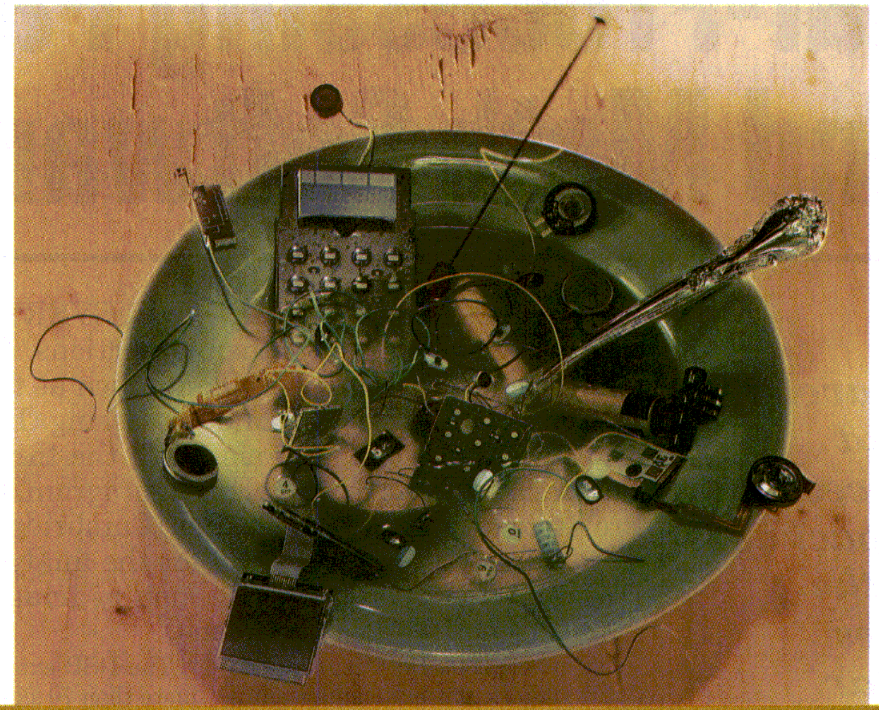
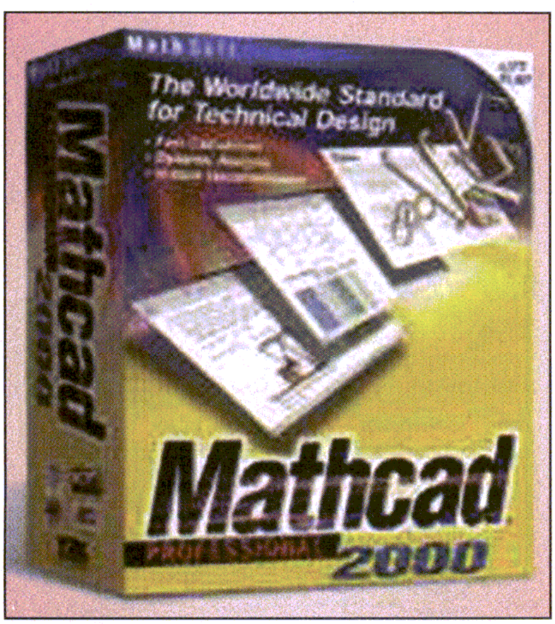


Signal-Processing Packs Extend Math Software

A trio of wavelet-, image-, and signal-processing extension packages enhances the capabilities of a popular mathematics-based analysis software tool.

MATH SOFTWARE IS USED FOR EVERYTHING FROM financial analysis to weather predictions. It is also useful for solving engineering problems such as the analysis and development of digital-signal-processing (DSP) algorithms for communications systems. With the three latest extension packages, the powerful math program, MathCAD 2000 Professional from MathSoft, Inc. (Cambridge, MA) becomes a creative and analytical tool for the analysis of advanced DSP functions, for the processing of images, and for the application of wavelet functions.

MathCAD 2000 Professional (see figure) offers a user-friendly environment for accurately solving and analyzing a broad array of technical problems. The software offers advanced math functionality and visualization capabilities to perform the most demanding calculations quickly and easily. Proprietary IntelliMath™ technology automates common routines for increased speed and productivity. MathCAD 2000 allows operators to integrate text, math, and graphics into a single worksheet to easily visualize and annotate complex calculations.



MATHCAD 2000 PROFESSIONAL *can be equipped with a number of new extension packs, including modules for image processing, DSP, and wavelets.*

MathCAD 2000 Professional's unique "live" interface automatically updates results, with minimal recalculation work. The program features easy-to-use equation entry and editing based on standard mathematical notation (rather than command-line programming), plus automatic unit conversion.

The DSP extension pack includes more than 70 signal-processing functions suited for audio and high-frequency electronics analysis as well as in telecommunications system analysis. A companion extension pack for wavelets features more than 60 wavelet functions that cover five orthogonal and biorthogonal families for use in signal reconstruction, noise reduction, data compression, and special numerical methods.

The image-processing extension pack, with more than 140 image-processing functions, provides a powerful solution for iterative exploration and investigative analysis. With its extensive image processing, analysis, and visualization capabilities, this extension pack is ideal for research scientists and engineers, design engineers, system analysts, and image specialists working on imaging or multimedia product development. P&A: $499.00; stock. **MathSoft, Inc., 101 Main St., Cambridge, MA 02142-1521; (617) 577-1017, FAX: (617) 577-8828, Internet: http://www.mathsoft.com.**

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ALAN ("PETE") CONRAD
Special Projects Editor

Designing VCOs and their buffers

Voltage-controlled oscillators (VCOs) are the tunable frequency sources widely used in communications receivers. An application note (AN1034) from California Eastern Laboratories (Santa Clara, CA) reviews the process by which designers choose their VCO topologies based on performance, size, and DC power requirements, and even provides a design example at 1.7 GHz using the company's UPA series of dual transistors.

The UPA series of silicon (Si) transistors mount two chips within a common six-pin surface-mount plastic package. The devices can be used as dual transistors or in a cascode configuration. One of the applications for the devices is for a VCO and buffer amplifier for cellular-telephone frequency synthesizers. In this type of application, the VCO must exhibit low phase noise in order to meet the requirements for digital modulation and bit-error rate (BER). The VCO must also operate on low supply voltages (below +3.5 VDC). The buffer amplifier is required to boost output power and provide load-pull isolation.

The UPA827TF is a member of the UPA family chosen for this VCO design. It provides low-noise performance past 3 GHz and features a gain-bandwidth product in excess of 12 GHz, which is more than enough for an L-band oscillator.

The application note follows the basic rules of low-noise oscillator design set forth by Ulrich Rohde in his fine article "Designing Low-Phase-Noise Oscillators" (from *QEX* magazine, October, 1994). The rules include: 1. Maximize the loaded quality factor (Q) of the tuned circuit in the oscillator; 2. Choose an active device that has a low-flicker corner frequency; 3. Maximize the power at the input of the oscillator; 4. Choose a varactor diode with a low equivalent noise resistance; and 5. Keep the voltage tuning gain to the minimum value required.

The application note reviews the choice of topology for the VCO design, using nonlinear circuit simulations to analyze the choices, as well as the choice of resonator, which turns out to be a coaxial resonator. A nonlinear model for the coaxial resonator is developed with the help of a free computer program called COAX available from Trans-Tech, Inc. (http://www.trans-techinc.com, Adamstown, MD).

The application note is available for download from the company's website at http://www.cel.com or free upon request from: **California Eastern Laboratories, Inc., 4590 Patrick Henry Dr., Santa Clara, CA 95054-1817; (408) 988-3500, FAX: (408) 988-0279, Internet: http://www.cel.com.**

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Applications suit a 40-GHz coaxial connector

Wideband applications require wideband interconnections. The K connector from Anritsu Co. (Morgan Hill, CA) is one such broadband interconnection, with a range in excess of DC to 40 GHz. It is compatible with other connector types including 3.5-mm and SMA connectors. An application note details the performance of the connector and applications for different configurations of the connector system. The application note is available free of charge from Anritsu Co. as part of a product catalog, "Precision RF & Microwave Components."

The K connector was first introduced in the early part of the 1980s. It brought continuous frequency coverage from DC to 40 GHz in a single interconnection, whereas components and systems had previous relied on more narrowband (26.5 to 40 GHz) waveguide interconnections to pass signals into and out of components. The K connector employs a precision glass bead in its launcher assembly that is appropriate for use with designs fabricated on soft Duroid as well as hard ceramic alumina substrates. The bead has a unique 0.30-mm center conductor that introduces minimal discontinuities, yielding better than 20-dB return loss at 40 GHz and better than 25-dB return loss below 18 GHz.

The K connector launchers do not rely on an epoxy pin to secure the center conductor, as commonly used in SMA connectors. Without the epoxy pin, the outer conductor remains solid, eliminating the leakage path common to pin-captivated coaxial connector designs. The K connector is available in a variety of configurations, including screw-in and flange-mount designs for use with packages and enclosures, and cable-mounted connectors.

For more on the K connector, ask for a copy of the product catalog. Copies of the catalog and its application note are free, from: **Anritsu Co., Microwave Measurements Div., 490 Jarvis Dr., Morgan Hill, CA 95037-2809; (800) ANRITSU, Internet: http://www.anritsu.com.**

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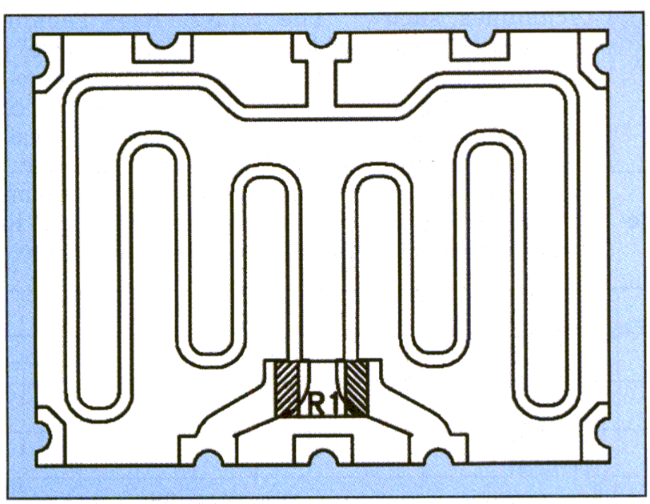
Technology Delivers High-Performance Components

A simple multilayer concept, yielding high performance and low cost, has been developed to shrink the many building-block components of RF front ends.

Synergy Engineering Staff
Synergy Microwave Corp., 201 McLean Ave., Paterson, NJ 07504; (973) 881-8800, FAX: (973) 881-8361, e-mail: sales@synergymwave.com, Internet: http://www.synergymwave.com.

MINITURIZATION drives many high-frequency designs. Compact components are needed not only to make handsets smaller and power efficient, but also to make infrastructure equipment, such as line-of-sight radios and cell sites, as unobtrusive as possible. After evaluating the many transmission-line approaches available to them, the engineers at Synergy Microwave Corp. (Paterson, NJ) chose to develop one of their own, a patent-pending approach to high-frequency circuitry known as SYNSTRIP® Technology. The technology has already been applied to the fabrication of extremely compact power dividers/combiners and broadband high-frequency mixers in support of the high-frequency drive for miniaturization.

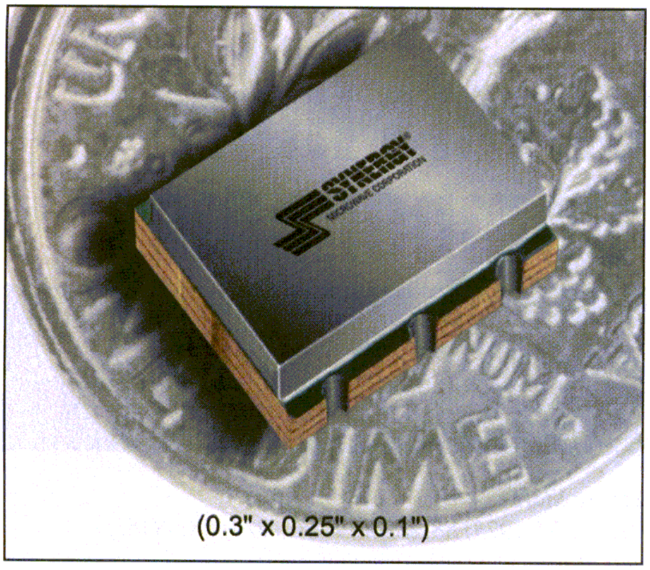
The demands for smaller wireless systems require smaller RF/microwave function blocks without compromising performance. A key is to realize the ultimate design through cost-effective fabrication techniques. A variety of planar transmission structures are available for high-frequency designers attempting to develop miniature surface-mount components. These structures include microstrip, stripline, suspended stripline, and coplanar waveguide. Substrate materials with high dielectric constants as well as multilayered circuit approaches have also been attempted in efforts to achieve true miniaturization of RF/microwave components. RF/microwave multilayer technology is considerably different from conventional multilayer approaches associated with, for example, personal computers (PCs), in that it is necessary to extensively model the layers in an RF/microwave design, including the polyamide layer that separates the transmission-line layers.



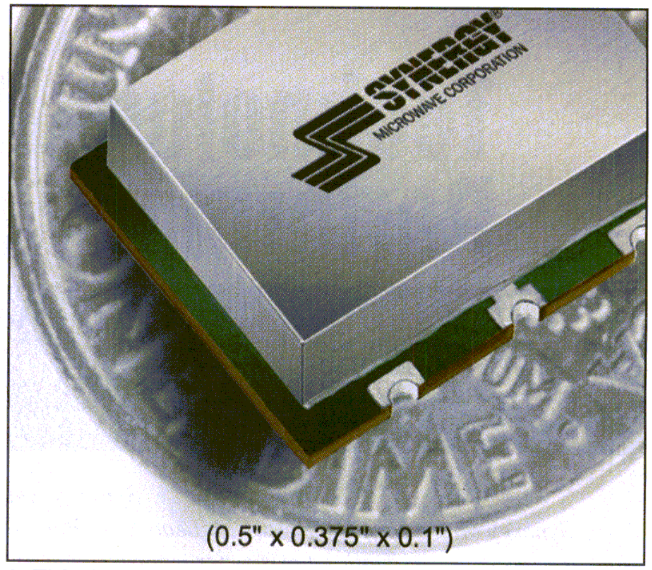
1. This is a conventional layout for a two-way power splitter for cellular-band applications designed with microstrip.

Fortunately, the advent of three-dimensional (3D) electromagnetic (EM) simulation software is making the task to a great extent simpler to the designer. However, in a commercial market, the chosen technology should ultimately lead to smaller size through standard low-cost fabrication processes that assure a high degree of repeatability and provide the required performance.

SYNSTRIP Technology provides an ideal



2. Two-way power splitters for the GSM cellular band and the PCS band were developed with the new SYNSTRIP Technology.



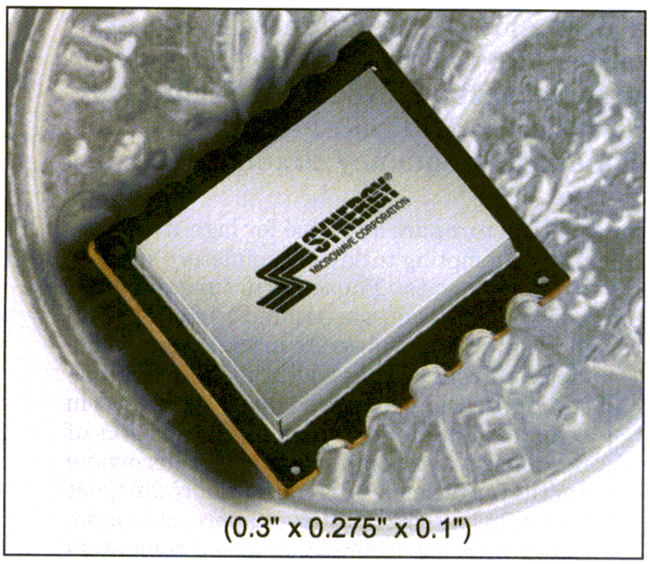
3. This four-way power splitter was developed for applications from 1800 to 2200 MHz using the new SYNSTRIP Technology.

solution to this pressing problem. The technology has led to the realization of miniature power splitters and broadband RF/microwave mixers with high levels of performance. The circuits are fabricated on low-cost, ceramic-filled soft substrates using standard printed-circuit-board (PCB) fabrication processing.

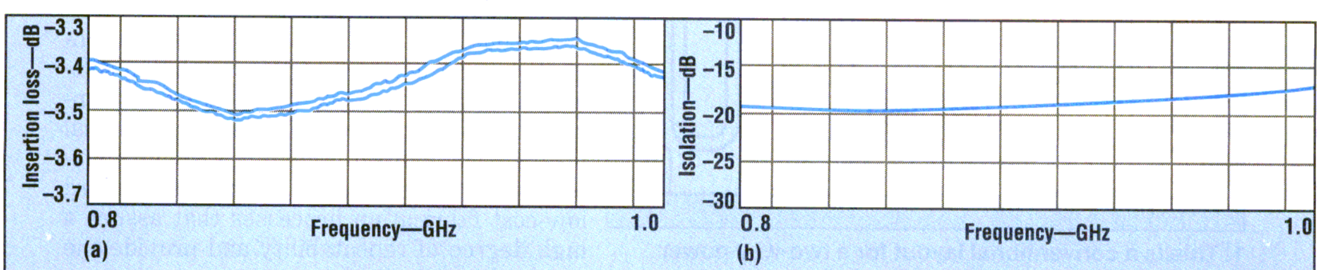
The salient feature of Synergy's SYNSTRIP Technology is that it has brought about a fusion of well-known planar transmission-line techniques, such as microstrip and stripline. RF/Microwave energy propagation in a "mixed mode" is the key to achieving a reduction in size without sacrificing performance. Figure 1 shows the layout for a two-way power splitter for cellular-band applications designed with conventional microstrip. The smallest size possible with this approach is 0.5 × 0.375 in. (1.27 × 0.95 cm). The meandering lines are evident at a number of points, leading to coupling between lines and resulting in discontinuities (and degradation in performance). In order to achieve reasonable performance, the coupling effects must be accurately modeled and accounted for in the final design.

MIXED MODE

The SYNSTRIP Technology, which uses the "mixed-mode" propagation concept, eliminates these problems. The mixed-mode concept enables a designer to optimally distribute a circuit in different layers involving different transmission media. The meandering of lines is greatly reduced, thereby avoiding



4. The SYNSTRIP Technology was used to create an extremely compact balun design for broadband double-balanced RF/microwave mixers.



5. The measured performance of the two-way power splitter is well suited for cellular and PCS applications.

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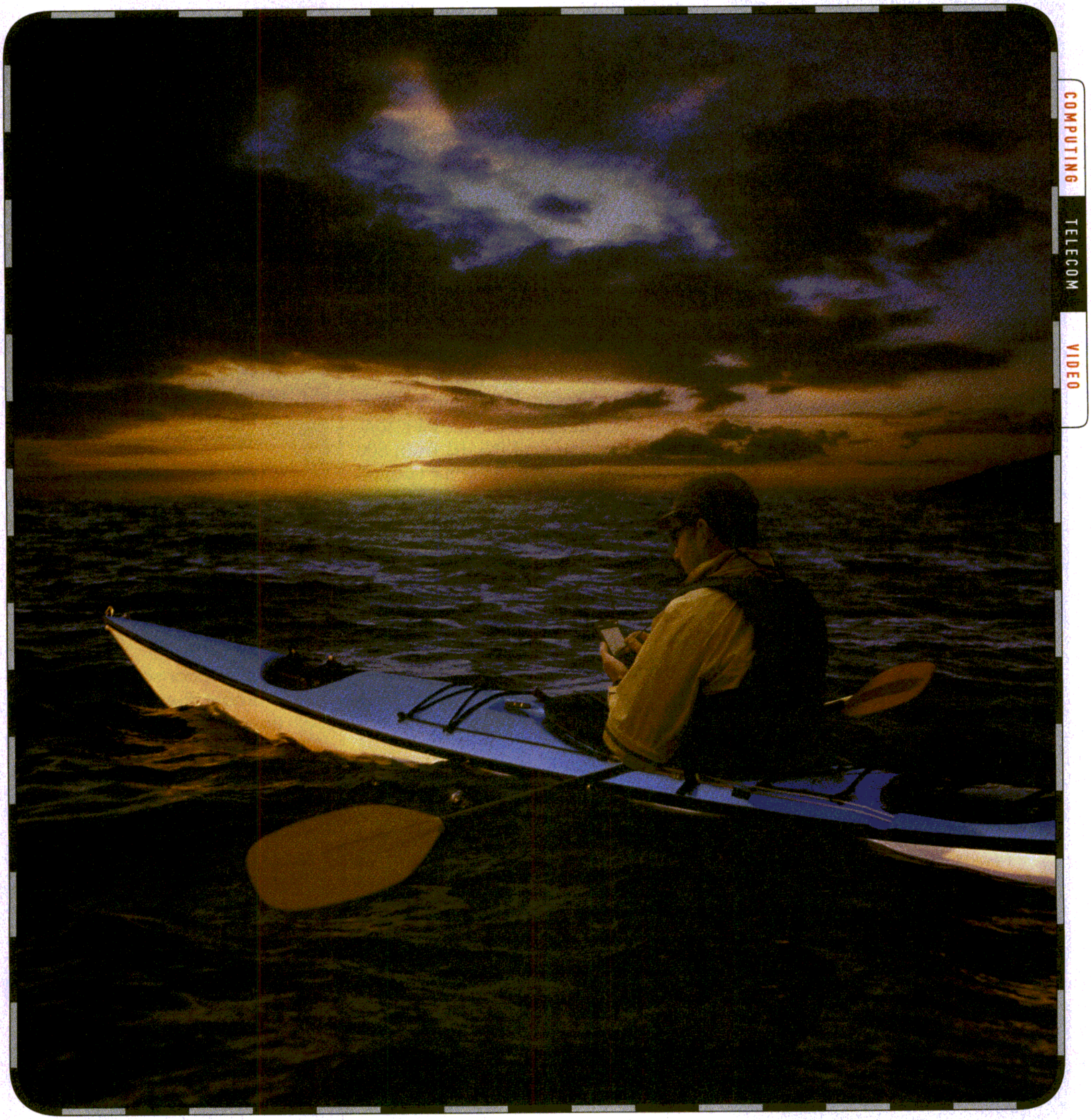
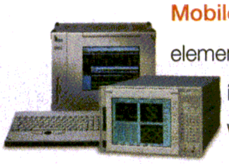
But got bread and milk instead. Isn't 3G great?





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coupling effects and discontinuities. The SYNSTRIP Technology has been applied to the successful design of two- and four-way power splitters. The two-way power splitters, designed for use in the Global System for Mobile Communications (GSM) and personal-communications-services (PCS) bands, measure only 0.3 × 0.25 in. (0.76 × 0.64 cm) [Fig. 2]. The four-way power splitter, which operates from 1600 to 2200 MHz, measures only 0.5 × 0.375 × 0.15 in. (1.27 × 0.95 × 0.38 cm) [Fig. 3]. The SYNSTRIP Technology was also applied to the development of a broadband balanced/unbalanced (balun) for use in broadband double-balanced mixers (Fig. 4).

The two-way surface-mount power divider achieves typical insertion-loss performance of 0.5 dB from 800 to 1000 MHz (Fig. 5). The typical port-to-port isolation is 19 dB. The typical input voltage standing-wave ratio (VSWR) is 1.50:1 and the typical output VSWR is 1.30:1. The two-way power divider achieves maximum amplitude imbalance between ports of 0.5 dB and phase imbalance of a mere 4 deg.

The four-way power splitter is equally impressive. It achieves a maximum insertion loss of 0.8 dB across the 1800-to-2200-MHz frequency range (Fig. 6). The typical port-to-port isolation is 19 dB. The typical input VSWR is 1.50:1 and the typical output VSWR is 1.30:1. The four-way power divider achieves maximum amplitude imbalance between ports of 0.5 dB and phase imbalance of 8 deg.

BROADBAND MIXER

Mixers are traditionally difficult to miniaturize due to their matching structures, using broadband balanced/unbalanced (balun) components. A typical layout for a standard high-frequency mixer using distributed baluns for impedance matching the RF and local-oscillator (LO) ports (50 Ω externally) to the low impedances of the mixer diodes is realized using planar-circuit approaches. These baluns are normally formed on 10-mil-thick soft substrate materials with a dielectric constant of 2.2. The approach

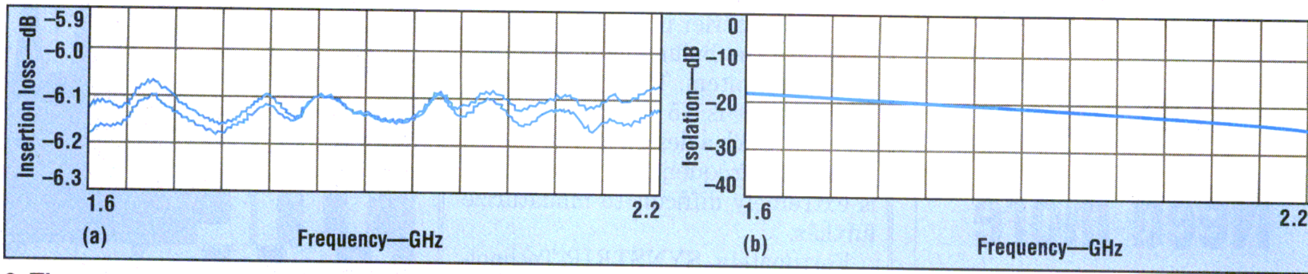
requires a carrier plate or housing to integrate the balun/mixer structure into a subsystem. The typical size of such a mixer is 0.5 × 0.25 in. (1.27 × 0.64 cm). Such a design is well known in the high-frequency industry, but it is extremely difficult to miniaturize further.

Fortunately, SYNSTRIP Technology provides a means to create truly miniature mixers by designing the structure in 3D. The technology was applied to the design of double-balanced microwave mixers that rival the size and performance of gallium-arsenide (GaAs) mixers. The surface-mount SYNSTRIP mixer (Fig. 7) measures only 0.3 × 0.275 in. (0.76 × 0.69 cm), with an RF and LO range of 3 to 4 GHz (typical) and an intermediate-frequency (IF) range of DC to 600 MHz. The maximum conversion loss is only 9 dB, with typical performance of 8 dB. The LO-to-RF isolation is better than 20 dB (and typically 25 dB), and the LO-to-IF isolation is better than 15 dB (and typically 17 dB). The mixer can be supplied for use with a wide range of LO drive levels, from approximately +7 to +20 dBm.

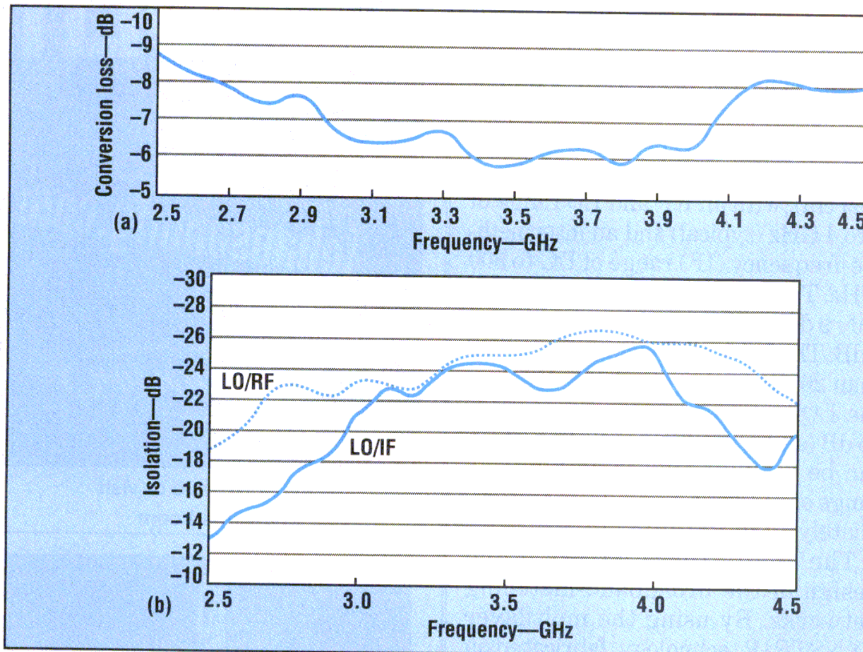
The key to these mixers is the design of the broadband-matching networks. By using the multilayer SYNSTRIP technology, fabricated on soft substrate materials, the mixer consists of a broad-side-coupled balun for RF and LO impedance matching that is printed on both sizes of a 5-mil-thick, ceramic-filled soft substrate with a dielectric constant of 10. The balun structure is bonded to a 25-mil-thick substrate, also with a dielectric constant of 10, which acts as a base. The only component that must be mounted in this assembly is a quad diode, which is placed on the top layer.

SYNSTRIP APPROACH

The SYNSTRIP approach considerably reduces fabrication requirements and costs. The simple structure is straightforward in order to manufacture in high-volume quantities, with high yield as well as repeatable performance. This novel assembly approach eliminates other techniques that are based on hard alumina substrates with thick-film technology and chip diodes, which require bonding.



6. The measured performance of the four-way power splitter demonstrates the electrical advantages of the new SYNSTRIP Technology.



7. SYNSTRIP Technology contributes to the performance of a compact double-balanced mixer designed for use from 3 to 4 GHz.

In short, SYNSTRIP Technology is a novel, yet straightforward approach to the design and fabrication of low-cost, miniature RF and microwave components for wireless applications. This straightforward approach eases fabrication requirements and translates into a manufacturing process with high yield and good repeatability. SYNSTRIP Technology offers the possibility for extremely compact RF and microwave components, such as broadband mixers and power dividers/combiners, leading to the further miniaturization of RF and wireless systems as well as subsystems. **Synergy Microwave Corp., 201 McLean Ave., Paterson, NJ 07504; (973) 881-8800, FAX: (973) 881-8361, e-mail: sales@synergymwave.com, Internet: http://www.synergymwave.com.**

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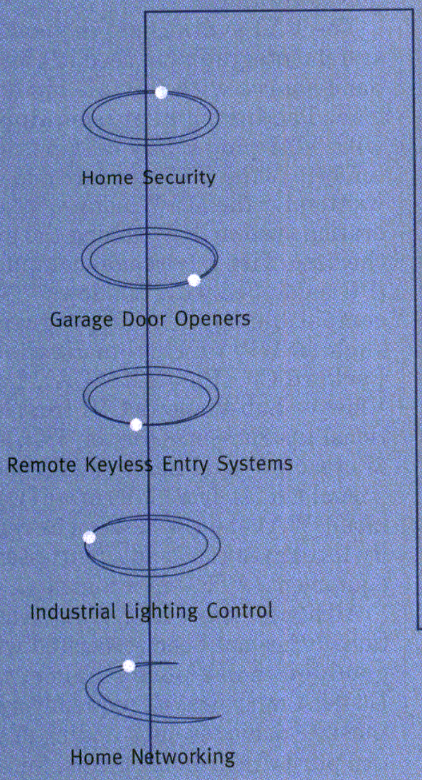
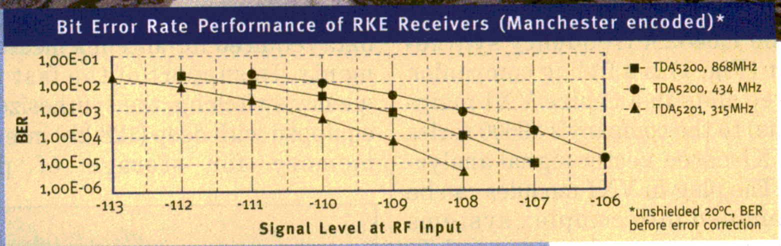
{PERPETUAL THINKING PROCESS}

INFINEON CYCLE





*unshielded 20°C, BER before error correction

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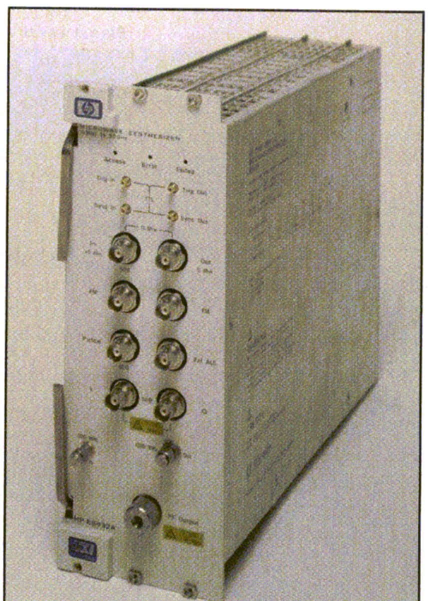
JACK BROWNE

Publisher/Editor

MODULARITY implies flexibility. This is the case with the E6432A microwave synthesizer from Agilent Technologies (Santa Rosa, CA). Leveraging the modular VXI format, the frequency synthesizer offers a basic range of 10 MHz to 20 GHz, but also a host of flexible options for expanding modulation and other capabilities to fit the needs of commercial and military testing.

The E6432A frequency synthesizer (Fig. 1) is a fitting companion (three slots in a C-size VXI mainframe) to the company's 89600 series of VXI-based vector signal analyzers. The plug-in VXI modules can be assembled into complex systems with or without modulation capabilities, including multichannel receivers for surveillance and signal analysis (see "VXI Receivers Scan VHF/UHF Range," *Microwaves & RF*, August 1998, p. 168). The E6432A is designed to operate with a host computer and a monitor, either as a stand-alone synthesizer or as part of a larger test system.

The E6432A microwave frequency synthesizer provides precise 1-Hz frequency resolution and a tunable output-power range of −20 to +20 dBm. An option offers an output-power range of −90 to +16 dBm. The power resolution in both cases is 0.02 dB. Engineers who are involved with antenna analysis and testing will take heart in the E6432A's fast 400-μs frequency-switching speed (as fast as 80 μs under some conditions for closely spaced frequencies), which supports capturing the massive multiple power and frequency data required for antenna measurements. In support of the fast frequency switching, the synthesizer is equipped with deep (128-kb) internal memory for storage of programmable memory points and related data. Data entries can include settings for frequency, amplitude, attenuation, settling time, and blanking, along with a marker.



1. The E6432A VXI microwave frequency synthesizer covers a range of 10 MHz to 20 GHz with 1-Hz resolution and an assortment of modulation formats.

The synthesizer supports frequency-switching dwell times of 5 μs to 32 ms. In addition, comprehensive trigger modes allow an operator to make the most efficient use of programmed frequency selections. The E6432A also supports rapid switching between amplitude levels, requiring less than 50 μs to switch between two amplitudes in its output-power range.

The VXI synthesizer is ideal for system integrators in need of a wideband source with flexible modulation. The instrument is equipped with VXI plug&play drivers that conform to the VXI standard and are written for the MS Windows NT operating system. By teaming the synthesizer with a personal computer (PC) equipped with Windows™ NT-compatible application programs, such as HP VEE from Hewlett-Packard Co. (Palo Alto, CA), LabView or LabWindows/CVI from National Instruments (Austin, TX), and Microsoft Visual Basic or Microsoft Visual C/C++ from Microsoft (Redmond, WA), the E6432A can be readily integrated into automatic-test-equipment (ATE) environments.

Although the VXI format traditionally has not been associated with good low-noise performance, the E6432A microwave frequency synthesizer achieves outstanding spectral purity. Harmonic levels, for ex-

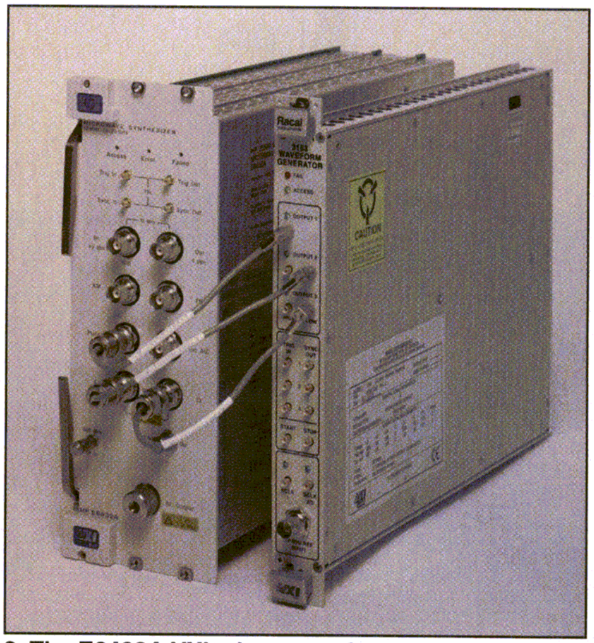
ample, are typically better than −65 dBc from 2 to 20 GHz, and are typically better than −35 dBc from 10 MHz to 2 GHz. Spurious responses are better than −60 dBc across the full operating band, and typically better than −70 dBc. The single-sideband (SSB) phase noise is −70 dBc/Hz offset 100 Hz from the carrier and −93 dBc/Hz offset 10 kHz from the carrier.

TRIMMING NOISE

Several steps were taken in the basic design to reduce noise. For example, the E6432A uses proprietary DC-to-DC converters, each with its own shielded enclosure, to minimize noise introduced by the power supplies. In addition, the VXI synthesizer features a patented gasketing technique that helps provide good suppression of RF interference (RFI) and electromagnetic interference (EMI). The synthesizer itself is based on a unique frequency architecture, where a voltage-controlled oscillator (VCO) is used to generate fundamental tones from 20 to 40 GHz. These signals are then translated to the 10-MHz-to-20-GHz range through a proprietary broadband microwave mixer. The mixer itself is an impressive design, operating over an RF and local-oscillator (LO) range of greater than 20 to 40 GHz.

The E6432A microwave frequency synthesizer boasts a wide range of modulation capabilities, including ports for conventional external analog-modulation sources, such as amplitude modulation (AM), frequency modulation (FM), and pulse modulation. It also features a new wideband in-phase (I) and quadrature (Q) modulator with a 40-MHz bandwidth for creating any number of complex modulation formats. With a modulation source, such as an arbitrary waveform generator or a function generator, the E6432A can generate AM with depths from 0 to 40 dB at rates to 100 kHz. The instrument can produce FM deviations from 50 kHz to 8 MHz at FM rates of 200 kHz to 8 MHz. Also, pulse modulation is available at on/off ratios of better than 80 dB for rise/fall times of 10 ns and minimum pulse widths of 15 ns.

Perhaps the real modulation power in the E6432A, however, lies in its optional broadband I/Q modulator. When teamed with a VXI arbitrary waveform generator (Fig. 2), such as the model 3153 waveform generator from Racal Instruments (Irvine, CA), the E6432A can produce carriers with a wide range of digital modulation formats, including quadrature amplitude modulation (QAM), frequency-shift-keying (FSK) modulation, minimum-shift-keying (MSK) modulation, and quadrature-phase-shift-keying (QPSK) modulation.



2. The E6432A VXI microwave frequency synthesizer can be teamed with an external waveform generator, such as the 3153 waveform generator from Racal Instruments (Irvine, CA), to produce complex digital modulation.

The E6432A is designed for use with an external monitor, as well as with a VXI mainframe and an external computer. The monitor shows a virtual synthesizer front panel, provided as part of the plug&play instrument driver. The virtual front panel supports direct control of RF output power, leveling, automatic level control, and modulation. It also provides access to various function panels, including configuration, list-mode, self-test, and calibration panels. When the wideband I/Q modulator option is selected, the calibration panel is also augmented with an I/Q modulation calibration panel that allows operators to correct for phase and amplitude unbalances on external modulation sources. The E6432A's plug&play instrument driver also contains a comprehensive on-line help system with complete documentation of the instrument's operation.

SIGNAL SOFTWARE

A soon-to-be announced software package, Signal Studio™, will allow operators to load external signal files into the E6432A and the 3153 waveform generator for exotic signal generation. These files may originate from the company's own software suite, the Advanced Design System (ADS), or from math programs, such as Matlab from The MathWorks, Inc. (Natick, MA). The Signal Studio software performs the file processing and compiling necessary to prepare the files for use by the waveform generator, then stores the files or downloads them to the waveform generator to create test signals from simulations or actual measurements of radar systems.

The E6432A VXI microwave frequency synthesizer packs a lot of power into a small package. With the I/Q modulator option and an external wideband waveform generator, the synthesizer can be programmed for virtually all existing digital modulation formats in commercial communications. In addition, due to its modulation capabilities and fast switching speed, the synthesizer is an ideal choice for aerospace and military test applications. **Agilent Technologies, Inc. (subsidiary of Hewlett-Packard Co.), Test and Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; Internet: http://www.agilent.com.**

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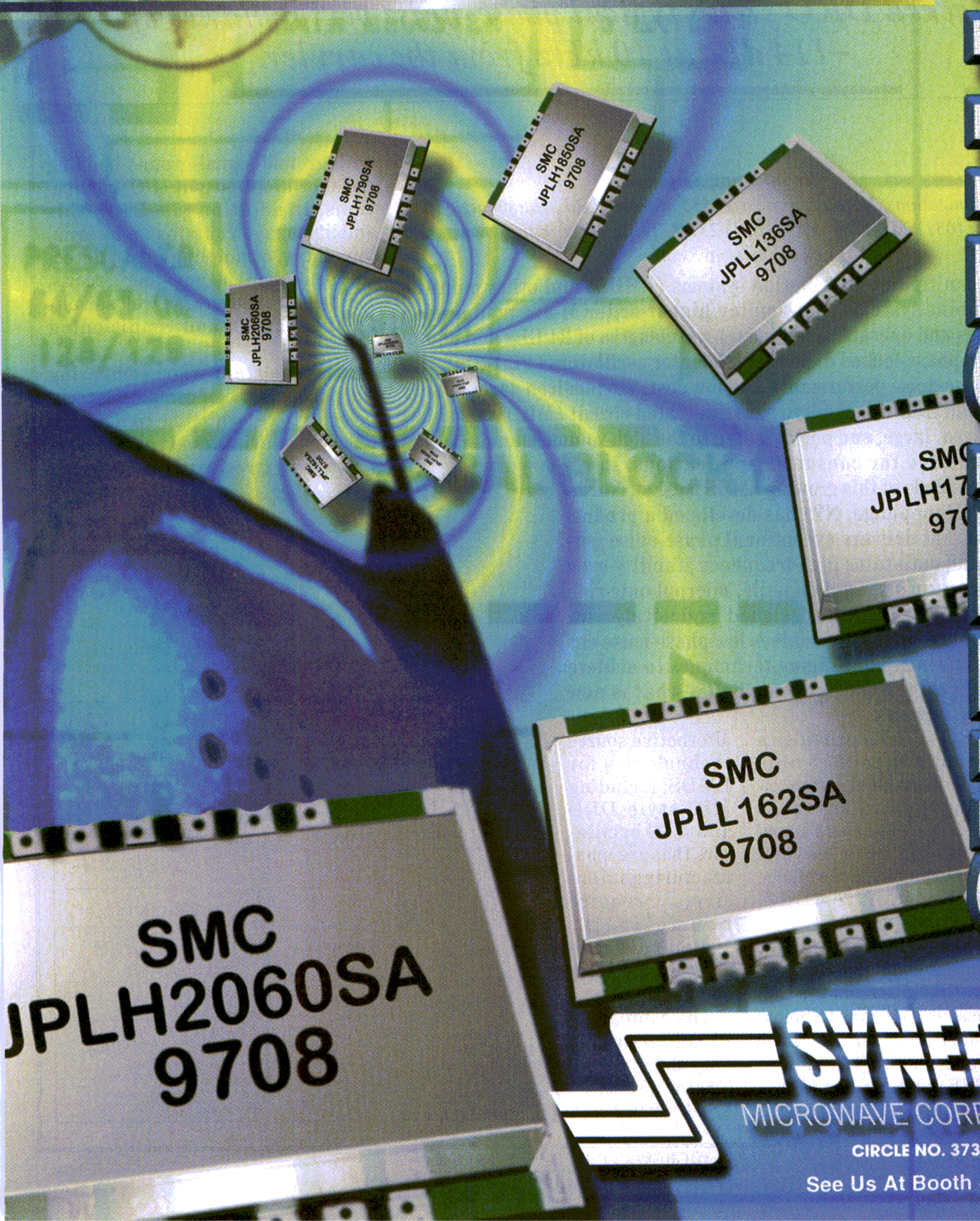

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LOCAL multipoint distribution systems (LMDS) and other point-to-multipoint systems that employ higher-order M-ary modulation schemes and operate at millimeter wavelengths of 24 GHz and above, require phase-locked dielectric resonator oscillators (PLDROs) with superior phase-noise performance and low cost. Yttrium-iron-garnet (YIG) oscillators and traditional microwave-integrated-circuit (MIC) assemblies are high in cost, large, and poorly suited to the high-volume manufacturing processes needed for consumer applications. In response to the needs of this growing LMDS market, Narda Microwave (Hauppauge, NY) has developed a production PLDRO that delivers exceptional phase-noise performance, and maintains high-frequency stability even when in long-term service in hostile, microphonic-rich environments. The PLDRO, designed exclusively with surface-mount technology, combines low-phase-noise circuitry and innovative packaging techniques to achieve outstanding performance at costs below what is now commercially available.

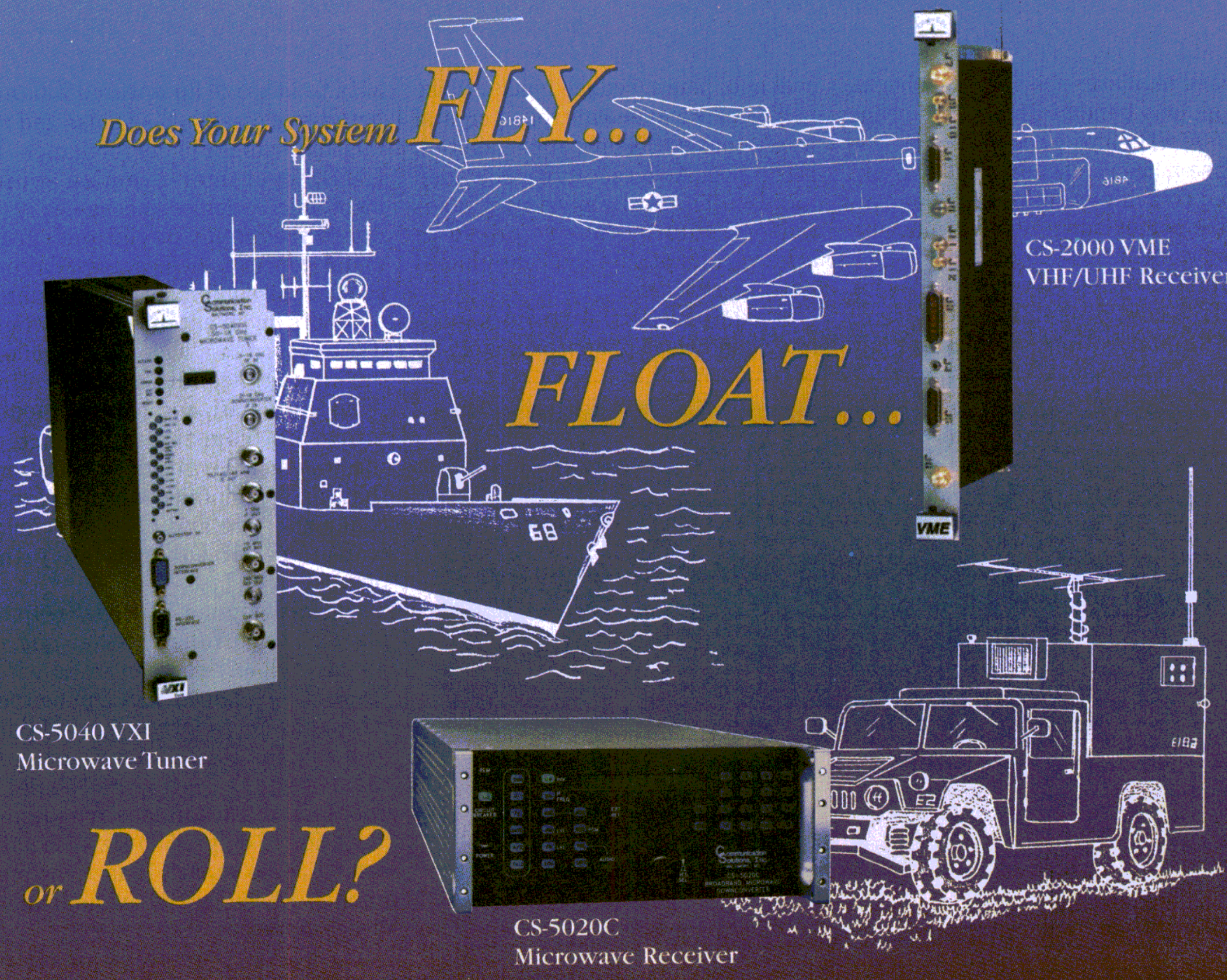
The PLDRO (Fig. 1) provides a nominal output power of +5 dBm with ±2-dB flatness over its specified operating temperature range and into a 50-Ω load. It boasts spurious content of −75 dBc or less and harmonic/subharmonic performance of −40 dBc or better. At 26.4 GHZ, the synthesizer's phase noise is typically better than −114 dBc/Hz offset 10 kHz from the carrier, and −112 dBc/Hz offset 100 kHz from the carrier. The phase noise drops to below −132 dBc/Hz for offsets of 1 MHz or greater (Fig. 2, table). The single-sideband (SSB) phase noise of this oscillator compares favorably with alternative source technologies for LMDS, including MIC-style DRO and YIG oscillators that are manufacturing intensive, require hermetically sealed packages that are heavier and more costly.

The company's PLDRO measures only 2.2 × 1.9 × 0.8 in. (5.588 × 4.826 × 2.032 cm), with ground-signal-ground bonding pads for input/output (I/O) connections. In addition to a DRO, this small package contains an internal loop filter, a sampling phase detector, multiplier and amplifier circuits, RF bandpass filters, as well as voltage regulation and conditioning (Fig. 3).

It is important when comparing the performance of competing technologies to recognize the significance of loop bandwidth. In typical phase-

The LMDS DRO at a glance

Parameter	Specification
Frequency	26.4 GHz
Nominal output power	+5 dBm
Spurious products	−75 dBc
Harmonics/subharmonics	−40 dBc
Phase noise	
Offset 1 kHz	−80 dBc/Hz
Offset 10 kHz	−105 dBc/Hz
Offset 100 kHz	−105 dBc/Hz
Offset 1 MHz	−115 dBc/Hz
Offset >1 MHz	−125 dBc/Hz
Frequency stability	Same as system reference
Shock test	0.5 J
Power supply	+8 VDC, 250 mA (max.)
Operating temperature range	−40 to +75°C



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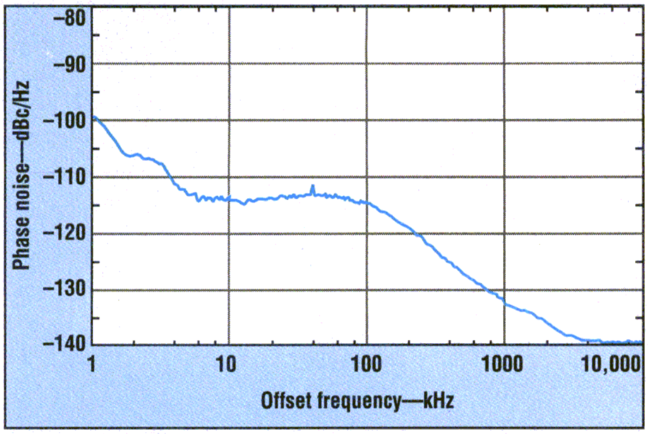
locked oscillator specification sheets, large loop bandwidths, on the order of 500 kHz and exceptionally low phase-noise reference standards are used to achieve impressive phase-noise performance. Unfortunately, the prices of these high-performance standards are well beyond present LMDS cost objectives. Practical LMDS applications must utilize low cost and, hence, reduced phase-noise performance oven-controlled crystal oscillators (OCXOs) for the system reference. As a result, narrow loop bandwidths and very-low phase-noise oscillators are required to achieve acceptable system phase-noise performance.

Narda's PLDRO features a loop-filter bandwidth of approximately 50 kHz to achieve an optimal balance between close-in phase noise and robust microphonic performance. In LMDS customer-premise equipment, microphonics (mechanically induced frequency deviations) are a major concern. Typical installations require the equipment to be mounted outdoors on an antenna mast, where it is exposed to a wide variety of environmental conditions, including wind, rain, hail, and low-frequency vibration from thunder. Each of these elements will induce vibrations that can be amplified within the system enclosure and produce variations in oscillator frequency and phase.

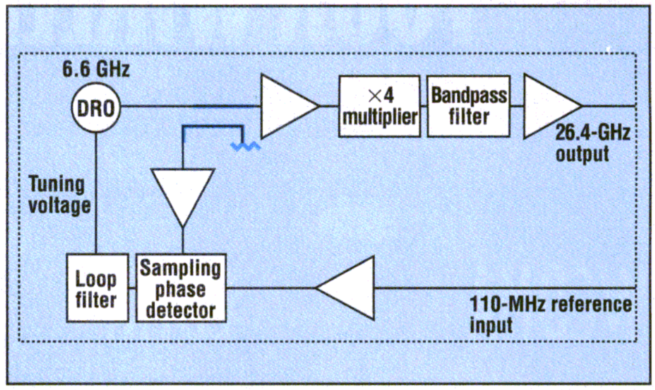
Narda designed its PLDRO to be placed on rooftops or other microphonic-rich environments and withstand significant impact from either mechanical or weather-related phenomena. The PLDRO undergoes extensive shock testing and experiences an instantaneous frequency deviation of only ±500 Hz with a direct 0.5 Joule impact. In fact, the unit remains phase-locked even during a direct 1J impact.

The PLDRO employs an active loop filter with integral aided acquisition circuitry and a transistor-transistor-logic (TTL) window comparator to indicate phase-locked status.

1. This phase-locked dielectric resonator oscillator (PLDRO) offers stable signals at 26.4 GHz for LMDS applications. It is rugged enough to operate capably in outdoor environments with minimal power consumption.



2. The low phase noise of the 26.4-GHz PLDRO can be traced to the use of low-noise SMT active devices and a high-Q dielectric resonator operating at 6.6 GHz.



3. This block diagram shows the basic architecture of the 26.4-GHz PLDRO, which is based on a 6.6-GHz dielectric resonator with two stages of frequency doubling to reach the 26.4-GHz output frequency.

The synthesizer has sufficient tuning bandwidth to remain phase-locked for the many years an LMDS installation may be left in the field.

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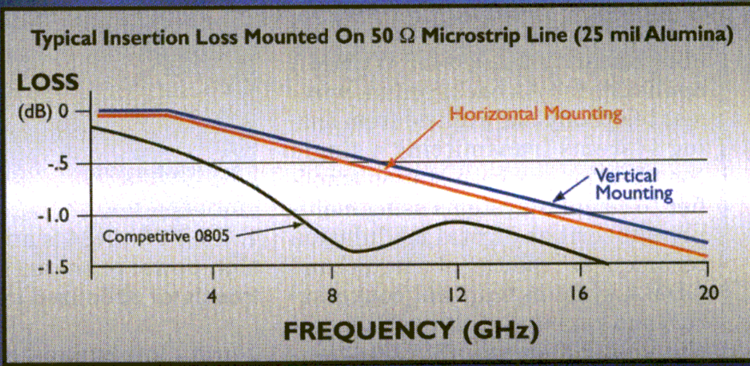

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LDMOS Device Powers WCDMA Amplifier

This rugged gold-metallized LDMOS transistor delivers better than 100-W PEP output power for WCDMA base-station amplifiers operating in the 2.1-GHz PCS band.

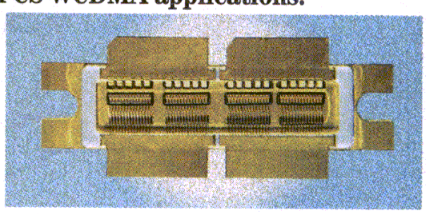
Tim Ballard

Senior RF Design Engineer

Ericsson Microelectronics, RF Power Products, 18275 Serene Dr., Morgan Hill, CA 95037; (877) GOLDMOS, (408) 776-0600, FAX: (408) 779-3108, Internet: http://www.ericsson.com/rfpower.

POWER transistors based on laterally-diffused-metal-oxide-semiconductor (LDMOS) technology offer high output levels with good linearity and simple biasing requirements. The PTF 10134 from Ericsson Microelectronics (Morgan Hill, CA) is an example of a gold (Au)-metallized LDMOS transistor that is well-suited for personal-communications-services (PCS) base-station applications in the 2.1-GHz band. The transistor offers 100-W peak envelope power (PEP) in wideband-code-division-multiple-access (WCDMA) communication systems operating from 2110 to 2170 MHz, with 10-dB typical power gain when biased under Class AB conditions with a +28-VDC supply. To demonstrate the performance of the device, a pair were incorporated into a pull-pull amplifier configuration to evaluate efficiency and linearity in PCS WCDMA applications.

Why are high output power and good linearity needed for WCDMA applications? As background, wireless telephony has evolved from analog systems transmitting a single conversation per base-station amplifier to complex systems using multiple-subscriber digital modulation techniques. Traditional narrowband CDMA systems transmit conversation and paging signals over a single channel. Emerging WCDMA networks will support a wider range of wireless digital services, such as Internet/intranet and other Internet-provider (IP)-based applications, video, high-speed data communications and interactive services. The information density of these more complex signals requires higher degrees of amplifier linearity to meet the necessary adjacent-channel-power-ratio (ACPR) specifications.



1. The PTF 10134 is an Au-metallized high-power push-pull LDMOS transistor optimized for WCDMA.

During low-cumulative probability distributions (CPRs), WCDMA waveforms have high peak-to-average power ratios. At high CPRs, WCDMA waveforms have lower peak-to-average power ratios, requiring amplifiers to operate significantly below saturation. As a result, amplifiers for WCDMA and other "spectrally efficient" modulation systems have significantly higher intermodulation-distortion (IMD) requirements for their active devices.

Most first-generation cellular base-station amplifiers used silicon (Si) bipolar power transistors. RF-transistor technology has improved over the years in terms of gain, output power, efficiency, and reliability. Linearity, however, is limited by the fundamental characteristics of bipolar transistors. Bipolars have two significant linearity problems: high-order IMD and low-level crossover distortion. Crossover distortion can be improved by changing from Class AB to Class A bias conditions. This, however, reduces efficiency and peak power when compared to Class AB bias.

Metal-oxide-semiconductor field-effect transistors (MOSFETs) have lower high-order IMD than bipolar transistors. Being majority-carrier devices, they do not require the ballasting that stabilizes minority-carrier bipolar devices. Combined, these MOSFET traits produce superior IMD at reduced output power. Additionally, thermally stable FET cells combine better than bipolar-transistor cells. This makes it more feasible to scale an active area when designing high-output-power components. Recently introduced LDMOS transistors have raised the operating frequency of Si power FETs. LDMOS devices incorporate a "p+ sinker" to connect the source terminal to the backside of the semiconductor material. With this structure, chips may be directly attached to metal flanges, improving grounding and reducing thermal resistance; it also eliminates

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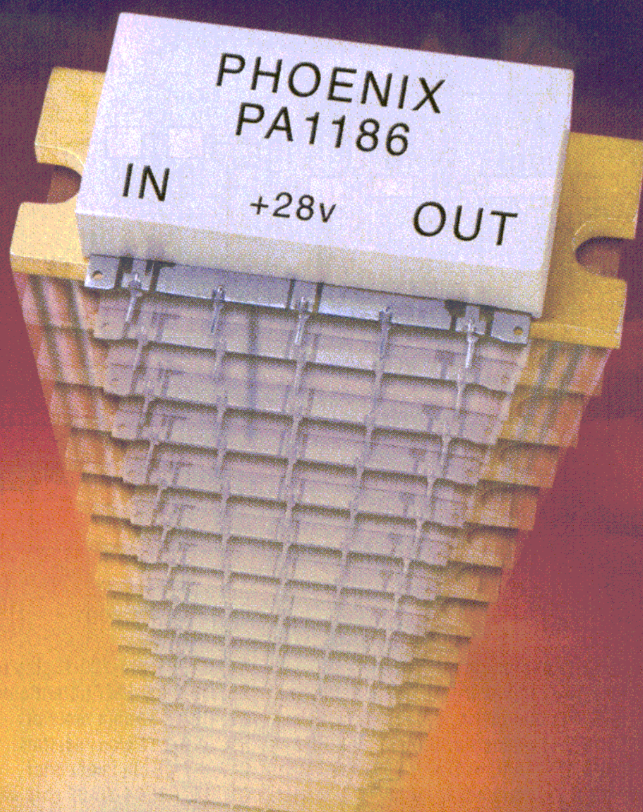

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Frequency (MHz.)	800-960	1930-1990	2300-2400
Gain (dB.)	29.0	26.0	23.0
Pout @ 1 dB. comp. (dBm.)	38.0	38.0	37.5
Noise Figure (dB.)	2.4	2.7	3.0
ACPR (30kHz BW)*	-50.0	-54.0	-47.0
VSWR (Input/Output)	1.5:1/2:1	1.5:1/2:1	1.5:1/2:1
IP3 (two tone)**	+56.0	+54.0	+53.0
Supply Required	+28/1000	+28/1000	+28/1000

* ±850kHz from fc at power level of 30 dBm. (IS-95)
** IP3 measured with 2 tones @ +25dBm. per tone

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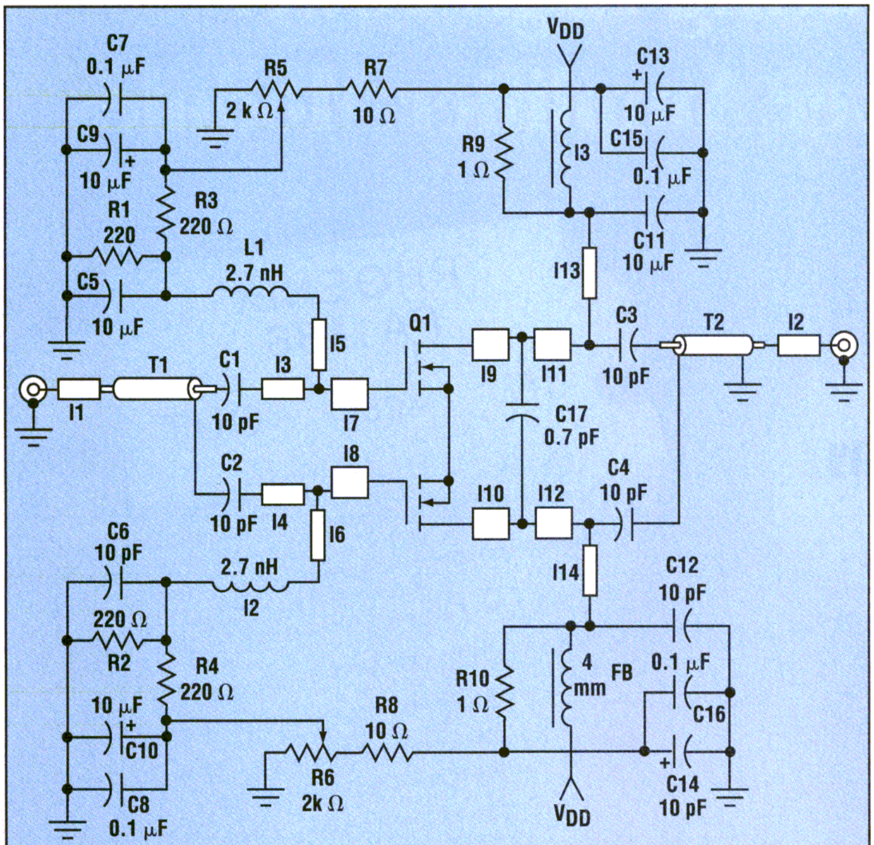
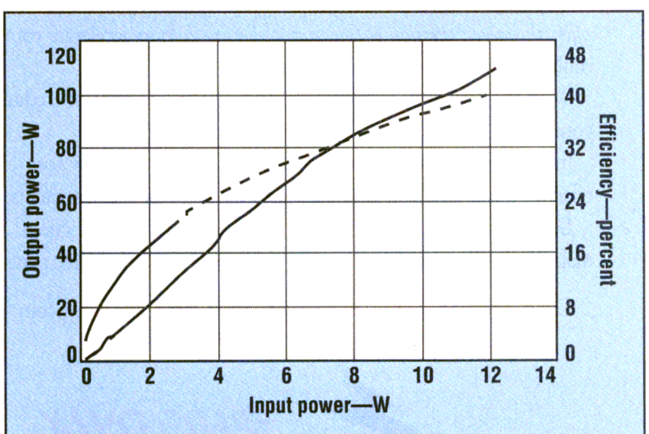


2. The high-power LDMOS transistor is connected in a push-pull configuration in this test circuit optimized for use from 2110 to 2170 MHz.

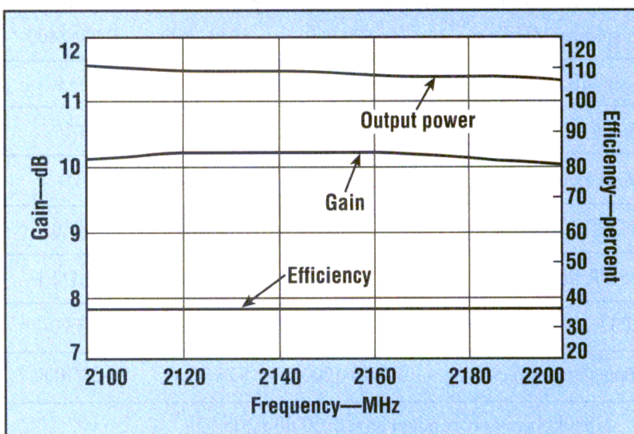
the need for source interconnects, and reduces parasitic-source inductance. LDMOS technology can produce RF power transistors with high gain, high efficiency, low thermal resistance, and superior IMD in wireless radio systems.

The PTF 10134 is an enhancement-mode LDMOS device that has been designed to provide all the benefits of LDMOS technology, using a proven high-volume semiconductor process with well-established packaging techniques (Fig. 1). Structurally, the transistor combines four active chips assembled in a push-pull configuration. Each chip contains 28 cells having 60 gates of 0.8-μm length. Input and output ports are internally matched (to 50 Ω) to optimize performance within the WCDMA band. Impedance matching consists of bond-wire inductors and MOS capacitors configured as a lowpass impedance-matching transformer on the input port, and a shunt-inductor (L) network (shunt inductor, series-blocking capacitor) on the output port.

All Ericsson LDMOS products employ full Au metallization. Developed in the 1970s, Au metallization has been used in place of less-reliable aluminum (Al) on microwave power chips to minimize device failures due to metal migration. All Ericsson products use Au wire interconnects to reduce wire temperature and eliminate wire fatigue occurring in systems that amplify time-varying waveforms. Ericsson's all-Au system eliminates intermetallic failures as-



3. Measurements of output power versus input power were made at 2170 MHz with quiescent drain current of 1.3 A and supply voltage of +28 VDC.



4. Measurements of output power, gain, and efficiency were made across the operating frequency range with bias of 1.3 A at +28 VDC.

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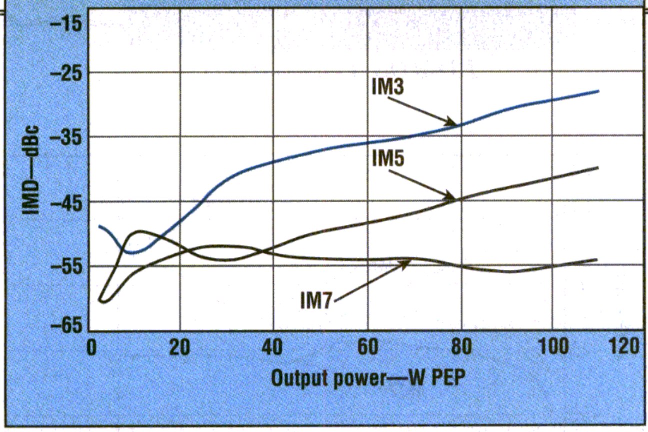


5. The third-, fifth-, and seventh-order IMD products were measured with tones at 2169 and 2170 MHz and bias of 1.3 A at +28 VDC.

sociated with mixed-metal systems.

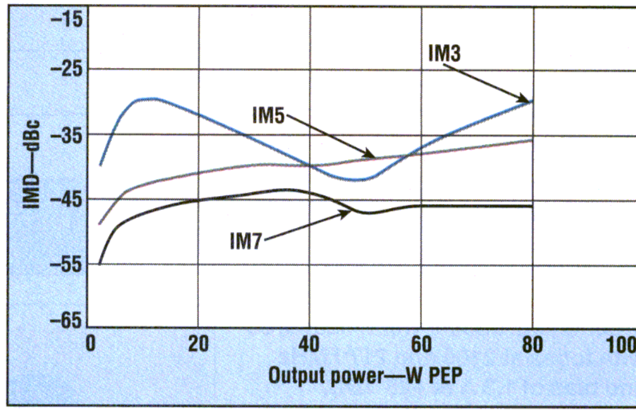
A push-pull test circuit was designed to cover 2110 to 2170 MHz using 1:1 compensated baluns at the PTF 10134's input and output ports. A cascaded input and tapered output are used as matching networks. Matching networks were designed to optimally transform the balanced source- and load-to-device impedances determined through point-by-point load-pull characterization using a manual impedance tuning system and a vector network analyzer (VNA). Matching networks combine distributed and lumped components in a lowpass configuration (Fig. 2).

The circuit was fabricated on a substrate with 0.028-in. (0.071-cm) dielectric thickness and having a dielectric constant of 4.0. The layout (available upon request from the author) illustrates the simplicity of LDMOS circuitry.

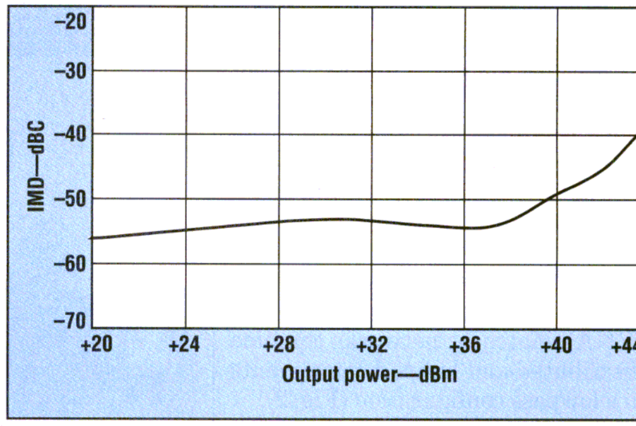
Biasing an FET is much simpler than biasing a bipolar transistor because FETs do not exhibit the high-current thermal runaway effect of bipolar transistors, where the gain (and current consumption) increases with increasing temperature. For the PTF 10134, the output-bias circuitry consists of a bypassed RF choke, similar to that used in bipolar circuits. Gate bias can consist of a simple resistive divider connected between the drain supply and ground.[1] A more-complex compensation network improves LDMOS linearity over temperature.[2,3]

The prototype amplifier circuit was evaluated with a +28-VDC voltage supply and typical drain current totaling 1.30 A (650-mA current for each side of the PTF 10134 transistor). Figure 3 shows the output power versus input-power characteristics of the test amplifier. The typical CW output power at 1-dB compression is 110 W. Figure 4 shows small-signal gain and efficiency at 1-dB compression, measured in a test fixture optimized from 2110 to 2170 MHz.

Figure 5 shows two-tone third-, fifth-, and seventh-order IMD versus output power. Note that, although not completely monotonic, the IMD generally decreases continually as the output decreases. Bipolar tran-



6. The typical third-, fifth-, and seventh-order IMD products for an Si bipolar transistor are shown for comparison purposes.



7. The ACPR performance of the PTF 10134 in a broadband circuit is shown as a function of WCDMA output power at 2130 MHz and bias of 1.3 A at +28 VDC.

sistors tend to have a noticeable "sweet spot," an output range corresponding to minimum distortion. This is mostly due to the more linear transfer function of LDMOS devices compared to bipolars. Figure 6 shows comparable two-tone third-, fifth-, and seventh-order IMD performance for a high-power Si bipolar transistor.

Testing on the PTF 10134 circuit was performed with a WCDMA spectral mask in a broadband circuit with a 15 DTCH signal. Figure 7 displays the higher of the two values of ACPR at 4.096-MHz offsets, clearly showing the suitability of LDMOS for complex waveforms.

Ericsson offers a wide range of bipolar and GOLDMOS™ Au-metallized LDMOS transistors for wireless communications and television-broadcast applications. **Ericsson Microelectronics, RF Power Products, Morgan Hill, CA 95037; (877) GOLDMOS, (408) 776-0600, FAX: (408) 779-3108, Internet: http://www.ericsson.com/rfpower.**

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References

1. Scott Porro, "FETs Address Linearity Challenge," *RF Power Products Data Book 1998/1999*, Ericsson Microelectronics, Morgan Hill, CA.
2. Cindy Blair, "Ericsson's High Power LDMOS Breakthrough," *Applied Microwaves & Wireless*, October 1998.
3. Cindy Blair, "Biasing LDMOS FETs for Linear Operation,"*RF Power Products Data Book 2000*, Ericsson Microelectronics, Morgan Hill, CA.

Integrated RF Synthesizer Conserves Space And Power

This RF synthesizer can generate frequencies up to 2.6 GHz, while reducing the number of components required to implement a complete synthesizer solution.

PETER STAVENICK
Managing Editor

FREQUENCY synthesizers are playing an increasingly important role in the growth of the wireless industry. The wireless revolution has created a need for synthesizers that consume less board space, are less expensive than their predecessors, and can perform the frequency synthesis function in wireless communications equipment effectively. The single-chip Si4136 industrial-scientific-medical (ISM) RF synthesizer from Silicon Laboratories, Inc. (Austin, TX) reduces the number of external components required, saving up to 60 percent of board space and cutting power consumption. It operates across the 2.0-to-2.6-GHz range and is suitable for IEEE 802.11-standard wireless local-area networks (WLANs), wireless modems, wireless headsets, cordless phones, and security systems. The Si4136 performs RF synthesis in two bands—2.3 to 2.6 GHz and 2.0 MHz to 2.4 GHz, as well as intermediate-frequency (IF) synthesis from 62.5 MHz to 1.0 GHz.

The Si4136 consists of three complete phase-locked loops (PLLs) with integrated voltage-controlled oscillators (VCOs), loop filters, as well as reference and VCO dividers. Divider and power-down settings are programmable through a three-wire serial interface (see figure). Each RF VCO is optimized over a particular frequency range. The RF_1 VCO operates from 2.3 to 2.6 GHz while the RF_2 VCO operates between the 2.0-to-2.4-GHz frequency range. The IF output can range from 62.5 to 1000 MHz. With 5-μA standby current at +3 VDC, the Si4136 offers 15.7-mA typical supply current at +3.6 VDC. It operates over a supply-voltage range of +3.0 to +3.6 VDC.

The RF_1 output phase noise at 2.4 GHz is −131 dBc/Hz offset 1 MHz from the carrier while the RF_1 integrated phase-error output at 2.4 GHz is 1.5 deg. root mean square (RMS) from 100 Hz to 100 kHz. RF_2 phase-noise output at 2.1 GHz is −131 dBc/Hz offset 1 MHz from the carrier and the RF_2 integrated phase-error output at 2.1 GHz is 1.2 deg. RMS from 100 Hz to 100 kHz.

The PLL architecture that is used in the Si4136 produces transient responses that are comparable in speed to fractional-N architectures without suffering the high phase noise or spurious modulation effects often associated with those designs. The IF PLL can tune ±5 percent from the center frequency of the VCO. The IF center frequency is established with the value of an external inductance that is connected to the VCO. P&A: $7.00 (10,000 qty.); evaluation board (Si4136-EVB), $150. **Silicon Laboratories, Inc., 4635 Boston Lane, Austin, TX 78735; (877) 444-3032, FAX: (512) 416-9669, Internet: http://www.silabs.com.**

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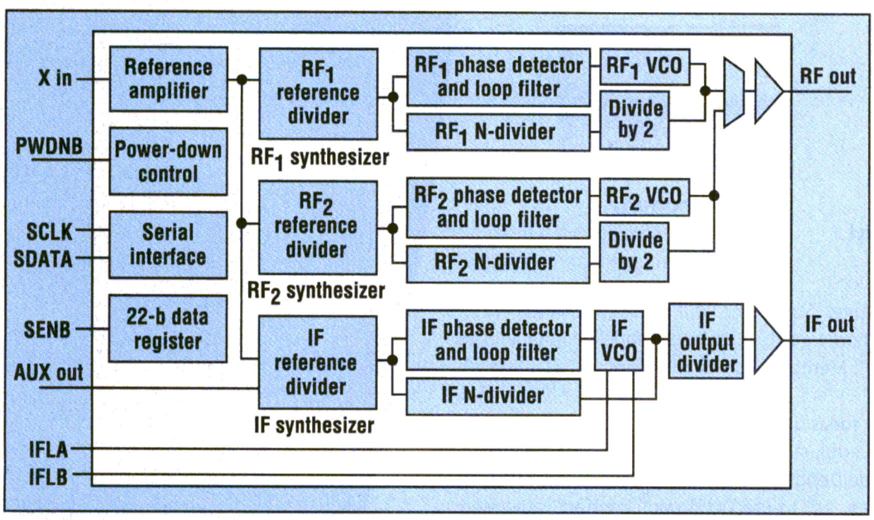

The Si4136 monolithic IC includes three VCOs, loop filters, reference and VCO dividers, as well as phase detectors.

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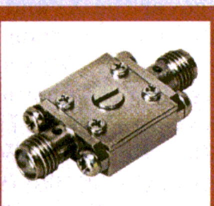
VSWR (Max.)	1.25:1	1.25:1	1.25:1
Incremental Phase Shift	90 degree min. @ 2GHz		
Electrical Delay	125 psec min.		
Nominal Impedance	50 ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	20W @ 2GHz		
Temperature Range	-30°C ~ +60°C		
Dimension (inch)	A type : 1.496*1.102*0.457 B type : 1.225*1.102*0.457		

KPH30OSCL000



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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		
Electrical Delay	41.7 psec min.			48.6 psec min.		
Nominal Impedance	50 ohm			50 ohm		
I/O Port Connector	Drop-In			SMA(F) / SMA(F)		
Average Power Handling	30W @ 2GHz			30W @ 2GHz		
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Dimension (inch)	0.709*0.433*0.244			0.630*0.551*0.244		

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GaAs FETs Offer Improved Specifications

Higher-performance data-communications systems require power GaAs FETs that provide upgraded linearity and greater gain.

GENE HEFTMAN
Senior Editor

ESCALATING data rates emerging in satellite and terrestrial communications are creating a need for gallium-arsenide (GaAs) power field-effect transistors (FETs) that deliver higher gain and better linearity than their predecessors. This has prompted Toshiba America Electronic Components, Inc. (Irvine, CA) to introduce a series of matched C-band GaAs FETs that deliver a 2-dB improvement in linearity and 1-dB higher gain than the company's existing line.

The TIM5964-xUL series achieves better gain and linearity performance over the original TIM5964 family based on refinements to the company's GaAs metal-semiconductor FET (MESFET) process technologies. Contributing to the enhanced performance are ion-implantation technology—which provides abrupt carrier concentration profiles and high carrier density—as well as a via-hole structure that reduces source inductance. In addition, the UL series has a new device structure using a plated heat sink at the source contact.

Another UL series change over the original family is the addition of three power ratings, 6, 12, and 25 W (these are the -4UL, -12UL, and -25UL in the table) plus the 4-, 8-, and 16-W devices. The original family has FETs with power ratings of 30, 35, 45, and 60 W. The 60-W device is the highest power rating for a C-band GaAs FET (5.9-to-6.4-GHz range).

All UL series FETs have a typical gain of 10 at the 1-dB compression point (G1dB) compared with values that range from 7 to 9 for the TIM5964 types. Output power at the 1-dB compression point (P1dB in dBm) varies with a device's power rating as seen in the table, but in general, is approximately +0.5 dBm better (typical) than that of the original family. The new series also offers better third-order intermodulation-distortion (IM3) specifications than the originals. IM3 is rated at −47 dBc for an output power of +25.5 dBm. The same specification for the original family is −45 dBc.

Also on the UL series of data sheets is a power-added-efficiency (PAE) specification η_{add}. The typical values vary between 36 and 40, depending on the device. Another benefit of the UL series compared to the original family is that they draw a smaller drain-to-source current (I_{DS}) for the same input power (P_{in}).

Typical applications for TIM5964-xUL FETs are in solid-state power amplifiers (PAs) for satellite earth-station communication transmitters and very-small aperture terminals (VSAT). The FETs also target other wireless communications systems as well as point-to-point radio applications. In all of these areas, the trend is away from voice-oriented communications and toward data.

Engineering samples of the UL series are available now and production quantities will be available in September. The series will also be developed to cover the X- and Ku-band frequency ranges in the future. **Toshiba America Electronic Components, Inc., 9775 Toledo Way, Irvine, CA 92168; (949) 455-2000, FAX: (949) 859-3963, e-mail: toshiaki.nakamura@taec.toshiba.com.**

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TIM5964-xUL C-band GaAs FET series

Parts number	G1dB (dB) (typical)	P1dB (dBm) (typical)	I_{DS} (A) (typical)	η_{add} (percentage) (typical)	IM3 (dBc) at SCL (dBm)	$Rth_{(c-c)}$ (°C/W) (typical)
TIM5964-4UL	10	36.5	1.1	37	−47 at 25.5	4.5
TIM5964-6UL	10	38.5	1.6	40	−47 at 25.5	4.0
TIM5964-8UL	10	39.5	2.2	36	−47 at 25.5	2.5
TIM5964-12UL	10	41.5	3.2	40	−47 at 25.5	2.0
TIM5964-16UL	10	42.5	4.4	36	−47 at 25.5	1.5
TIM5964-25UL	10	44.5	6.8	37	−47 at 25.5	1.3

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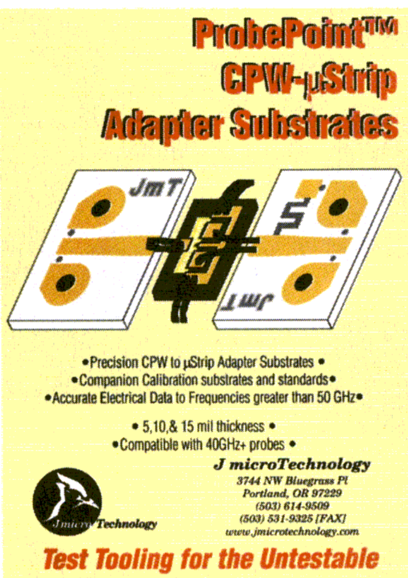

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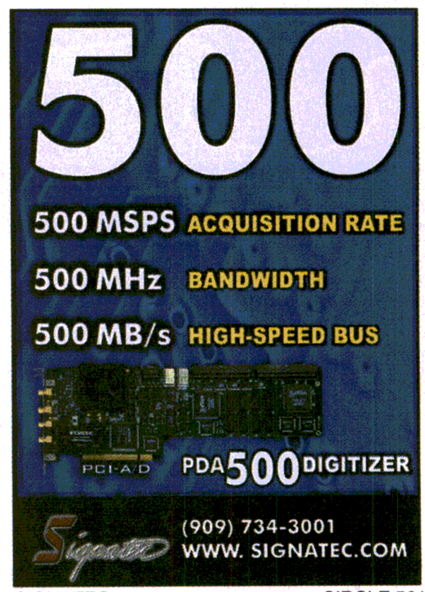

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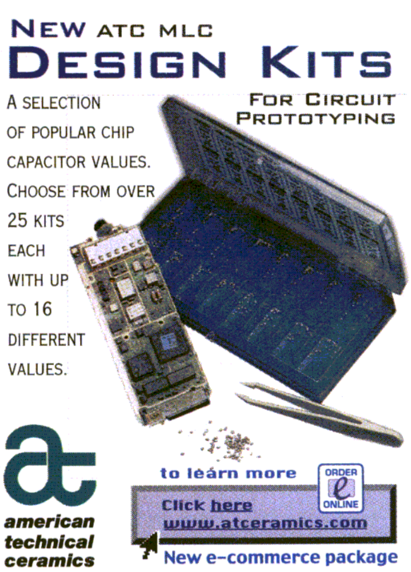

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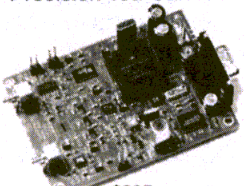

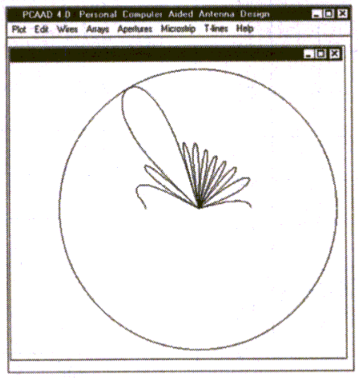

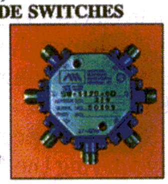

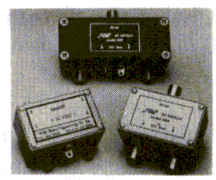

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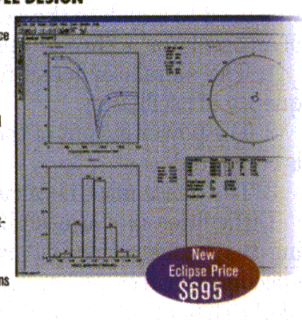
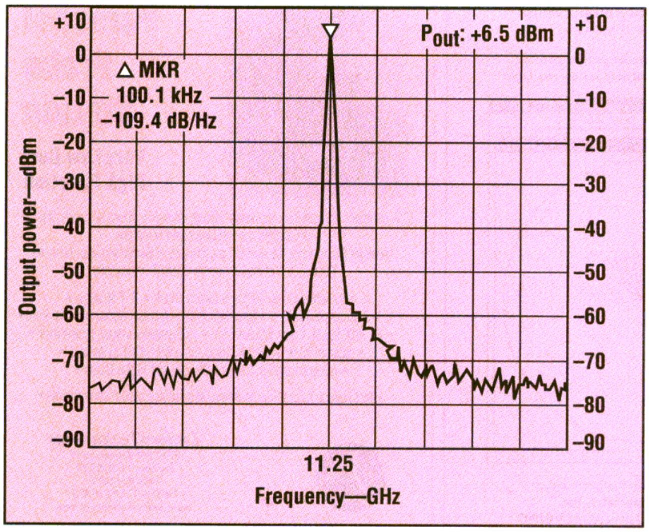
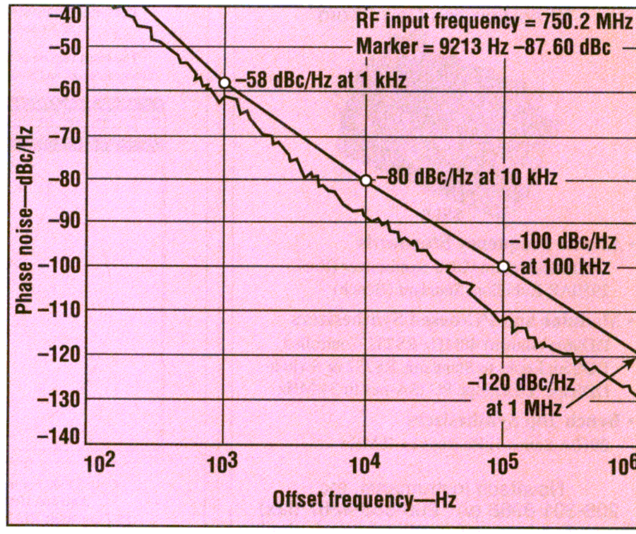




10. The measured performance of the 11.25-GHz DRO shows good spurious performance.



11. The measured phase-noise performance of the 11.25-GHz DRO exceeds the minimum requirements.

(continued from p. 89)

$= 1/S_{11}$ and that the phase relation is equal to 0 deg. at f_0. These two relations are easily seen in Fig. 5, where clearly both reflection coefficients have a 0-deg. phase relation and the magnitude relation is respected under small-signal conditions. As signal builds-up, $|S_{11}|$ will decrease and $|1/S_{11}|$ (M1 in Fig. 5) and the resonator's refection (M2 in Fig. 5) will merge at the desired frequency at steady state.

After tuning the matching circuit and determining the proper resonator model, the nonlinear model can be substituted for the *.s2p file and used to simulate and optimize the phase noise and power performance of the circuit. Note that accurate and complete modeling of the biasing network is needed at this point to ensure the model will more closely predict the actual circuit.

The Libra simulator from Agilent Technologies (formerly HP-EEsof) was used to simulate the performance of an oscillator in three steps:

1. The simulator looks for the frequency of oscillation.
2. The power output of the oscillator is computed.
3. The phase noise is calculated.

Difficulties in successfully simulating the oscillator circuit are typically encountered in steps 1 and 2. It is more likely that problems will be encountered in step 2 and the simulator will be unable to converge on the oscillator's output power. If this problem is encountered, the following steps may help convergence problems:

1. Change the Q of the resonator circuit by varying the R of the parallel RLC.
2. Vary the coupling of the resonator by varying the N of the transformer.
3. Vary the source and drain stub lengths.

Using a detailed schematic diagram (available from the author or from the full application note), the simulator predicted the results shown in Figs. 7 and 8. Compared to the measured performance of Table 1, it can be seen that the simulation was useful in predicting actual circuit behavior.

Upon achieving satisfactory results with the simulation and choosing the appropriate circuit values for the different components, a prototype board was constructed and tested for compliance with the proposed specifications. When turned on, the DRO exhibited a lower-than-expected output power (+2 dBm) and the tuning range (via the tuning screw) was less than the preferred 100-MHz minimum, even after optimizing the puck placement. This was due to the non-optimal length of the two tuning stubs (source and drain). Decreasing the length of the drain stub by approximately 20 mils brought the oscillator's center frequency back to 11.25 GHz, slightly increased the output power and provided the required tuning range. Decreasing the source stub granted the expected output power (+6.5 dBm).

Once basic oscillation conditions were reached, and the two start-up conditions (slow with a power supply and fast by clipping the supply on) were verified, the phase-noise performance was investigated and the puck placement optimized. Although it usually is a time-consuming and tedious activity, it is also fairly straightforward. The puck is first moved along the 50-Ω transmission line to optimize output power, fairly close to the line (to provide a strong coupling).

Once that location is defined, the puck will be moved to that place of reference, either closer to or away from the line. This will reduce the output power, but increase the loaded Q of the DRO and dramatically improve phase noise. Figure 9 presents the layout of the DRO that was tested, and Figs. 10 and 11 present the measured output power and phase-noise performance that was achieved. As can be reviewed in Table 1, these results matched the simulated performance quite well and meet all of the design's specifications. ●●

For further reading

Roger Muat, "Choosing Devices For Quiet Oscillators," *Microwaves & RF*, August 1984.

"Converting GaAs FET Models For Different Nonlinear Simulators," California Eastern Laboratories, Santa Clara, CA, Application Note AN1023.

"Designing VCOs And Buffers Using The UPA Family Of Dual Transistors," California Eastern Laboratories, Santa Clara, CA, Application Note AN1034.

J.S. Sun, L. Wu, and C.C. Wei, "Network Analysis Simplifies The Design Of Microwave DROs," *Microwaves & RF*, May 1990.

"An Introduction To Dielectric Resonators," Trans-Tech, Application Note 821.

D.B. Leeson, "A Simple Model Of Feedback Oscillator Noise Spectrum," *Proceedings of the IEEE*, Vol. 54, February 1966, p. 329.

"1/f Noise Characteristics Influencing Phase Noise," California Eastern Laboratories, Santa Clara, CA, Application Note AN1026

Randall W. Rhea, *Oscillator Design And Computer Simulation*, Nobel Publishing, Stone Mountain, GA, 1995.

LNA serves multiple systems

Model MAX2374 is a miniature low-noise amplifier (LNA) in an ultra-chip-scale package (UCSP). It is intended for code-division-multiple-access (CDMA) applications but can be used in Personal Digital Cellular (PDC), Global System For Mobile Communications (GSM), and enhanced data for GSM (EDGE) applications. The device has 15-dB typical high gain at a supply current of 9 mA. In low-gain mode, the gain is reduced by 1 dB with a reduction in supply current to 4.5 mA. The part is packaged in the UCSP, significantly reducing the required printed-circuit-board (PCB) area. The chip measures only 1.0 × 1.5 mm and occupies only 40 percent of the area of a 6-pin SC70 package. P&A: $0.49 (300,000 qty.). **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: http://www.maxim-ic.com.**

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Signal monitor checks satcom quality

The model P9116 satcom signal monitor is a 1.6-GHz spectrum analyzer for local or remote monitoring of C-, X-, or Ku-band downlink signals. Its 0.5 parts-per-million (PPM) frequency accuracy is achieved by locking the fully synthesized local oscillator (LO) to each point in a sweep. This is performed in small steps so that every frequency point that the instrument displays is the equivalent of the reference oscillator. The unit possesses a frequency resolution of 2 Hz and a synthesizer step time of <150 μs, with an absolute level accuracy of ±0.5 dB over the −120- to +20-dBm amplitude range. In a remote-monitoring application, located at any designated ground station, the analyzer simulates a server and can be accessed and controlled from any "client-designated" personal computer (PC) or laptop through an RS-232 modem, Ethernet local-area network (LAN), or the Internet. This enables data processing, storage, display, transfer, or printing from anywhere in the world using normal PC techniques. **Morrow Technologies Corp., 2300 Tall Pines Dr., Largo, FL 33771; (727) 531-4000, FAX: (727) 531-3531, Internet: http:// www.morrow-corp.com.**

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IDPs reach 2.5 Gb/s

The first 2.5-Gb/s integrated detector and preamplifiers (IDPs) have been introduced. Operating from a single +3.3-VDC supply, the models AMT8300T46F/L and AMT8400T46F/L provide high-speed data handling for 800- and 1300-nm fiber applications. They detect fiber-optic signals and convert them to electrical signals, and enable small-form-factor transceivers for high-speed 2X fiber channel and emerging 2.5-Gb/s Infiniband fiber-optic networks. Using automatic gain control (AGC), the AMT8300 offers a minimum sensitivity of −20 dBm and an optical overload of better than 0 dBm for 850-nm applications. The AMT8400 features a minimum sensitivity of −23 dBm and an optical overload of better than 0 dBm for 1300-nm systems. The units offer a bandwidth of 1800 MHz and a wide dynamic range that supports greater flexibility in system designs and applications. The wide dynamic range enables designers to expand the transmission distance of fiber links and provides additional margin in the overall receiver design, supporting greater flexibility in the selection of subsequent components in the receive (Rx) chain. **ANADIGICS, 35 Technology Dr., Warren, NJ 07059; (908) 668-5000, FAX: (908) 668-5132, Internet: http://www.anadigics.com.**

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Features enhance channel emulator

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Yagi antennas span 806 to 960 MHz

Models ASP-998 and ASPG998 are Yagi antennas that operate across the 806-to-894- and 890-to-960-MHz frequency ranges, respectively. Both of the models have 8-dBd minimum (10-dBi typical) gain with a typical VSWR of 1.5:1. The ASP-998 Yagi antenna has a front-to-back ratio of greater than 11 dB with a 42-to-51-deg. E-plane and a 53-to-68-deg. H-plane beamwidth. The ASPG998 has a front-to-back ratio of greater than 10 dB with a 44-to-50-deg. E-plane and a 55-to-64-deg. H-plane beamwidth. Both antennas weigh 1.2 lb. (0.54 kg) with a length that consists of 23.2 in. (58.9 cm). The antennas are vertically polarized with a maximum power rating of 125 W. P&A: $98.50. **Antenna Specialists, 30500 Bruce Industrial Parkway, Cleveland, OH 44139; (440) 349-8400, FAX: (440) 349-7430, Internet: http://www.antenna.com.**

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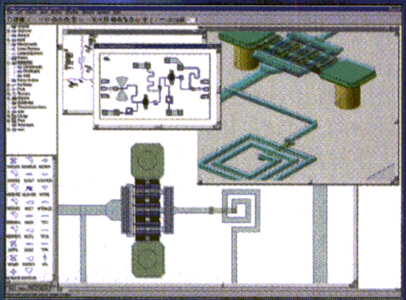

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Diplexers suit LMDS

A range of WR28 (WG22) precision diplexers is suited to current point-to-multipoint telecommunication applications such as local multipoint-distribution services (LMDS). Spanning 26 to 40 GHz the duplexers are available in H- and E-plane geometries. Electrical and mechanical customizations are available to include non-standard flange configurations, fixing brackets, and heat sinks. The design uses the millimeter-wave precision-casting process, enabling complex multipart assemblies to be produced as one precision component, reducing parts count, weight, and assembly time. **Mirco Metalsmiths Ltd., Thornton Road Ind. Est., Pickering, N. Yorks. YO187JB, United Kingdom; +44 (0) 1751 475058, FAX: +44 (0) 1751 476364, e-mail: micromarketing@dial.pipex.com, Internet: http://www.micrometal.co.uk.**

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Upconverter MMIC serves CDMA and AMPS

Model HPMX-7201 is a dual-band, dual-mode upconverter monolithic microwave integrated circuit (MMIC) designed for use in dual-mode, mobile-phone handsets, combining 1900-MHz digital personal-communications-services (PCS), code-division-multiple-access (CDMA), and 800-MHz Advanced Mobile Phone Service (AMPS) capabilities. It has a maximum frequency of 40 GHz and operates from +3 VDC nominal (+2.27 to +3.30 VDC), making it ideal for use with a single-cell, lithium-ion (Li-ion) battery. The PCS CDMA transmit chain provides typical adjacent-channel power rejection of −59 dBc/30 kHz at P_{out} = +11 dBm and a low-noise floor for compliance with Telecommunication Industries Association (TIA) standard TIA98-C. The CDMA driver has a high output power (up to +10 dBm) to permit it to directly drive handset power amplifiers (PAs), and incorporates a switch on the output to support split-band filtering. The driver is adaptively biased to reduce current consumption and extend battery life. Drivers can be directly powered from the battery. A power-down function typically reduces the supply current to 1 μA to support gated operation and eliminate the need for a power-supply switch. **Agilent Technologies, Inc., 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; (800) 452-4844, Internet: http://www.agilent.com.**

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Varactor targets +3-VDC platforms

The model SMV1763-079 silicon (Si) hyperabrupt junction tuning varactor diode is designed specifically for +3-VDC platforms. The hyperabrupt junction tuning varactor features a high capacitance ratio at low reverse voltage, making it suitable for low-phase-noise, voltage-controlled oscillators (VCOs) in wireless systems to 2.5 GHz and beyond. The varactor is designed for high-volume, low-cost battery-powered applications. **Alpha Industries, Inc., 20 Sylvan Rd., Woburn, MA 01801; (781) 935-5150, FAX: (617) 824-4579, Internet: http://www.alphaind.com.**

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Model MAX2240 is a power-amplifier (PA) integrated circuit (IC) designed specifically for applications from 2.4 to 2.5 GHz. The IC operates from a +2.7- to +5-VDC single-supply voltage and generates a nominal +20-dBm (100 mW) output power in the highest power mode with a typical current consumption of 105 mA. The PA is compliant with Bluetooth, HomeRF, and 802.11 wireless local-area-network (WLAN) standards, as well as other frequency-shift-keying (FSK) modulation systems. The PA includes a digital power-control circuit in order to greatly simplify control of the output power. Four digitally controlled output-power levels are provided from +3 to +20 dBm. A digital input controls the active or shutdown operating modes of the PA. P&A: $1.75 (1000 qty.). **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (408) 737-7600, FAX: (408) 737-7194, Internet: http://www.maxim-ic.com.**

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A brochure discusses a software package that offers a set of planning tools for wireless communication systems applications. Multiple map displays, support for Windows™ printer/plotter device drivers, clipboard support, and toolbars are highlighted. **EDX Engineering, Inc.;** *(541) 345-0019, FAX: (541) 345-8145, e-mail: info@edx. com, Internet: http://www.edx.com.*

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Process cleaning

A four-page brochure details power generators for wet process cleaning. Generator features are included. Power and frequency range, generator and operator controls, footprint choices, RF output channels, and an operating protocol are specified. **Lambda RF Systems;** *(408) 653-1675, FAX: (408) 653-1660, e-mail: bruce_chinich@Lambdaaa.com, Internet: http://www.lambdarfsystems.com.*

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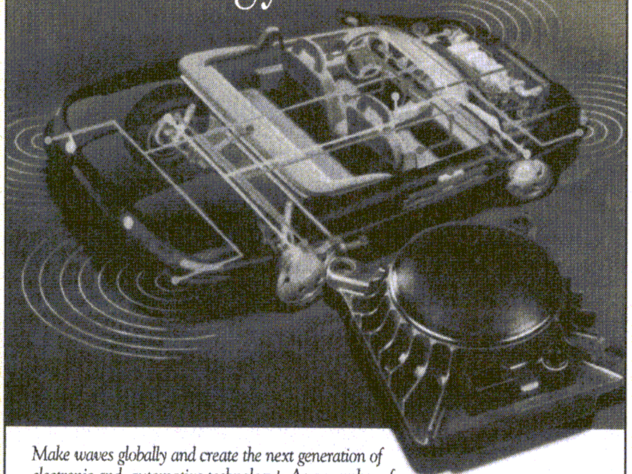

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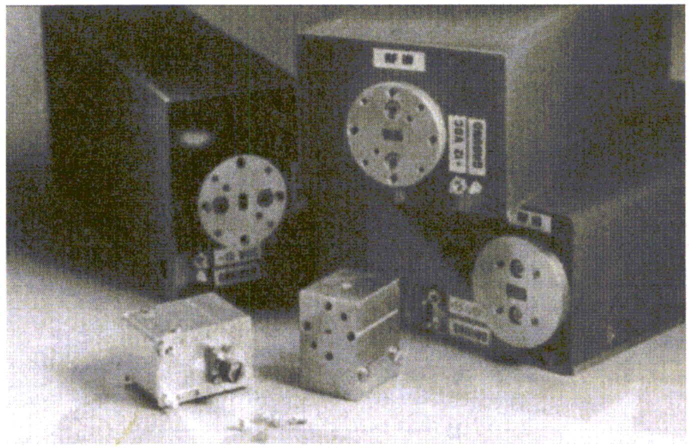

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Microwaves & RF July Editorial Preview

Issue Theme: Fiber-Optics Technology

News

Fiber-optic technology has often been viewed as an alternative to RF technology. Increasingly, RF designers are viewing fiber optics as a companion technology. Already, device manufacturers are looking ahead to rates of 40 Gb/s. This technology is already well-entrenched in portions of wireless systems, with many high-speed applications on the way.

Design Features

Several of July's contributed articles are devoted to noise analysis. In one, authors from France explain how a powerful system-level software simulator can be used in order to predict the noise power ratio (NPR) of RF and wireless modules. In another, a world-renowned author in frequency-synthesizer design reviews recent advances in linear voltage-controlled-oscillator (VCO) calculations and design.

Product Technology

July's Product Technology section features several components that are aimed at high-power solutions, including a four-port drop-in circulator for personal-communications-services (PCS) applications and a line of high-power transistors designed for pulsed avionics applications.

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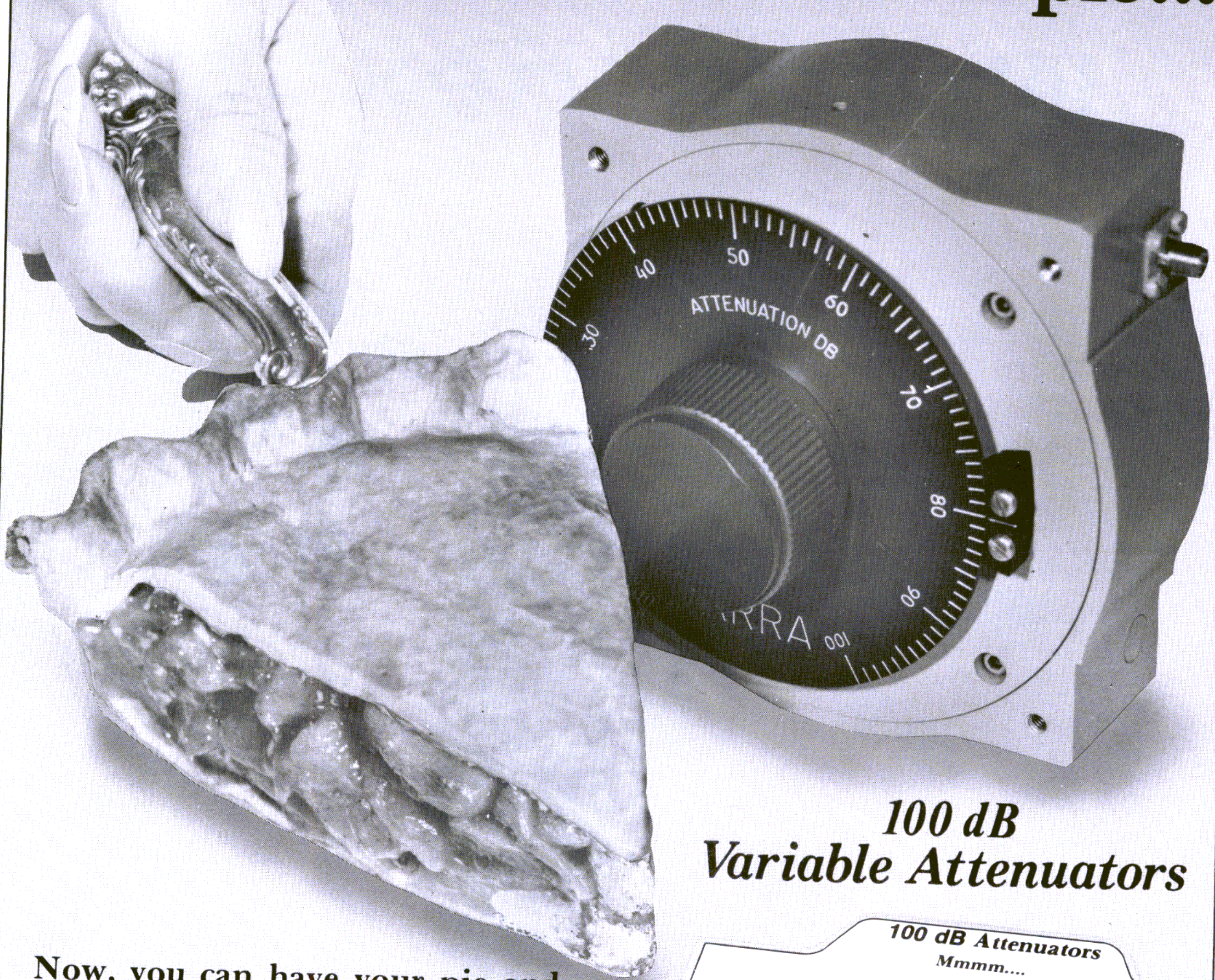

100 dB Variable Attenuators

100 dB Attenuators
Mmmm....

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

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