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Microwaves & RF

A PENTON PUBLICATION ▪ JULY 1995

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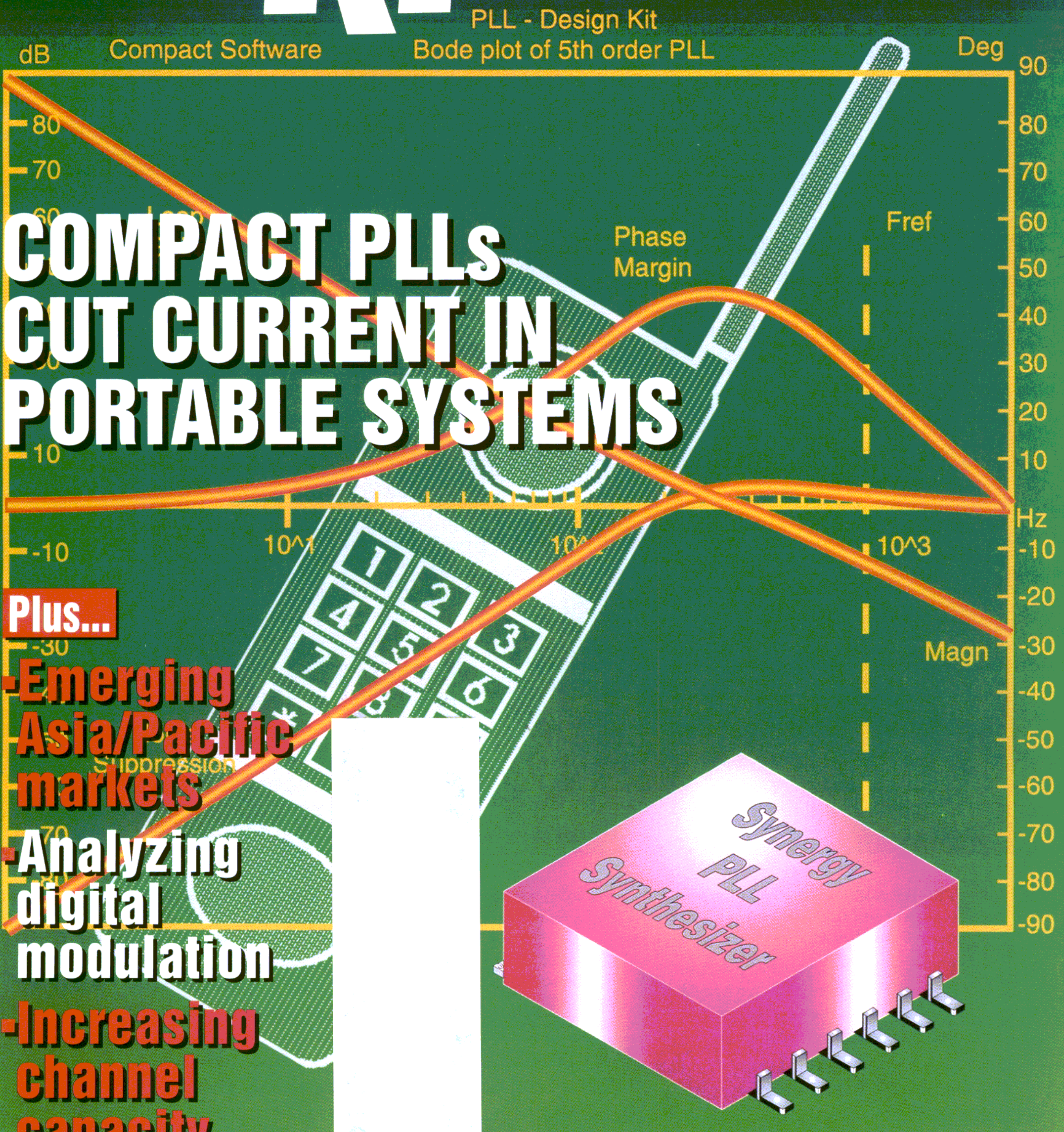

Plus...

- Emerging Asia/Pacific markets
- Analyzing digital modulation
- Increasing channel capacity

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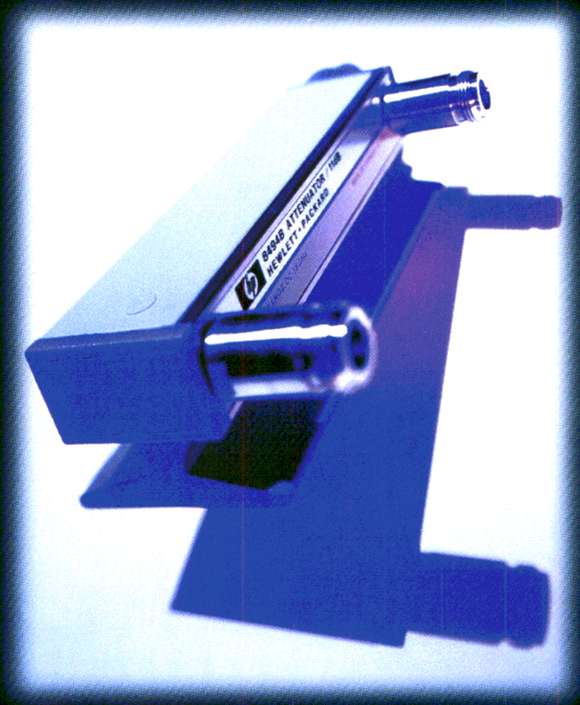

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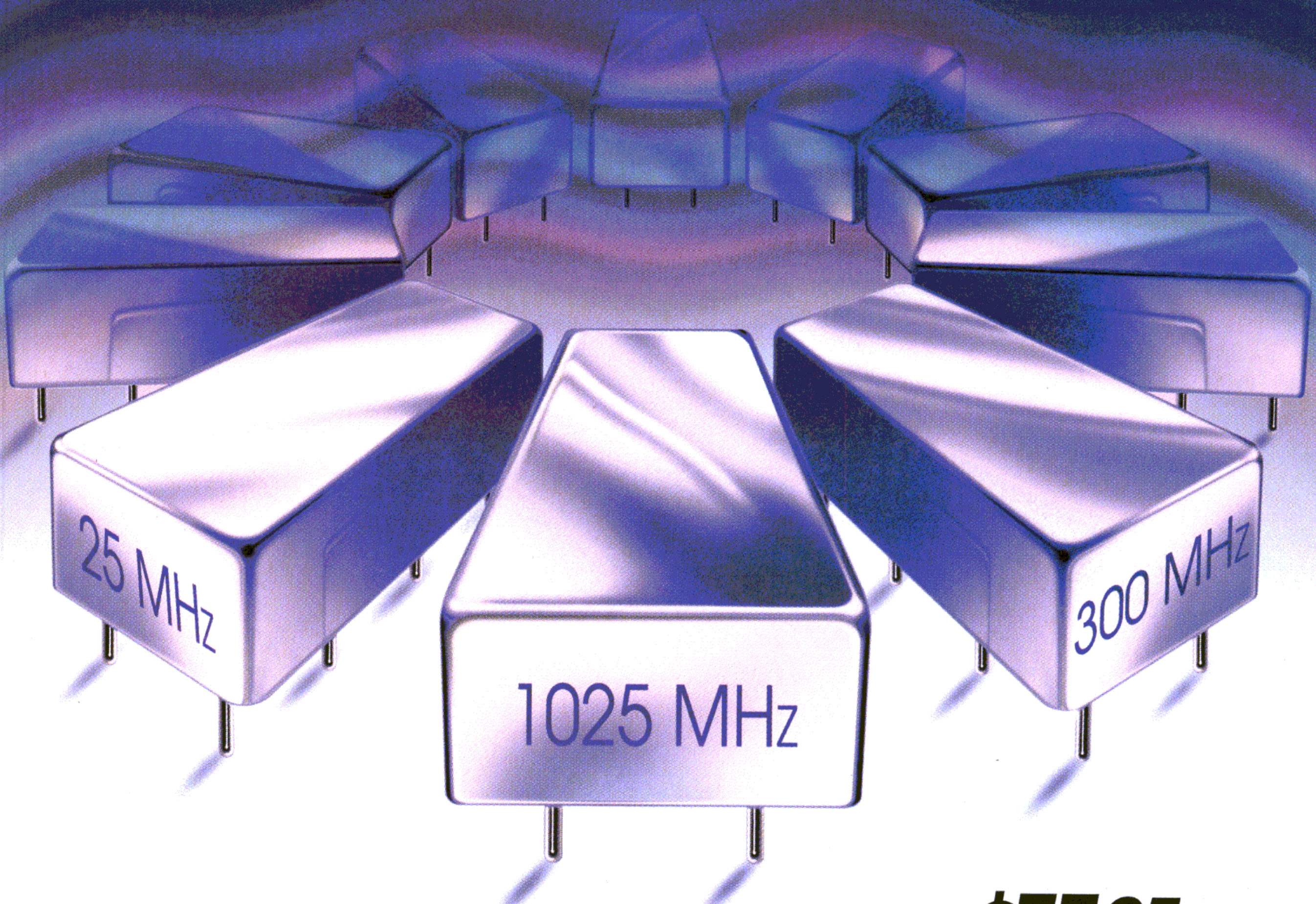

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POS-75	37.5-75	-110	-27	17	11.95
POS-100	50-100	-107	-23	18	11.95
POS-150	75-150	-103	-23	18	11.95
POS-200	100-200	-102	-24	18	11.95
POS-300	150-280	-100	-30	18	13.95
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POS-765	485-765	-85	-21	22	14.95
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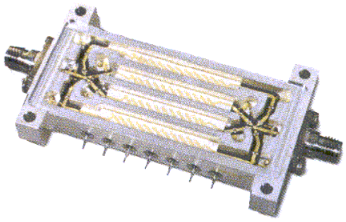
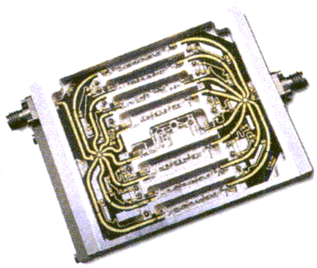


Ku-Band Switched Filter



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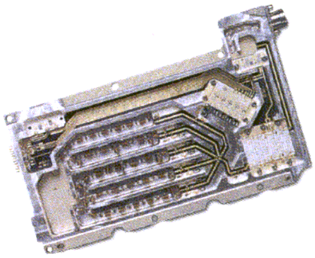
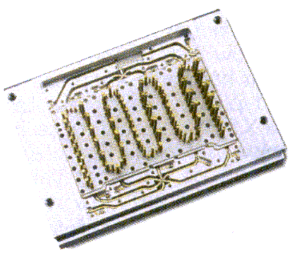


5-Channel Switched Filter Amplifier Assembly



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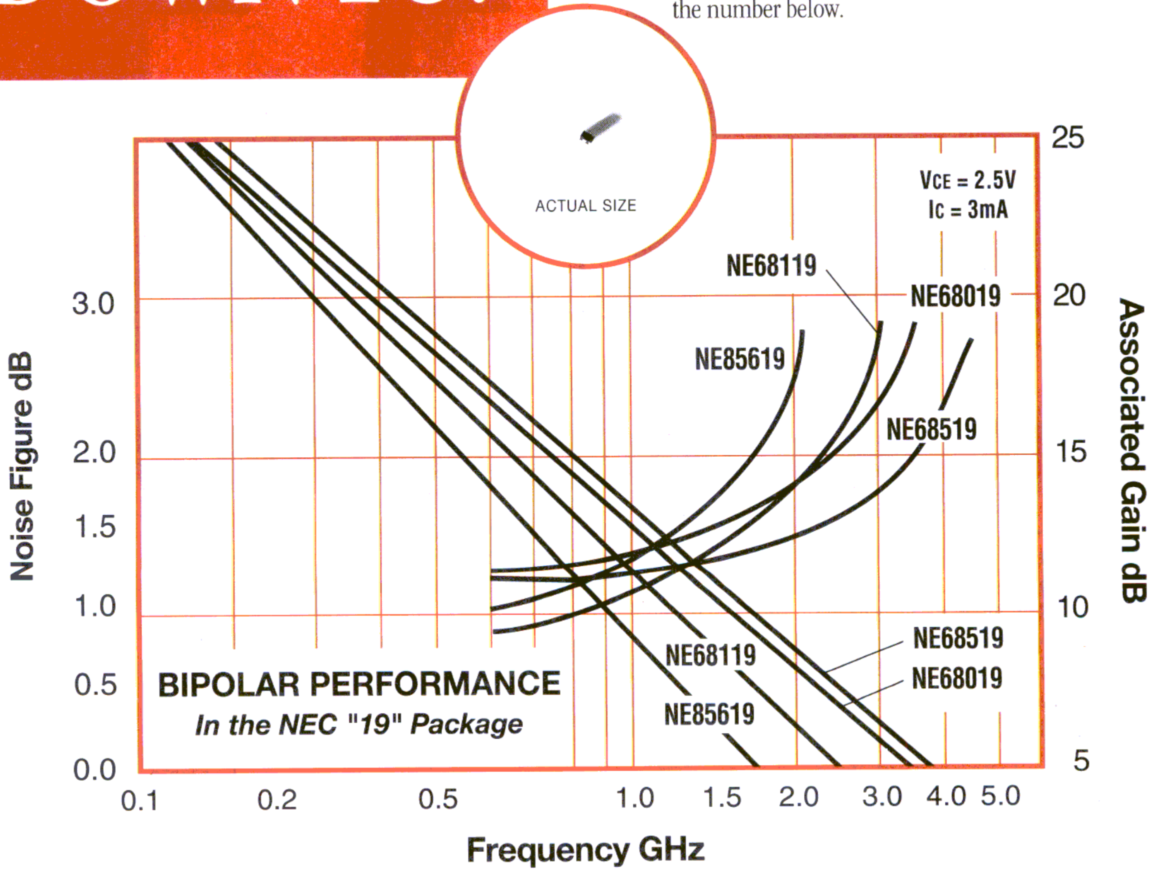
They're available now, on tape and reel, and priced to meet your needs. For Data Sheets and a copy of *Automated Assembly of Miniature Parts*, call your nearest CEL Sales Office or circle the number below.



NEC Bipolars are available in these packages (shown approx. 2X size)

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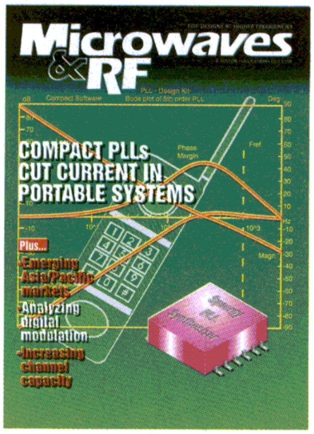
JULY 1995 VOL. 34, NO. 10

Cover feature



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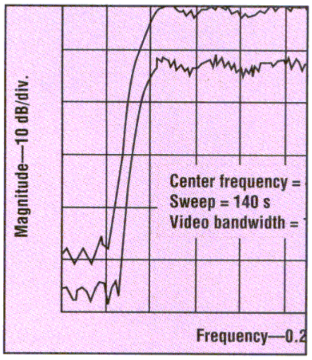
News

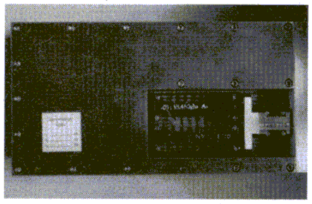
Wireless growth

Design features



Noise level

Product technology



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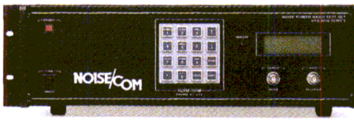

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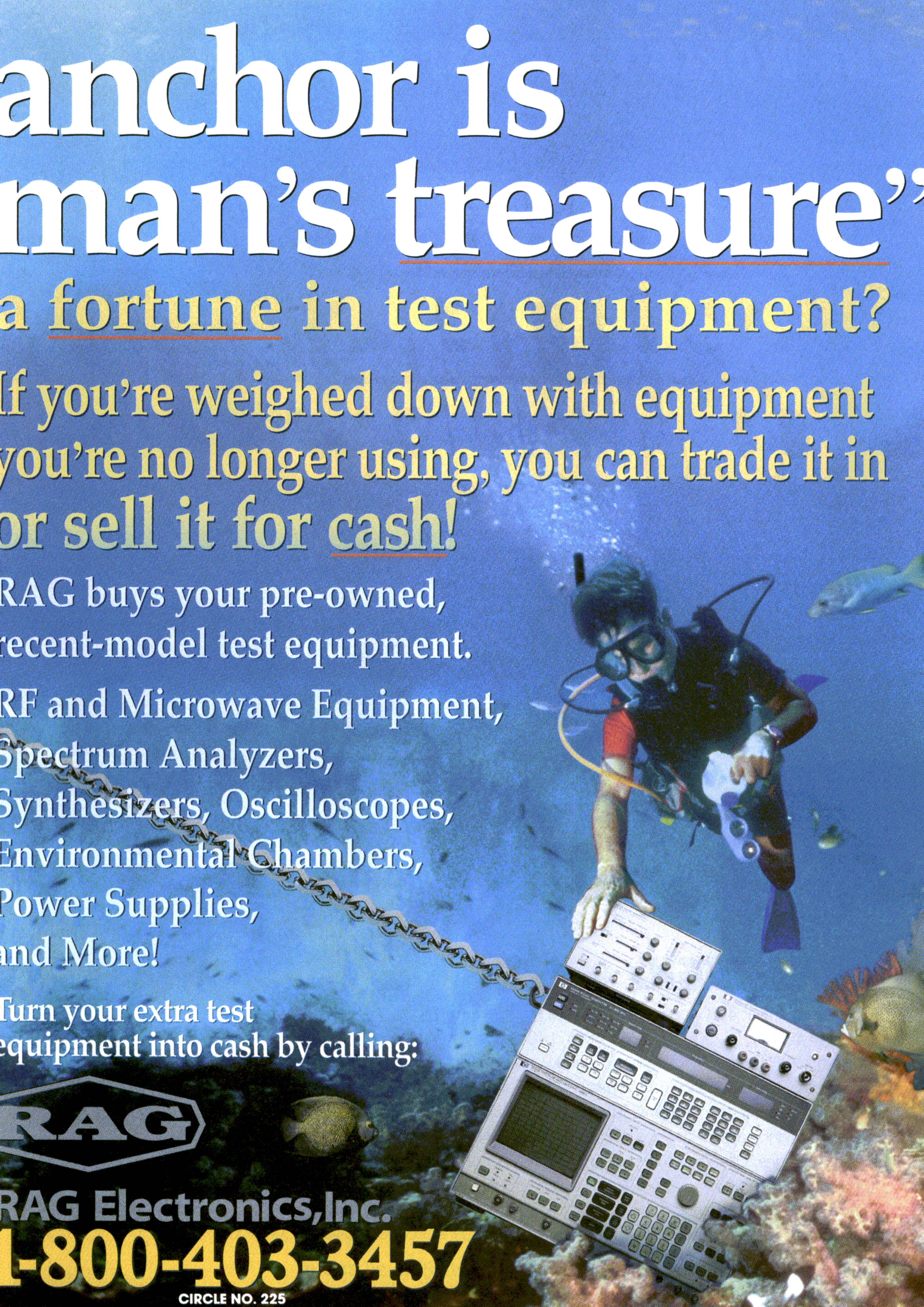
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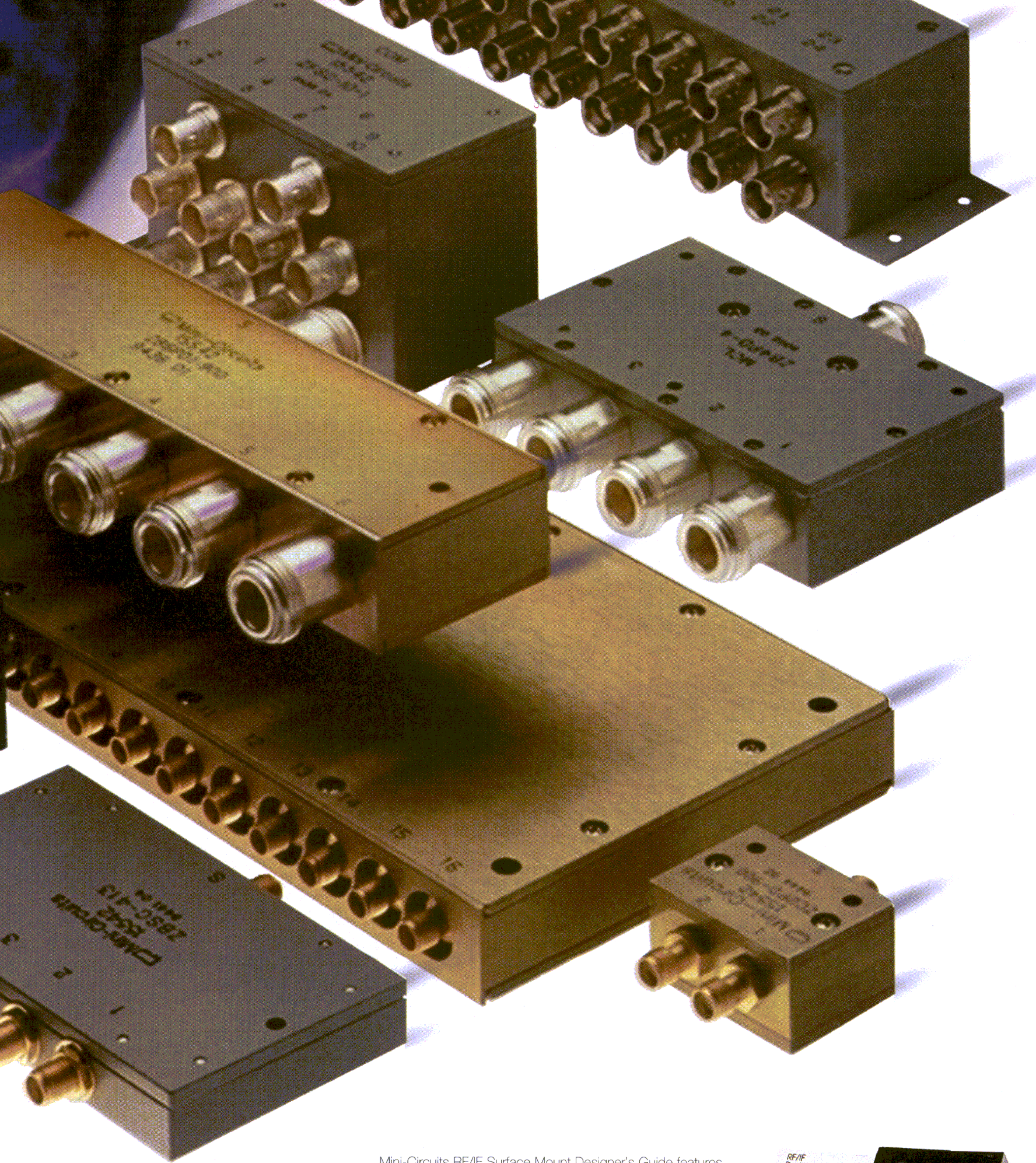

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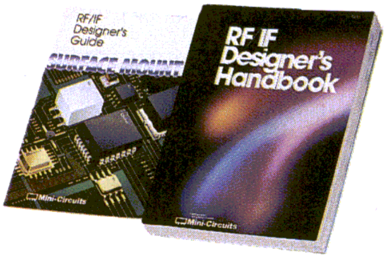

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Noise factors

To the editor:

The error in the letter on noise figure/factor in the April 1995 issue ("Feedback," p. 13) pretty much destroys the writer's argument. The letter states that power, voltage, and current gain in decibels are calculated as $10\log_{10}$ of the ratio. In fact, voltage and current gain are $20\log_{10}$. The point here is that "gain" by itself is an incomplete description. For example, voltage gain and power gain are different concepts, and thus affect a design's specifications differently.

The same is true with "noise factor" and "noise figure." If everyone would give the number in decibels when talking about noise figure as defined in the Hewlett-Packard application note Bill Pastori refers to in his letter, there would be no problem. Unfortunately, people frequently omit the decibel unit after the number, leaving the reader wondering exactly what specification was meant. Creating and observing a distinction between noise figure (a log) and noise factor (a number) provides additional information which can be critical.

I have not looked at the 1957 IRE definition that Pastori references, but I'd be willing to bet that the Hewlett-Packard application note (No. 57-1) is a lot more valuable to the working engineer.

Barrie Strachan
Electrical Engineer
Lakeside, CA

Noise feedback

To the editor:

In regard to the comment by Bill Pastori that "noise figure" and "noise factor" are the same ("Feedback," April 1995, p. 13), it may be that in the obsolete (1957) IRE definition and in the old book by Mumford and Scheibe the concepts are the same. However, in antennas, they are not.

Noise figure refers to the measurement of receiver noise with an attached load, so that the noise temperature divided by T_0 is given by NF – 1. Noise factor, as used by antenna folk, is defined as the ratio of antenna (or system) temperature to standard temperature T_0. Noise factor is used as a ratio and in decibels. See, for example, the internationally-used CCIR-ITU report 322-2 (1983) "Characteristics and Applications of Atmospheric Radio Noise Data."

Robert C. Hansen
Consulting Engineer
Tarzana, CA

Please comment

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

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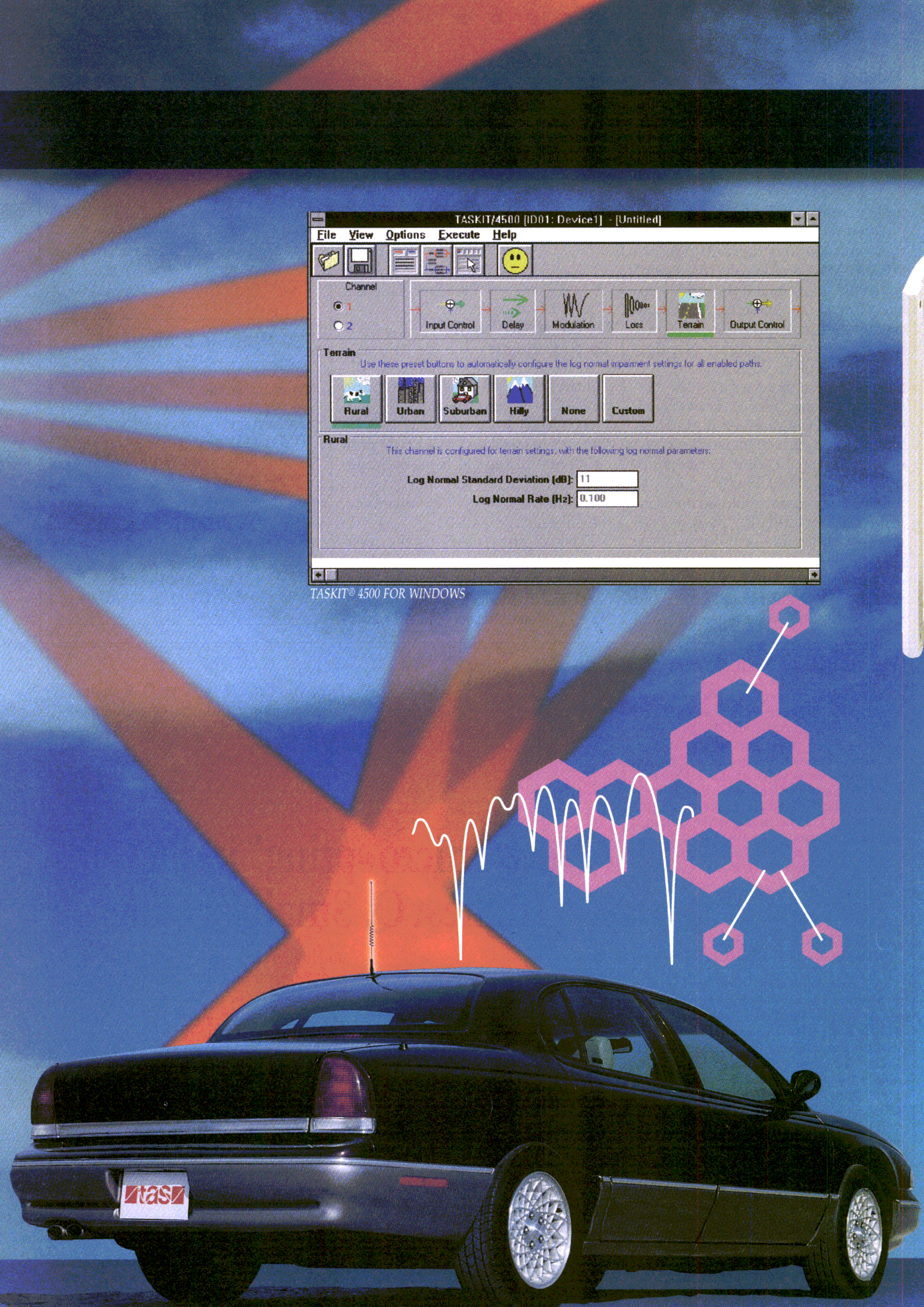

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CIRCLE NO. 217

IF YOU CAN'T KILL THE MESSAGE, KILL THE MESSENGER

Several years ago while attending an industry reception at one of the large Washington, DC hotels, I spotted then-Federal Communications Commission (FCC) Chairman Richard E. Wiley standing alone at the far end of the crowded room.

It seemed like a good opportunity to interview the top guy at the nation's communications regulatory agency, so I walked over and introduced myself. Hoping to break the ice (I didn't know how he felt about reporters), I thought I would try something fairly innocuous.

"Wouldn't it make more sense if the chairman of the FCC were an engineer rather than a lawyer?" I asked.

"No," Wiley, a lawyer, quickly replied, "it wouldn't."

I thought about that meeting when House Speaker Newt Gingrich (R-GA) said recently that the FCC should be phased out over the next three to five years. Two conservative "think tanks," the Heritage Foundation and the Progressive & Freedom Foundation, have made similar suggestions.

Industry groups, such as the Wireless Cable Association (WCA), have been quick to pick up the cudgel. The WCA will hold a session at its annual meeting in July called *FCC—Less Regulation, More Market Opportunities*. It's not a question.

George Keyworth, who heads the Progressive & Freedom organization and who served as science adviser to the Reagan Administration, would like to see the 61-year-old FCC replaced by a much smaller Office of Communications, located in the Old Executive Office Building next to the White House. In other words, more political and less independent.

Keyworth believes that free and open markets will take care of themselves. But with industry political action committees spending millions of dollars to lobby Congress on new telecommunications legislation, how "free" will these markets be?

Of course, current FCC Chairman Reed Hundt doesn't like the idea of abolishing the FCC. "It is obvious that this group (the Keyworth-led foundation) has a rhetorical and political mission that pushes their logic beyond the limits of good sense," Hundt said in a recent speech.

Would the public be better served by less regulation of an industry that is growing very rapidly in complexity as well as in size? Would eliminating an independent regulatory body such as the FCC open the US to foreign communications carriers, and is that a good idea? Would the industry rather go to court than to the FCC in order to solve its problems? Who in the federal government is better technically qualified than the FCC to represent the US at international communications conferences? Should new wireless carriers and broadcasters have the right to unrestricted use of their assigned spectrum, as the Heritage Foundation suggests, with little or no future oversight?

Wiley was right; the job does require a lawyer.••

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Executive Editor
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Editorial Office
Penton Publishing
611 Route #46 West
Hasbrouck Heights, NJ 07604
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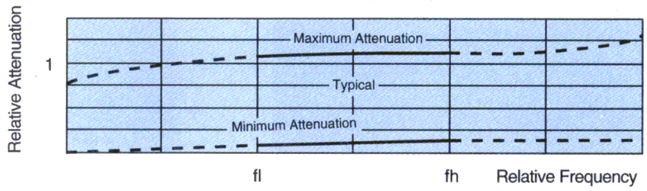
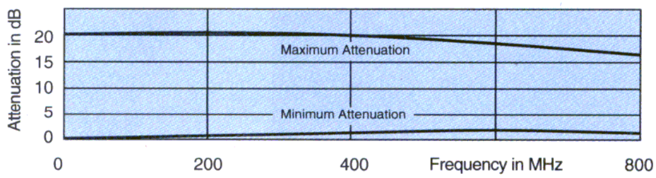
Attenuation vs. Frequency Series AV



Attenuation vs. Frequency Series LAV



Typical RLC Attenuators

Types:	Precision Step, Miniature Step, Switchable, Programmable, Continuously Variable, Miniature Fixed, High Power Fixed
Frequency Range:	DC to 40 GHz

Attenuation Range:	0 to 130 dB
Power:	Milliwatts to Kilowatts
Connectors:	SMA, N, BNC, TNC
Environmental Conditions:	MIL-A-3933
Programmable Options:	Fail Safe, Latching, TTL, Indicators, Voltages

Typical AV & LAV Series Specifications

Model No.	Frequency Range (GHz)	Attenuation Range (dB) (Min)	VSWR (Max)	Insertion Loss (dB) (Max)
AV-0915	.95 - 1.5	10	1.5	0.3
AV-1020	1.0 - 2.0	10	1.5	0.4
AV-1922	1.9 - 2.2	20	1.3	0.4
AV-2040	2.0 - 4.0	25	1.5	0.5
AV-3060	3.0 - 6.0	20	1.5	0.5
AV-3742	3.7 - 4.2	20	1.4	0.5
AV-4080	4.0 - 8.0	20	1.5	0.5
AV-5964	5.9 - 6.4	20	1.4	0.5
AV-70124	7.0 - 12.4	20	1.5	0.5
LAV-	DC - .20 .20 - .45 .45 - .70 .70 - .80	18 17 16 15	1.25 1.50 1.80 2.00	0.5

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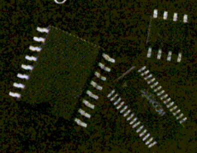

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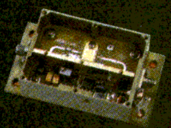

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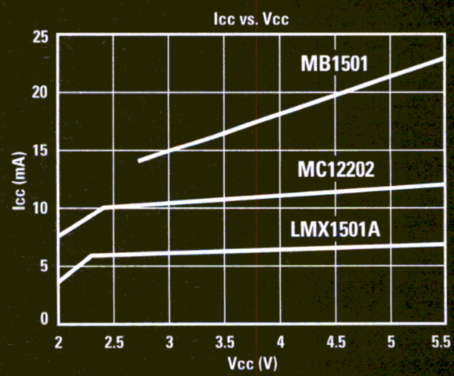

	LMX1501A	LMX1511	LMX2314/15	LMX2320	LMX2325	LMX2330A	LMX2331A	LMX2332A	LMX2335	LMX2336	LMX2337
RF Input-Main PLL	1.1GHz	1.1GHz	1.2GHz	2.0GHz	2.5GHz	2.5GHz	2.0GHz	1.2GHz	1.1GHz	2.0GHz	550MHz
RF Input-Aux PLL						510MHz	510MHz	510MHz	1.1GHz	1.1GHz	550MHz
I_{cc} (typ) @3V	6mA	6mA	6mA	10mA	11mA	15mA	14mA	8mA	9mA	11mA	9mA
Powerdown (typ)	N/A	N/A	30μA	30μA	30μA	1μA	1μA	1μA	1μA	1μA	1μA

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Slow start for digital cellular use

WHEATON, MD—The latest in a series of quarterly studies by Herschel Shosteck Associates, Ltd. indicates that relatively high prices, restricted market availability, limited geographic coverage, and little perceived benefit will slow the growth of the digital cellular market.

Of the two US digital standards—TDMA/IS-54 (IS-136) and CDMA/IS-95—TDMA has a clear, early lead. Shosteck says that 80,000 TDMA/IS-54 telephones were shipped in 1993. In 1994, shipments increased to 400,000. Shosteck estimates that one million units will be shipped to the US market during 1995.

Two reasons for the relatively slow digital start in the US, according to Shosteck, are that TDMA/IS-54 technology in its early stages has performed no better, and sometimes worse, than conventional analog and that TDMA handsets are more expensive than analog.

"CDMA/IS-95 lags three years or more behind TDMA/IS-54 in development," states Shosteck. "In common with all new technologies, CDMA/IS-95 will undergo an arduous and extended debugging which will retard early sales." Shosteck anticipates that CDMA/IS-95 sales will follow the same growth curve as did early TDMA/IS-54.

The challenge that CDMA/IS-95 faces is that it will compete against analog and TDMA/IS-54. "Analog will be fully-mature and TDMA/IS-54 will be semi-mature. Both may deliver more benefits than initial CDMA/IS-95 products. More importantly," says Shosteck, "the handsets for both will be less expensive."

Based on the replies to Shosteck's survey, he anticipates that very few to 3000 "fully-commercial" CDMA/IS-95 phones will be shipped in 1995, and these will be for the US market only. He also expects total terminal sales to contract by 30 percent in 1997 as the consumer market peaks. He believes this contraction will be exclusively in the analog sector. Sales of digital phones—purchased primarily by businesses—will continue to expand in 1997.

Shosteck says his estimates of the market from 1992 to 1994 and projections for 1995 are based on reports from key cellular manufacturers and carriers. Forecasts of 1996 through 1998 are based on the rate of early analog sales, and in the case of CDMA/IS-95, it may be at the rate of early TDMA/IS-54 sales.

Varian to sell Electron Devices

PALO ALTO, CA—Varian Associates, Inc. has agreed to sell its Electronic Devices business unit to Leonard Green & Partners, L.P. (LGP) on behalf of its equity fund, Green Equity Investors II, L.P., for approximately $200 million in cash, plus the assumption of certain liabilities.

LGP is a private merchant banking firm based in Los Angeles, CA that specializes in organizing, structuring, and sponsoring management buyouts of established companies. The transaction is subject to customary conditions and the arrangement of financing; however, the sale is expected to be closed by mid-September.

Varian announced that it would seek a buyer for the Electron Devices business last fall. With net assets of approximately $120 million and 1994 sales of about $250 million, the operations being sold rank as the smallest of Varian's four major businesses. The units to be sold are located in Palo Alto, San Carlos, and Santa Clara, CA; Beverly, MA; and Georgetown, Ontario, Canada.

J. Tracy O'Rourke, Varian's chairman and CEO, says the sale allows the company to exit what is largely a components business and concentrate on its faster-growing equipment operations. He says most of the proceeds from the sale will be used to repurchase shares of Varian stock.

LGP plans to change the name of the operations being acquired to Communications & Power Industries. Upon completion of the sale, Al D. Wilunowski, Varian executive vice president and head of the Electron Devices business, will become CEO of the renamed operation.

Analog Devices adds DBS

NORWOOD, MA—Analog Devices, Inc.'s Communications Division is adding to its product repertoire with a new, dual high-speed analog-to-digital converter designed expressly for the direct-broadcast-satellite (DBS) market.

The new device (AD9066) is an integrated pair of matched 6-b converters, each with a 60-MSamples/s sampling speed. Although designed for DBS, ADI says its low power (400 mW) and price ($4.59 for orders in the thousands of units) make the integrated device suitable for other communications applications, including wireless local-area networks (WLANs), microwave radio links, or very-small-aperture terminals (VSATs) for satellite communications.

"DBS is real and it is a huge opportunity," says David Duff, product manager for the new ADI product segment. "Much of the world will never see a coax; DBS delivers everything cable can do without needing the wire."

ADI formed the Communications Division in May to address high-growth market segments, concentrating on areas requiring a combination of analog, digital, and mixed-signal expertise. The division's initial target market was wireless; ADI supplies components for handsets and base stations.

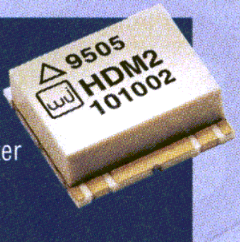
Duff says other DBS products are planned by the company.

How to Equip Your Base Station with One Call:

Mixers and Amplifiers for Base Station Applications

HDM11
High Dynamic Range FET Mixer for Cellular Applications

HDM2
High Dynamic Range FET Mixer for PCS/PCN Applications



HDA1010
High Dynamic Range Amplifier for Cellular Applications

MODEL	RF/LO	IF	3IIP	LO DRIVE
HDM11	800-1000 MHz	10-100 MHz	+37 dBm	+17 dBm
HDM2	1700-2200 MHz	10-200 MHz	+37 dBm	+21 dBm

MODEL	FREQUENCY	GAIN	NOISE FIGURE	3OIP
HDA1010	800-1000 MHz	15 dB	2.7 dB	+40 dBm

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MC2310
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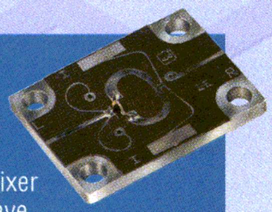

MC2410
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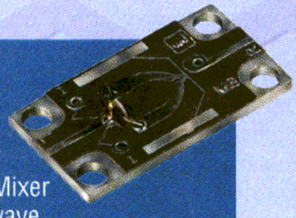

MC2710
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MODEL	RF	LO	IF	LO DRIVE	CONVERSION LOSS
MC2310	3.4-7 GHz	2.2-8 GHz	DC-2 GHz	+10 dBm	6.0 dB
MC2410	4.5-7 GHz	4.5-7 GHz	DC-2 GHz	+10 dBm	5.5 dB
MC2710	10-15 GHz	10-15 GHz	DC-2 GHz	+10 dBm	6.0 dB

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New DSP core-based program

FOSTER CITY, CA—Cadence Design Systems, Inc.'s Alta Group has formed the DSP Core Integration Program to advance the early co-verification of customized hardware and software for DSP core-based application-specific-integrated-circuit (ASIC) designs and printed-circuit boards (PCBs) for wireless-communications applications. Alta Group says that three DSP vendors—AT&T Microelectronics, DSP Group, and Texas Instruments—have independently entered into a relationship with Alta Group as part of the program.

Alta Group is offering specialized design services to support the integration between its Signal Processing WorkSystem (SPW) system-level simulation process and the vendors' instruction-level DSP models. Specifically, SPW will initially be linked to AT&T's 1616/17/18 models, DSP Group's PineDSPCore and OakDSPCore models, and TI's TMS320c5X family of devices.

Baruch Deutsch, Alta Group's product-line manager, says the development of the program was driven primarily by the group's customer base in the wireless-communications market. "Advances in process technology, coupled with the economics required in high-volume wireless applications, are driving Alta Group's customers toward more highly-integrated, core-based, single-chip realizations," and his customers now need new techniques to verify increasingly complex designs in the context of a system environment.

Sprint may spin off cellular

KANSAS CITY, MO—The board of directors of Sprint, the nation's eighth largest cellular carrier, says it is considering several options for the company's cellular unit, including a possible spin-off of the unit to Sprint's shareholders.

William T. Esrey, Sprint's chairman and CEO, says the board is seeking the most effective marketing identity and technological infrastructure for its wireless businesses. "With the wireless industry expected to triple or quadruple in size over the next decade, we want to maximize opportunities for Sprint Cellular, for our new venture with our cable partners, and for our shareholders."

Esrey says all options, including a spin-off of the cellular unit to Sprint shareholders, the sale or exchange of selected properties, or the sale of Sprint Cellular, are being assessed by the board.

In the recent Federal Communications Commission (FCC) auction of personal-communications-services (PCS) spectrum, the Sprint Telecommunications Venture—which includes Sprint, Tele-Communications, Comcast, and Cox Communications—won the rights to licenses covering markets which overlap several service territories operated by Sprint Cellular. Under FCC rules, Sprint will be required to divest or reduce its cellular operations in certain market areas to clear conflicts after the PCS licenses are awarded to the venture.

New focus for The Allen Group

BEACHWOOD, OH—The Allen Group, Inc. has decided that wireless communications holds more promise for growth than the trucking business.

The communications equipment and truck components manufacturer says it will spin off a new company consisting of its Crown and G&O Manufacturing Co. divisions (which comprise the company's Truck Product segment) together with GO/DAN Industries, a manufacturer of heat-transfer products for the automotive aftermarket.

In place of the trucking operation, The Allen Group will concentrate on its faster-growing wireless-communications equipment and services and automotive emissions testing businesses.

Robert G. Paul, president and CEO of The Allen Group, says, "The spin-off we are pursuing will enable the two separate companies to reach their maximum potential by providing each with a highly-focused management team and strong financial resources for future growth. The Allen Group, as a highly-focused telecommunications company, should also be able to utilize its stock as a possible acquisition currency for future growth in the telecommunications industries."

The spin-off is expected to become effective by the end of this year.

Lucas sells aerospace unit

RESTON, VA—In two separate transactions, Lucas Industries plc has sold Lucas Aerospace Communications & Electronics, Inc., which designs and manufactures components and subsystems for microwave and satellite communications, to Sierra Technologies (Dallas, TX).

In one transaction, Sierra Technologies acquired Aul (Garden City, NY) from Lucas. In the other transaction, Sierra Networks, Inc., a newly-formed company, acquired the Epsco (Hopkinton, MA), Weinschel (Gaithersburg, MD), and Zeta (San Jose, CA) businesses of Lucas. Aul, Epsco, Weinschel, and Zeta were all business units of Lucas Aerospace Communications & Electronics.

The sale forms part of a restructuring program by Lucas Industries to divest businesses not vital to its core activities in the aerospace and automotive markets. The combined asset value of the four businesses is approximately $40 million. The purchase price was not disclosed.

Sierra Technologies was formed in 1991 to acquire the assets of Sierra Research (Buffalo, NY), a developer, integrator, and producer of electronic systems and products for military and commercial applications.


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Nokia to supply GO

ALEXANDRIA, VA—Nokia Telecommunications, Inc. will provide $200 million in personal-communications-services (PCS) base-station equipment to GO Communications Corp. in the first three years of a definitive 10-year supply agreement.

GO Communications will bid on 30-MHz PCS licenses at the auction established by the Federal Communications Commission (FCC) for entrepreneurial companies. The auction is scheduled to begin on August 2, 1995. Following the auction, GO plans to form a nationwide alliance of winners of the A-, B-, and C-block auctions that have selected PCS-1900 technology in the US. Delivery under the agreement hinges on GO winning the required licenses.

Nokia's PCS-1900 base stations are based on the Global System for Mobile Communications (GSM) technology standard. GO intends to use GSM smart-card technology under its trademark "GO Card" worldwide. GO customers will be able to use their GO Cards in the 69 countries that have selected GSM for cellular or PCS networks. They will automatically be able to make and receive calls after the GO Card has been inserted into the phone, subject to roaming agreements in the GSM industry.

GO Communications expects to deploy the base stations beginning in the fourth quarter of 1996.

GaAs conference goes global

SAN DIEGO, CA—The executive committee of the US Conference on Gallium Arsenide (GaAs) Manufacturing has unanimously approved opening future meetings to participants from around the world to address the globalization of GaAs and its development in the commercial market.

US citizenship will no longer be a requirement for attending the meeting. In addition, starting with the 1996 conference in San Diego, the name of the meeting will be changed to the International Conference on Gallium Arsenide Manufacturing Technology.

The governing committees will be expanded to include international representation. A 1997 conference site outside the US is under consideration.

Neal Mellen (505-822-8801 ext. 236) is the conference chairman and James Oakes (508-470-9779) is the technical program chairman of the 1996 meeting.

Merix to acquire HP unit

LOVELAND, CO—Hewlett-Packard Co. has agreed to sell some of its Loveland printed-circuit fabrication operation to Merix Corp. (Forest Grove, OR). At closing, Merix expects to pay HP $23.6 million in cash. Further financial details were not disclosed.

Merix will lease approximately 120,000 sq. ft. of the HP printed-circuit facility for up to five years, while Merix establishes other manufacturing facilities in northern Colorado. The company will produce printed-circuit boards for HP under a supply agreement and also expects to produce printed-circuit boards in the facility for other customers.

The agreement is expected to be completed by October 31, 1995, the end of HP's fiscal year.

Merix, which began as the Circuit Board Division of Tektronix in 1959, was formed through an initial public offering (IPO) in May 1994 to operate as an independent company. Reported sales for 1994 were $78.4 million.

Lockheed Martin, GER venture

SYRACUSE, NY—Targeting a growing commercial market for airborne ground-imaging systems, Lockheed Martin's Ocean, Radar & Sensor Systems unit has joined with Geophysical & Environmental Research Corp. (Millbrook, NY) to market a radar system for detecting oil spills, monitoring crops, and surveying natural disasters, among other applications.

The radar is a derivative of Lockheed Martin's APG-67 design, which is used on fighter aircraft and modified for use as a synthetic-aperture radar (SAR). The first of the units will be sold in July to a major oil company. GER is a specialist in remote sensing.

Siemens to acquire AT&T unit

CUPERTINO, CA—Siemens Components, Inc.'s Optoelectronics Division will acquire the optically-coupled solid-state relay business of AT&T Microelectronics. Financial terms were not disclosed.

Siemens and AT&T had jointly developed products as a result of a June 1994 agreement. The new agreement calls for the Siemens division to design and develop packaging for solid-state relays, which are then assembled with AT&T's silicon photodetectors.

Under the acquisition agreement, AT&T will continue to supply the silicon photodetectors for Siemens' solid-state relays. The agreement also calls for production to shift from AT&T to Siemens' optoelectronics site in Penang, Malaysia.

Siemens estimates the worldwide market for this type of solid-state relay to be about $75 million annually.

Kudos....

Three companies have received ISO 9000 certification—the Fremont, CA facility of C-COR Electronics, Inc. (State College, PA); Wiltron Co. (Morgan Hill, CA); and Glasteel Industrial Laminates (Collierville, TN).

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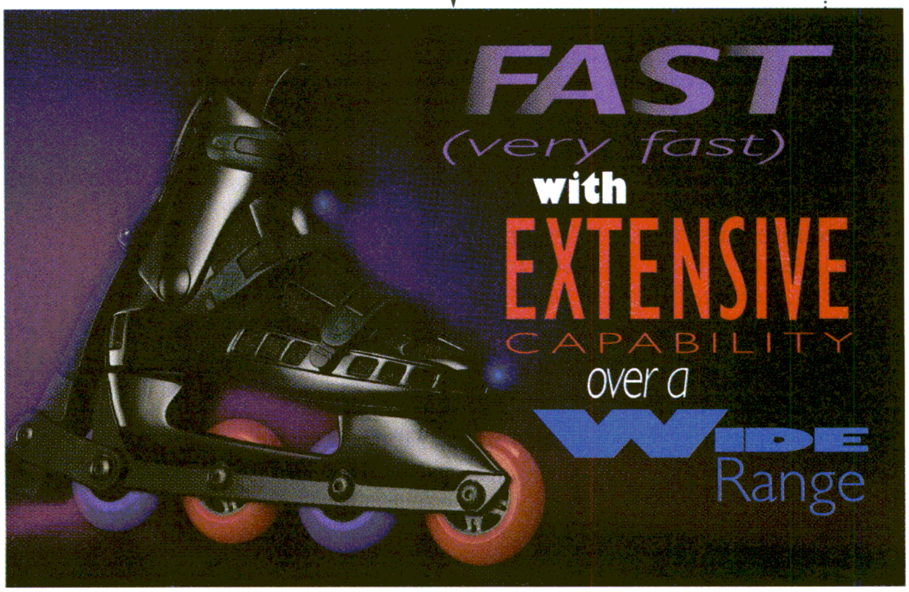

Hewlett-Packard specifications are from the HP 437B and HP 438A technical data sheets dated April 1988 and July 1984, respectively.

Capabilities	Giga-tronics 8541	Hewlett-Packard HP 437B	Giga-tronics 8542	Hewlett-Packard HP 438A
Measurement Speed over GPIB (rdgs/sec)	200	20	200	20
Measurement Speed using Fast Modes (rdgs/sec)	4,000	Not Available	4,000	Not Available
Maximum Dynamic Range with a Single Sensor	90 dB	50 dB	90 dB	50 dB
Direct CW and Peak Power Measurements	Yes	No	Yes	No
Built-in Frequency Cal Factors	Yes	No	Yes	No
Measurement Channels/Display Lines	One/Two	One/One	Two/Two	Two/One
Display Pulse Waveform on External Scope	Yes	No	Yes	No

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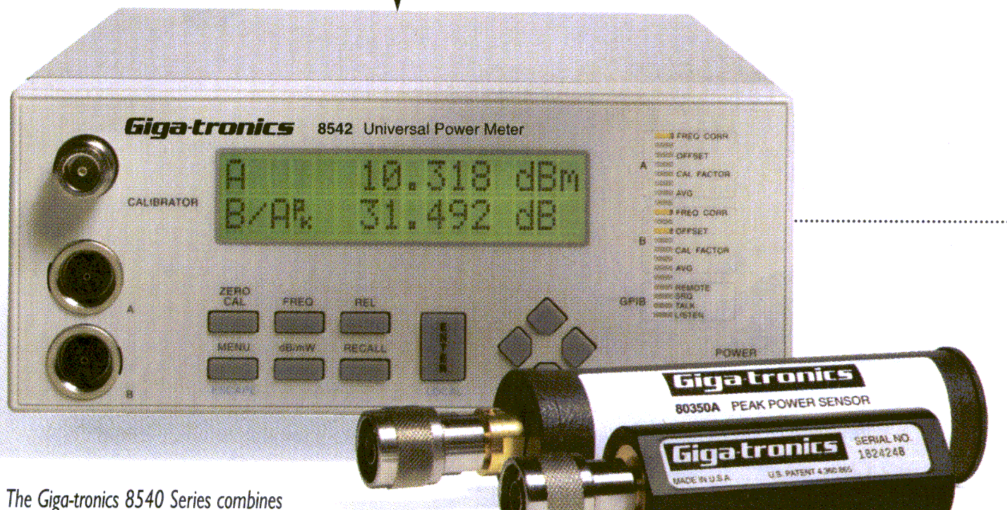

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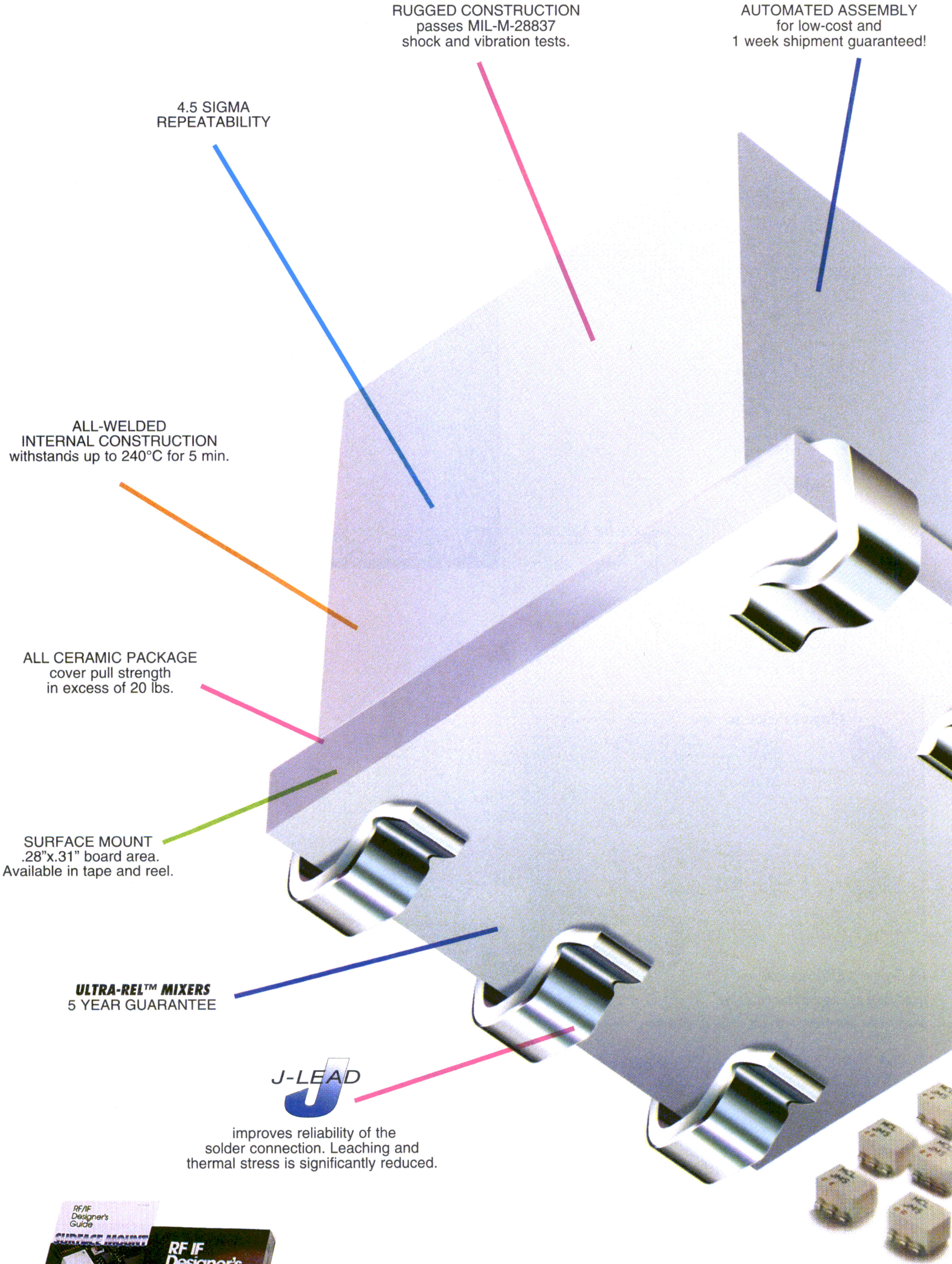

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ASIA/PACIFIC AREA HOLDS VAST WIRELESS MARKET POTENTIAL

The Asia/Pacific region may soon be the fastest-growing market in the world for wireless personal communications.

RON SCHNEIDERMAN
EXECUTIVE EDITOR

WITH more than half of the world's population, the Asia/Pacific region has the greatest potential for wireless personal-communications market growth in the world. The market has been slowed at times by restrictive government regulations and incompatible systems. But most of these problems have been solved, creating an extraordinary opportunity for hardware manufacturers and service providers.

One industry consulting group, EMCI (Washington, DC), projects the region will have 78 million cellular subscribers by the year 2000.

The 1995 MultiMedia Telecommunications Association's (MTA) Market Review & Forecast says mature mobile-communications markets (such as Japan, Australia, and Singapore) are growing at an average rate of 60 percent per year. The level of international telephone traffic confirms the increased importance of telecom trading links within the region. According to the MTA, intraregion calling now accounts for nearly 55 percent of all traffic originating in Asia and the Pacific—a percentage equivalent to that of the European Community. China's international calling traffic has been growing at more than 50 percent a year, pushing its global telecom revenues to $2.6 billion annually. A growing share of that traffic is wireless.

Cellular technology is also spreading quickly to the developing economies of Thailand, Indonesia, Malaysia, and to some of the world's poorest countries, including Bangladesh, Cambodia, India, Laos, and Vietnam.

The pager market is even more impressive. The most recent data developed by EMCI indicates that of the more than 44 million paging subscribers in the world, 44 percent of them are in Asian/Pacific countries, which is only a few percentage points behind North America with 46 percent of the world market. Fueled by growth in China, EMCI expects the Asian/Pacific region to comprise more than half of the world's pager unit sales by 1999. (At that point, EMCI believes North American pager sales will have dropped to approximately 35 percent.)

China, which has about two phone lines for every 100 people, is logging the fastest growth in the region, jumping from only 40,500 cellular subscribers at the end of 1991 to almost 1.3 million at year-end 1994 (see table). To meet the demand for new mobile and fixed wireless installations, China is signing contracts valued in the hundreds of millions of dollars.

In China, Motorola recently completed the initial deployment of the largest contiguous Total Access Communications System (TACS) analog cellular network in the world. The system interconnects Motorola's current cellular phone systems in the country's 18 provinces and the cities of Beijing, Shanghai, and Tianjin.

"To give you a perspective on the extensive capabilities of the network's automatic roaming," says Pertti Johansson, vice president and general manager of Motorola's International Cellular Infrastructure Division (Arlington Heights, IL), "a

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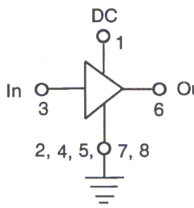

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subscriber to the service in China's Heilongjiang Province in the far northeast can travel 3000 km to the city of Kunming in the southern province of Yunnan and automatically make or receive cellular calls." So far, Motorola (which set up a marketing team in Beijing in 1981) has won cellular systems in 23 of China's 27 mainland provinces, as well as in three autonomous cities, covering a total population of more than one billion people.

Nokia Telecommunications (Espoo, Finland) also picked up its third contract from China this year when it agreed to deliver the second phase of the China Unicom Global System for Mobile Communications (GSM) network in Shanghai. Earlier this year, Nokia signed GSM contracts with Beijing PTA and Fujian PTA.

Nokia also opened an office in Shanghai last month to support its activities in the East-China region, covering the provinces of Shanghai, Zhejiang, Anhui, and Jiangsu.

Japan recently added its four millionth cellular customer—not a lot by western standards; however, Japan's Ministry of Post and Telecommunications (MPT) projects the number of radio terminals—mostly cellular and personal-communications-services (PCS)-type systems—will reach 104 million in Japan by 2010 and could jump as high as 130 million. Virtually all of the new systems in Japan will be digital: Starting in April 1996, Japan's MPT will progressively ban new analog subscribers.

Last month, Motorola's Cellular Infrastructure Group won separate contracts from TU-KA Tokyo and TU-KA Tokai to expand their one-year-old Personal Digital Cellular (PDC) networks. The combined contracts are valued at more than $80 million. PDC, a time-division-multiple-access (TDMA)-based technology, is Japan's digital standard for 800-MHz and 1.5-GHz systems. Both operators launched their PDC networks in 1994 with Motorola 9600 cellular base stations and NEC switches.

The expansions, scheduled to be completed by early 1996, will increase system capacity by 33 percent for the TU-KA Tokyo network and will nearly double the capacity of the TU-KA Tokai network.

JAPAN ADDS PHS SERVICE

Japan's MPT has also issued 1.9-GHz Personal Handyphone System (PHS) licenses to 21 carriers, several of which will begin service this month.

Early projections for PHS, which operates as a cordless phone with no airtime charges in the home and as a cellular phone outside the home, indicate the market could reach 20 million subscribers within 10 years and 38 million by 2010. However, existing Japanese cellular operators have been cutting their registration fees,

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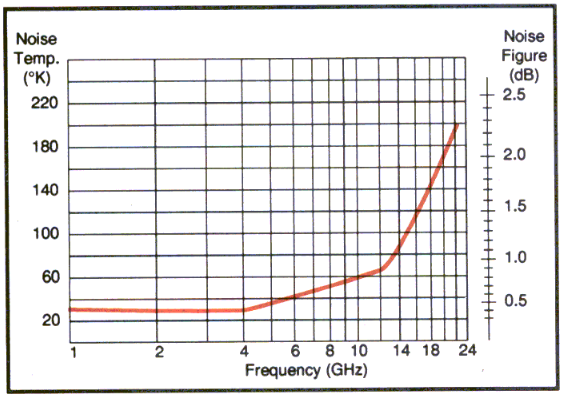

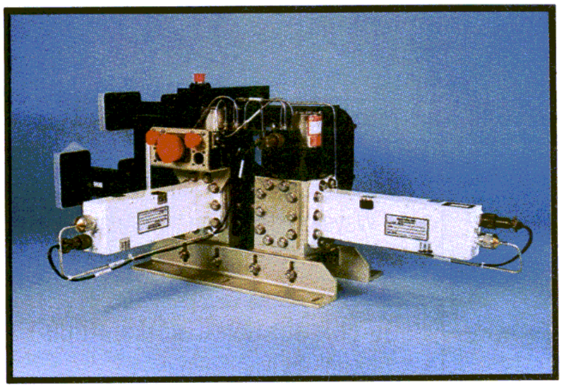

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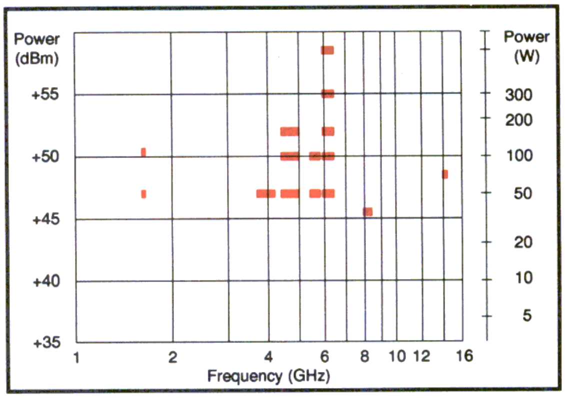

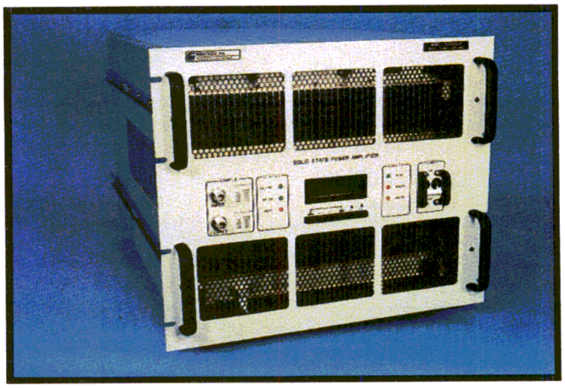

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handset prices, and monthly charges in anticipation of new competition from PHS.

"Until 12 months ago, everyone was pretty much convinced that there would be a huge difference in the two services, but analog [cellular] prices have dropped," says Don Burtis, vice president for corporate marketing at Pacific Communication Sciences, Inc. (San Diego, CA), which supplies chip sets to several PHS handset manufacturers. "PHS will ramp-up rapidly, but maybe not as quickly as everyone thought."

Still, Burtis believes PHS will be a huge market. "We're talking minor degrees of whether its growth will be super explosive or merely explosive."

So far, digital cellular is doing well in Japan.

"The digital cellular market in Japan has experienced extremely robust growth, with more than 1 million subscribers currently being served by PDC systems today," says Richard Sell, vice president and general manager of Motorola CIG's Japan cellular infrastructure market division. Major Japanese shareholders in the two digital cellular networks include Daini Denden (DDI)—one of three long-distance carriers in Japan and the most active in wireless markets—Hitachi, Nissan, and Sony. Motorola and British Telecom are also shareholders.

Korea Mobile Telecom Corp. has doubled its analog Advanced Mobile Phone System (AMPS) cellular subscribers each year since 1984. The company passed the one million mark last January. The Korean cellular market is expected to double again by the end of this year.

Singapore Telecommunications has about 230,000 cellular subscribers, but demand is growing—and so is the competition. Four international organizations will enter the market in Singapore with new services beginning in April 1997. Cellular and paging licenses have been granted to MobileOne, a consortium formed by the Keppel Group, Singapore Press Holdings, Hong Kong Telecommunications, and Cable & Wireless of Britain. Paging licenses also went to Intraco Ltd. of Singapore and the Singapore Technologies Group.

Singapore Telecom's own projections call for a better than 25-percent penetration rate for cellular phones by the year 2000.

Taiwan's Directorate General of Telecommunications (DGT), under pressure from consumers and legislators to meet the growing demand for cellular service, is expanding its AMPS network capacity through software upgrades provided by Ericsson, which is the country's sole supplier of cellular network equipment. DGT's AMPS network currently has a capacity of 590,000, but the waiting list in Taiwan is more than 120,000 and is growing by 10,000 a month.

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Implementation of the most recent equipment tender in Taiwan (for a nationwide GSM network, won by Northern Telecom) has been delayed. Further AMPS expansion could include the purchase of 50 additional base stations, valued at $15 to $18 million. However, a decision on AMPS hardware expansion will not be made until the software has been upgraded.

This is also going to be a big year for India with eight GSM startups, including two in New Delhi, two in Bombay, two in Calcutta, and two in Madras. Each of the new systems will be operated by a different licensee.

Currently, Motorola is the primary equipment supplier of at least four of the Indian systems, and it shares one of the systems in Bombay with Ericsson. Nokia Telecommunications will supply Modi Telstra Pvt. Ltd. with a GSM network for Calcutta. Nokia is also supplying one of the cellular networks in Madras.

Thirty-three consortia, involving more than 60 companies, are bidding for licenses in India. All bidders for these systems, which are not scheduled to go on the air until next year, are required to have a foreign partner. NYNEX Corp. of the US, for example, has teamed with Reliance Industries Ltd. of India to compete for 18 of the 20 most-heavily-populated areas in the country, called "telecom territorial circles." AT&T and the Aditya V. Birla Group (AT&T owns 49 percent of the Indian company) are expected to bid on licenses in at least three high-capacity areas, while Bell Atlantic Corp. has formed a joint venture with the Bombay-based Essar Group to bid for mobile services. Several Indian companies are still seeking partners and reportedly have been talking to Sprint and Nippon Telegraph & Telephone (NTT).

India's Communications Ministry plans to study the proposals through July before awarding the 10-year licenses (two in each region for a total of 40 licenses). All of the systems will use GSM.

The Philippines (with six cellular operators, including one GSM network supplied by Ericsson, Motorola, and Siemens) will add a second Nokia-supplied GSM system to begin operation this year.

Indonesia has had two GSM operations in place since last year, but their capacity is limited. One of them, Telkomsel, which currently uses Ericsson network equipment, plans to build out its network in four phases. The handsets are from Alcatel, Ericsson, Motorola, Nokia, Philips, and Siemens. The second GSM system, P.T. Satelit Palapa Indonesia (Satelindo), also uses Alcatel network equipment and handsets from Alcatel, Ericsson, Motorola, Nokia, Philips, and Siemens. In addition, a state-owned company called Industri Telekomunikasi Indonesia (INTI) has a joint venture with Motorola to

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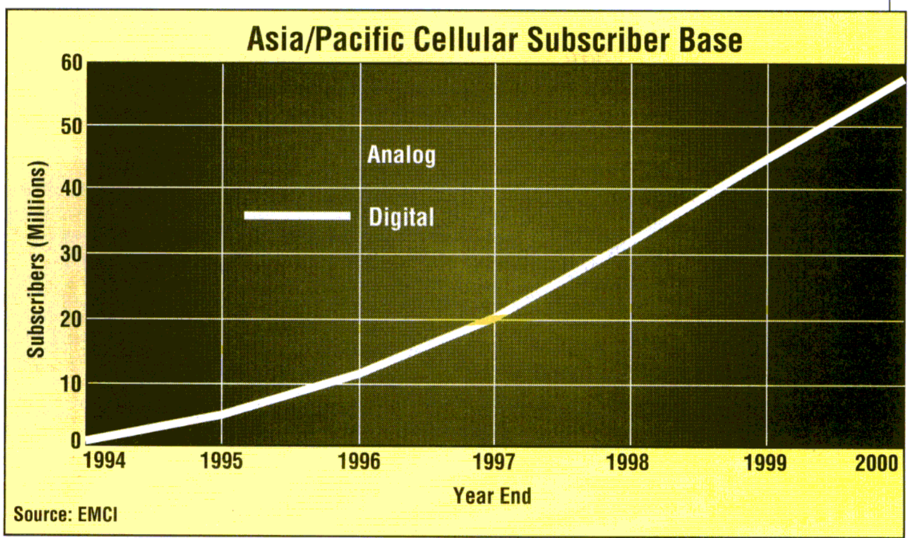
assemble cellular phones for the Indonesian market.

Overall, EMCI says it expects digital subscribers in the region will surpass analog users by the end of 1997. By 2000, EMCI says subscribers on GSM, PDC, code-division-multiple-access (CDMA), and other digital systems will account for more than 70 percent of the total subscriber base in the region. "The driving forces behind this phenomenon," EMCI says in a recent study, "are the introduction of GSM in China and India, the two most populous countries in the world, and rapid subscriber growth on PDC systems in Japan and on CDMA systems in South Korea."

Also by 2000, EMCI expects China to replace Australia as the second largest cellular market, with almost 30 percent of the total subscribers in the region. (However, Australia will likely have the highest penetration rate by 2000 at 31.5 percent.) Furthermore, EMCI believes that by the end of the decade, India will become the fifth largest market in the region with more than 6 million subscribers, all on GSM systems. Japan, meanwhile, is expected to account for about one-third of the region's cellular subscriber base, with much of that coming from PDC growth.

CDMA got a critical leg up in June when NEC Corp. of Japan signed a multi-million-dollar, worldwide infrastructure agreement with QUALCOMM, Inc. (San Diego, CA). NEC



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entered into a subscriber equipment license agreement with QUALCOMM last year. The new agreement makes NEC the first Japan-based company to be licensed to manufacture and sell subscriber and infrastructure equipment.

"Based on the agreement, we will develop mobile-communications systems to enter the CDMA digital cellular phone and PCS infrastructure markets in the North, Central, and South Americas," says Yoshitake Matsuo, assistant general manager for NEC's Mobile Communications Systems Division. "NEC's CDMA products are expected to be commercialized in the latter half of 1996."

Korea has selected CDMA as its national digital cellular standard and QUALCOMM recently received orders valued at $8 million from LG Information and Communications, Goldstar's telecommunications division, and Samsung Electronics Co. for application-specific integrated circuits (ASICs) for CDMA-based products. Korea Mobile Telecom has named LG its CDMA cellular infrastructure supplier and will soon begin switching over its analog systems to CDMA. Korea Mobile Telecom is building the digital system to handle up to 600,000 subscribers. Also, Shinsegi Telecom, a Korean consortium, has ordered CDMA-based equipment from Samsung

Mobile-communications satellite activity is also increasing in the region. In addition to the group of Japanese companies that form a major segment of investors and users of Motorola's 66-satellite Iridium system, a consortium of 25 Japanese companies has established Satellite Phone Japan Corp. of Tokyo to manage the Japanese portion of the proposed 10-satellite Inmarsat-P global mobile phone system. KDD Corp., Japan's leading international telephone carrier, will head the consortium with a 53.2-percent stake in Satellite Phone Japan.

Toyota Motor Corp. and NTT Docomo Corp., Nippon Telegraph and Telephone Corp.'s mobile subsidiary, will each take an 11-percent position in the new organization. Four new regional and mobile phone carriers will form a group to take another 11-percent stake. In addition, three trading houses,—Sumitomo Corp., Marubeni Corp., and Nissho Iwai Corp.—each will take a 3-percent stake in Satellite Phone Japan.

AirTouch Communications (San Francisco, CA) and Sime Darby, a Malaysian multinational conglomerate, have formed a joint venture to act as the exclusive service provider for Globalstar (San Jose, CA) in Malaysia. (Globalstar, the low-earth-orbit (LEO) 48-satellite system founded by Loral Corp. and QUALCOMM, already has several international partners.) Sime Darby, with more than $3.3 billion in annual revenues and operations in more than

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22 countries, will provide general and financial management while AirTouch will serve as the technical leader in the venture. AirTouch has also formed a joint venture with Itochu Corp., a major Japanese trading company, to market Globalstar services in Japan.

Lockheed Martin Corp. (Calabasas, CA) is negotiating a contract valued at $650 million or more to build a satellite mobile phone system covering most of Asia—from India to Japan to southern China to northern Australia.

The ASEAN Cellular System, called ACes, will only use one satellite and, as a result, is expected to be much cheaper to use than the Iridium, Globalstar, or Inmarsat-P networks.

The ACes consortium, which includes Philippine Long Distance Telephone Co., PT Pasifik Satelit Nusantara of Indonesia, and Jasmine International PCL of Thailand, plans to launch its satellite by late 1997 or early 1998. Lockheed Martin will build and launch the satellite, as well as provide all of the communications systems, except the subscriber handset.

Alcatel, through its subsidiary Alcatel Espace, partnered with Space Systems/Loral (Palo Alto, CA) to win a $200 million contract from Mabuhay Philippines Satellite Corp., a Philippine-based private company created to provide transponder capacities to domestic and regional users. The contract allows Alcatel to build the first Philippines domestic satellite.

In March, Hughes Electronics Corp.'s Hughes Telecommunications and Space Co. won a contract from Afro-Asian Satellite Communications Ltd. in Bombay to provide handheld satellite mobile phone service across Asia, the Middle East, and Africa. The service will be provided using a new geostationary satellite based on Hughes' HS 601 satellite using unfurlable large antennas, spot beams, and on-board processing.

If there is any concern about the Asia/Pacific market, it is among US equipment suppliers who have seen occasional flare-ups by China in response to the Clinton Administration's position on human-rights issues and the US government's relationship with Taiwan. As one US trade association official points out, "China obviously wants and needs to advance its telecommunications infrastructure, but it doesn't have to buy from us." ••

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NEW STUDY PLOTS GPS IMPROVEMENTS

The National Research Council proposes commercial enhancements to the global positioning satellite system.

RON SCHNEIDERMAN
EXECUTIVE EDITOR

THE DOD-owned and -operated global positioning system (GPS) proved its value in the Persian Gulf War and is on the verge of becoming a multi-billion-dollar commercial and consumer electronics market. A committee organized by the National Research Council (NRC), an operating agency of the National Academy of Sciences and the National Academy of Engineering, now wants to enhance the system in order to greatly broaden its use in civilian applications.

Currently, civilian users must work around a GPS security feature known as selective availability (S/A). Imposed by the DOD, S/A deliberately reduces the navigation and timing accuracy of the system for most non-military users. The military currently relies on S/A and anti-spoofing (A/S) procedures to deny full GPS accuracy to the enemy while maintaining the use of a highly-accurate spoof-resistant signal. Anti-jam antennas and antenna electronics are also deployed on many weapons systems to provide increased jam resistance, while integrated GPS/inertial navigation systems provide a means of finding a target in spite of successful jamming.

The NRC committee believes that S/A, which is normally on at all times, should be replaced with jamming or other signal-denial techniques that would be used in the event of war or other hostilities to block enemy forces from effective access to GPS signals.

The NRC study notes that such a move would better ensure a US military advantage in the use of GPS, while at the same time greatly improve the ability of civilians to take advantage of GPS. The strategy of interfering with the GPS signal via S/A no longer offers the US military much advantage because of commercial systems that are designed to improve the accuracy of the basic GPS signal, essentially rendering S/A virtually useless.

Once the use of S/A is discontinued, the NRC committee says other technological improvements to enhance non-military use of GPS are possible, such as adding a new, non-encrypted signal to improve the accuracy obtained directly from the GPS. According to the committee, the ability to generate this new signal should be added to the new GPS satellites currently being built and should be part of the planned next generation of satellites.

The NRC group also suggests upgrading the military's GPS receivers to allow US troops to accurately receive GPS signals even when the US and its enemies are using signal-jamming techniques.

One of the key concerns of the committee is RF interference. Anti-spoofing limits the ability of GPS receivers to deal with RF interference from known sources, such as the third harmonic of some very-high-frequency (VHF) transmitters. The interference problems must be solved if GPS is to become the primary navigation and surveillance system for aviation; several technical groups are studying the issue. However, the committee points out that resistance to interference can be greatly improved through the use of dual-frequency receivers that can track the code on both GPS L-band signals—1227.6 and 1575.42 MHz—because it is unlikely that interference from a single source will simultaneously affect both frequencies.

Other improvements that would ensure that the system operates continuously range from implementing new techniques that monitor the health of GPS satellites to ensuring the continuous availability of a back-up, master control station for the system.

Part of the reason for the success of GPS as a commercial/consumer technology is the availability of new models which are smaller, easier to use, and less costly. (Some handheld

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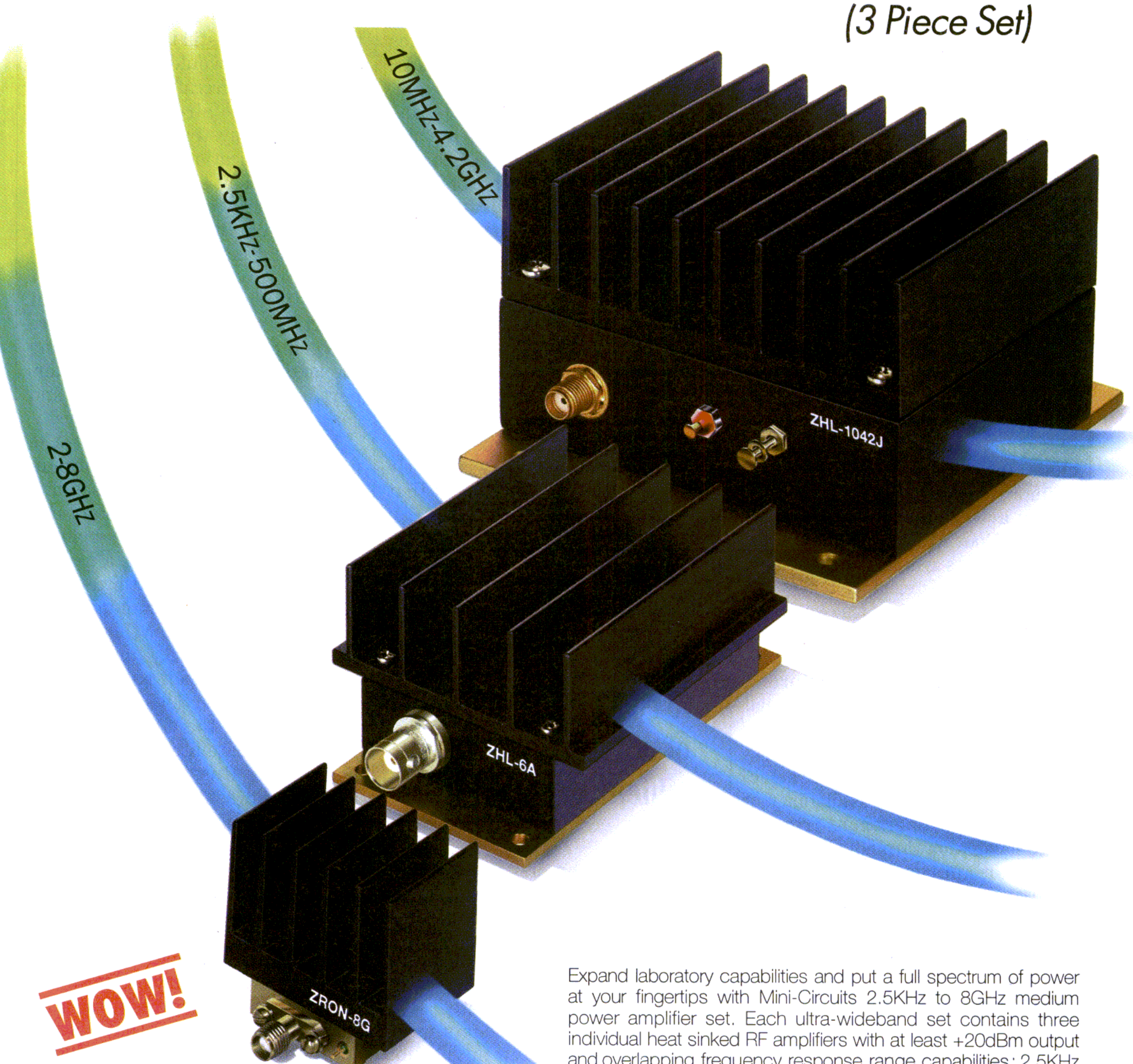

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GPS STUDY

units are now available for recreational use for less than $500.) The NRC report quotes a Booz Allen & Hamilton (Bethesda, MD) market study that anticipates the cost of GPS to continue to decline while its technical performance increases dramatically.

Booz Allen also expects that all categories of the North American GPS market will increase through the year 2003. Booz Allen projects the cumulative market from 1994 through 2003 at $64 billion.

"It is possible that the DOD will relax the present policy on S/A," says Booz Allen. "This event will have a profound impact upon GPS markets in most sectors." Factors that will likely affect the market include an acceleration in the trend to improve accuracies. "With higher utility available at the throw of a switch," Booz Allen says, "most identified markets will mature and new niches will be fostered."

The consulting firm also suggests that turning GPS over to civilian control will generate new opportunities for equipment manufacturers, particularly in related international markets.

The Federal Aviation Administration (FAA) plans to improve the accuracy, integrity, and availability of GPS for flight operations from en route navigation through Category I precision approaches by using a wide-area differential-GPS (DGPS) concept known as the Wide-Area Augmentation System (WAAS). (Category I approaches can be flown when the visibility is no less than 0.5 miles and the ceiling is no lower than 200 ft.)

WAAS, a ground-based communications network, will consist of 24 wide-area reference stations, two wide-area master stations, and two satellite uplink sites. Differential corrections (which involves the precise measurement of the relative positions of two receivers tracking the same GPS signals) and integrity data derived from the ground-based network, as well as additional ranging information, will be broadcast to users from the geostationary satellites using a GPS L-band signal at a frequency of 1574.42 MHz. The FAA expects the WAAS to be in place by the end of 1997. Several countries have expressed an interest in WAAS participation, including Canada, Australia, New Zealand, and Japan.

Local-area DGPS systems are also being considered by the FAA to support landing operations beyond Category I. The airline industry estimates that there are approximately 120 runways in the US that will require this type of service through the year 2005.

Civilian pilots have been using GPS in uncontrolled airspace for applications such as crop dusting, aerial photography and surveying, search and rescue, and basic point-to-point navigation for some time.

The US Coast Guard is currently establishing a DGPS network that will meet, for the first time, the extremely-accurate navigation requirements of commercial and recreational mariners in US harbors. When fully operational in 1996, the system is expected to reduce the number of navigation-related collision and grounding incidents by 50 percent over existing navigation methods. Fifty reference stations will be installed at sites along the coastal US, the Great Lakes, Puerto Rico, Alaska, and Hawaii. Navigational accuracies as good as 1.5 meters up to 250 nautical miles (460 km) from the reference station are anticipated.

When operational in 1996, the DGPS system is expected to reduce the number of navigation-related incidents by 50 percent.

The NRC committee says "GPS also shows promise" for use in traffic-alert/collision-avoidance systems (TCAS) and automatic dependent surveillance (ADS) systems. TCAS is already used by US airlines and by many airlines in Europe. ADS systems, which are still under study and development, would automatically broadcast an aircraft's GPS-derived position to the air-traffic-management (ATM) system via geostationary communications satellites positioned in oceanic airspaces, as well as through terrestrial-based communications links in domestic airspace. This would make navigating ocean crossings by commercial aircraft more efficient than the current ATM reporting system. ADS systems are also being considered for monitoring the land-based operations of an airport, such as aircraft taxiing, and service-vehicle collision avoidance.

Internationally, Inmarsat—the not-for-profit international organization that provides global satellite services to the maritime, land mobile, and aviation markets—plans to augment GPS by placing a navigation payload onboard its third-generation geostationary communications satellites. Plans call for this payload to broadcast integrity and ranging information, as well as wide-area differential corrections, on a "GPS-like" signal on the GPS and Global Navigation Satellite System (GLONASS), the Russian GPS system, which broadcasts only unencrypted navigational signals.

Future Inmarsat plans include the possible development of a fully civil global-navigation satellite system based on light satellite (so-called "lightsat") navigation payloads placed in intermediate circular orbits and geostationary orbits.

The report is the result of a request from Congress that a study on the future of GPS be conducted jointly by two independent organizations—the National Academy of Sciences (NAS) and the National Academy of Public Administration (NAPA). The report represents the NAS results of the NAS portion of the study, which was conducted by the NRC. NAS was asked to identify technical improvements while NAPA addressed GPS-management and funding issues. When completed, the NAPA segment of the study will be combined with the NAS report.●●

MEASUREMENT GROUP EXAMINES PRODUCTION TESTING METHODS

The 45th ARFTG meeting emphasized the need for accurate, high-speed testing in high-volume production environments.

VICTOR PERROTE
SENIOR EDITOR

USERS of high-frequency components continue to demand products that offer compact size and high performance at an attractive price. This forces manufacturers to examine different methods of testing these components to ensure good performance while minimizing cost and time to market. In response to this need, the 45th meeting of the Automatic RF Techniques Group (ARFTG) was held May 19, 1995 at the Orange County Convention Center in Orlando, FL to address the theme "Testing and Design of RFICs."

Antoni Niedzwiecki of the Hewlett-Packard Communications Components Division (Newark, CA) opened the meeting with an overview of a test process used in the manufacturing of commercial RF and microwave components. As Niedzwiecki noted, the number of tests required in the production stage is dependent on the product's functionality. Daren Bridges and co-workers from Texas Instruments (Dallas, TX) followed with a description of a technique for determining the accuracy of nonlinear device models with respect to measured load-pull data. Termed the "load-pull template," the benchmarking technique was applied to 1200-μm pseudomorphic high-electron-mobility-transistor (PHEMT) models developed with the modified Materka method.

Frans Verbeyst and Marc Vanden Bossche of Hewlett-Packard NMDG (Brussels, Belgium) described a black-box model extraction method that employs swept two-tone measurements to provide more accurate prediction of spectral regrowth than that achieved with single-tone measurements. The technique is based on the Volterra input-output map (VIOMAP) and was applied to the analysis of a 16-state quadrature-amplitude-modulation (16QAM) signal. Alexander Chenakin from the Kiev Polytechnic Institute (Kiev, Ukraine) presented a measurement technique that uses a rectangular-waveguide section to gauge minimum-standing-wave shifts, which determine transistor parameters at millimeter-wave frequencies. The technique was demonstrated using the analysis of a low-noise transistor amplifier.

Mark Roos of Roos Instruments (Santa Clara, CA) introduced a production test system for RF power modules. The test scheme incorporates error correction to compensate for thermal effects and a calibration routine to compensate for the device socket and test fixture. Michael DeHaan and co-workers at Texas Instruments followed with an overview of on-wafer intermodulation-distortion (IMD) and third-order-intercept (TOI) measurements using computer-controlled microwave tuners. As the authors noted, this test procedure offers the ability to gauge the effects of load impedance on microwave device linearity.

John Barr from the Hewlett-Packard Santa Rosa Systems Division (Santa Rosa, CA) highlighted the key factors in RF integrated-circuit testing, paying special attention to high-volume environments. Among the topics he covered were automated part handling, fixturing techniques, and test strategy development. Robert Kornowski at the Motorola Land-Mobile Products Sector (Schaumburg, IL) outlined a coaxial probe developed for non-destructive, broadband testing of high-density, surface-mounted circuits. The probe features an open tip architecture, allowing its use in a wide range of circuit topologies.

Joel Dunsmore from the Hewlett-Packard Microwave Instruments Division (Santa Rosa, CA) examined calibration techniques for printed-circuit-board (PCB) test fixtures and probes. As Dunsmore pointed out, improved measurements can be achieved by performing a calibration

TEST CONFERENCE

at the contact plane of the device under test. This requires the creation of calibration standards. Vahe Adamian of ATN Microwave (Billerica, MA) then outlined a simplified vector-network-analyzer (VNA) configuration in which a multi-state electronic-transfer standard is used during both calibration and device measurement. The design results in a more economical analyzer due to the injection of the test signal only in the forward direction, thereby reducing the hardware complexity. Laird Snowden of AT&T Microelectronics (Allentown, PA) overviewed the use of process-control-monitor (PCM) production test data in device modeling. By taking PCM data at different points in the wafer-fabrication process, the effects of process variations can be accounted for, resulting in a more reliable prediction of device performance.

In the conference's final scheduled paper, J.L. Carbonero and G. Morin of SGS-Thomson Microelectronics (Crolles, France) and B. Cabon from LEMO/ENSERG/INPG (Grenoble, France) described an automatic on-wafer measurement station for production environments. The authors examined the various problems affecting calibration and measurement validity, describing device-parameter extraction procedures.

Due to the one-day length of the conference, six papers were presented as poster sessions in the ARFTG exhibit section. Marty Jones and Michael DeHaan from Texas Instruments discussed a method that determines the large-signal input impedance of microwave devices via a modified source/load-pull technique. The method provides improved reliability via reflected-power measurement capability at the input tuner. Another Texas Instruments paper, given by Ryan Stewart and co-workers, outlined the use of a VXI-based pulsed I-V (current-voltage) measurement scheme to characterize GaAs heterojunction bipolar transistors (HBTs). The technique is useful for pulse widths shorter than 1 μs.

Sunchana Pucic and William Daywitt from the National Institute of Standards and Technology (Boulder, CO) described the single-port adapter efficiency evaluation (SPAEE) method, which uses swept-frequency measurements to assess the broadband efficiency of reciprocal two-port networks. The technique provides simplicity by requiring only a single-port analyzer calibration, and is bandlimited by the availability of two reflective terminations. Hans-Gerd Krekels, Burkhard Schiek, and Astrid Schweer of Ruhr-Universitat Bochum (Bochum, Germany) examined a self-calibration technique for dual six-port network analyzers. The method allows a dual six-port instrument to be characterized in the same manner as a heterodyne network analyzer.

Holger Heuermann, also with Ruhr-Universitat Bochum, presented the LZY self-calibration procedure, which is designed for measurements on planar structures and requires only two standards. The method's simplicity makes it especially useful for on-wafer measurements. Y.A. Tkachenko and colleagues from Lehigh University (Bethlehem, PA) examined the use of high-frequency waveform probing in order to gauge gate-drain breakdown effects in GaAs field-effect transistors (FETs). The method was used to analyze the breakdown performance of a 0.5-μm-gate GaAs metal-semiconductor FET (MESFET) at 2 GHz.

As more applications for wireless technology are realized, computer-aided design and testing will play a key role in reducing cost and time to market. Appropriately, the 46th ARFTG meeting, to be held November 30-December 1, 1995 in Phoenix, AZ, will cover the theme "Testing for Wireless Applications." Information on attending the conference can be obtained by contacting Conference Chairman William Pastori at Maury Microwave Corp., 2900 Inland Empire Blvd., Ontario, CA 91764; (909) 987-4715, FAX: (909) 987-1112. Information on booth space is available from Exhibits Chairman Michael Fennelly at ATN Microwave, 11 Executive Park Dr., Billerica, MA 01821; (508) 667-4200 ext. 18, FAX: (508) 667-8548.••

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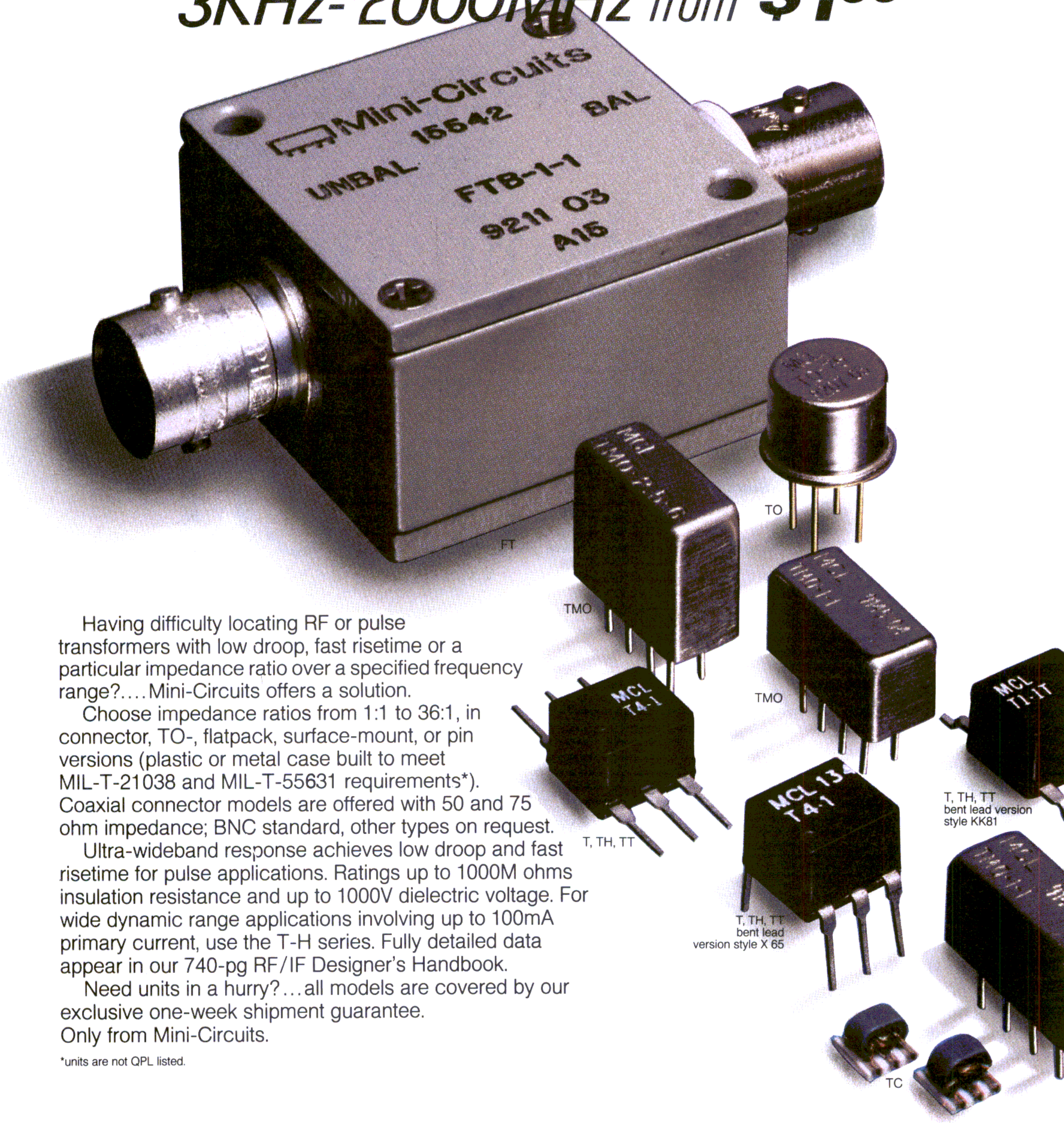

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CROSSTALK

Jerry A. Arden *is chairman and chief executive officer of California Eastern Laboratories (Santa Clara, CA), NEC's exclusive sales and marketing arm for RF and microwave semiconductors in North America.*

MRF: *How about a little history on CEL? Is it true that your relationship with NEC is based on a handshake?*

Arden: Originally it was. The company was founded in 1959 as a US rep company for Japanese electronics manufacturers. Over the years, we gravitated to NEC and microwave products—and the relationship evolved and developed.

The move was very synergistic. We happened to be at the right place at the right time with the right group of people.

As far as the handshake, we now have contracts and agreements. But it's not like the US, where a contract might be the size of a phone book. If a problem arises, we discuss it.

Our relationship with NEC is not just a thread, it's a fabric. We're not just business partners, we're very good friends.

MRF: *CEL has been promoting its new joint NEC/CEL Design Center, established to develop integrated circuits (ICs) specifically for domestic markets. Why a design facility now?*

Arden: Actually, the Design Center has been evolving for some time. We put together a plan [for the center] for GaAs devices in 1984, but that sort of dwindled because GaAs didn't take off. The only people who made any money in GaAs were the equipment and clean-room manufacturers. Then we got into silicon and that started to really move around 1991.

The primary reason for this activity is that NEC has long been aware of the fact that the US is really the cradle of new technologies and new systems—much more so than Europe.

There are also economic issues that come into play. For example, the shortage of microwave engineers in Japan. Most of the microwave technology in the US was driven by the military; there wasn't a similar structure in Japan. Most of Japan's applications were for telecommunications.

But now that all of the consumer markets are moving up into the higher frequencies, everyone is using all the technologies that were developed by or for the US military.

MRF: *The move to higher frequencies often means the use of GaAs devices. Is it true that GaAs continues to be an important technology for NEC and CEL?*

Arden: Yes, that's true. There is still some debate about its cost versus performance. We believe GaAs is an essential technology, but it will not be as widely used as silicon.

MRF: *How important is the Design Center in terms of influencing what NEC does in North American markets?*

Arden: I think we now have five designs in production with another 10 in development, and we're now seeing sales as a result of the work we have done in the Design Center.

As far as having an influence on NEC, it's not only the design group, it's also our strategic business-de-

CROSSTALK

velopment group, which does the marketing and ferrets out all of our projects.

The way it works is that our marketing group develops a requirement, either through our customers or through a market need. We then prepare a business plan and submit that to our strategic business-development people. They approve it, reject it, or modify it. Then they work with us under the contract to design the product.

MRF: *Does the Design Center work with customers in order to develop products and solve technical issues?*

Arden: A lot of that type of work is done by our applications engineering group, whereas the focus of the Design Center is three to five years off. The center spends all of its time developing and designing parts for the future.

MRF: *Are you satisfied with your ability to stay on top of the market and to anticipate market requirements?*

Arden: This is an area in which we can always improve. There are so many new wireless applications and so many companies blossoming around the US, we cannot cover all of them through advertising and our literature programs. But we do try to cover as many of them as possible.

We make a point of covering all of the consulting engineers because good consultants move around from project to project and have a good handle on what's going on in the marketplace. We keep them loaded up with samples and data sheets.

Trying to pick the winners is very difficult. Of all the products we design, I believe that if we have a 30-percent hit rate, we have done pretty well. But even the biggest companies have difficulties in this area.

MRF: *Are you finding the kind of engineering people you want?*

Arden: We place certain demands on new engineers. We want to hire engineers and then send them to NEC in Japan for about a year. In this way, they become familiar with NEC's design rules and they establish relationships. This is very important not only at my level, but for all of the engineers and designers throughout the company.

To find an engineer who is willing to go to Japan for a year, come back here, and then return to Japan two or three years later for another few months can create not only some familial problems, but also cultural issues. So we try to find good microwave engineers that have a personality fit with CEL.

MRF: *CEL's growth has been fairly significant, from $32.4 million in sales in 1985 to $60 million in 1995. Do you expect to continue to grow at about the same pace?*

Arden: I think our growth is pretty representative of everyone else's. Some companies have grown faster, but I think we're fairly typical.

■

"We try to find good microwave engineers that have a personality fit with CEL."

■

MRF: *What impact has "wireless" had on your business?*

Arden: It has had a significant impact. Back during the 1980s, 10 percent of our business was commercial and 50 percent was government. Now it's about 10 percent government business and 50 percent consumer.

There are so many [wireless] applications and so many projects underway that will revolutionize the way we live. We're looking at larger volumes with lower prices and higher levels of integration. Instead of the government pushing the technology, the drive is going to come from the Motorolas, the Nokias, the Matsushitas, and other large communications companies.

That's one of the strengths we derive from NEC's business, which is producing large volumes of products.

MRF: *You mentioned moving to higher levels of integration, but many of the discrete houses are doing well. Do you expect that to continue?*

Arden: Discretes will always be around because there are a lot of applications where the volume does not dictate the advantages of single-chip or multichip solutions. Also, time to market is an issue. A lot of the products with higher levels of integration require several months to a year to go from design to production. Some of these applications require a design, a prototype, and small-quantity production within just a few months. Therefore, discretes will be around for a long time.

MRF: *You have been promoting your power products fairly heavily. What is happening in that product sector?*

Arden: Power products are important to the wireless market. We have supported our power products for years, but now it's sort of a full-court press to develop a substantial market position in this area. That's reflected in some of our work in the Design Center and at NEC.

MRF: *Are you increasing the pace of new product introductions?*

Arden: You can tell what's going on by the number of new product sheets we publish. Years ago, we probably introduced 10 or 15 products a year. Now, it's closer to 10 or 15 products a quarter, maybe even 10 or 15 a month. We have had to expand the marketing department just to keep track of all our new product introductions.

MRF: *As part of CEL's expansion, you have announced plans to conduct at least some customer-service functions via the Internet. What is the status of that program?*

Arden: We're investigating the use of the Internet for customer service, and it looks like it's a medium worthy of investment.

Our approach is to find out what our customers want and what they expect of us. ●●

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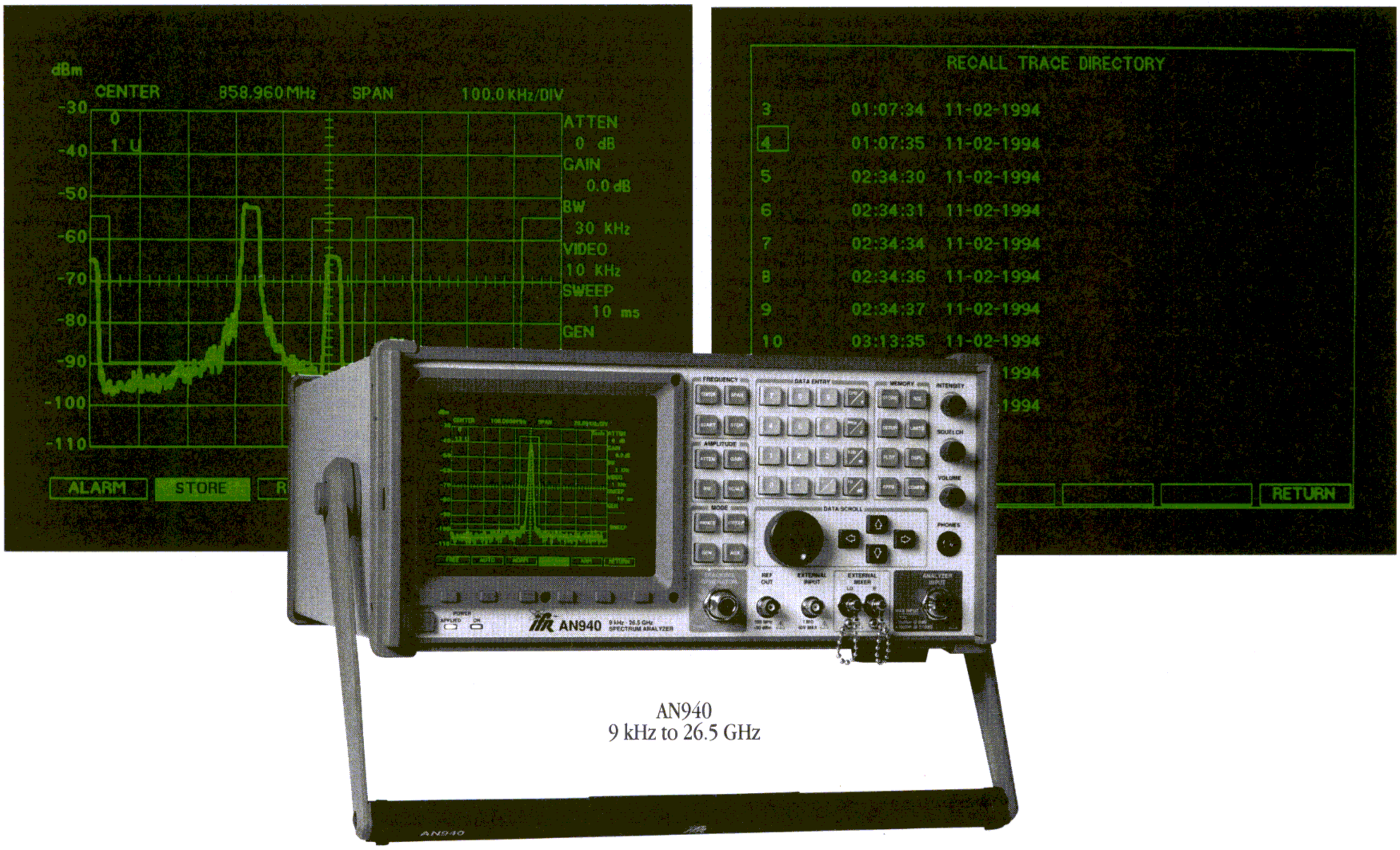

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CIRCLE NO. 240

Amtech acquires Cardkey

Amtech Corp. (Dallas, TX) has almost doubled its size with an agreement in June to substantially acquire all of the net assets of Cardkey Systems from ASSA Abloy AB of Sweden.

A leader in the RF-based electronic-access-control (EAC) business, Cardkey's sales in 1994 were approximately $65 million. Amtech's 1994 sales were about $61 million.

According to the terms of the agreement, Amtech will pay an initial purchase price of approximately $16 million in cash, with further payments of $3 million each in 1997 and 1998. Closing is expected to occur by mid-August.

Cardkey sells, installs, and services proximity RF-identification (RFID) cards and readers through an extensive international network of direct sales offices and resellers. Amtech says it sees substantial synergy between Cardkey and Cotag International Limited, a subsidiary acquired by Amtech in January. Cotag, with headquarters in Cambridge, England, produces low-frequency proximity EAC products and systems. Cotag has not marketed its products in North America, only selling as a hardware OEM supplier to resellers and integrators.

Amtech says it plans to form an Electronic Security Group (ESG) within the company to focus on the EAC market, maintaining and enhancing both Cardkey and Cotag as strong brand names in access control.

Stuart Evans, currently chairman and CEO of the Cotag unit, will be chief executive for the combined business unit. Spencer Hall will continue as managing director of Cardkey in the United Kingdom. Amtech will name a chief operating officer for Cardkey in the US.

Evans says, "Cardkey's recent operating losses have been disappointing. However, with Cotag's already state-of-the-art product line, vertically-integrated manufacturing, and ongoing research and development, we expect to strengthen Cardkey's overall performance."

Amtech plans to consolidate manufacturing at existing production facilities in the UK and US.

At the same time, Amtech announced that it will participate in a joint study of Japanese electronic-toll-collection systems with Mitsubishi Corp., Nippon Telegraph and Telephone (NTT), Yazaki Corp., Japan's Ministry of Construction, and four regional Japanese public highway corporations. Mitsubishi, which will act as the consortium's leader, has been Amtech's distributor in Asia since 1988.

The purpose of the study is to jointly collect technical information that will lead to a set of specifications for a "non-stop" electronic-toll-collection system in Japan. System implementation is scheduled for 1997.●●

Contracts

Raytheon Co.—$105.8 million from the US Air Force for 82 AN/ALQ-184 electronic-countermeasures (ECM) pods and support equipment for Taiwan's F-16 aircraft. Also, $19.7 million to Raytheon Electronic Systems from the US Army Communications-Electronics Command for one air-traffic navigation, integration, and coordination system (ATNAVICS) and one fixed-base precision approach radar system for the US Army Aviation Systems Command. In addition, $3.1 million from the municipality of Johnson City, TN for an intelligent transportation system (ITS) to address parking-management needs.

Texas Instruments—$57.7 million from the US Naval Air Systems Command to TI's Defense Systems & Electronics Group for 313 guidance and warhead sections for the AGM-88 High-Speed Antiradar Missile (HARM).

Hughes Network Systems, Inc.—A multi-million contract from Woolworth Corp. to provide 3500 Woolworth-owned stores with very-small-aperture-terminal (VSAT) satellite systems.

Teradyne, Inc.—$56 million from Northrop Grumman Corp. for circuit-board test equipment for the B-2 Stealth bomber.

Scientific-Atlanta, Inc.—$10 million from Transtel, the communications division of South Africa's transportation-services provider, for a digital voice and data satellite network.

Harris Corp.—$8 million from the Rural Cellular Corp. (RCC) for digital microwave radio-communications systems to replace leaded-line facilities currently used by RCC.

Milcom International, Inc.—$6 million from In-Flight Phone Co. for 1-kW multichannel feedforward ground-station amplifiers and dual-channel air amplifiers for air-to-ground telephony for commercial aircraft.

Sanders/Lockheed Martin—$5.2 million to Sanders' Defense Systems Division from the US Navy for four air-traffic-control radar beacon systems and associated spares.

Fresh Starts

GTE—Has combined its cellular businesses into one organization under the GTE Mobilnet brand. GTE is also in the process of integrating Contel Cellular's operations with those of GTE Mobilnet, except in California where they will continue to operate as GTE Mobilnet and Contel Cellular in accordance with a California Public Utilities Commission order. GTE recently completed the acquisition of all of Contel's shares.

Microwave Networks, Inc.—Has opened a regional service center in the Philippines Stock Exchange Center in Manila.

Harris Corp.—Has signed an agreement with Ericsson, Inc. in which Harris' RF Communications Division will embed communications-security (COMSEC) devices in Ericsson digital wireless-communications products. Harris will supply National Security Agency (NSA)-approved Type 1 and Type 2 encrypted products and key management systems for use in Ericsson digital trunking systems and non-trunked radio systems. Also, Harris has signed an agreement with Coasin Communicaciones SA of Buenos Aires to establish a digital microwave radio service center in Argentina. Coasin Communicaciones will provide technical assistance, processing of repairs, field-service support, and customer training for Harris Farinon products.

RF Industries, Ltd.—Has relocated to 7610 Miramar Rd., San Diego, CA 92126; (619) 549-6340.

Stanford Telecommunications, Inc.—Has signed a joint-development agreement with DSC Communications Corp. that will expand DSC's wireless-access Airspan system. DSC Communications currently uses Stanford Telecom's orthogonal code-division-multiple-access (OCDMA) technology in the Airspan system. The agreement now covers RF and modem technology.

Meta-Software, Inc.—Has established a new European sales and service center located in Munich, Germany. The new office phone number is (49) 89-5455-8211. The company's European headquarters is located near Geneva.

Applied Science and Technology, Inc.—Has opened a new installation and service center at 1900 Wyatt Dr., Suite 2, Santa Clara, CA 95054; (408) 727-7116.

Crystal Semiconductor Corp.—Has announced a corporate reorganization, adding a Networking and Broadcast Products Division to focus on wide-area data-networking, personal-digital-assistant (PDA), and set-top applications. Crystal also is expanding its Austin, TX facilities by 88,000 sq. ft., with an option for an additional 88,000 sq. ft.

Telecom Analysis Systems, Inc.—Has announced plans to work cooperatively with AT&T Paradyne to develop a standard suite of laboratory-based testing procedures for field tests of cellular modems.

Windata, Inc.—Has announced a marketing agreement with I-NET in which I-NET will market and sell Windata's AirPort family of wireless interbuilding communications systems and FreePort wireless Ethernet local-area-network systems (WLANs).

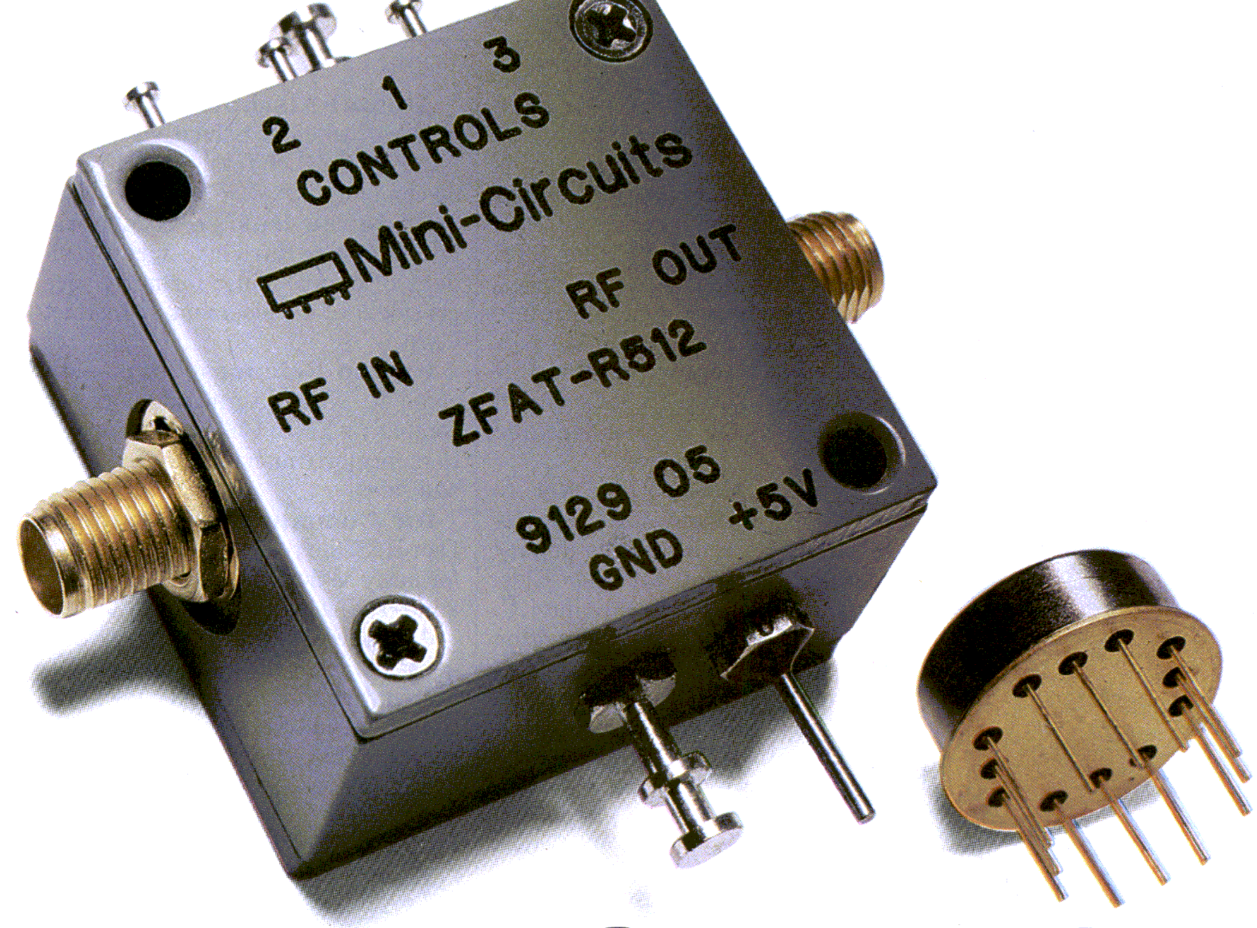
California Microwave, Inc.—Has completed the acquisition of Microwave Networks, Inc. MNI, formerly a privately-held manufacturer of microwave radios primarily for the international cellular market, is now a wholly-owned subsidiary of California Microwave.

PCT Holdings, Inc.—Has completed, through a wholly-owned subsidiary, a merger with Ceramic Devices, Inc. Within the next 12 months, CDI will relocate from San Diego, CA to PCT's facilities at 434 Olds Station Rd., Wenatchee, WA 98801; (509) 664-8000.

Stellar GPS Corp.—Has changed its corporate name to the Absolute Time Corp.

BIS Strategic Decisions—Has been acquired from Friday Holdings, Ltd. by the Giga Information Group, an investment group headed by Gideon I. Gartner.

Motorola, Inc.—Has signed an agreement with Vanguard Cellular Systems, Inc., the 15th largest cellular operator in the US, in which Vanguard will market Motorola's new INReach in-building wireless-communications system to Vanguard's customers in Pennsylvania, South Carolina, Florida, West Virginia, and Maine.



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GTE Mobilnet, Inc.—William E. Pallone to vice president for market deployment of the company's 1.8-GHz personal communications services (PCS); formerly general manager for 1.8-GHz PCS for GTE Personal Communications Services, which was dissolved and folded into the GTE Mobilnet organization.

General Microwave Corp.—Sherman A. Rinkel to chairman of the board; formerly president and CEO.

Raytheon Co.—C. Dale Reis to senior vice president; formerly vice president. He continues as deputy general manager of Raytheon Electronic Systems. Also, Michael C. Kerby to vice president-Washington Operations; formerly vice president-Washington Operations for the Grumman Corp.

Bell Atlantic Corp.—Keiko Takeuchi Harvey to vice president for network planning and engineering; formerly vice president of operations for central and southern New Jersey at Bell Atlantic-New Jersey. Also, Robert J. Bonometti to executive director of technology strategic planning; formerly served on the staffs of the White House Office of Science and Technology Policy and at the DOD's Advanced Research Projects Agency (ARPA).

Johnstech International—Fred Snyder to vice president for sales and marketing; formerly director of marketing and sales at Visu-Com, Inc.

Sprint—A. Allan Kurtze to senior vice president of the Sprint Telecommunications Venture, composed of Sprint, Tele-Communications, Comcast Corp., and Cox Communications; formerly senior vice president of operations at Sprint's Local Telecommunications Division.

Northrop Grumman Corp.—W. Dean Baker to vice president and general manager of precision weapons and electronic systems; formerly vice president and program manager for the Tri-Service Standoff Attack Missile (TSSAM) program at the company's Military Aircraft Division.

Silicon Systems—Yoshihito Yamamoto to vice president for corporate planning and control; formerly director of product engineering.

Alcatel-Alsthom SA—Serge Tchuruk to chief executive officer; formerly CEO of Total SA, a French oil company.

Cadence Design Systems, Inc.—Misha Burich to vice president of engineering; formerly vice president of development at Instinct Corp.

Kaman Sciences Corp.—Michael R. Wilson to manager of the company's State College, PA operation; formerly manager of marketing and sales.

Air Communications, Inc.—Dan H. Seale to president and CEO; formerly senior vice president of Advanced Wireless Communications.

ANADIGICS, Inc.—Larry Nagel to manager of simulation, modeling, and characterization; formerly technical manager of the TCAD Product Development Group at AT&T Microelectronics.


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Allen Telecom Group—Reed Wilson to director of systems engineering for the Allen Telecom Group Systems Division; formerly manager of business development for strategic alliance partners at Ericsson GE Mobile Communications, North American sales group.

MFS Network Technologies, Inc.—Robert Thurman to vice president for project development; formerly a project and systems engineer for Communications Transmission, Inc.

Texas Instruments—James T. Skelly to business manager for TI's Registration and Identification System (TIRIS); formerly worldwide sales and marketing manager for TI's Materials & Controls Group.

Lockheed Martin's Sanders Operation—Dave Mahoney to director of contracts for the Surveillance Systems Division; formerly manager of contracts administration for the division.

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Principles and Applications of Millimeter-Wave Radar
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Georgia Institute of Technology
Atlanta, GA 30332; (404) 894-3068

Technical Cellular
July 31-August 3 (Madison, WI)
University of Wisconsin-Madison
Department of Engineering Professional Development
432 North Lake St.
Madison, WI 53706; (800) 462-0876

Microwaves & RF Measurements & Applications
October 2-5 (Encino, CA)
University Consortium for Continuing Education
16161 Ventura Blvd.
M/S C-752
Encino, CA 91436; (818) 995-6335

Meetings

IEEE Vehicular Technology Conference
July 26-28 (Rosemont, IL)
James Mikulski, Technical Program Chair
Motorola, Inc.
1301 E. Algonquin Rd.
Schaumburg, IL 60196

25th European Microwave Conference
September 4-8 (Bologna, Italy)
Alessandra Costanzo, 25th EuMC Conference Secretary
University of Bologna
Dipartimento di Elettronica Informatica e Sistemistica
Viale Risorgimento 2
40136 Bologna, Italy

5th International Symposium on Recent Advances in Microwave Technology
September 11-16 (Kiev, Ukraine)
Banmali Rawat, Technical Program Co-Chair
Dept. of Electrical Engineering
University of Nevada
Reno, NV 89557; (702) 784-6927

6th IEEE International Symposium on Personal, Indoor, and Mobile Radio Communications
September 27-29 (Toronto, Canada)
Elvino S. Sousa
Dept. of Electrical and Computer Engineering
University of Toronto
10 Kings College Rd.
Toronto M5S 1A4, Canada; (416) 978-3652

Wireless Circuits, Internconnection, and Assembly Workshop
October 8-11 (Tucson, AZ)
Sharon Aspden
Wireless Workshop
100 S. Roosevelt Ave.
Chandler, AZ 85226; (602) 961-1382

Asia-Pacific Microwave Conference (APMC '95)
October 10-13 (Taejon, Korea)
Prof. Dong-Chul Park, Program Chairman
APMC '95
Dept. of Radio Sciences & Engineering
Chungnam National University
220 Kung-dong, Yusong-gu
Taejon 307-764, Korea

Wireless Power Transmission Conference
October 16-19 (Kobe, Japan)
Nobuyuki Kaya
Dept. of Computer and Systems Engineering
Kobe University
Rokkodai, Nada, Kobe 657, Japan
(81) 78-803-1197

IEEE Vehicular Technology Society (North Jersey Section) Mini-Symposium
October 28 (Secaucus, NJ)
Arthur Greenberg
c/o RS Microwave Co.
22 Park Place
Butler, NJ 07405

IEEE GaAs IC Symposium
October 29-November 1 (San Diego, CA)
c/o IEEE
Attn: Ms. Gina Sacchi
445 Hoes Lane
Piscataway, NJ 08854; (908) 562-3878

Wireless APPS
October 30-November 1 (Las Vegas, NV)
Cellular Telecommunications Industry Association
1250 Connecticut Ave., N.W.
Suite 200
Washington, DC 20036; (202) 785-0081

IEEE Military Communications Conference
November 5-8 (San Diego, CA)
Joe M. Straus
Electronics Systems Division
The Aerospace Corp.
M4/933
P.O. Box 92650
Los Angeles, CA 90009

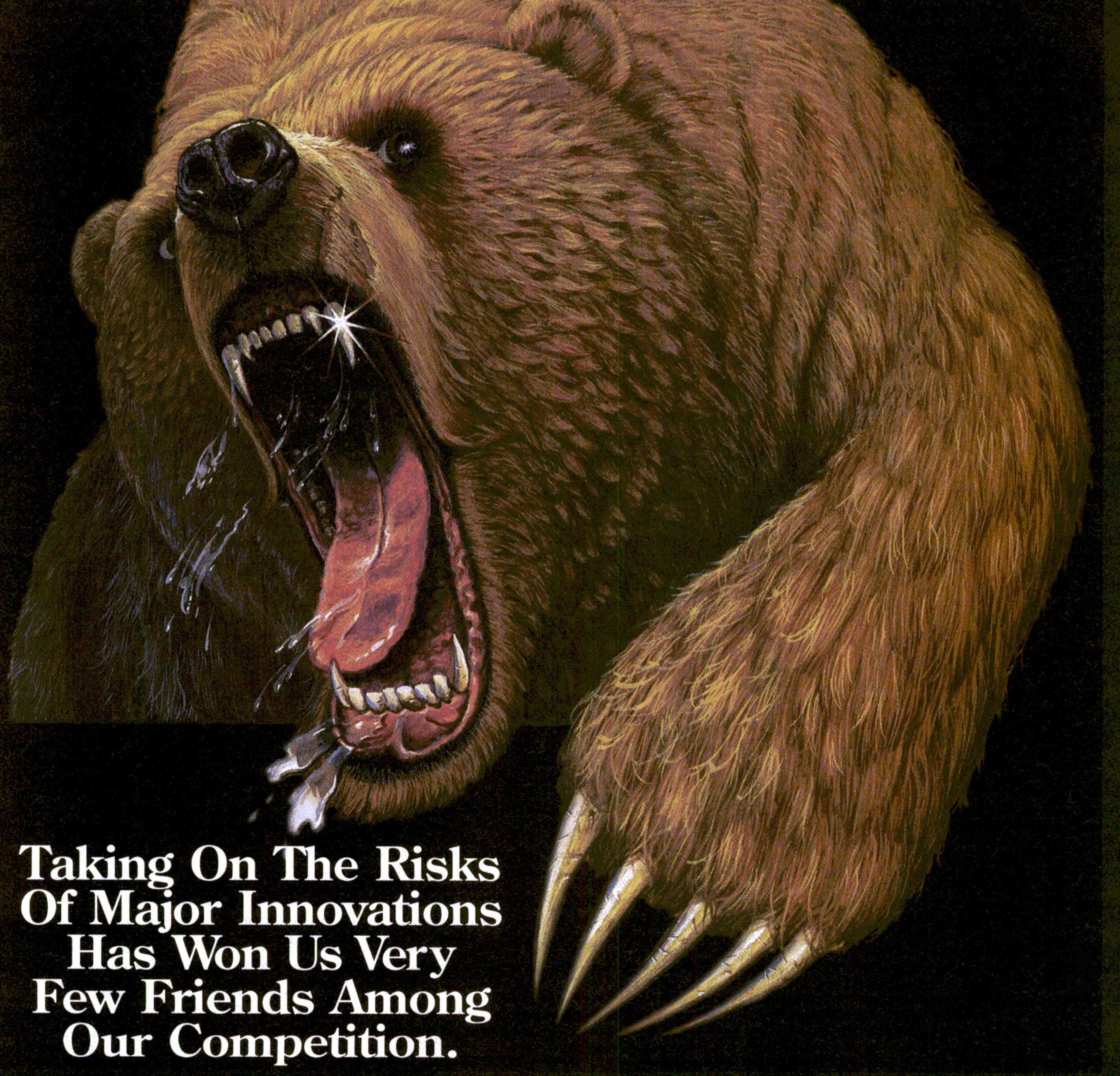
BEMC Conference and Exhibition
November 7-9 (Malvern, England)
Jane Tsakalou
Building 2
National Physical Laboratory
Queens Rd., Teddington, Middlesex
TW11 OLW, United Kingdom
44 (81) 943-6400

International Electron Devices Meeting
December 10-13 (Washington, DC)
Melissa Widerkehr
IEDM
Suite 270
101 Lakeforest Blvd.
Gaithersburg, MD 20877; (202) 986-1137

Call for Papers

1996 IEEE International Solid-State Circuits Conference
February 8-10 (San Francisco, CA)
Prof. John H. Wuorinen
2 School St.
Castine, ME 04421; (207) 326-8811
Deadline for abstracts and summaries: September 8, 1995

1996 IEEE International Symposium on Phased-Array Systems and Technology
October 15-18 (Boston, MA)
Robert Mailloux, Technical Program Chair
IEEE Phased-Array Symposium
Rome Laboratory/ER
31 Grenier St.
Hanscom AFB, MA 01731; (617) 377-3710
Deadline for summary papers: December 4, 1995



NEWS UPDATE

TRACKING STORIES PREVIOUSLY REPORTED IN MICROWAVES & RF

FCC SCHEDULES MORE AUCTIONS. The Federal Communications Commission (FCC) will hold several more spectrum auctions this year, beginning August 2 when nearly 500 personal-communications-services (PCS) licenses become available for small businesses—the so-called "entrepreneurs block." FCC Commissioner Reed Hundt says this is a key auction because it "essentially guarantees vigorous competition in all geographic markets." The auction will not be delayed despite the US Supreme Court's June 12 decision imposing stricter standards on Federal affirmative action programs, including those covering minority- and women-owned businesses. Hundt says the auctions focus on size rather than race, but the FCC plans to continue to study the court's decision. The FCC also plans to hold specialized-mobile-radio (SMR) auctions for the first time in November and then complete the PCS auctions by starting the broadband D-, E-, and F-block auctions in December. These are the 10-MHz licenses that may be combined to form mobile phone businesses in some markets. By then, the commission will have begun to auction licenses for interactive television and wireless cable-television services. "We don't make predictions," says Hundt, "but there isn't much doubt that these auctions will total more than a billion extra dollars for the Treasury."

IS GSM BAD FOR YOUR HEALTH? It is, according to a new Washington, DC-based coalition called HEAR-IT NOW (Helping Equalize Access Rights in Telecommunications Now). In the ongoing battle between the Global System for Mobile Communications (GSM) and code-division multiple access (CDMA)—QUALCOMM, Inc.'s proprietary digital cellular technology—the group has petitioned the FCC to investigate the "safety and interference dangers" of GSM. Along with their petition, coalition members from the Wireless Communications Council (WCC), Self Help for the Hard of Hearing, and the Alexander Graham Bell Association for the Deaf have given the FCC copies of technical papers and news reports, published in Europe, which describe how GSM may cause heart pacemakers to skip beats and automobile airbags to deploy without warning, among other alleged problems. Jim Valentine, chairman of the WCC and president and CEO of North American Wireless (Vienna, VA), a PCS licensee, says the materials filed with the FCC "show that GSM technology in wireless communications devices, such as portable telephones, would have disastrous consequences for those people who are hard of hearing, and present serious safety concerns for millions of Americans." (North American Wireless has already committed to CDMA, having signed a contract in February with QUALCOMM for the production of CDMA-based PCS handsets.) Valentine says, "Reports have shown that GSM interferes with hearing aids, causing buzzing, sharp pain, and rendering the aids useless." The HEAR-IT NOW filing follows an FCC promise in May to look into possible problems caused by wireless devices that might fall under the Hearing Compatibility Act of 1988. In response to the filing, Thomas Wheeler, president of the Cellular Telecommunications Industry Association (CTIA), says HEAR-IT NOW references to the dangers of GSM are not relevant since GSM normally operates at power levels almost four times higher than the planned levels for GSM phones in the US. Wheeler also suggested in a letter to Valentine that he attend a two-day conference of hearing-aid and wireless industry leaders to jointly develop information collection and test systems to address the compatibility issue.

—RON SCHNEIDERMAN

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CIRCLE NO. 236

MMIC amplifier melds HBTs, HEMTs, and PIN diodes

Monolithic integration of high-electron-mobility transistors (HEMTs) and heterojunction bipolar transistors (HBTs) is desirable so that the performance advantages of both technologies can be combined. K.W. Kobayashi *et al.* at the TRW Electronic Systems and Technology Division (Redondo Beach, CA) outline a variable-gain amplifier composed of HEMTs, HBTs, and PIN diodes on a single GaAs substrate. The amplifier achieves a nominal gain of 10 dB across a 10-GHz bandwidth. The amplifier was fabricated using selective molecular beam epitaxy (MBE) and is contained in a 1.50 × 0.76-mm monolithic-microwave-integrated-circuit (MMIC) chip. See "A Novel HBT-PIN-HEMT Integrated Circuit with HBT Active Feedback and PIN-Diode Variable Gain Control," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 43, No. 5, May 1995, p. 1004.

Model depicts HBT noise performance

The improvement of heterojunction-bipolar-transistor (HBT) noise performance would be facilitated by the availability of physics-based models incorporating noise sources. L. Escotte *et al.* at Universite Paul Sabatier (Toulouse, France) and A. Gruhle at Daimler-Benz (Ulm, Germany) present an HBT model that includes emitter and base resistances, and accounts for the correlation between the intrinsic-current noise sources. The model was verified using on-wafer measurements performed on 1 × 20-μm Si/SiGe HBTs at collector current (I_c) values of 2.7 to 9.7 mA with a collector-emitter voltage (V_{ce}) of 1 V. Good agreement was obtained between the measured and simulated noise parameters from 4 to 20 GHz. See "Noise Modeling of Microwave Heterojunction Bipolar Transistors," *IEEE Transactions on Electron Devices*, Vol. 42, No. 5, May 1995, p. 883.

RTDs exhibit picosecond switching times

Resonant tunneling diodes (RTDs) have attracted attention for their potential as high-speed switching devices. N. Shimizu *et al.* at NTT LSI Laboratories (Kanagawa, Japan) examine the measurement of picosecond switching times in $In_{0.53}Ga_{0.47}As/AlAs$ RTDs using an electro-optic sampling method. To perform the on-wafer switching measurements, the electric-field change at the RTD's collector electrode was gauged by a laser pulse. Measurement results indicated a switching time of 2.2 ps for an RTD with a barrier width of 1.4 nm and peak current density of 4.5×10^5 A/cm^2. See "Picosecond Switching Time of $In_{0.53}Ga_{0.47}As/AlAs$ Resonant Tunneling Diodes Measured by Electro-Optic Sampling Technique," *IEEE Electron Device Letters*, Vol. 16, No. 6, June 1995, p. 262.

LC resonators improve T/R switch linearity

The maximum transmit power and linearity of conventional field-effect-transistor (FET) transmit/receive (T/R) switches is hindered by RF voltage swings. T. Tokumitsu, I. Toyoda, and M. Aikawa at NTT Radio Communication Systems Laboratories (Kanagawa, Japan) detail a T/R switch design that minimizes RF voltage swings by employing FET-switchable inductive-capacitive (LC) resonant circuits. A 1.9-GHz switch was built and measured, exhibiting third-order intermodulation rejection of better than 40 dB for a +31-dBm input power and 2-VDC supply. In transmit mode, the switch had a 1.5-dB maximum insertion loss and 35-dB minimum isolation from 1.8 to 2.0 GHz. See "A Low-Voltage, High-Power T/R Switch MMIC Using LC Resonators," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 43, No. 5, May 1995, p. 997.

Ion-implanted MESFETs form Ka-band LNA

Ion implantation offers excellent uniformity, high throughput, and low cost, making it an attractive technique for high-volume production. M. Feng *et al.* and M.J. McPartlin, B.D. Lauterwasser, and J.D. Oliver at the Raytheon Advanced Device Center (Andover, MA) describe a five-stage Ka-band low-noise amplifier (LNA) formed with ion-implanted 0.25-μm-gate GaAs metal-semiconductor field-effect transistors (MESFETs). On-wafer measurements of 10 samples indicated an average gain of 30 dB from 27 to 33 GHz, with a standard deviation of 0.6 dB. The LNA employs a self-biased MESFET arrangement and is contained on a 3.530 × 1.815-mm chip. See "Ka-Band Monolithic Low-Noise Amplifier Using Direct Ion-Implanted GaAs MESFETs," *IEEE Microwave and Guided Wave Letters*, Vol. 5, No. 5, May 1995, p. 156.

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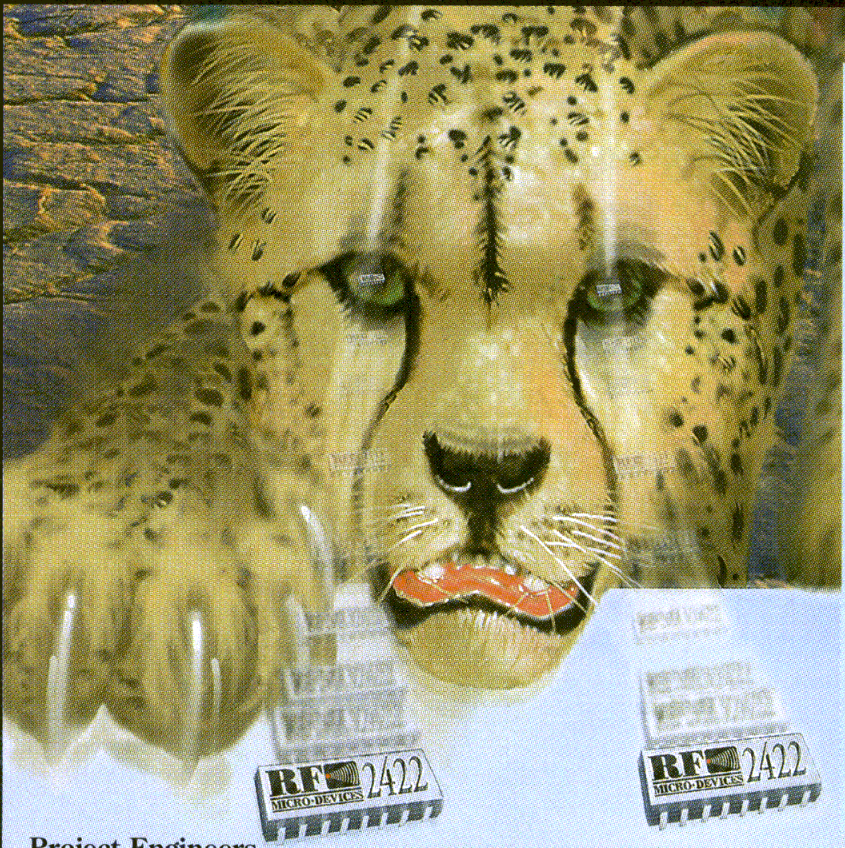

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Project Engineers

Project Engineers work closely with key customers on custom IC development projects managing all phases of project development: schedules, resources, and technical goals. This position requires an engineering degree and experience with project management methods and tools.

Applications Engineers

Applications Engineers provide RF technical product support for customers at the RF system level with design and component selection. This support includes characterization and documentation of RF and IF components such as modulators, demodulators, mixers, amplifiers, and switches. Also included in this support is the design of external matching and support components for RF and IF ICs. This position requires an electrical engineering degree and a minimum of 3 years RF design/ product experience.

Design Engineers

Design Engineers perform electrical design of RF and IF integrated circuits working with state-of-the-art wafer processing technologies including both Si- and GaAs-based devices. Analog and mixed-signal design opportunities exist with heavy emphasis on innovative, low cost solutions to complex RF, IF and digital requirements. This position requires an electrical engineering degree and a minimum of 5 years experience in RF circuit design.

Engineering Test Technicians

Engineering Test Technicians perform electrical characterization and optimization of RF and IF components and maintaining product documentation. Familiarity with bench RF test equipment operation and RF measurement procedures is required.

Senior Buyers/Planners

Senior Buyers/Planners support and plan all aspects of material procurement from wafer fab, through assembly and test of critical manufacturing commodities. This position assumes a leadership role for subcontract management and coordination of material to satisfy diverse customer needs. This position requires 4-6 years applicable supplier management, and inventory management experience in the commercial semiconductor industry and a working knowledge of MRP systems from design through implementation.

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CIRCLE NO. 238

MEASUREMENT METHODS ANALYZE DIGITAL MODULATION SIGNALS

A variety of display techniques is needed to accurately portray the wide range of possible modulation impairments.

THE emergence of complex digital modulation methods is creating a need for novel methods of displaying modulated signals for testing purposes. Digital methods are becoming the modulation techniques of choice in the wireless-communication revolution, as they promise communications capabilities well beyond the mobile voice transmission offered by analog cellular phones. Digital cellular, as supported by PCN (personal communications network) in Europe and emerging PCS (personal communications services) in the US, provides a link that includes voice, video, data, and two-way paging.

Bringing such possibilities to reality has required the development of bandwidth-efficient digital modulation techniques. This, in turn, requires new methods of viewing modulated signals and analyzing various modulation impairments and their effects. Techniques such as the in-phase/quadrature (I/Q) vector display, for example, allow isolation and analysis of the various aspects of digital modulation.

BOB BUXTON, Product Marketing Manager, Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077-0001; (503) 627-7111, FAX: (503) 627-5139.

VIEWING MODULATION

The basic methods of viewing digitally-modulated signals include:

- Spectrum display
- Eye diagram
- Vector diagram
- Constellation diagram

Although the viewing method to be used depends on the type of information desired about the modulation signal, each method's attributes determine its suitability for a particular modulation signal measurement (see sidebar).

The spectrum display (Fig. 1a) is the most common method for viewing RF modulation. The major benefits of this technique are the ability to view the overall channel bandwidth, center frequency, and sidebands. Gross out-of-band anomalies can also be viewed and measured. However, many deviations or impairments associated with digital modulation may not be readily seen in a spectrum display. For example, phase and intermodulation errors may not be apparent or may not be distinguishable from each other.

The eye diagram is a familiar engineering tool for the analysis of digital communications systems. In its most common form, it consists of a clock-triggered plot of digital data versus time. For the quadrature-modulation signals used in digital wireless systems, the eye diagram plots the I or Q modulation component versus time (Fig. 1b). A key feature of this plot is that the greater the amplitude or phase errors, the greater the closing of the eye in the pattern.

A vector display (Fig. 1c) plots the I component versus the Q component. This type of display is useful for viewing the transitions between states in quadrature-modulated signals. The widths and symmetry of the transition paths provide an indication of the modulation quality. The key feature of this display is that if the error vector is small, the transition trajectories intersect in a tight pattern at each symbol point.

Constellation diagrams show the relationships between the different phase and amplitude states of quadrature-modulated signals. Various degrees of noise, I/Q-origin offset, and quadrature offset can be determined from the spreading and positions of the constellation dots relative to a calibrated grid. For $\pi/4$ differential quadrature-phase-shift-keying (DQPSK) or eight-state phase-shift-keying (8PSK) modulation, there are eight phase states (symbols) represented by dots arranged at 45-deg. intervals around a circle (Fig. 1d). Quadrature amplitude modulation (QAM) has variants consisting of 4, 8, 16, 32, 64, 128, or 256 data states (symbols). It is displayed on a grid pattern as equally-spaced dots that are equally distributed across all four quadrants.

MODULATION IMPAIRMENTS

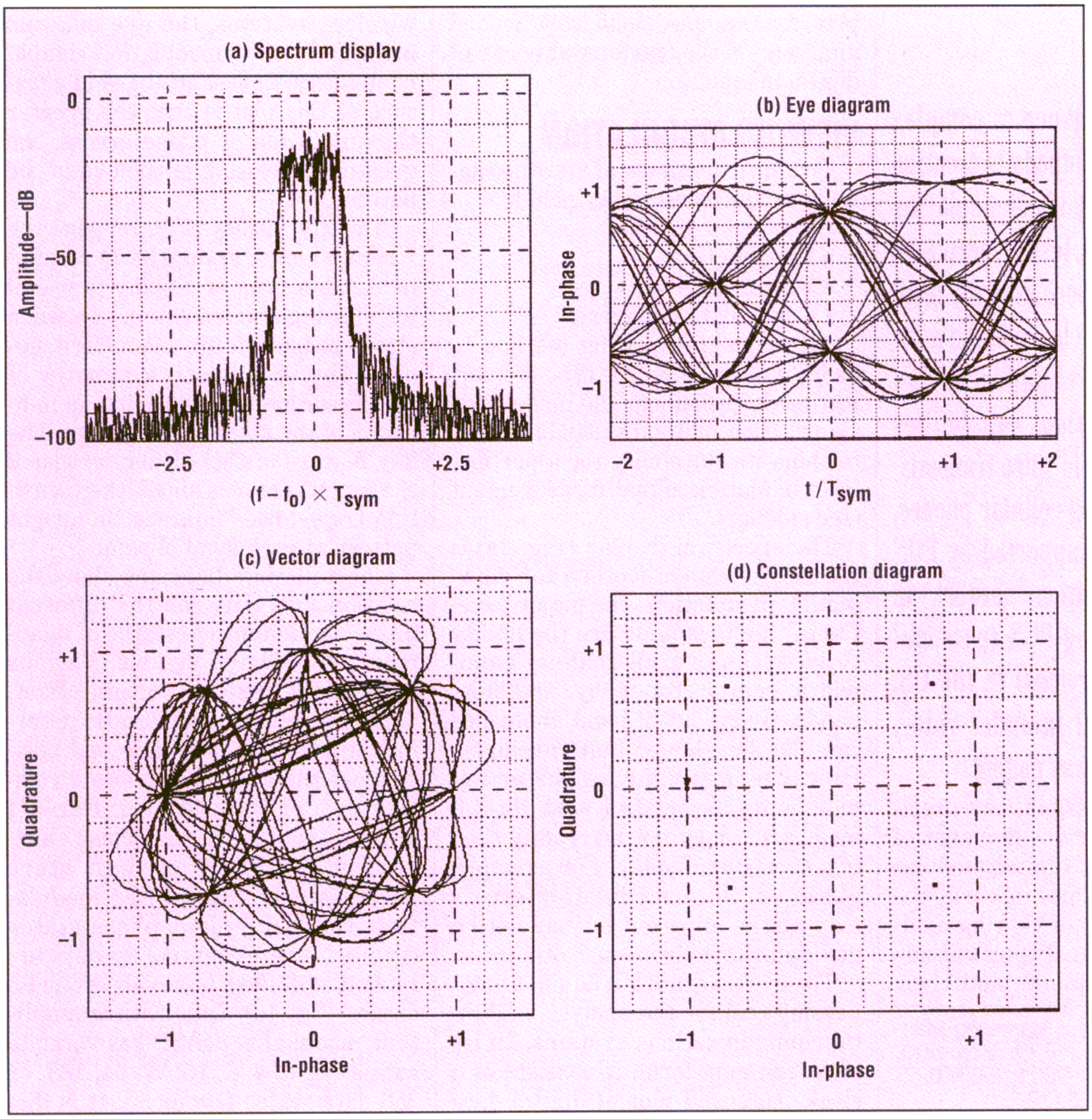
The needs for viewing modulation displays fall into two main categories. The most obvious and common need is to gauge the modulation quality of a transmitter. Just as important, however, is the need to generate digitally-modulated signals with quantifiable impairments for test receivers.

Transmitter modulation quality can be addressed in several ways. The transmitted spectrum can be viewed in a conventional manner using a spectrum analyzer. This provides an overall view of the channel spectrum. As an alternative, more specific and detailed information can often be obtained by employing an analysis tool that provides eye-diagram, I/Q-vector, and constellation displays.

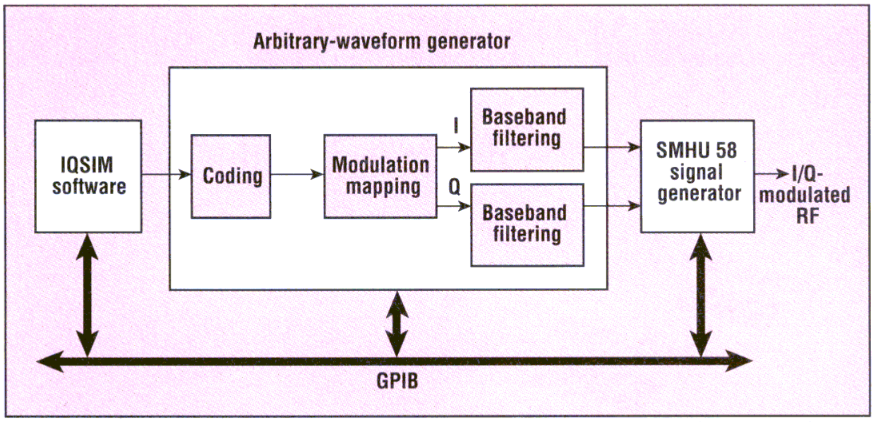
To accurately read the transmitted signal, the analyzer must have selectable demodulation and filtering capabilities corresponding to the transmitter's filtering and modulation methods. In essence, the analyzer acts as an idealized receiver for the transmitter and its specific modulation scheme. Typical modulation techniques include 0.3 Gaussian minimum phase-shift keying (GMSK) used in Global System for Mobile Communications (GSM) systems and π/4 DQPSK used in North American Digital Cellular (NADC) systems.

Receiver testing is important for design verification and for establishing bit-error-rate (BER) sensitivity to various impairment types and impairment levels. This type of testing is more complex since it requires a system that generates ideally-modulated signals while providing the capability to inject controlled amounts of selected impairments.

Such a system can be created by using software to program the I- and Q-signal data points. The I/Q data points are then loaded into a dual-channel arbitrary-waveform generator which outputs the I/Q signals and feeds them to an RF signal generator with I/Q modulation capabilities. Figure 2 shows a block diagram of a sys-



1. Spectrum (a), eye (b), vector (c) and constellation (d) diagrams are shown for ideal I/Q modulation schemes without impairments.



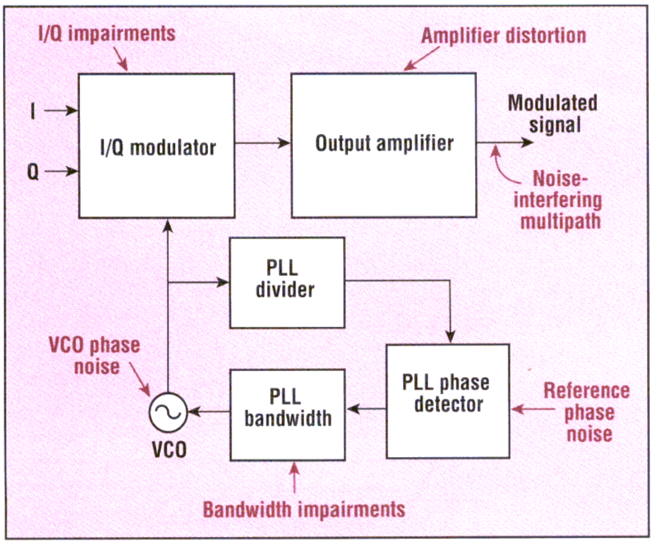
2. A system composed of signal generation and control software, arbitrary-waveform generation, and I/Q-modulated RF signal generation can be used to verify receiver design sensitivity to modulation impairments.

tem used to implement this concept and to generate the various signal display examples. IQSIM software from Rohde & Schwarz (Munich, Germany) was used to provide a graphical interface for setting up and controlling I/Q modulation via the arbitrary-waveform generator.

Through software generation and control, a wide variety of specific impairments can be added (individually or in combination) to the test signal (Fig. 3). Among the I/Q impairments that can be added are carrier leakage, I/Q signal imbalance, quadrature-phase offset, AM-to-AM conversion, and AM-to-PM conversion. Other impairments include phase noise injected at the voltage-controlled oscillator (VCO) and at the frequency reference, as well as a variable phase-locked-loop (PLL) bandwidth.

For demonstration purposes, it is useful to take a closer look at some of these impairments and their corresponding displays. Unmatched or poorly-matched transmitter/receiver filtering is one impairment that is readily seen with a constellation display (Fig. 4a). Excessive phase noise can also be readily identified with a constellation display (Fig. 4b), although this type of display does not show the distinction between close-in (reference-oscillator) and far-out (VCO) phase noise. A spectrum display is generally better for distinguishing close-in and far-out phase noise, as well as for viewing the spectrum shoulders caused by intermodulation distortion.

It should be noted, however, that combined impairments (for example,



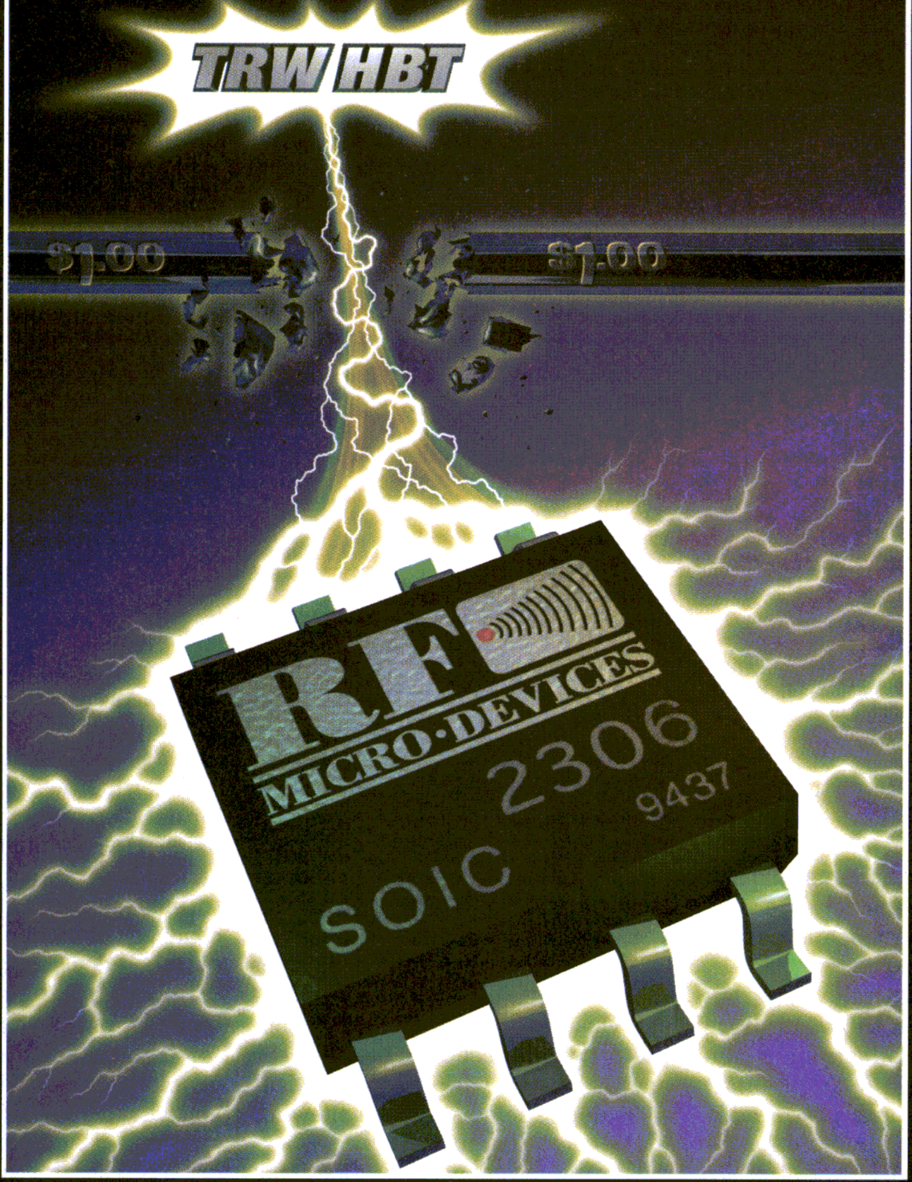
3. Different types of modulation impairments can be injected by controlling various elements of the carrier-generation and -modulation system.

DIGITAL MODULATION METHODS

Various methods of digital modulation have been implemented to achieve higher bandwidth efficiency while reducing unwanted modulation effects. An example is π/4 DQPSK used in NADC phones. Compared to binary phase-shift keying (BPSK), π/4 DQPSK reduces the symbol rate and bandwidth requirement by a factor of two. However, QPSK methods have less tolerance to noise than BPSK. Also, rapid phase-state changes can cause unwanted amplitude dips in the phase-modulated RF carrier. This results in spectrum spreading.

Gaussian minimum-shift keying (GMSK), as implemented in the European Global System for Mobile Communications and in the offshoot DCS-1900 scheme for PCS in the US, maintains decreased bandwidth. This is accomplished via Gaussian baseband filtering that smoothes the frequency changes in the MSK signal. The tradeoff is greater sensitivity to intersymbol interference (ISI) due to the Gaussian response being spread across more than one bit period. The various applications for these modulation methods are summarized as follows:

- π/4 DQPSK: NADC, Personal Handy Phone (PHP, used in Japan), PDC (Japanese Digital Cellular), Trans European Trunked Radio (TETRA), and Terrestrial Flight Telephone System (TFTS).
- Frequency-shift keying (FSK): Cordless Telephone 2 (CT-2) and Mobile Data Communication (MODACOM).
- GMSK: Digital Cordless Telephone 3 (DCT-3), DCT-900, Global System for Mobile Communications (GSM), PCN (an extension of GSM), DCS-1900 (a GSM implementation for US PCS at 1900 MHz), and Mobile Data System (MOBITEX).
- Quadrature Amplitude Modulation (QAM): Digital Television by Cable (DTV, 64-b QAM). ••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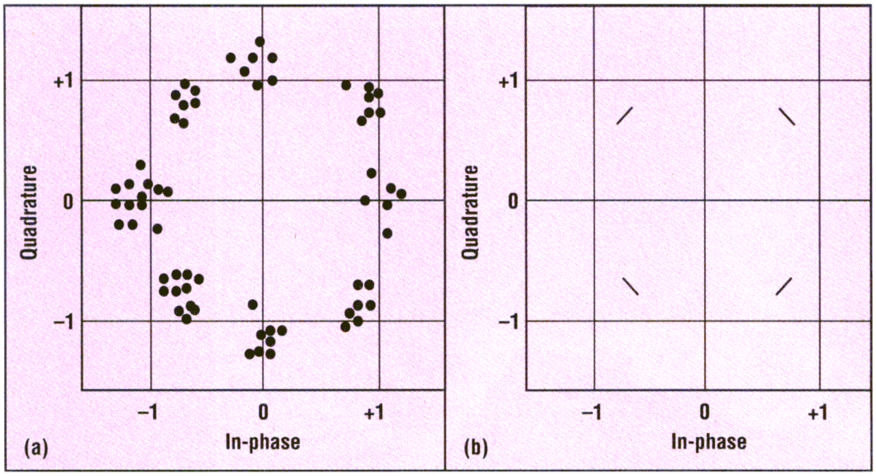


4. Poorly-matched transmitter/receiver filtering is seen as amplitude/phase spreading of data symbols in the constellation display (a). Phase noise alone confines spreading to angular (rather than radial) symbol positioning on the display (b).

phase noise plus amplitude noise plus intermodulation) may mask each other in a spectrum display. For these situations, the constellation diagram is a useful tool for determining whether phase noise is part of the impairment mix.

Most quadrature-related errors are best viewed on the quadrature displays of a vector diagram or constellation diagram. I/Q origin offset and I/Q imbalance are most readily apparent on a vector display. In-phase origin offset (the result of unmodulated-carrier leakage through the I modulation section) is seen as an offset of the vector display horizontally along the I axis. Leakage in the Q section would cause a vertical (Q-axis) offset of the vector display.

An I/Q imbalance (unequal I and Q path gains) is seen as a dimensional change in the vector display. For example, reduced I-channel gain would cause horizontal narrowing of the vector display.

Another type of I/Q modulation that is of interest is quadrature offset. Quadrature offset occurs when the phase difference between the I and Q channels varies from the ideal of 90 deg. This is seen as a skewing of the constellation display.

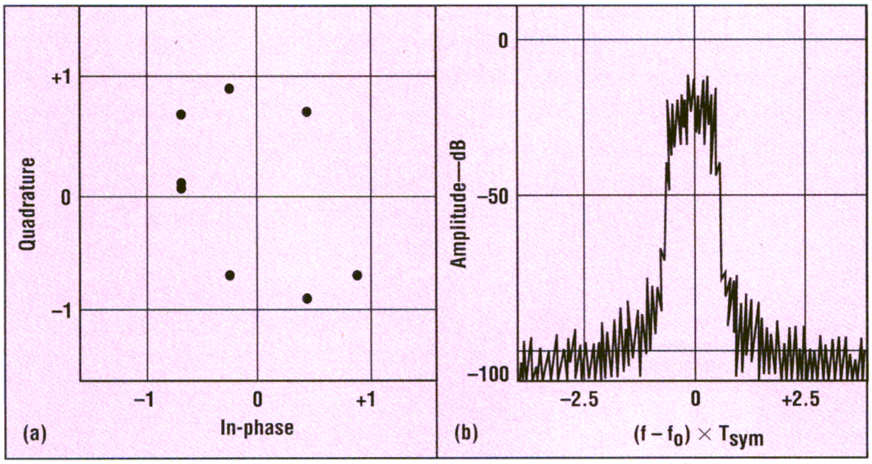
Excessive quadrature offset (for example, 20 deg. for a Q axis at 110 deg. relative to I) is quite obvious in a constellation display (Fig. 5a) but is not readily seen on a spectrum display (Fig. 5b). This is perhaps the best example to demonstrate why a variety of tools (other than just a spectrum display) is crucial for comprehensive design analysis and verification of systems incorporating quadrature modulation.

IMPAIRMENT EFFECTS

I/Q modulation impairments produce two basic effects on digital cellular communications systems. One effect is increased receiver BER and the other is receiver interference via adjacent-channel leakage. Both phase noise and intermodulation distortion cause adjacent-channel leakage. Detection, analysis, and correction of phase noise and intermodulation problems can be performed by employing standard spectrum displays and test techniques.

Other methods are often required for detailed analysis and isolation of many BER problems. Quadrature offset, for example, can be expected to increase BER since the offset changes the symbol location relative to the bit decision points.

Being able to detect quadrature offset is therefore an important tool for isolating and correcting BER problems. Moreover, in the design and verification of communications systems, it is important to establish error margins for various system components. For example, it is necessary to know how much quadrature offset can be tolerated in a communication system. Alternatively, an engineer may want to determine the best cost/benefit tradeoff for tightening quadrature-offset tolerances in transmitters in order to allow looser tolerances in receivers. The solution to these and other problems requires I/Q modulation-analysis tools that provide information well beyond what spectrum analysis by itself can offer.●●



5. Quadrature offset is clearly seen as a skewing of the constellation display (a), but has no apparent effect on the corresponding spectrum display (b).

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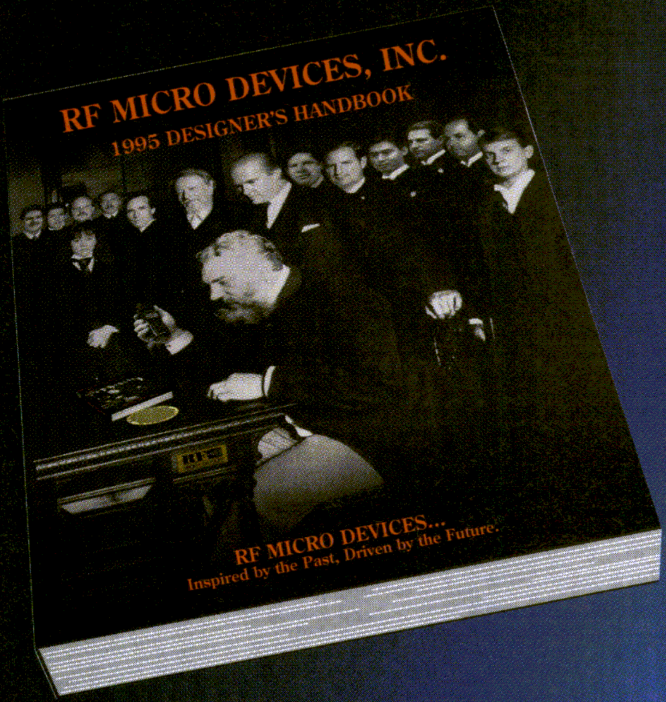

Quadrature Demodulators

RFMD Quadrature Demodulators

Part	IF Input Freq.	I/Q Output Freq.	LO Freq.
RF2701	0.1-70 MHz	DC-10 MHz	2xIF
RF2702	0.1-70 MHz	DC-10 MHz	2xIF, 8xIF
RF2703	0.1-300 MHz	DC-50 MHz	2xIF

Quadrature Modulators

RFMD Quadrature Modulators

Part	Output Freq.	Conversion	Process
RF2402	300-1000 MHz	Direct	MESFET
RF2412	200-1000 MHz	Dual	MESFET
RF2413	200-1000 MHz	Dual	MESFET
RF2422	900-2500 MHz	Direct	HBT
RF2423	800-1000 MHz	Direct	MESFET
RF2703	0.1-250 MHz	Direct	Si
RF2802	20-250 MHz	Direct	Si
RF2803	250-1000 MHz	Dual	Si

Receiver, IF, and Spread Spectrum Components

RFMD LNA/Mixers

Part	RF Freq.	IP3i	NF	Vcc	Process
RF2401	300-1000 MHz	-18 dBm	4.0 dB	5V	MESFET
RF2411	700-1800 MHz	-5 dBm	2.5 dB	3 to 5V	HBT
RF2418	700-1100 MHz	-10 dBm	3.5 dB	3 to 6V	MESFET
RF2431	1.8-2.4 GHz	-10 dBm	3.5 dB	3 to 5V	MESFET

RFMD IF Components

Part	Description	Freq.
RF2601	Dig. Gain Control IF Amp	0.1-70 MHz
RF2602	Dig. Gain Control IF Amp/Down Converter	0.1-350 MHz
RF2604	Anl. Gain Control IF Amp w/ RSSI	0.1-200 MHz
RF2410	UHF Dig. Programmable Attenuator	500-1700 MHz

RFMD Spread Spectrum Components

Part	Description	Freq.	Process
RF2903	Integrated Spread Spectrum Receiver	10-930 MHz	Si
RF2423	Integrated Spread Spectrum Xmtr.	800-1000 MHz	MESFET
RF9906	CDMA/FM LNA/Mixer	500-1500 MHz	HBT
RF9907	CDMA/FM Receive AGC Amp	12-285 MHz	HBT
RF9908	CDMA/FM Upconverter	800-2000 MHz	HBT
RF9909	CDMA/FM Transmit AGC Amp	0.1-200 MHz	HBT

Amplifiers

RFMD Power Amplifiers

Part	Frequency	Output Power	Max. Eff.
RF2103	450-1000 MHz	750mW at 6.5V	47%
RF2105	800-930 MHz	1.25W at 5.8V	50%
RF2115	800-930 MHz	1.25W at 5.8V	50%
RF2128	1.7-2.5 GHz	100mW at 5.0V	47%
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RF2131	450-1000 MHz	1.25W at 4.8V	63%

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EQUATIONS DELIVER AM/PM TRANSFER CHARACTERIZATION

Only the measurement of AM/PM conversion is needed to describe the nonlinearity of multicarrier systems.

AMPLITUDE-to-phase-modulation (AM/PM) conversion results in the transfer of amplitude modulation (AM) on one carrier to phase modulation (PM) on other carriers (so-called AM/PM transfer) which are passed through the same repeater. The values of the AM/PM conversion and AM/PM transfer determine the degree of system nonlinearity and, consequently, the system's suitability as a communications medium with acceptable crosstalk between users.

Measurement of the AM/PM transfer coefficient is difficult and time-consuming. Fortunately, a formula has been derived that describes the relationship between AM/PM conversion on one carrier and AM/PM transfer on other carriers. The formula indicates that the worst-case value of AM/PM transfer is twice as much as the AM/PM conversion for signals passed through the same repeater.

A.M. KHILLA, Bosch Telecom GmbH, Space and Avionics Product Group, Gerberstrasse 33, D-71522 Backnang, Germany; (+49) 7191-13-3579, FAX: (+49) 7191-13-4141.

Consequently, only the measurement of AM/PM conversion is needed to determine system nonlinearity. This results in reduced measurement time and cost.

AM/PM TRANSFER

AM transfer through AM/PM conversion is a major source of intelligible crosstalk between frequency-modulated carriers. Therefore, AM transfer is a key factor of overall system performance. AM/PM conversion can be examined by considering an input waveform representing the sum of an AM carrier and an unmodulated carrier:

$$V_{in} = A_1[1 + a(t)]\ \cos(\omega_1 t) + A_2\ \cos(\omega_2 t) \qquad (1)$$

where:
$a(t)$ = the modulation index,
ω_1, ω_2 = the frequencies of the AM and unmodulated carriers, respectively, and
A_1, A_2 = constants.

The input waveform can also be represented by the expression:

$$V_{in} = V(t)\cos\left[\left(\frac{\omega_1 + \omega_2}{2}\right)t + \psi(t)\right] \qquad (2)$$

where:

$$V^2(t) = A_1^2[1 + a(t)]^2 + A_2^2 + 2A_1A_2[1 + a(t)] \times \cos[(\omega_1 - \omega_2)t] \qquad (3)$$

and

$$\psi(t) = \tan^{-1}\{[A_1(1 + a(t)) - A_2] \times \sin[(\omega_1 - \omega_2)t/2] / [A_1(1 + a(t)) + A_2] \times \cos[(\omega_1 - \omega_2)t/2]\} \qquad (4)$$

The output waveform produced after AM/PM conversion can be described by the following formula:

$$V_{out} = V(t)\cos\left[\left(\frac{\omega_1 + \omega_2}{2}\right)t + \psi(t) + \theta(t)\right] \qquad (5)$$

where:
$\theta(t) = k_1V^2(t)$, and
k_1 = constant.

If it is assumed that $|a(t)| \ll 1$, then:

$$[1 + a(t)]^2 \approx 1 + 2a(t) \qquad (6)$$

and

$$\theta(t) = k_1\{A_1^2 + A_2^2 + 2A_1^2a(t) + 2A_1A_2[1 + a(t)] \times \cos[(\omega_1 - \omega_2)t]\} \qquad (7)$$

If the constant term $k_1(A_1^2 + A_2^2)$ is neglected, algebraic manipulation can be used to represent the output waveform in the following form:

$$V_{out} = A_1[1 + a(t)]\cos\{\omega_1 t + 2k_1A_1^2a(t) +$$

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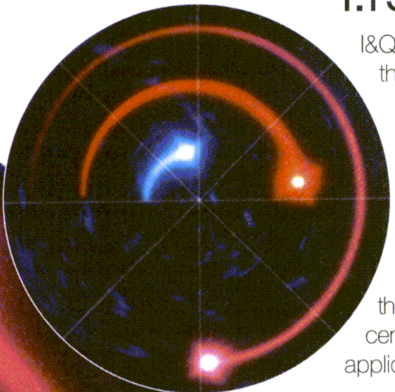

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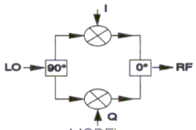

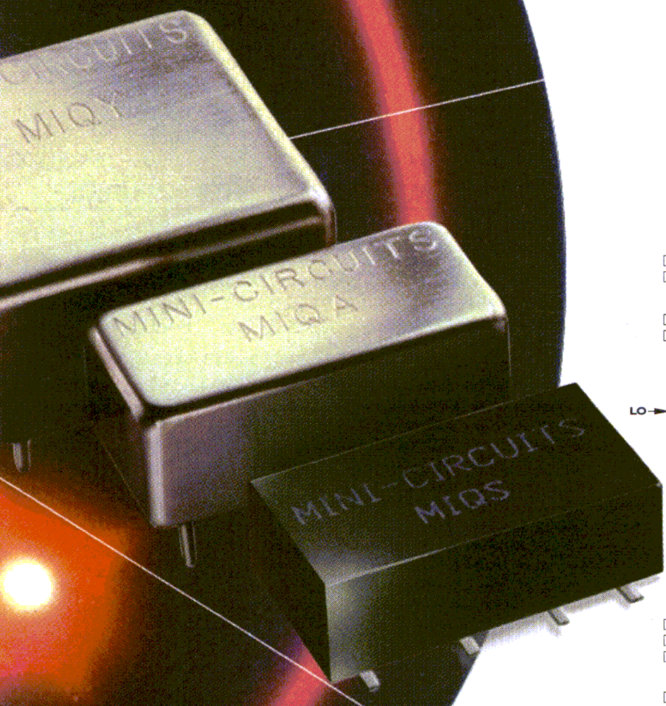

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MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQC-38M	34	38	5.6	0.10	48	37	54	65	49.95
MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
☐ MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
☐ MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95
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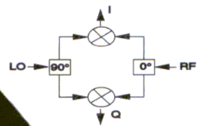
☐ JCIQ-88M	52	88	5.6	0.1	40	35	45	65	49.95
☐ JCIQ-176M	104	176	5.6	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

MODEL	FREQ. (MHz) f_L	FREQ. (MHz) f_U	CONV. LOSS (dB) $\bar{x}$	CONV. LOSS (dB) σ	AMP. UNBAL. (dB) Typ.	PHASE UNBAL. (Deg.) Typ.	HARM. SUPPRESS (-dBc) Typ. 3xI/Q	HARM. SUPPRESS (-dBc) Typ. 5xI/Q	PRICE $ Qty. (1-9)
MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
MIQA-70D	66	73	6.2	0.10	0.15	0.7	56	58	49.95
MIQC-38D	34	38	5.5	0.10	0.10	0.5	60	65	49.95
MIQC-60WD	20	60	5.3	0.10	0.15	1.0	55	67	79.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
☐ MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
☐ MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
☐ MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95
Surface Mount Models									
☐ JCIQ-176D	104	176	5.5	0.1	0.15	2	52	65	54.95
☐ JCIQ-895D	868	895	8.6	0.1	0.2	1	45	65	99.95
☐ JCIQ-1785D	1710	1785	8	0.2	0.2	2	50	65	99.95
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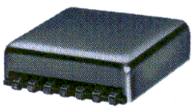

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718FC	100W CW	20-1000 MHz	50dB	$ 29,800
7100LC	100W CW	80-1000 MHz	50dB	$ 19,500
*757LC	100W CW	.01-1000 MHz	50dB	$ 29,950
122FC	250W CW	.01-225 MHz	55dB	$ 19,950
723FC	300W CW	500-1000 MHz	55dB	$ 29,995
LA500V	500W CW	10-100 MHz	56dB	$ 12,900
LA500UF	500W CW	100-500 MHz	57dB	$ 46,000
LA500G	500W CW	500-1000 MHz	57dB	$ 55,000
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AM/PM TRANSFER

$$2A_1A_2[1 + a(t)] \times \cos[(\omega_1 - \omega_2)t]\} \quad (8)$$

Assuming that $2k_1A_1A_2 \ll 1$, the following formula is obtained for the output waveform:

$$V_{out} = A_1[1 + a(t)] \cos[\omega_1 t + 2k_1A_1^2a(t)] - 2k_1A_1^2A_2[1 + a(t)]^2 \times \cos[(\omega_1 - \omega_2)t] \sin[\omega_1 t + 2k_1A_1^2a(t)] + A_2 \cos[\omega_2 t + 2k_1A_1^2a(t)] - 2k_1A_1A_2^2 \times [1 + a(t)] \cos[(\omega_1 - \omega_2)t] \times \sin[\omega_2 t + 2k_1A_1^2a(t)] \quad (9)$$

By expanding the cross-product terms and setting $[1 + a(t)]^2 \approx [1 + 2a(t)]$, the output waveform then becomes:

$$V_{out} = A_1[1 + a(t)] \cos[\omega_1 t + 2k_1A_1^2a(t)] - k_1A_1^2A_2[1 + 2a(t)] \sin[(2\omega_1 - \omega_2)t + 2k_1A_1^2a(t)] - k_1A_1^2A_2[1 + 2a(t)] \times \sin[\omega_2 t + 2k_1A_1^2a(t)] + A_2 \cos[\omega_1 t + 2k_1A_1^2a(t)] - k_1A_1A_2^2[1 + a(t)] \times \sin[(2\omega_2 - \omega_1)t + 2k_1A_1^2a(t)] - k_1A_1A_2^2[1 + a(t)] \sin[\omega_1 t + 2k_1A_1^2a(t)] \quad (10)$$

After combining the common-frequency terms, the following expression is obtained for the output waveform:

$$V_{out} = A_1[1 + a(t)]\{\cos[\omega_1 t + 2k_1A_1^2a(t)] - k_1A_2^2 \sin[\omega_1 t + 2k_1A_1^2a(t)]\} + A_2\{\cos[\omega_2 t + 2k_1A_1^2a(t)] - k_1A_1^2[1 + 2a(t)] \times \sin[\omega_2 t + 2k_1A_1^2a(t)]\} + [\text{terms at } (2\omega_1 - \omega_2) \text{ and } (2\omega_2 - \omega_1)] \quad (11)$$

By making the small-argument approximation:

$$\tan^{-1}\{k_1A_1^2[1 + 2a(t)]\} \approx k_1A_1^2[1 + 2a(t)] \quad (12)$$

and neglecting the constant-phase term on each carrier, the output waveform is simplified to:

$$V_{out} = A_1[1 + a(t)] \cos[\omega_1 t + 2k_1A_1^2a(t)] + A_2 \cos[\omega_2 t + 4k_1A_1^2a(t)] + [\text{terms at } (2\omega_1 - \omega_2) \text{ and } (2\omega_2 - \omega_1)] \quad (13)$$

Equation 13 is extremely important, as it shows that the transfer of AM on carrier 1 (with frequency ω_1) to PM on carriers 1 and 2 (where carrier 2 has a frequency ω_2) causes carrier 2 to be phase-shifted by twice the amount of carrier 1.

■

The transfer of AM on carrier 1 to PM on carriers 1 and 2 causes carrier 2 to be phased-shifted by twice the amount of carrier 1.

■

This means that a 1-dB peak-to-peak AM on carrier 1 causes a peak-to-peak phase shift of $2k_1A_1^2$ for carrier 1 and $4k_1A_1^2$ for carrier 2. The worst-case transmission in terms of AM/PM transfer occurs when the largest carrier is amplitude-modulated and the affected carriers are very small.●●

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Active filters, Part 2

OPAMPS PROVIDE FLEXIBLE ACTIVE-FILTER DESIGN

Infinite-gain-amplifier topologies produce low active-filter sensitivity to element values.

THROUGH proper circuit design, active-filter implementations based on operational amplifiers (opamps) can achieve a wide range of frequency responses. These filters are smaller in size than their passive-filter counterparts and provide gain at a low power consumption. They can also be realized entirely in integrated-circuit (IC) form.

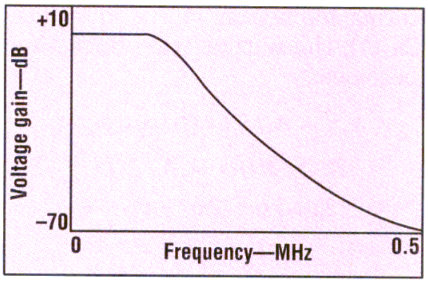
The first article in this two-part series (see *Microwaves & RF*, June 1995, p. 71) presented designs using an opamp in a fixed-gain configuration (chosen as a non-inverting amplifier). In these circuits, the gain is an integral part of the second-order-stage designs, as it is one of the terms used to place the poles in their desired locations. The requirement for a fixed non-inverting gain demands the use of additional resistors (which set this gain) that contain associated tolerance errors.

ROBERT L. HOWALD, Staff Engineer, General Instrument Corp., GI Communications Division, 2200 Byberry Rd., Hatboro, PA 19040; (215) 674-4800.

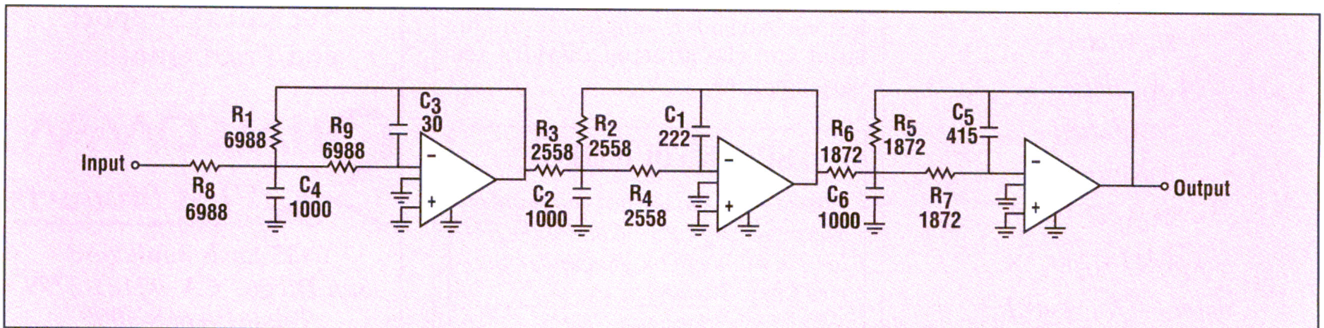
There are some basic filter examples, however, that do not require gain-setting resistors, such as an integrator circuit or the lead-lag active filter often used in phase-locked-loop (PLL) configurations. Interestingly, such a topology (which takes advantage of the theoretically infinite gain of opamps) also exists for a second-order active filter. This topology is aptly referred to as an infinite-gain filter.

The most important advantage of this type of filter design is the lower sensitivity of the filter's response to circuit element values and pole quality factors (Qs). This is most evident in bandpass designs, where the Q values are higher (resulting in greater inherent sensitivity to element values). As was mentioned in Part 1 of this series, higher-order bandpass designs can exhibit other practical problems (for instance, excessively-high gain values) using the fixed-gain topology.

Equation 1 clearly illustrates that as opamp gain A goes to infinity, the



9. This voltage-gain response was obtained for the three-section Butterworth lowpass design.



8. The element parameters for this six-pole Butterworth lowpass circuit were easily obtained by initially setting the value of capacitance C_5.

transfer function of the active-filter network in Fig. 1 becomes:

$$H(s) = -Y_{31} / Y_{32} \quad (19)$$

where Y_{31} and Y_{32} represent Y-parameters.

By replacing the gain block in Fig. 1 with an opamp, admittance Y_4 is eliminated from the circuit because the inverting-input terminal represents a virtual ground. The transfer function of Eq. 2 is then simplified to:

$$H(s) = -Y_1 Y_3 / [Y_6(Y_1 + Y_2 + Y_3 + Y_5) + Y_2 Y_3] \quad (20)$$

The procedure for determining the admittances from this point is the same one used for the finite-gain designs. Thus, given Eq. 19, admittances Y_1, Y_2, Y_3, Y_5, and Y_6 can be chosen as needed to provide a lowpass or bandpass second-order solution in the form of Eq. 3 or Eq. 16, respectively.

LOWPASS FILTER

A lowpass solution is easily implemented by selecting $Y_1 = R_1$, $Y_2 = R_2$, $Y_3 = R_3$, $Y_5 = sC_5$, and $Y_6 = sC_6$. The same Butterworth lowpass configuration used in the finite-gain example is implemented. The evaluation of the poles and the corresponding Q and ω_n terms remains unchanged. By inserting the aforementioned elements in Eq. 20, the transfer function becomes:

The infinite-gain filter provides lower response sensitivity to circuit element parameters and pole Q values.

$$H(s) = -G_1 G_3 / [s^2 C_5 C_6 + sC_6(G_1 + G_2 + G_3) + G_2 G_3] \quad (21)$$

As a simple design approach, $G = G_1 = G_2 = G_3$ is selected. This reduces the transfer function to:

$$H(s) = -G^2 / (s^2 C_5 C_6 + 3sGC_6 + G^2) \quad (22)$$

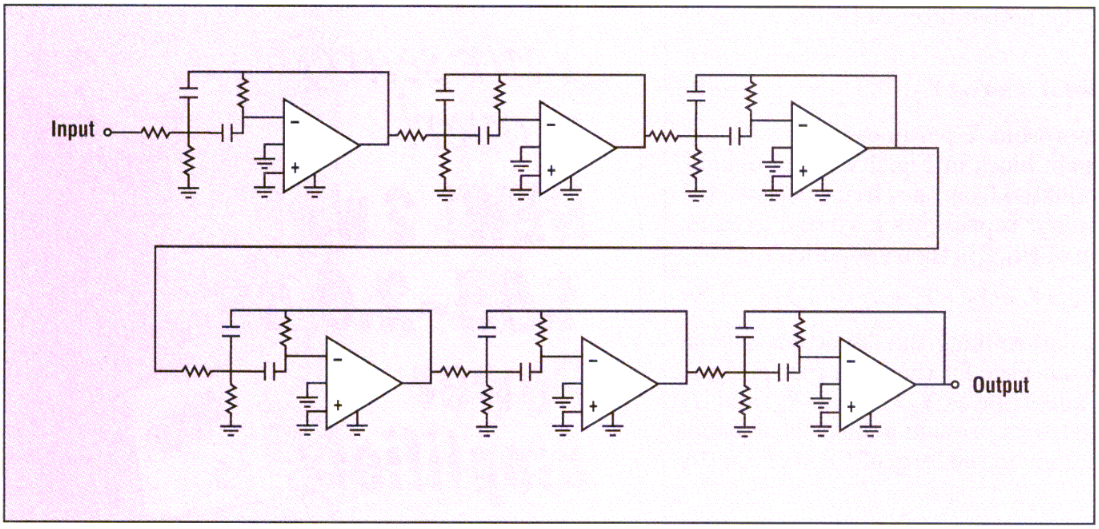
By comparing this formula to Eq. 3 and choosing a convenient value for C_5, enough constraints will be obtained to permit the following unique solution:

$$H_o = -1 \quad (23a)$$

$$C_6 = C_5 / 9Q^2 \quad (23b)$$

$$G = \omega_n C_5 / 3Q \quad (23c)$$

By using the ω_n and Q terms associated with the Butterworth poles in the cascade of three second-order sections employed for the finite-gain design, the same filter-response shape can be achieved with this topology. By choosing $C_5 = 1000$ pF, the other circuit elements are



10. The element values for this sixth-order Butterworth bandpass filter were computed using MathCAD analysis software.

easily determined (Fig. 8).

Figure 9 shows the frequency response for the infinite-gain-amplifier filter design. This design approach again fixes the gain (in this case at a convenient 0 dB). Other design procedures instead constrain the gain and C_5 while solving for the remaining elements.

BANDPASS FILTER

In the bandpass design, the circuit elements are selected so as to enact a solution in the form of Eq. 16. This is achieved by setting $Y_1 = G_1$, $Y_2 = sC_2$, $Y_3 = sC_3$, $Y_5 = R_5$, and $Y_6 = R_6$. A design approach based on equal C values with H_o as a parametric term results in the following R values:

$$R_1 = Q/\left(\omega_n C|H_o|\right) \quad (24a)$$

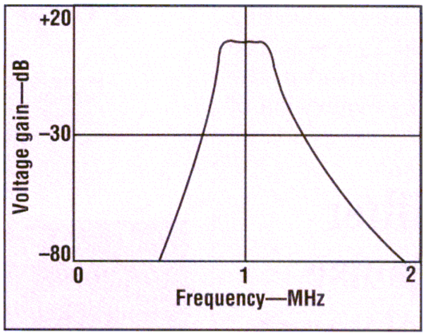
$$R_5 = Q/\left(2Q^2 - |H_o|\right)\omega_n C \quad (24b)$$

$$R_6 = 2Q/\omega_n C \quad (24c)$$

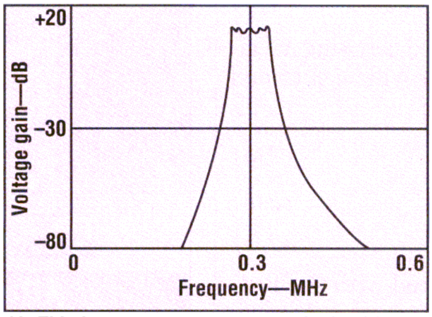
The freedom to vary H_o is a significant feature, as it provides the ability to select the gain level, with the only constraints being practical values for the resistors. However, it must be kept in mind that simply combining H_o terms does determine the cascaded gain, since H_o represents the gain only at the pole ω_n, which is not the same as the filter center frequency.

The element-value computation is easily performed using mathematical analysis software. Figure 10 shows the bandpass filter topology with element values determined using MathCAD software from MathSoft, Inc. (Cambridge, MA). The software also calculates the individual pole locations and the overall filter gain.

The filter's frequency response was simulated using Libra from HP EEsof, Inc. (Westlake Village, CA).



11. In contrast to the fixed-gain design, the infinite-gain-amplifier approach produces a reasonable passband gain for a sixth-order Butterworth bandpass filter.



12. This frequency response was obtained for the Chebyshev bandpass design incorporating an infinite-gain-amplifier topology.

The response plot (Fig. 11) indicates the desired shape, as well as the center-frequency gain, which matches the value predicted by the analysis.

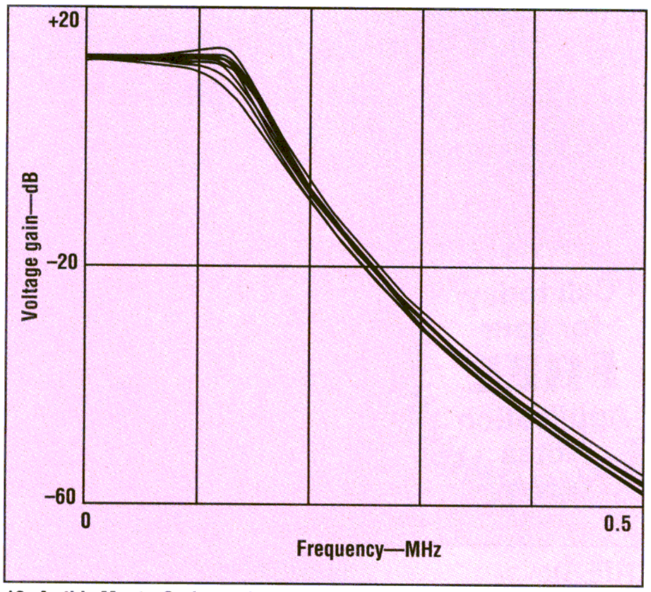
The infinite-gain design procedure implemented on the Chebyshev bandpass filter (which was described in Part 1 of this series) results in the frequency response shown in Fig. 12. The circuit element values in the Chebyshev design exhibit a larger spread than those in the Butterworth circuit. This is due to the higher Q values of the Chebyshev filter sections. In order to maintain practical element values, a higher H_o term was implemented for the infinite-gain filter. The direct result was a wider spread of resistances R_1 and R_6 (as predicted by Eq. 24).

FILTER SENSITIVITY

While it is necessary to achieve practical values for the circuit elements, it is also important to achieve these values with standard families of resistors and capacitors. Furthermore, it must be considered that even when the values of the standard element families are within a small percentage of the design values, the tolerance of the part in question is critical. These issues arise due to the sensitivity characteristics of active-filter designs. A detailed sensitivity analysis is presented by Huelsman.[1]

Monte-Carlo analysis can be used to illustrate the effect of these variations on the frequency response. The values of each circuit element are

ACTIVE FILTERS

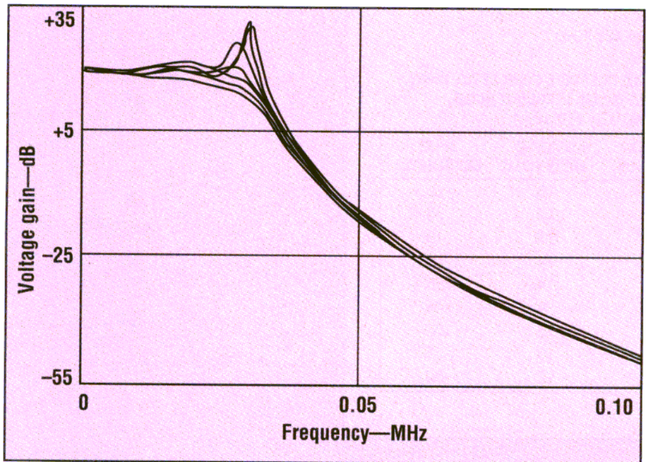


13. As this Monte-Carlo-analysis plot indicates, the fixed-gain Butterworth lowpass filter exhibits considerable gain deviation at the cutoff frequency.

varied independently of the others and no distinction is made between the tolerance of a part and how close its value is to a common family value. Equivalently, the simulation assumes that the exact design value is available. This parameter is used as the nominal element value.

The probability distribution of the variation is uniform. This is generally a conservative approach, as a sizable sample of a single family value will cluster toward a bell shape (with some standard deviation). For simulation purposes, resistor values of less than 10 kΩ were used with precision to 1 Ω. Values up to 100 kΩ were rounded to the nearest 10 Ω, while values greater than 100 kΩ were rounded to the nearest 100 Ω.

Figure 13 shows the Monte-Carlo analysis applied to



14. The frequency response of the fixed-gain Chebyshev filter shows high sensitivity at the equiripple cutoff. Tweaking of element values is needed to reduce this effect.

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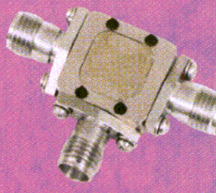

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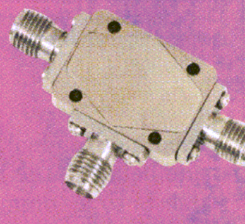

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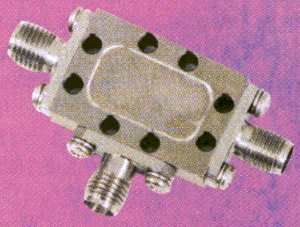

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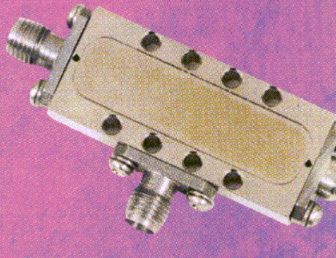

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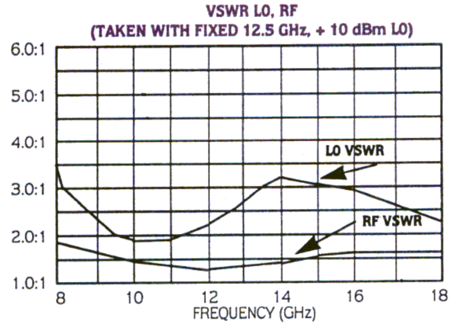
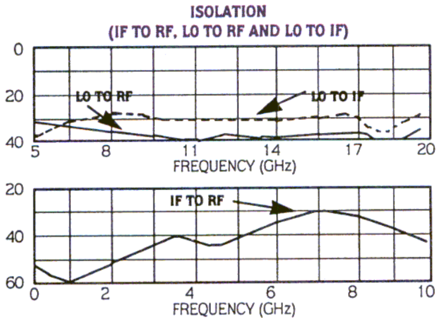
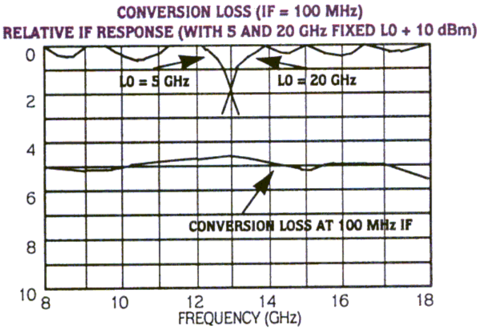
DM0208LW2	2 - 8	DC - 2	10 - 13	6 / 8	40 / 30	40 / 30
DM0812LA1	8 - 12	DC - 4	10 - 13	4.5 / 6	35 / 30	40 / 30
DM0818LW1	8 - 18	DC - 7	10 - 13	5 / 7	40 / 30	40 / 20
DM0520LW1	5 - 20	DC - 8	10 - 13	6 / 8	35 / 30	40 / 20

TYPICAL DATA: MODEL DM0818LW1







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(TYPICAL AT MIDBAND RF, LO, IF FREQUENCIES,
RF = -10 dBm, LO = +10 dBm)

SPUR (m) RF X (n) LO	RF TEST FREQ. (GHz)	LO TEST FREQ. (GHz)	SPUR LEVEL (dBc)
1 x 1	11	15	0
1 x 2	14.4	9.2	-38
1 x 3	16.4	6.8	-13
2 x 1	9	14	-50
2 x 2	12	14	-55
2 x 3	15.5	9	-46
3 x 1	7.33	18	-56
3 x 2	8	10	-55
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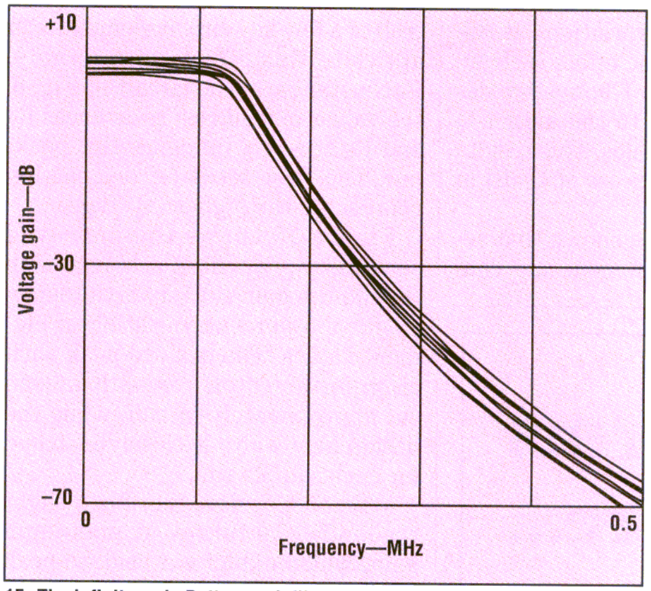
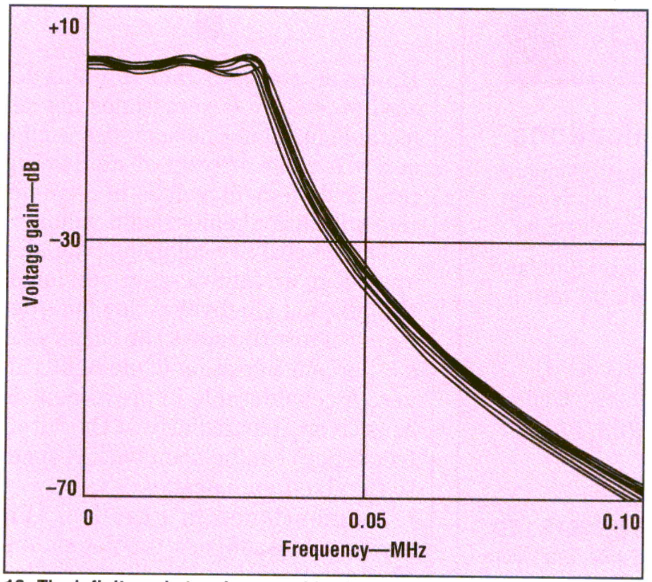


15. The infinite-gain Butterworth filter exhibits much better sensitivity near cutoff than the fixed-gain design.

■

the constant-gain Butterworth design with 5-percent variation of element parameters. As the plot indicates, this variation does not affect the shape of the rolloff characteristic far from the cutoff frequency, nor does it strongly affect the passband frequencies that are much less than the cutoff frequency. In fact, the gain magnitude does not vary by more than 1.5 dB. However, the 5-percent element variation does influence the circuit response near the cutoff frequency, resulting in more than 6 dB of gain variation at cutoff. The cutoff frequency shows no tendency to exceed the design value but it can undershoot the goal—in the worst case, exhibiting



16. The infinite-gain topology provides improved sensitivity for the lowpass Chebyshev filter implementation. This improvement is most evident at the cutoff frequency.

■

ACTIVE FILTERS

an undershoot of about 20 kHz (or 15 percent). It appears that a slight tweaking of element values would yield the desired response.

Figure 14 shows the 5-percent tolerance results for the finite-gain Chebyshev lowpass filter. Similar to the Butterworth case, the lowpass response exhibits considerable sensitivity to element variations at the equiripple cutoff. The effect is clearly intensified in the Chebyshev design, primarily due to the higher-Q nature of the filter poles. This results in gain peaking in excess of 15 dB in the worst case.

However, it can be shown that selective tweaking (or moderate control) of a few key circuit elements can alleviate this effect considerably. For instance, in the circuit of Fig. 6, the values of feedback resistances R_6 and R_7 strongly influence this peaking. The first second-order section represents the highest-Q stage.

Figure 15 shows the improved sensitivity near cutoff achieved with the infinite-gain Butterworth topology for a 5-percent variation of element values. The peak-to-peak variation in the cutoff region has been cut approximately in half, while the design bandwidth is closely-matched for each sample run.

With this design, there is a slight tradeoff of accuracy at maximum gain, which exhibits a peak-to-peak variation of approximately 2 dB.

By selectively tweaking key circuit elements, the filter's sensitivity to element tolerances may be reduced.

However, the gain value for this design procedure is sometimes not selectable at all and is sometimes chosen with the intent of achieving practical element values in conjunction with a convenient gain value.

The sensitivity analysis was also applied to an infinite-gain version of the original Chebyshev lowpass design. Figure 16 shows the results for a 5-percent variation of element values. A considerable improvement in sensitivity (particularly at the cutoff frequency) can be seen with respect to the fixed-gain design.

As mentioned in Part 1 of this series, the bandpass topologies implemented with a fixed-gain design method (when utilizing the equal-R, equal-C design approach for multiple sections) produced impractical gain

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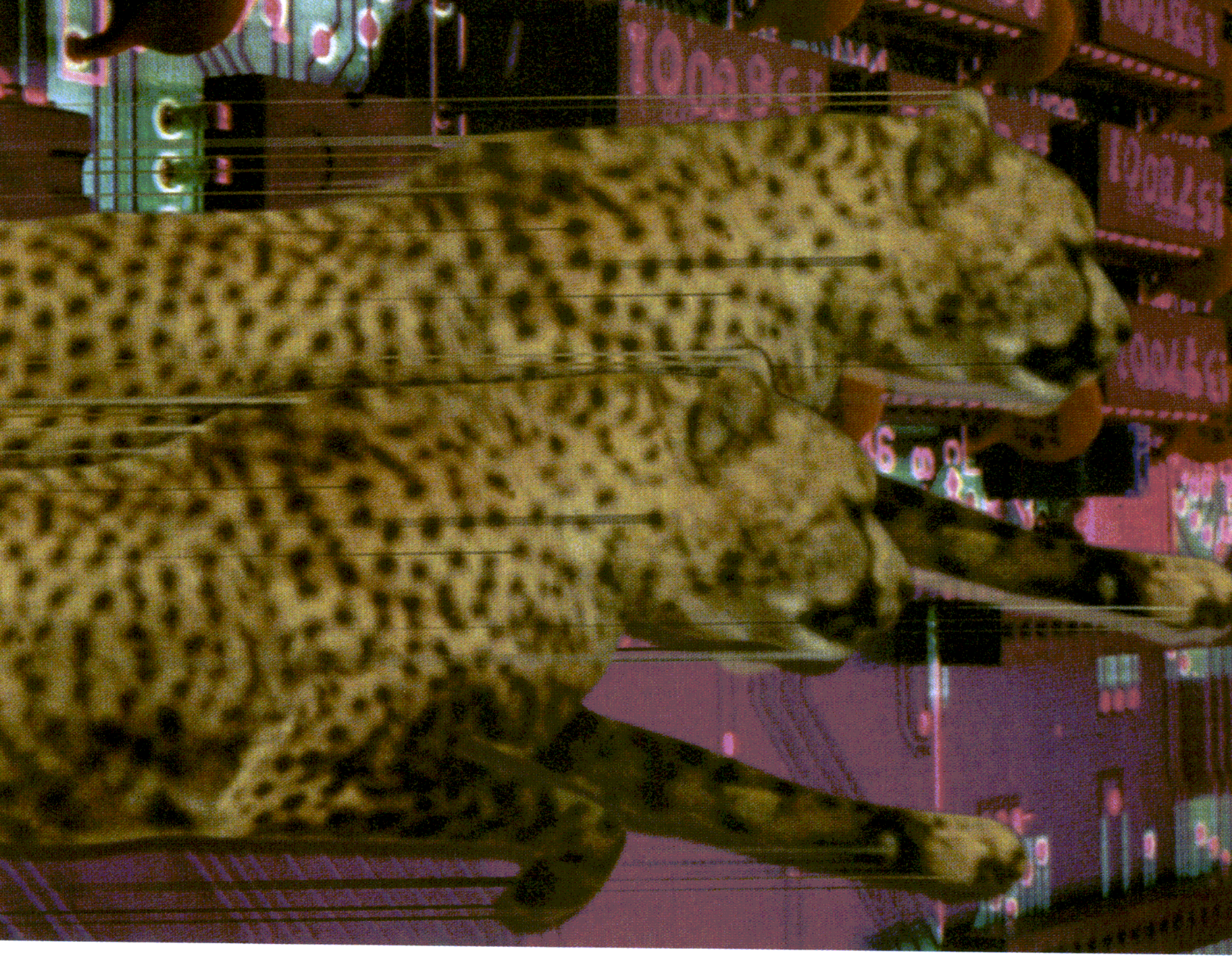
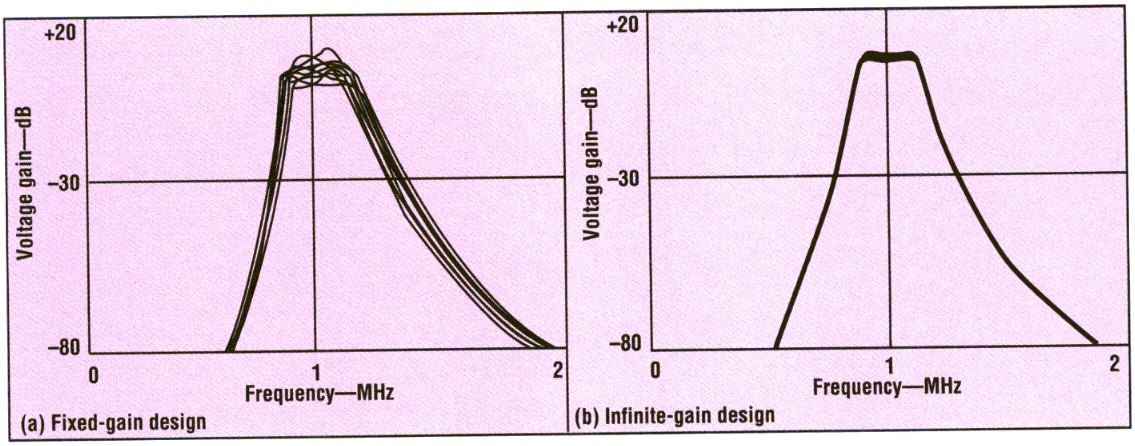
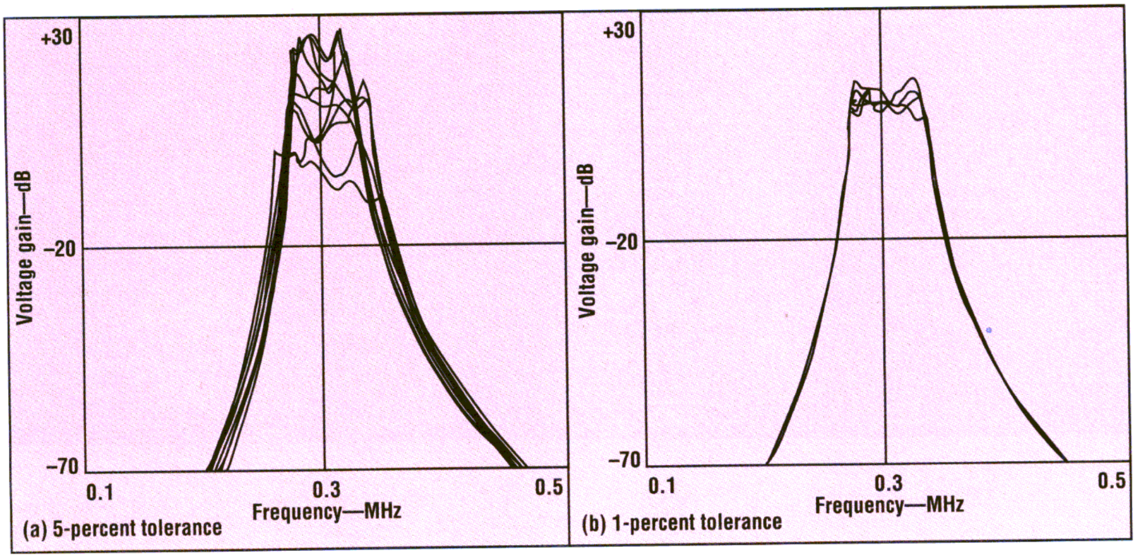




17. Even for a 1-percent variation of element values, the fixed-gain Butterworth design exhibits considerable response sensitivity (a). Better sensitivity is achieved with the infinite-gain topology (b).



18. The Chebyshev bandpass response exhibits extremely-high sensitivity to a 5-percent variation in element values (a). A much more reliable response is obtained for a 1-percent variation (b).

values. For reference purposes, however, the Monte Carlo analysis was applied to a fixed-gain Butterworth design with a 1-percent parts variation. The analysis results (Fig. 17a) demonstrate high sensitivity in the passband. While the Butterworth shape is recognizable using this degree of parts tolerance, the response still contains 10 dB of gain variation at the center frequency, with even greater variation at the passband edges. The peak-to-peak variations are very close to those achieved with a 5-percent variation of element values with the infinite-gain design.

With the infinite-gain design, the peaking at cutoff with respect to the passband is lower, although the absolute gain in the passband exhibits slightly more variation. This tradeoff is similar to that exhibited in the lowpass case. Figure 17b shows the analysis results for an infinite-gain Butterworth bandpass design with 1-percent element variation.

Figures 18a and 18b show the Monte-Carlo analysis plots for the Chebyshev bandpass design with 5- and 1-percent element variation, respectively. It is clear from Fig. 18a that the high-Q nature of the poles significantly affects active-filter sensitivity. In fact, the passband under 5-percent tolerance is indistinguishable in the response plot. Although the element values that most strongly contribute to sensitivity can again be tuned, a shape with this much degradation makes the tuning procedure more tedious. Figure 18b shows a shape function that can be dealt with much more easily, as the response exhibits excessive peaking only at the equiripple band edges.

Note that the realization of higher-order active filters by cascading sections amplifies filter sensitivity. For instance, a third-order filter with 5-percent element variation exhibits about a third of the peak-to-peak deviation at maximum gain that is exhibited by the fifth-order filter response. ●●

Reference

1. L. Huelsman and P. Allen, *Introduction to the Theory and Design of Active Filters*, McGraw-Hill, 1980.

For further reading

W. Jung, *IC Opamp Cookbook*, Sams (Macmillan), 1986.
F. Stephenson, *RC Active-Filter Design Handbook*, John Wiley & Sons, 1985.
A. Zverev, *Handbook of Filter Synthesis*, John Wiley & Sons, 1967.

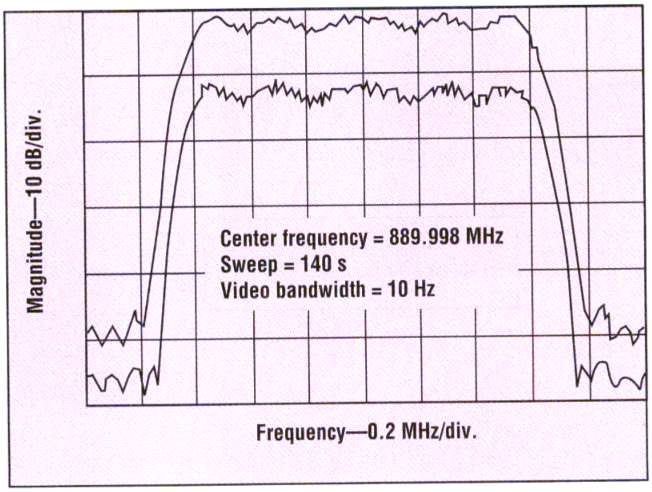
GAUGE THE EFFECT OF NOISE FIGURE ON SPECTRUM ANALYZERS

A novel figure of merit provides bandwidth-independent characterization of an analyzer's dynamic range.

SENSITIVITY is an indicator of the smallest signal that can be detected, identified, or measured with a receiver such as a spectrum analyzer. The usual numeric measure of sensitivity is provided by the instrument's noise level. A novel figure of merit, termed the dynamic-range figure (DRF), describes the measurement range of spectrum analyzers independent of the measurement bandwidth.

An instrument's noise level is determined by the power product kTBF, where k is the Boltzmann constant, T is the absolute temperature, B is the effective noise bandwidth, and F is the noise figure due to the excess noise generated by the spectrum analyzer. A perfect analyzer, with no excess noise at 0-dB noise figure, will have a sensitivity of –174 dBm for a 1-Hz operating bandwidth. Sensitivity will change at the rate of 10 log B and 10 log F with varying operating bandwidth and noise figure, respectively.

MORRIS ENGELSON, Consulting Chief Engineer, and **LEN GARRETT,** Product Marketing Manager, RF/Transmission Test Group, Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077-0001; (503) 627-7111.



1. This spectrum-analyzer display shows signals measured at resolution-bandwidth settings of 3 kHz (bottom trace) and 30 kHz (top trace).

Clearly, there are multiple values of B and F that will yield the same sensitivity. A 10-Hz bandwidth and 30-dB noise figure yield a –134-dBm sensitivity. Likewise, a 1-kHz bandwidth and 10-dB noise figure produce a –134-dBm sensitivity. The two specifications are identical but the measurement capability is not the same. Other factors (such as large-signal compression point) being equal, a lower noise figure permits a wider range of measurements.

In theory, it is possible to reduce the noise figure of a spectrum analyzer to a very low level by simply placing a high-gain, low-noise preamplifier in front of the instrument. The noise figures of cascaded sections combine in accordance with the following formula:

$$F = F_1 + (F_2 - 1)/G_1 \qquad (1)$$

where:
F = the overall noise figure,
F_1, F_2 = the noise figures of stages 1 and 2, respectively, and
G_1 = the gain of stage 1.

The resulting noise figure is low when the preamplifier noise figure (F_1) is low and the preamplifier gain (G_1) is high. For example, when the spectrum-analyzer noise figure (F_2) is 30 dB, F_1 is 3 dB, and the preamplifier gain (G_1) is 33 dB, the resultant F will be 4 dB. The noise figure (and sensitivity) is improved by a factor of 26 dB. However, this improvement is obtained at the expense of dynamic range.

Dynamic range is an indicator of the instrument's ability to measure both small and large signals. Every circuit has a limit on the magnitude

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NF, db, max*	1.6 1.5	1.6 1.5	1.6 1.5	1.5	1.5	1.5
Gain dB, min.	20	20	20	30	30	30
Output Pwr., dBm 1dB Comp.	+8	+10	+10	+26	+26	+26
Intercept Pt. 3rd order, dBm typ.	18	25	22	36	36	36
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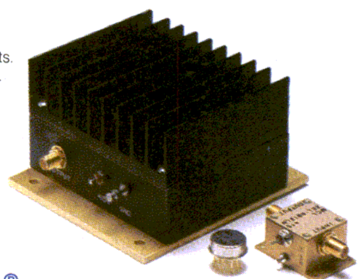

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of a signal that it will respond to. Specifications of the largest permissible signal include the 1-dB gain compression point and the third-order intermodulation intercept point. These limitations apply to both the spectrum analyzer and the preamplifier. Therefore, even if the preamplifier is perfect (without any upper signal-level limit), there is still a maximum allowable input level that is determined by the spectrum analyzer. This means that the maximum signal level applied to the preamplifier will be the maximum signal level applied directly to the spectrum analyzer minus the preamplifier gain.

In the measurement example, the preamplifier gain is 33 dB, resulting in a noise-figure improvement of 26 dB. Hence, there is a gain of 26 dB in the small-signal range and a loss of 33 dB in the large-signal range. Thus, the total dynamic range is degraded by 7 dB even with a theoretically perfect preamplifier. With a practical preamplifier, the loss in dynamic range would probably be about 10 dB.

A low noise figure is a desirable feature in a spectrum analyzer, but only when the dynamic range is not critical and when the noise figure is achieved without a front-end preamplifier. The higher the preamplifier gain, the lower the high-signal-level input capability.

The usual high-signal-level figure of merit for signals with multiple frequency components is the third-order intercept point (I). Knowing I and the sensitivity noise level (N), given by:

$$N = kTBF \qquad (2)$$

it is customary to compute the best possible (or optimum) dynamic range from the relationship:

$$DR = (n - 1)(I - N)/n \qquad (3)$$

where:

n = the intermodulation order.

The optimum dynamic range does not depend separately on F or B but on the product F × B (which determines N). This is the desired result for sinusoidal signals, where a change in either F or B will produce a change in the signal-detection sensitivity. However, the optimum-dynamic-range calculation using the aforementioned formula is useless (and indeed misleading) for the random-like signals generated by digital modulation.

The ability to detect and measure dynamic range for digital modulation signals is independent of the measurement bandwidth. Only a lower noise figure will improve the measurement sensitivity for these signals. However, the use of a preamplifier to improve noise figure will degrade the large-signal-input limit and reduce dynamic range. Hence, the optimum-dynamic-range formula cannot be used as an operating

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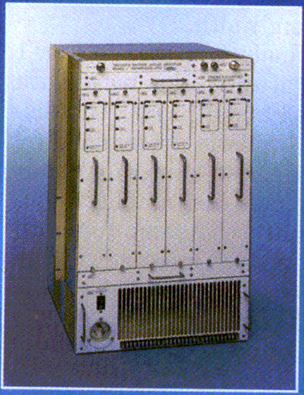

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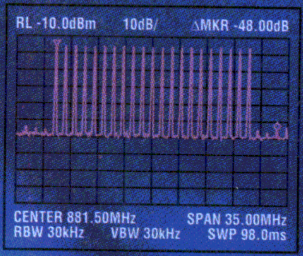

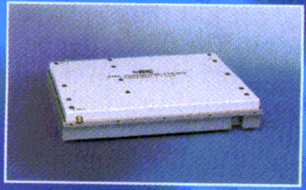

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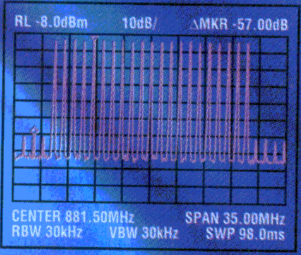

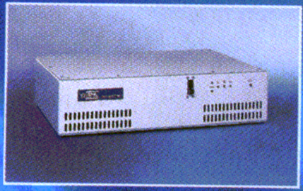

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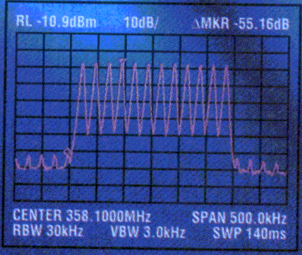

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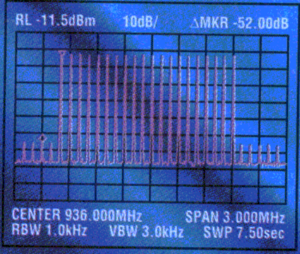

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figure-of-merit indicator.

A better figure of merit is proposed for the testing of digital modulation signals. This parameter is designated the DRF and defined as DRF = I – F. The lower the noise figure and higher the intercept point, the better the DRF.

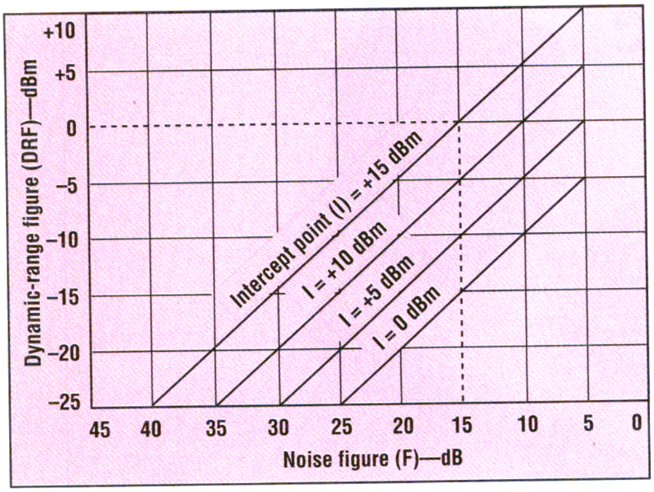
To properly analyze the implications of using this performance measurement, it is necessary to fully understand the sensitivity and dynamic-range aspects of noise-like digital modulation signals.

Figure 1 shows the frequency response of a code-division-multiple-access (CDMA) spread-spectrum signal. The signal appears as a broadband random-noise spectrum to the spectrum analyzer. The displayed amplitude, as well as the analyzer's sensitivity noise level (kTBF), depends on the measurement bandwidth. The dynamic-range difference between the two parameters, however, is independent of the measurement bandwidth.

The two analyzer traces in Fig. 1 were taken at resolution-bandwidth settings of 3 and 30 kHz. The displayed amplitude is determined by the measurement bandwidth, but the signal shape and amplitude-to-noise ratio are the same for both traces. No measurement advantage (for instance, improved dynamic range) is gained by changing the measurement bandwidth. Both the noise signal and the spectrum-analyzer sensitivity noise change with the measurement bandwidth.

Unlike the case for a continuous-wave (CW) signal, the displayed dynamic range for a digitally-modulated signal cannot be improved by using a narrower resolution bandwidth. To make matters worse, the distributed spectrum of a digitally-modulated signal is displayed at a lower level than the actual total input power. Hence, the actual dynamic range is worse than that displayed on screen because the front-end circuits will overload due to the total input level (and not just the displayed amplitude level). The difference between the displayed signal level and the total power level to which the spectrum analyzer is subjected is approximately 10 log (signaling rate/measurement noise bandwidth).

This calculation indicates that while the displayed dynamic range is independent of the measurement bandwidth, the actual measurement dynamic range does depend on the bandwidth. The higher the bandwidth, the lower the ratio of input signal to displayed signal (known as the overrange) and the better the measurement capability. Unfortunately, the measurement bandwidth cannot be increased indefinitely because that would distort the intercepted spectrum shape to be measured. Furthermore, regulatory requirements usually specify the



2. This nomograph provides a graphical calculation of DRF as a function of intercept point and noise figure.

measurement bandwidth to be used.

For the CDMA signal of Fig. 1, the specified measurement bandwidth is 30 kHz. This is the widest bandwidth that will not lose the fine spectral-shape details. The overrange computed for this bandwidth is 18.6 dB. A good rule of thumb is that an overrange of about 20 dB is needed when using the widest reasonable measurement bandwidth. This means that for digital modulation signals, the measurement dynamic range is inherently about 20 dB worse than that of sine-wave signals. Furthermore, the dynamic range cannot be improved by using a narrower measurement bandwidth. Hence, the key parameters are the noise figure on the low-signal side and the intercept point on the high-signal side. Combining the two terms yields the dynamic-range figure of merit: DRF = I – F.

UNDERSTANDING DRF

The virtue of the DRF parameter is that it is a very simple, generalized performance figure of merit. A larger DRF implies a better instrument in terms of digital-signal dynamic range. Thus, the DRF permits a direct comparison between different instruments.

However, the DRF concept is not perfect. Unlike the optimum dynamic-range relationship for sinusoidal signals, DRF does not directly indicate the dynamic range that will be achieved in a measurement situation. To obtain this information, a more complicated indicator is used.

The use of DRF to characterize the measurement of digitally-modulated signals can be examined by considering the small-signal sensitivity for a noise-like signal normalized to a 1-Hz bandwidth, which is given by kTF/1 Hz = (–174 + F) dBm/Hz. The large-signal input level is determined by the intercept point reduced by the ratio of signaling rate to measurement bandwidth (an overdrive range of approximately 20 dB) and by how close the input signal can get to the intercept point before the front-end circuits leave their linear operating range. The range of linear operation before the instrument reaches the intercept point is 30 to 50 dB (depending on instrument factors). For the purpose of this discussion, it is approximated at 40 dB.

Therefore, the large-signal limit falls at (I – 60) dB. The measurement dynamic range is determined as the decibel difference between the large-signal limit and the small-signal sensitivity:

$$\begin{aligned} \text{Dynamic range (in dBm / Hz)} &= \\ (I - 60) - (-174 + F) &= \\ (I - F) + 114 &= \\ DRF + 114 & \qquad (4) \end{aligned}$$

This is the dynamic range when the measurement bandwidth is set at the widest usable value (where the overrange loss is approximately 20 dB). This generally represents a bandwidth of approximately 1/100 of the modulation signaling rate.

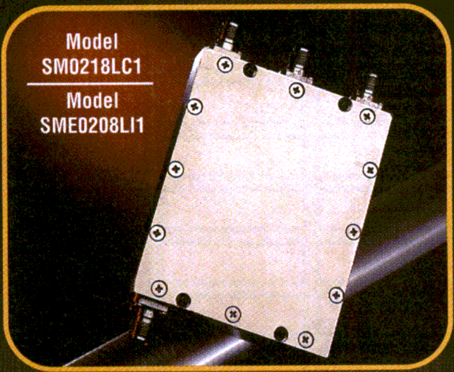
Note that the measurement does not have to be made at this bandwidth. The measurement dynamic range for noise-like signals is independent of the measurement bandwidth. However, it is not independent of the "ideal" measurement bandwidth computed.

The CDMA signal in Fig. 1 can be used as an example. The specified "ideal" resolution bandwidth is 30 kHz, which yields a noise bandwidth of 34 kHz. At a signaling rate of 2.45 MHz, there is a dynamic-range loss due to overrange of 10 log (2450/34) = 18.6 dB. For an intercept point of 15 dB and a signal drive within 40 dB of the intercept point, there is a normalized dynamic range of 15 – 40 – 18.6 + 174 – F = (130.4 – F) dBm/Hz. At a 34-kHz bandwidth, there is a dynamic-range loss of 10 log (34 kHz) = 45.3 dB. This results in a normalized dynamic range of (85.1 – F) dB.

If, however, a 3-kHz bandwidth (3.4-kHz noise) is used for the measurement, the overrange loss is 28.6 dB. The normalization adjustment from 1 Hz to 3.4 kHz is 35.3 dB, resulting in a dynamic range of 15 – 40 – 28.6 + 174 – 35.3 – F = (85.1 – F) dB. This result is independent of the measurement bandwidth.

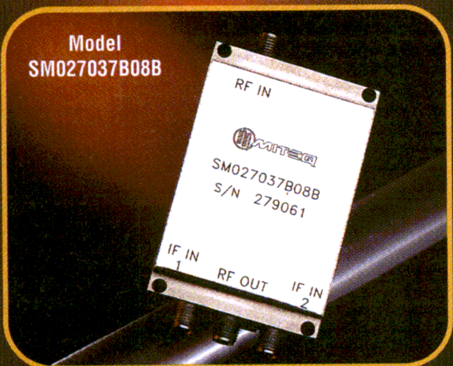
It should be noted that a measurement dynamic range for digitally-modulated signals of 70 dB is about the best that can be obtained. This is in contrast to the measurement of sine waves, where a 100-dB dynamic range is not unusual. As a simple approximation, the measurement dynamic range for digitally-modulated signals can be estimated to be 70 dB + DRF. The DRF will usually be a negative decibel value, resulting in a typical measurement dynamic range of about 50 dB. Figure 2 shows a simple nomogram for the calculation of DRF as a function of intercept and noise figure.••

WIDE AND NARROW BANDWIDTH SSB MODULATORS

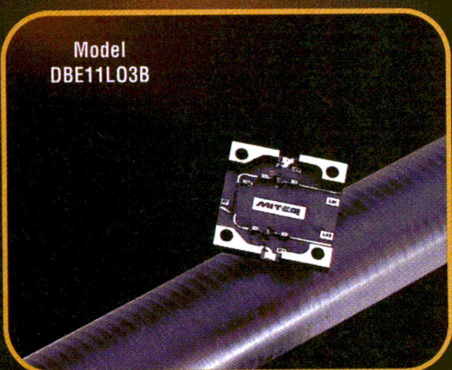


Multioctave, SSB, I/Q - 2 to 18 GHz
Achieves high carrier and lower sideband suppression over wide RF bandwidths, but large I/Q power causes high f_0 - 3 IF levels.

Enhanced Sideband - 2 to 8 GHz
Cascaded coupler topology yields high lower sideband rejection, but also has high f_0 - 3 IF levels.



Low-Loss Linear Upconverter - 2.7 to 3.7 GHz
Reversing f_0 and f_{IF} power levels improves f_0 ±3 IF rejection. Carrier suppression still maintained by ultra-high LO-RF isolation (45 dB typ.).



Even Harmonic Suppressed Carrier - 7 to 10 GHz
Achieves highest carrier suppression with simultaneous high f_0 ±3 IF rejection, but CL and output power capability is moderate.

Multioctave, SSB, I/Q - Model SM0218LC1

Freq. (GHz)	Conv. Loss* (11 dB Max.)	f_0 - IF (15 dB Min.)	f_0 (25 dB Typ.)	f_0 - 2 IF (20 dB Typ.)	f_0 + 2 IF (20 dB Typ.)	f_0 - 3 IF (12 dB Typ.)	f_0 + 3 IF (12 dB Typ.)
2.0	7.9	16.8	21.3	33.2	37.6	10.4	29.0
4.0	9.5	24.6	33.9	44.2	49.4	13.0	46.9
6.0	9.3	22.7	40.8	43.5	50.1	14.4	33.9
8.0	9.2	21.1	36.5	40.8	47.5	13.6	30.8
10.0	9.6	27.6	37.8	42.9	43.5	11.9	26.6
12.0	9.7	18.9	38.4	38.5	41.1	11.1	26.1
14.0	9.6	22.8	31.1	43.7	41.5	12.0	26.6
16.0	9.0	21.2	29.5	39.9	39.6	10.4	27.1
18.0	9.7	21.9	21.3	37.1	38.8	11.8	23.6

I/Q = 30 MHz, +10 dBm, f_0 = 0 dBm

Enhanced Sideband Rejection - Model SME0208LI1

Freq. (GHz)	Conv. Loss* (9.5 dB Max.)	f_0 - IF (28 dB Min.)	f_0 (30 dB Typ.)	f_0 - 2 IF (30 dB Typ.)	f_0 + 2 IF (30 dB Typ.)	f_0 - 3 IF (15 dB Typ.)	f_0 + 3 IF (15 dB Typ.)
2.0	8.6	34.4	42.9	43.5	52.9	14.7	33.8
3.0	7.6	44.1	28.2	43.9	51.0	16.6	31.8
4.0	8.0	30.3	28.8	49.3	43.8	14.9	35.8
5.0	8.2	35.3	33.3	51.9	45.8	15.7	30.9
6.0	8.6	38.8	38.7	40.4	40.6	15.1	35.5
7.0	9.4	31.5	22.7	44.1	36.8	14.7	32.9
8.0	9.1	32.0	28.0	33.3	42.8	17.8	29.9

I/Q = 60 MHz, +10 dBm, f_0 = 0 dBm

Low-Loss, Linear Upconverter - Model SM027037B08B

Freq. (GHz)	Conv. Loss* (8 dB Max.)	f_0 - IF (25 dBc Min.)	f_0 (25 dBc Min.)	f_0 - 2 IF (30 dBc Min.)	f_0 + 2 IF (30 dBc Min.)	f_0 - 3 IF (30 dBc Min.)	f_0 + 3 IF (30 dBc Min.
2.7	6.1	28.8	29.6	53.0	43.5	47.4	51.5
2.8	5.4	28.8	30.3	51.4	44.5	45.4	52.2
3.0	5.7	29.2	29.4	48.9	44.8	43.7	50.6
3.1	5.6	29.2	29.6	48.7	44.9	42.5	50.6
3.3	6.3	28.0	28.5	47.7	45.0	40.4	51.0
3.4	6.3	28.3	28.4	48.0	44.4	40.0	50.9
3.5	6.0	28.6	28.4	48.2	45.4	40.1	52.5
3.6	5.3	29.3	28.2	50.1	45.0	39.5	51.1
3.7	5.2	30.0	27.1	53.8	46.1	37.8	50.3

f_0 = +10 dBm, I/Q = 0 dBm, 200 MHz

Even Harmonic, Suppressed Carrier - Model DBE11LO3B

Freq. (GHz)	Conv. Loss* (10 dB Max.)	f_0 - IF (20 dBc Min.)	f_0 (35 dBc Min.)	f_0 - 2 IF (30 dBc Min.)	f_0 + 2 IF (30 dBc Min.)	f_0 - 3 IF (20 dBc Min.)	f_0 + 3 IF (20 dBc Min.
7.0	9.0	20.0	55.0	60.0	50.0	27.0	40.0
7.5	9.4	20.0	55.0	60.0	48.0	25.0	49.0
8.0	8.6	24.0	50.0	55.0	48.0	24.0	38.0
8.5	8.5	32.0	48.0	55.0	50.0	24.0	33.0
9.0	8.2	31.0	47.0	50.0	48.0	23.0	35.0
9.5	8.2	29.0	48.0	50.0	48.0	23.0	42.0
10.0	8.6	25.0	47.0	50.0	47.0	24.0	44.0

f_0 = + 7 dBm, I/Q = 100 MHz, 0 dBm

* Conversion Loss (CL) is relative to lowest power input (f_0 or f_{IF}). All other outputs (including f_0) are relative to the desired upper (f_0 + f_{IF}) output.

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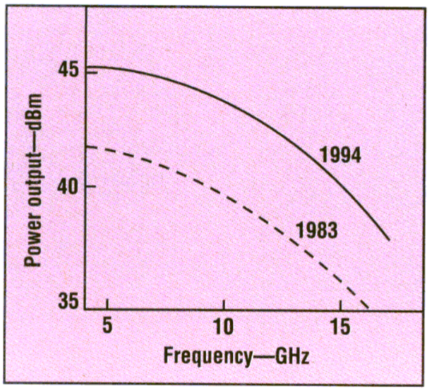
HIGH-POWER SOLID-STATE AMPS PROVIDE TWTA REPLACEMENT

SSPAs are gaining popularity due to their better reliability, lower operating voltages, and increasing power levels.

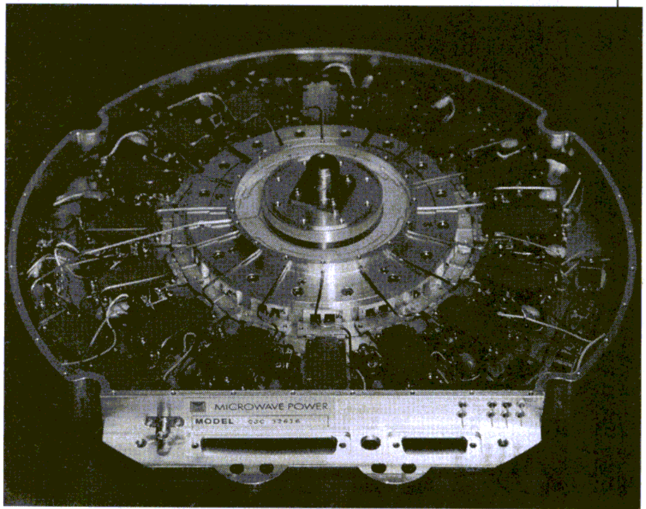
AS technical improvements produce higher device output powers and increasing competition yields lower prices, solid-state power amplifiers (SSPAs) are becoming increasingly competitive with conventional traveling-wave-tube amplifiers (TWTAs).

M. BUJATTI, Vice President, and **F.N. SECHI,** President, Microwave Power, Inc., 3350 Scott Blvd., Building 25, Santa Clara, CA 95054; (408) 727-6666, FAX: (408) 727-2246.



1. The maximum power output from a single internally-matched device is shown for commercially-available devices in 1983 and 1994.

During the past 10 years, the power output per unit gate width obtained from discrete GaAs field-effect transistors (FETs) has not undergone any dramatic change. However, the combination of refinements in manufacturing, improved yields, and increased sophistication in matching techniques has allowed manufacturers to increase the power output of internally-matched devices in most of the commercial operating bands. Figure 1 compares the maximum output power available from commercially-available internally-matched devices in 1983 and 1994.[1]

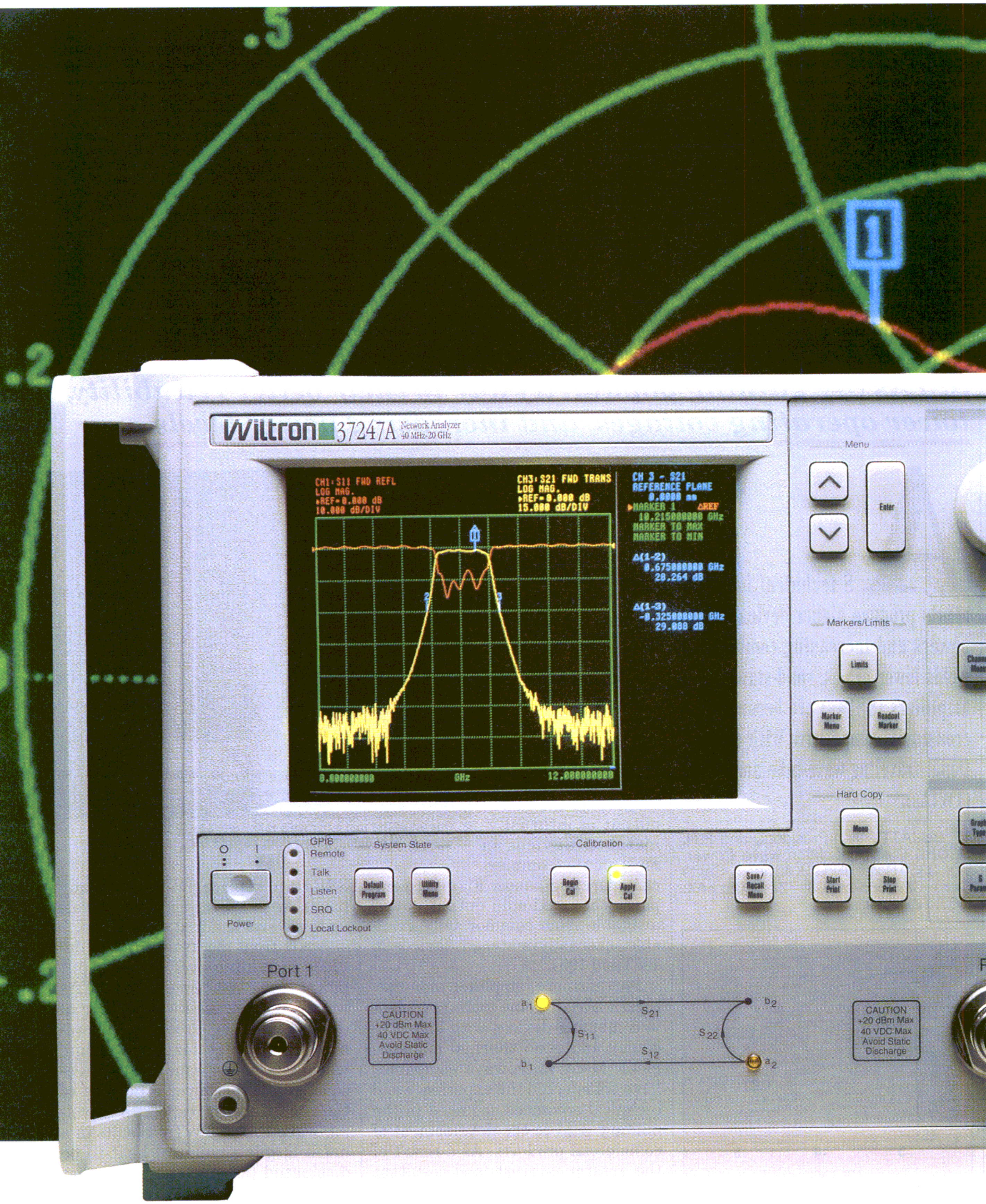


2. This amplifier unit employs a radial waveguide combiner to achieve 30 W of output power from 14 to 16 GHz.

Furthermore, amplifier manufacturers have become more proficient in combining devices with high efficiency and good thermal management. Many microwave companies have transferred the experience and technical advances acquired in the military field to the development of commercial products. As a result of the greater interest (and resultant competition) in commercial markets, the overall solid-state power available in the commercial bands has grown significantly in the last few years. This makes it possible for SSPAs to replace TWTAs in many bands, with operating power levels up to several hundred watts.

Apart from the availability of devices providing sufficient output power, the replacement of TWTAs with SSPAs presents a number of design challenges. Probably the foremost problem is heat dissipation, which is a major issue for two reasons. First, the lower efficiency of GaAs FETs with respect to traveling-wave tubes (TWTs) results in a much larger amount of heat to be dissipated (as much as twice that of TWTs). Second, TWTs can withstand much higher temperatures than GaAs FETs.

Another key issue is the ability to provide a fully interchangeable re-



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MARKER TO MIN
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Enter
Markers/Limits
Limits
Marker Menu
Readout Marker
Hard Copy
Menu
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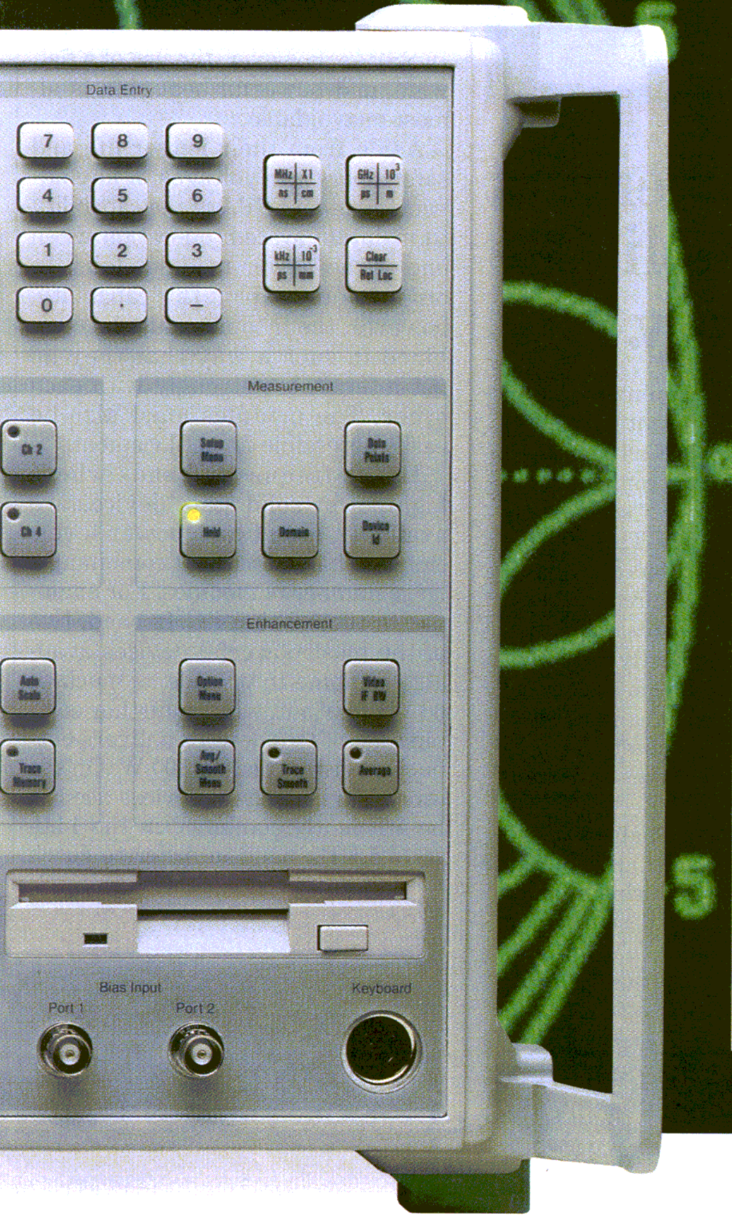

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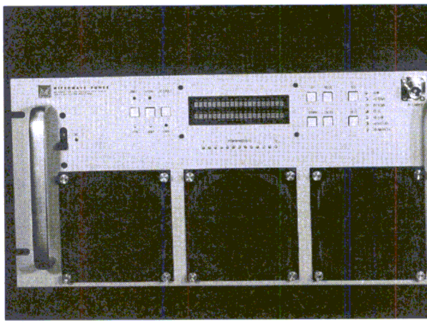
placement without sacrificing the advantages that an SSPA provides with respect to a vacuum tube. Users of TWTs generally require complete compatibility of controls and a fit/form replacement.

However, the two types of amplifiers are quite different. TWTAs generally contain a single tube while SSPAs combine a number of power modules to achieve their output-power levels. TWTAs employ high bias voltages while SSPAs require low bias voltages. In TWTA designs, heat sinking may not be important. In SSPAs, however, the use of a flat, wide, and powerful heat sink is almost unavoidable.

Aside from their longer life and safer operating voltages, a key advantage of an SSPA is the capability to maintain system operation when one of the power modules fails. In order to fully exploit this capability, however, the modules must be combined in such a way that they do not interact too strongly with each other. The modules must also be easily accessible for replacement.

In the frequency bands where high-power solid-state devices are available, significant power levels can be achieved without combining a large number of modules. For example, in the 5.9-to-6.4-GHz band, two of the most powerful devices available combine to provide as much as 60 W of output, while a further combination of two devices delivers output powers exceeding 100 W. On the other hand, about 10 devices need to be efficiently combined in the 14.0-to-14.5-GHz band in order to reach



3. The CJQ-81112 SSPA system from Microwave Power (Santa Clara, CA) allows TWTA replacement, delivering 125-W output power from 14.0 to 14.5 GHz.

POWER AMPLIFIERS

the 100-W level.

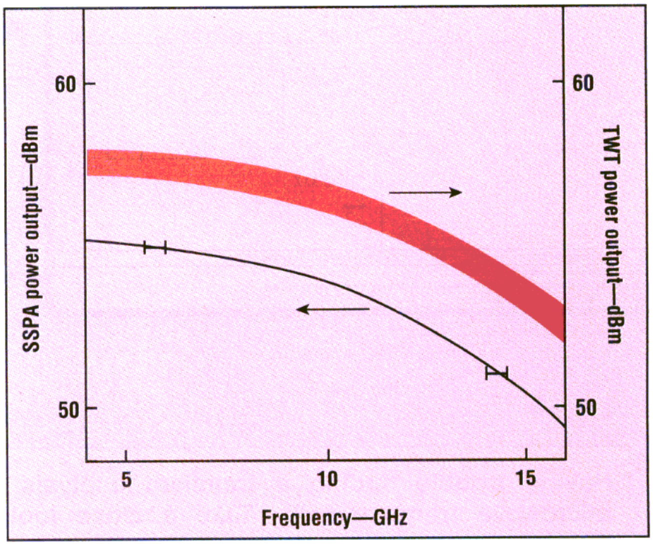
A proprietary approach[2] from Microwave Power, Inc. (Santa Clara, CA) provides high power levels by using a radial waveguide combiner. The technique is based on earlier experiments carried on by various groups under defense contracts.[3,4] However, the combiner unit's configuration has been transformed into a planar one in order to improve heat sinking and accessibility. Figure 2 shows a wideband amplifier unit developed by Microwave Power in cooperation with Sandia National Laboratories (Albuquerque, NM).[5] The amplifier provides 30-W output power from 14 to 16 GHz. In this case, 16 power modules (each providing 2-W output power) are combined in-phase to provide the desired performance. Because of the wide and non-standard operating band, internally-matched devices could not be used. Consequently, the required power modules were specifically designed for this application.

In the standard commercial bands where internally-matched devices are readily available, much higher output powers can be achieved using the same design approach. For instance, the model CJQ-81112 SSPA from Microwave Power provides 125-W output power and 65-dB gain from 14.0 to 14.5 GHz (Fig. 3).

Solid-state devices are typically more linear than TWTs, especially if they are tuned for optimal linearity. Despite its lower power, the CJQ-81112 provides a signal quality comparable to that of a TWTA featuring twice as much output power. In fact, the unit is designed as a direct replacement for a specific 300-W TWTA. All signals and controls are fully compatible with the TWTA design. A useful feature of the CJQ-81112 is that each power module is separately monitored so that should one degrade or fail, it can be replaced in the field without interruption of service.

The replacement's operation is simplified by the planar structure of the internal amplifier. The unit's structure is similar to the one shown in Fig. 2, except that only 12 modules are used. In fact, the ability to vary the SSPA output power almost continuously by using the same basic design and changing only the number of combined modules is one of the advantages of the radial-combiner approach.

As a result of the higher output powers available from internally-matched devices, as well as the increased sophistication of combining techniques and the reduced prices generated by keen competition in commercial markets, the performance gap between TWTAs and



4. This plot compares the power levels (across a 0.5-GHz bandwidth) available from SSPAs and TWTAs with comparable intermodulation levels.

SSPAs has closed significantly in the last couple of years. This is especially true in many communications applications, where the higher linearity of solid-state devices generally allows the replacement of a high-power TWTA with a lower-power SSPA without loss of performance. Although the actual power ratio between TWTAs and SSPAs depends on the specific application, a ratio of 2.0:1 to 2.5:1 is not uncommon.

One of the main advantages of replacing TWTAs with SSPAs is the drastic reduction in logistic costs. This is due to the longer life of SSPAs, as well as the easier and safer maintenance allowed by the SSPAs' better accessibility and low-voltage operation. Furthermore, if the system design allows the replacement of single modules rather than the entire amplifier, the cost of spares can be dramatically reduced.

Figure 4 presents the power levels available from SSPAs today. The plot includes bars representing commercially-available units in the two most popular communication bands. For reference purposes, the output powers of TWTAs with similar intermodulation characterstics are also shown. In applications where intermodulation is the most important parameter, the shaded area represents the upper limit of power where TWTAs can be replaced by SSPAs using current technology.

Higher-power active devices have recently become available in a variety of operating bands. Consequently, SSPAs will be able to provide even greater output power. Within the next couple of years, the power curve is likely to advance by as much as a factor of two, thereby allowing SSPAs to compete with TWTAs offering power outputs of 1 kW in C-band and 0.5 kW in Ku-band.

Many of the newer TWTA replacements incorporate microprocessors for monitoring and control. Some of these designs (for instance, the CJQ-81112) allow for separate monitoring of each individual power module, permitting easier maintenance and field replacement. Given the low cost and increasing popularity of microprocessors, the trend toward computer-controlled TWTA replacements is sure to continue.

Because of the fundamental differences between SSPAs and TWTAs, it would be economically advantageous if systems were designed initially with SSPAs in mind. Probably the most obvious example of the differences in the design approaches for SSPAs and TWTAs is the output-power issue. The cost of an SSPA is almost proportional to output power, while the cost of a TWTA remains fairly constant. In fact, a 300-W TWTA may be only marginally more expensive than a 100-W TWTA. Therefore, in a TWT transmitter design, there is no significant incentive

POWER AMPLIFIERS

to save power. For example, a TWT-based design often contains connections that are long and lossy. When using an SSPA, however, it is worthwhile to invest in low-loss connections or to house the amplifier next to the antenna.

Since the largest present market is in TWTA replacements, SSPA manufacturers are also striving to become competitive with TWTA vendors when replacing amplifiers into existing systems. Currently, a complete solid-state amplifier system is only 10-to-20-percent more expensive than the TWTA it can replace. Because of its longer life and its "graceful degradation" characteristics, an SSPA composed of 12 power modules will typically need the replacement of less than one module every 10 years—at a cost of about 8 percent of the entire system. During that same time period, the tube in a TWT transmitter is typically replaced two or three times—at a cost of more than half of the entire system.

In addition, the limited shelf life of TWTAs forces users to operate these systems with a "hot standby." In other words, they must keep two tubes powered even though only one is used. This minimizes the chance of failure when turning on the spare. As a result, two tubes (rather than one) must be replaced every four to five years (on the average). With SSPAs, it is possible to operate with only one or two modules as spares. Morever, even if a full spare amplifier is used, it does not have to be powered while on standby. Assuming that a full spare is kept in both cases, a typical cost comparison may run as follows:

- The initial cost of two amplifiers is $85,000 for the SSPA and $70,000 for the TWTA.
- Replacement costs over five years are $4,000 for the SSPA and $50,000 for the TWTA.
- This yields an overall equipment cost over five years of $89,000 for the SSPA and $120,000 for the TWTA.

Other maintenance costs are considerably smaller for the SSPA because of the lower voltages and operating temperatures, better stability, and overall trouble-free performance of solid-state devices. ●●

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3. E. Belohoubek *et al.*, "30-Way Radial Power Combiner for Miniature GaAs Power Amplifiers," *IEEE MTT-S Symposium Digest*, 1986, pp. 515-518.
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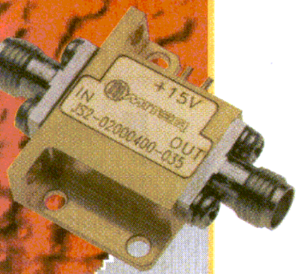

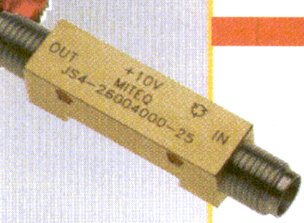

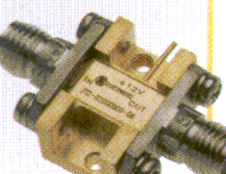

Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Variation (±dB, Max.)	Noise Figure (dB, Max.)	VSWR (Input/Output) (Max.)	Output Power at 1 dB Compr. (dBm, Min.)	Current at +15 V (mA, Typ.)
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JS2-01000200-035-8P	1–2	35	1	**0.35**	2:1 / 2:1	8	250
JS2-02000400-035-8P	2–4	28	1	**0.35**	2:1 / 2:1	8	200
JS2-04000800-050-0P	4–8	22	1	**0.5**	2:1 / 2:1	0	150
JS2-08001200-07-5P	8–12	18	1	**0.7**	2:1 / 2:1	5	150
JS2-12001800-15-5P	12–18	15	1	**1.5**	2:1 / 2:1	5	100
JS2-18002600-20-5P	18–26	14	1	**2.0**	2:1 / 2:1	5	100
JS2-26004000-30-5P	26–40	11	2	**3.0**	2:1 / 2:1	5	100
JS3-04000800-050-8P	4–8	30	1	**0.5**	2:1 / 2:1	8	175
JS3-08001200-07-8P	8–12	25	1	**0.7**	2:1 / 2:1	8	175
JS3-12001800-14-8P	12–18	25	1	**1.4**	2:1 / 2:1	8	175
JS3-18002600-18-8P	18–26	22	1	**1.8**	2:1 / 2:1	8	175
JS3-26004000-28-8P	26–40	18	2	**2.8**	2.5:1 / 2.5:1	8	175
JS4-12001800-13-8P	12–18	35	1.5	**1.3**	2:1 / 2:1	8	200
JS4-18002600-16-8P	18–26	31	1.2	**1.6**	2:1 / 2:1	8	200
JS4-26004000-25-8P	26–40	26	2.5	**2.5**	2:1 / 2:1	8	200
MULTIOCTAVE BAND							
JS2-00500200-050-8P	0.5–2	34	1	**0.5**	2:1 / 2:1	8	125
JS2-01000400-07-8P	1–4	28	1	**0.7**	2:1 / 2:1	8	125
JS2-02000600-07-5P	2–6	24	1	**0.7**	2:1 / 2:1	5	100
JS2-02000800-08-0P	2–8	22	1	**0.8**	2:1 / 2:1	0	100
JS3-02001800-23-5P	2–18	21	2	**2.3**	2.5:1 / 2.5:1	5	120
JS3-06001800-18-5P	6–18	23	1.3	**1.8**	2:1 / 2:1	5	120
JS3-08001800-17-5P	8–18	24	1.2	**1.7**	2:1 / 2:1	5	120
JS3-02002600-28-5P	2–26	21	2	**2.8**	2:1 / 2:1	5	125
JS3-12002600-23-5P	12–26	22	2	**2.3**	2:1 / 2:1	5	125
JS3-08002600-25-5P	8–26	21	2	**2.5**	2:1 / 2:1	5	125
JS3-18004000-30-5P	18–40	16	2.5	**3.0**	2.5:1 / 2.5:1	5	125
JS4-02001800-20-5P	2–18	30	2	**2.0**	2.5:1 / 2.5:1	5	200
JS4-06001800-15-8P	6–18	31	1.5	**1.5**	2:1 / 2:1	8	200
JS4-08001800-14-8P	8–18	32	1.5	**1.4**	2:1 / 2:1	8	200
JS4-08002600-23-5P	8–26	30	2	**2.3**	2:1 / 2:1	5	200
JS4-12002600-20-5P	12–26	32	1.7	**2.0**	2:1 / 2:1	5	200
JS4-18004000-30-8P	18–40	23	2.5	**3.0**	2.5:1 / 2.5:1	8	200
ULTRAWIDE BAND							
JS2-00100200-05-8P	0.1–2	34	1	**0.5**	2:1 / 2:1	8	250
JS2-00100400-08-8P	0.1–4	27	1	**0.8**	2:1 / 2:1	8	200
JS2-00100600-10-3P	0.1–6	23	1.5	**1.0**	2:1 / 2:1	3	175
JS2-00100800-13-0P	0.1–8	18	1.5	**1.3**	2:1 / 2:1	0	175
JS3-00101000-17-5P	0.1–10	26	1.5	**1.7**	2:1 / 2:1	5	150
JS3-00101200-18-5P	0.1–12	25	1.5	**1.8**	2:1 / 2:1	5	150
JS3-00101800-20-5P	0.1–18	23	1.5	**2.0**	2:1 / 2:1	5	150
JS3-00102600-27-5P	0.1–26	20	1.8	**2.7**	2.5:1 / 2.5:1	5	150
JS4-00102000-20-5P	0.1–20	28	1.8	**2.0**	2:1 / 2:1	5	200
JS4-00102600-26-5P	0.1–26	27	2	**2.6**	2.5:1 / 2.5:1	5	200
JS4-00103000-35-5P	0.1–30	20	2.5	**3.5**	2.5:1 / 2.5:1	5	200
JS4-00104000-55-5P	0.1–40	14	2.7	**5.5**	2.5:1 / 2.5:1	5	200

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CIRCLE NO. 220

Wireless Communications, Part 1

UNDERSTAND THE LIMITS OF DIGITAL CELLULAR FORMATS

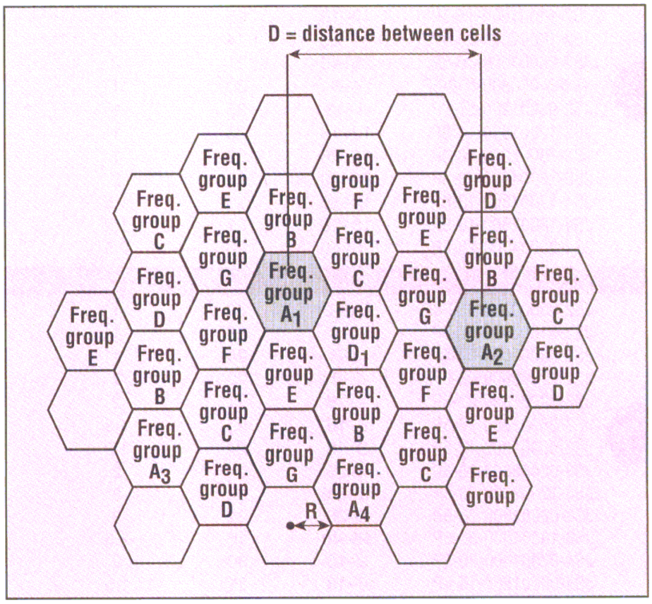
Classical theory does not accurately predict the carrying capacity of modern digital cellular communications.

CELLULAR capacity is often a choice of modulation format. The gradual worldwide move from analog cellular formats to digital cellular systems is designed to increase channel capacities. By examining the fundamental interference limits of various cellular architectures as well as Shannon's digital communications classical capacity bound theory and combining these observations with Feher's transmit RF power technology and spectral-efficiency theories, it may be possible to arrive at the most efficient modulation formats for cellular transmission systems.

Between 1985 and 1995, the number of cellular radio subscribers increased from about 0.5 to 24 million. This growth forced engineers to find original solutions to design systems that can accommodate increasingly more subscribers than the original analog Advanced Mobile Phone Service (AMPS) system established for cellular communications.

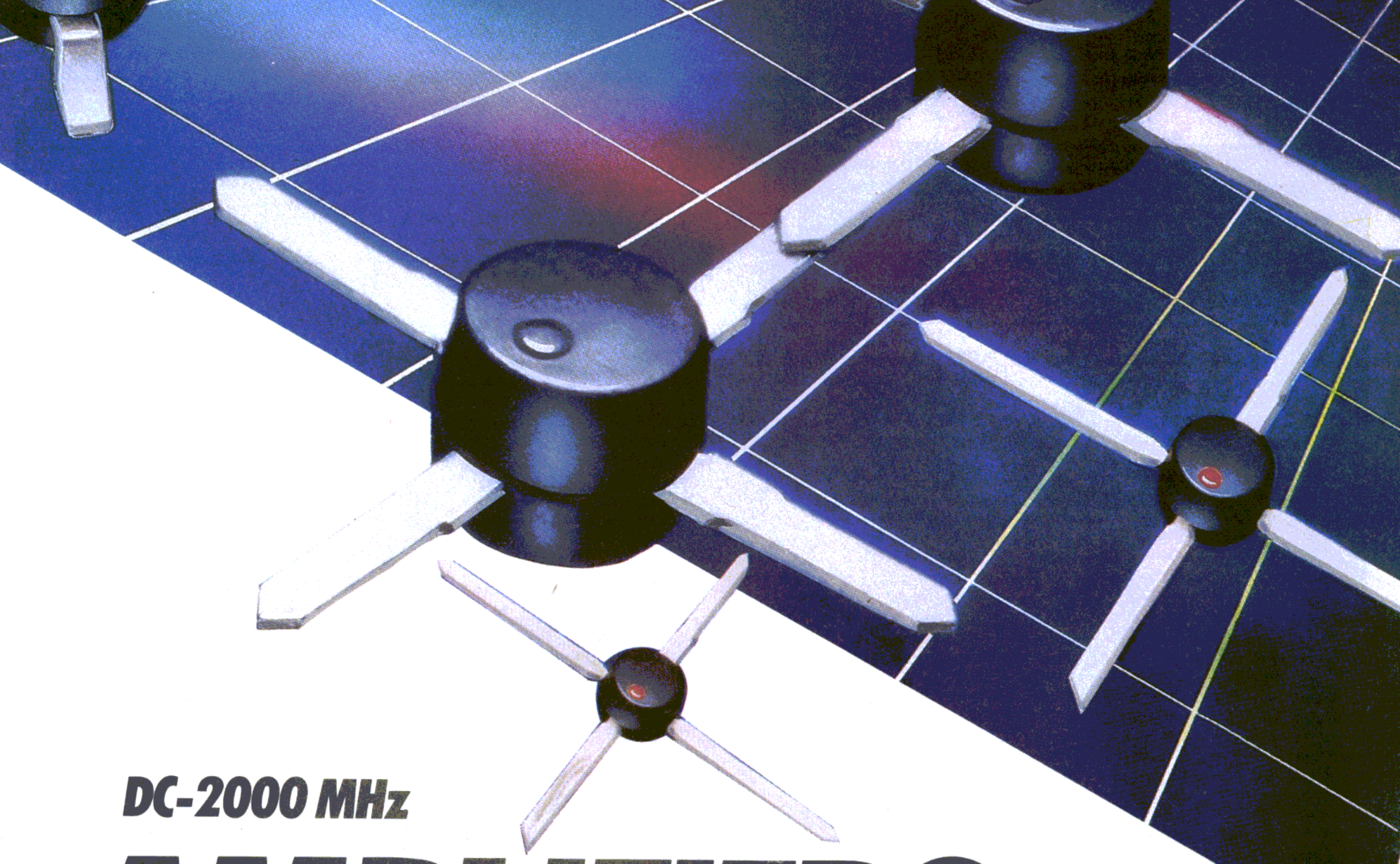
Because digital modulation techniques offer more capacity in a given cellular system, such techniques have been explored and applied to newer cellular systems. In addition, access methods such as time-division multiple access (TDMA) and code-division multiple access (CDMA), as well as new infrastructures (consisting of normal cells, microcells, picocells, and so on) have also had an impact on capacity. Classical communications theory and, in particular, the Shannon-Hartley capacity bound, provide the definitive theoretical capacity limit of "single-channel" systems.

In line-of-sight (LOS) microwave, satellite, cable, or wired communications systems, spectral efficiency is defined in terms of number of bits per second per Hertz (b/s/Hz). In omnidirectional non-line-of-sight (non-LOS) applications, such as cellular systems, public land mobile radio, personal communications services (PCS), and other digital wireless systems, the spectral efficiency and capacity concepts must be extended to the entire geographic service area (Fig. 1). The spectral efficiency of the complete area (in m^2) is defined in $b/s/Hz/m^2$ or $erl/Hz/m^2$. Frequency reuse leads to increased capacity and "area" spectral efficiency. Seven-



1. In cellular architectures, spectral efficiency and capacity concepts are extended across a geographic area.

KAMILO FEHER, Ph.D. Director, Digital and Wireless Communications Lab, Department of Electrical and Computer Engineering, University of California at Davis, Davis, CA 95616; (916) 752-8127, FAX: (916) 752-8428.



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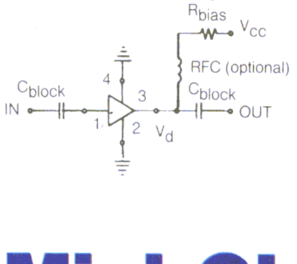
120x60	.022, .047, .068, .1 μf

Typical Circuit Arrangement



	MODEL	Freq. (MHz) DC TO	GAIN (Typ. dB) At 100MHz	MAX. Power (@ 1dB Compr.) dBm	NF dB (Typ.)	Price $ea. (Qty. 50)
MAR	MAR-1	1000	18.5	1.5	5.5	.99
	MAR-2	2000	12.5	4.5	6.5	1.35
	MAR-3	2000	12.5	10.0	6.0	1.45
	MAR-4	1000	8.3	12.5	6.5	1.55
MAR SM	MAR-6	2000	20.0	2.0	3.0	1.29
	MAR-7	2000	13.5	5.5	5.0	1.75
	MAR-8	1000	32.5	12.5	3.3	1.70
RAM	RAM-1	1000	19.0	1.5	5.5	*6.40
	RAM-2	2000	12.5	4.5	6.5	*6.40
	RAM-3	2000	12.5	10.0	6.0	*6.40
	RAM-4	1000	8.5	12.5	6.5	*6.40
	RAM-6	2000	20.0	2.0	2.8	*6.40
	RAM-7	2000	13.5	5.5	4.5	*6.40
	RAM-8	1000	32.5	12.5	3.0	*6.40
MAV	MAV-1	1000	18.5	1.5	5.5	1.10
	MAV-2	1500	12.5	4.5	6.5	1.40
	MAV-3	1500	12.5	10.0	6.0	1.50
	MAV-4	1000	8.3	11.5	7.0	1.60
MAV SM	MAV-5SM	50-1500	8.0	18.0	6.5	2.07
	MAV-11	10-1000	12.7	17.5	3.6	2.10
VAM	VAM-3	2000	11.5	9.0	6.0	1.45
	VAM-6	2000	19.5	2.0	3.0	1.29
	VAM-7	2000	13.0	5.5	5.0	1.75

*Qty. 10

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CIRCLE NO. 254

Table 1: Spectral efficiency for the modulation formats

Requirements	Linearly-amplified system requirements				Power- and cost-efficient nonlinearly-amplified modems and RF ICs			
	BPSK	QPSK & π/4QPSK	16QAM	64QAM	GMSK	GFSK	FQPSK	FBPSK
SNR (in dB) required for BER = 10^{-4}	8.4	11.4	19.2	25.5	13	19	12.5	12.5
E_b/N_o (in dB) required for BER = 10^{-4}	8.4	8.4	13.2	17.8	10	16	9.5	9.5
Theoretical spectral efficiency (b/s/Hz)	1.0	2.0	4.0	6.0	1.2	1.3	2.0	1.0
Practical spectral efficiency in linearly-amplified systems (b/s/Hz)	0.8	1.6	3.2	5.0	0.9	1.1	1.6	1.8
Practical spectral efficiency in nonlinearly-amplified RF power-efficient transmitter systems (b/s/Hz)	0.3	0.7	1.0-1.5	2.0-2.5	0.9	1.0	1.5	0.7

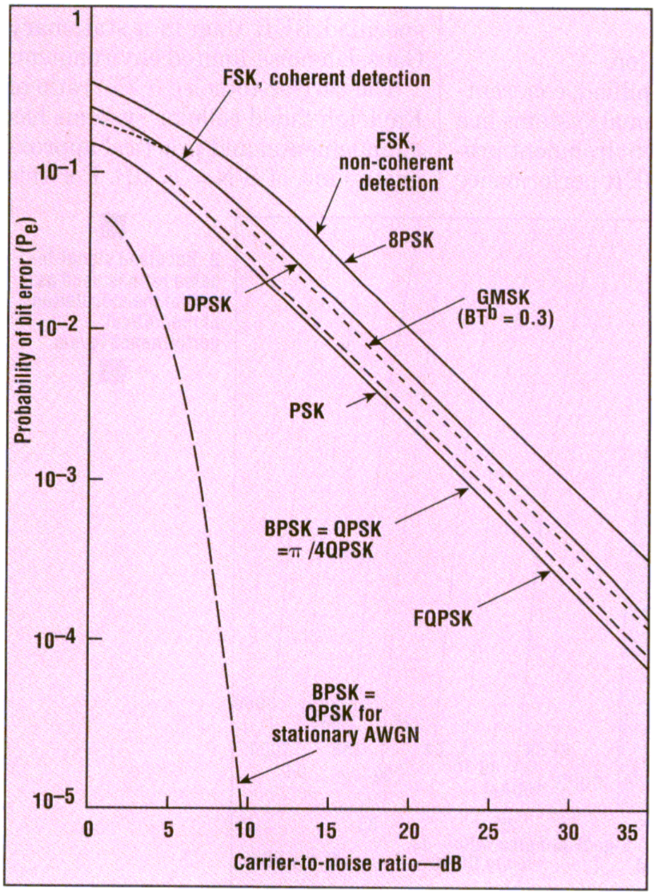
cell-pattern cellular systems have often been implemented, since this pattern leads to the highest capacity in analog and TDMA dual-mode (digital/analog) cellular systems.

In this seven-cell configuration, the same frequencies are reused in frequency groups A, B, C, D, E, F, and G. In geographical locations designated by the same letter, as in groups A_1 to A_4, the same group of frequencies is reused. Adjacent locations, such as locations A_1 and D_1, do not reuse the same frequencies. Parameter d is the distance between cells which use or reuse the same group of frequencies, while r is the radius of the cell.

The real power of the cellular idea is that interference is not related to the absolute distance between cells but to the ratio of the distance between same-frequency cells (d) to the cell radius (r). Reduction of cell size increases the spectral efficiency of a geographic area. When the traffic demand increases and reaches a point in a particular cell so that the existing spectral allocation in that cell could no longer support a good grade of service, the cell could be subdivided into a number of smaller cells (cell splitting), each with lower transmitter power levels than the full-sized cell. The reuse pattern of channels could be repeated on a new, smaller scale.[1]

Frequency reuse in a cellular communications pattern introduces a fundamental limit on the available desired carrier-modulated signal-to-interference (S/I) ratio. Extensive experimental results and computer simulations (combined with theoretical studies) demonstrate that the average S/I ratio in a seven-cell-pattern cellular system in a typical Rayleigh-faded environment is about 17 dB. In Rayleigh-faded systems, the impact of the unavoidable signal-to-noise (S/N) ratio and of the S/I ratio on the bit-error rate (BER) is practically the same.

It is possible to illustrate the theoretical BER or probability of error



2. This comparison of different modulation formats shows that relatively-high S/N ratios are needed in mobile non-LOS systems.

(P_e) performance of binary-phase-shift-keying (BPSK), differential-phase-shift-keying (DPSK), quadrature-phase-shift-keying (QPSK), π/4QPSK, and Feher's FQPSK modulation systems in stationary additive-white-Gaussian-noise (AWGN) and Rayleigh-faded environments (Fig. 2). Narrowband Gaussian frequency-shift keying (GFSK) requires a much higher S/N ratio for a specified BER; thus it has, from a theoretical point of view, inferior performance when compared to other formats (Table 1).

In many references, the BER is expressed as a ratio of the available energy per bit (E_b) to the noise density (N_o). A simple and useful expression for the conversion of the modulated S/N ratio to E_b/N_o is:

$$E_b/N_o = (S/N)(BW/f_b) \qquad (1)$$

where:

BW = the receiver noise bandwidth,

E_b = the available energy per bit, with $E_b = ST_b$,

S = the signal power at the receiver input, and

T_b = the bit duration.

Ideal linearly-amplified, coherently-demodulated optimal systems in a stationary AWGN environment provide high levels of BER performance for a given S/N ratio (Fig. 3). In general, more signal states and larger constellation systems require a much higher S/N ratio than simpler 4QAM or 4PSK (QPSK) systems. In a mobile non-LOS Rayleigh-faded environment, much higher S/N or E_b/N_o ratios are required to meet a specified BER than in a stationary Gaussian noise-limited environment.

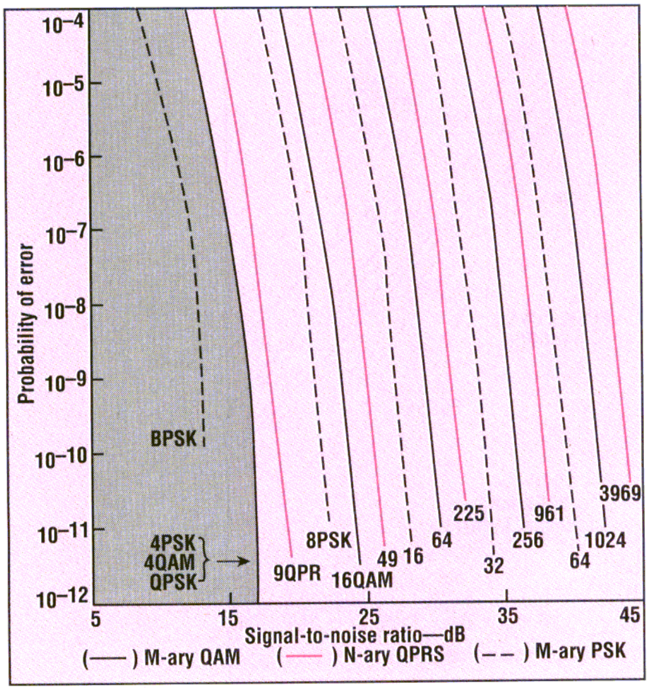
The carrier-to-noise (C/N) ratio of Rayleigh-faded cellular systems has a fundamental and practical approximate limit of S/N = 17 dB. For this reason, it is necessary to use "power efficient" or robust modulators or demodulators. Even though a 64QAM wireless system has a theoretically-higher spectral efficiency (6 b/s/Hz) than QPSK systems with only 2 b/s/Hz, the high-spectral-efficiency 64QAM system may have a fundamental cell-pattern limit.[2-9]

Part 2 of this series will examine the Shannon-Hartley capacity bound as well as the power efficiencies of the various modulation schemes.●●

MORE ON MODULATION

Those interested in learning more about optimizing the capacity of cellular transmission systems and wireless systems in general can enroll in a series of courses offered by Kamilo Feher and associates. Theoretical and practical design principles, regulations, standards, and performance constraints of the cellular mobile environment are discussed, including architectures for the design of combined modulation and power-efficient radio transceivers. Standardized GMSK, GFSK, π4DQPSK, and other modem/radio design, error-control, and access-method technologies are described. Feher's GMSK, GFSK, filter-processor, and FBPSK/FQPSK-related patents and inventions are also examined.

Registrants also receive a free copy of Dr. Kamilo Feher's book, *Digital Wireless Communications: Modulation and Spread Spectrum Applications* (for a review, see Part 2 of this article series next month). For more information, contact DigCom, Inc., 44685 Country Club Dr., El Macero, CA 95618; (916) 753-0738, FAX: (916) 753-1788.●●



3. Received signal-to-noise ratio is used as part of the calculations of theoretical performance levels.

Note

Dr. Feher is also president of DigCom, Inc., 44685 Country Club Dr., El Macero, CA 95618; (916) 753-0738, FAX: (916) 753-1788.

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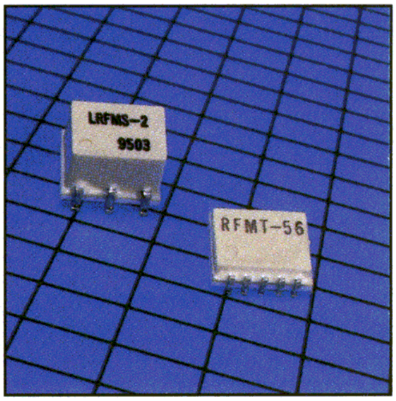

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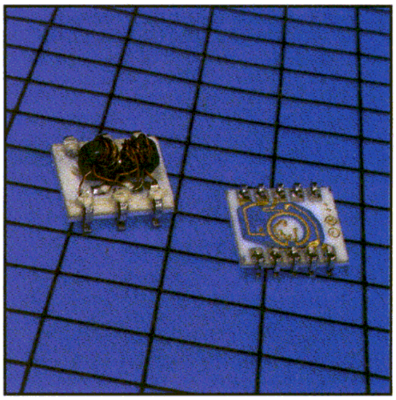

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RFMT-25-SM10	2000-3000 MHz	DC-1000 MHz
RFMT-35-SM10	3000-4000 MHz	DC-1000 MHz
RFMT-42-SM10	3600-4800 MHz	DC-1000 MHz
RFMT-56-SM10	4400-6000 MHz	DC-1200 MHz

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RFST-22-SM10	2000-2600 MHz
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CIRCLE NO. 332

Employing SAW filters

The small size and low cost of surface-acoustic-wave (SAW) filters render them useful for commercial applications, such as cellular telephones. The performance characteristics and use of SAW filters are highlighted in an application note titled "Digital Cellular Phone Illustrates SAW Filter Design Basics," which is included in the February/March 1995 issue of Technology Partner.

As the note explains, SAWs propagate along the surface of an elastic medium, penetrating the medium to a depth of less than one acoustic wavelength. The waves are transmitted onto the crystal by parallel metallization strips known as interdigital transducers (IDTs).

While a variety of materials are used to form SAW filters, four types of materials are most prominent. ST-cut quartz is often employed in narrowband intermediate-frequency (IF) filters for its thermal stability, while zinc-oxide thin films are used in low-cost television IF filters. The wideband filters used in cellular telephone applications employ lithium niobate ($LiNoO_3$) and lithium tantalite ($LiTaO_3$). The high coupling coefficient of these materials results in low insertion loss.

SAW bandpass filters generally serve three roles in cellular phone applications. These filters are used between the receive antenna and demodulator to block the transmitter signal and pass the received signal with minimal loss. After the low-noise amplifier (LNA), a SAW filter is used to further isolate the received and transmitted signals. In the transmit chain, SAW filters attenuate noise outside the intended bandwidth.

The note also defines a number of SAW-filter performance parameters (including insertion loss, in-band ripple, and temperature stability) and provides specifications for the model HWCA606 filter, which is designed for Advanced Mobile Phone System (AMPS) applications. A copy of the note can be obtained by contacting: **Hitachi America, Ltd., Semiconductor & IC Division, 2000 Sierra Point Pkwy., Brisbane, CA 94005-1835; (415) 583-4207.**

CIRCLE NO. 194

Using reflective surfaces

Reflector antennas employ parabolic designs to make use of the geometric properties of reflected waves. A six-page application note overviews the FLAPS™ ("Flat Parabolic Surface") line of reflector antennas, which have a flat surface but provide the electromagnetic characteristics of parabolic antennas.

The FLAPS design uses an array of dipole scatterers positioned approximately 0.125 wavelengths above a ground plane. This configuration generates a standing wave between the dipoles and ground plane. The combination of the standing wave and the dipole reactance causes incident RF energy to be radiated with a phase shift that can be controlled by varying the dipole length.

The high polarization isolation between orthogonal dipoles (better than 50 dB) allows independent control of the surface reflections. This allows the surfaces to achieve left- or right-hand circular polarization as well as horizontal or vertical polarization with a single linear polarized feed. Dual linear polarization can be achieved by simply using separate focal points.

The FLAPS structures can be fabricated in a variety of ways. For instance, surfaces for ground-based radar applications have been etched from double-layer printed-circuit boards (PCBs). Low-cost reflectors for direct-broadcast-satellite (DBS) television applications have been produced via silk screening of plastic panels.

In order to reduce the effects of wind-load forces encountered in satellite earth stations, FLAPS surfaces can be produced by fabricating a frame and attaching Kevlar string in "tennis-racket" fashion, with a grid spacing of about 0.5λ (where λ is the wavelength). The dipoles are then attached to the string.

As the note explains, the FLAPS surfaces achieve bandwidths of 3 to 10 percent with center frequencies of 1 to 100 GHz. For copy of the note, contact: **Malibu Research, 26670 Agoura Rd., Calabasas, CA 91302-1974; (818) 880-5494, FAX: (818) 880-5499.**

CIRCLE NO. 195

Applying CVD diamond

The increased densities and faster operation of today's integrated circuits are magnifying the importance of heat dissipation in multichip modules (MCMs). An application note, titled "Diamond for MCM Applications," describes the properties of diamond and overviews its use for heat removal in electronic packages.

Diamond sheets are produced via chemical vapor deposition (CVD). Metallization is applied (typically using a titanium/platinum/gold-layered structure) to the sheets before they are diced into substrates. Because of the extreme hardness of diamond, dicing is achieved with a Nd:YAG laser.

Diamond sheets can be grown with thicknesses from 1 μm to greater than 1 mm. At thicknesses over 100 μm, diamond provides sufficient rigidity to be used as a "drop-in" component in an electronic package. Electronic components are then attached to the diamond substrate. As an alternative, cost can be reduced by decreasing the diamond-layer thickness and using the layer as a thin coating on another substrate material (such as AlN).

Highly-pure diamond crystals offer thermal conductivities as high as 2400 W/m-K. By comparison, copper and aluminum nitride provide thermal conductivities of 400 and 200 W/m-K, respectively. The low dielectric constant of CVD diamond (about 5.6 across a wide range of microwave frequencies) makes the material useful for MCM applications, where it allows faster signal transmission between chips.

To obtain a copy of the note, which is reprinted from *Electronic Packaging and Production*, contact: **Diamonex, Inc., 7150 Windsor Dr., Allentown, PA 18106; (610) 366-7100, FAX: (610) 366-7111.**

CIRCLE NO. 196

COVER FEATURE

COMPACT PLLs CUT CURRENT IN PORTABLE SYSTEMS

These surface-mount synthesizers are ideal for handheld wireless-communications systems requiring clean signals.

SYNTHESIZER designers are being seriously challenged by designers of portable, handheld wireless systems. These system-level architects want frequency accuracy, but at a low price and with almost no current consumption. The response from Synergy Microwave Corp. (Paterson, NJ) is the production of the SPLL series of phase-lock-loop (PLL) frequency synthesizers. The compact components cover bandwidths to 25 MHz at cellular frequencies from 700 to 1100 MHz with only 35-mA current consumption.

The tiny PLL units are supplied in 12-lead surface-mount housings measuring only 0.625 × 0.515 × 0.200 in. (15.88 × 13.08 × 5.08 mm). They provide output signal levels of 0 dBm with ±3-dB flatness (see table). The minimum single-sideband (SSB) phase noise is –110 dBc/Hz when measured 30 kHz from the carrier frequency. Spurious reference sideband levels are –60 dBc or better at the same offset frequency.

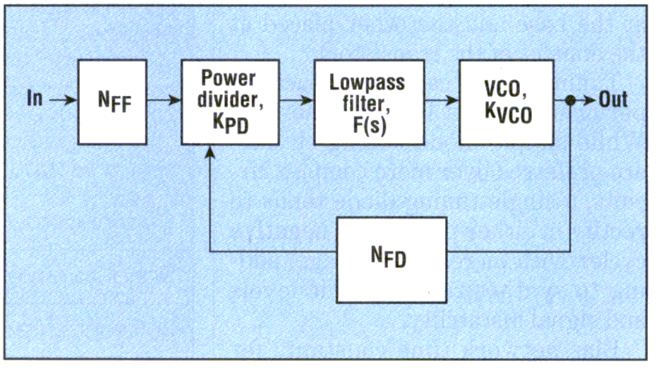
One of the challenges in building such a small synthesizer relates to packaging limitations. Because certain packages are adopted (more or less) as standards, a synthesizer must be designed to fit the limited dimensions allowed by a given package. Packaging problems can cause ground loops, which introduce instability to either the synthesizer or to the circuit which it is driving.

Synthesizer power consumption is determined by the technology used in the packaged PLL as well as the number of active components required with the PLL. Such components include a voltage-controlled oscillator (VCO), loop filter, and a possible voltage regulator (Fig. 1).

Designers of PLLs follow one of two basic approaches: single-loop synthesizers or fractional-N (division) synthesizers. The single-loop synthesizer approach has a higher division ratio than the fractional-N version, with compromises between locking time and reference suppression. Single-loop synthesizer performance can be improved with a higher-order loop filter, but this requires additional components.

The fractional-N approach reduces the division ratio in the loop by a factor of five, eight, or higher. This is done partly at the expense of spurious sidebands, with another compromise necessary between spurious suppression and the number of components in the PLL. Since synthesizer performance outside the loop bandwidth is determined by the VCO, it is important to look at the mechanism which allows the quality

ULRICH L. ROHDE, Chairman, and **SHANKAR JOSHI,** Chief Engineer, Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (201) 881-8800.



1. This simplified PLL includes a voltage-controlled oscillator (VCO) and lowpass filter.

PLL SYNTHESIZERS

factor (Q) of the tuned circuit to be as high as possible.

Due to volume and cost restrictions, many designs have fairly close coupling between the VCO circuit and the output. However, good designs must have sufficient isolation between the output port and the tuned circuit responsible for determining the frequency range. The design also changes somewhat based on the frequency range and tuning range. Narrowband applications, which also require very good phase-noise performance, may use ceramic resonators, even though such resonators tend to be large.

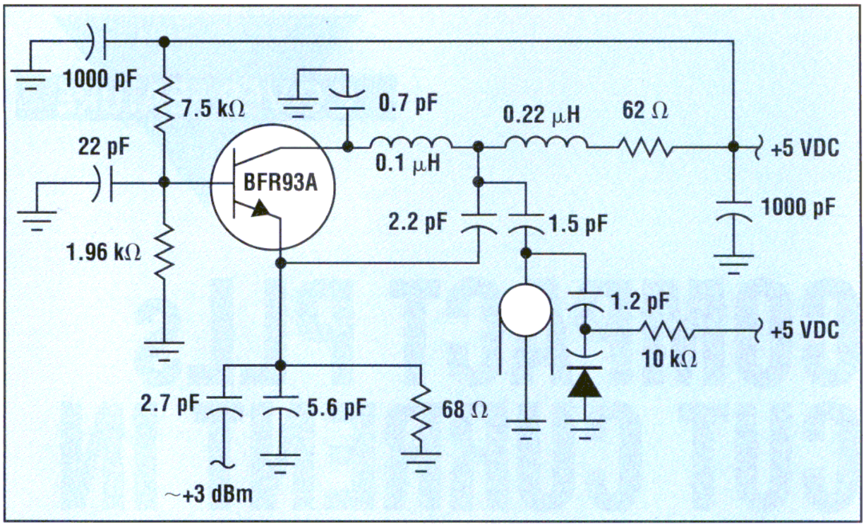
High-Q inductors are often used to achieve high performance levels in PLL synthesizers. Hybrid printed-circuit inductances can be reduced on high-dielectric-constant circuit boards, but this may still lead to a multilayer arrangement while adding to the cost of the VCO. Air-coil inductors may also be used in PLLs to achieve the high Qs needed for tuning over narrow bandwidths.

As tuning bandwidths increase, new design problems arise. For example, from 800 to 2000 MHz, packaged transistors used as the active devices in VCOs show fairly rapid phase shifts in the transductance and the input impedance. Since an oscillator must adhere to the Barkhausen criteria (which means that the product of forward-gain time feedback under sustaining conditions is to be larger than 1 or equal to 1.01), computer-aided-engineering (CAE) stability analysis can easily show that simple circuits may not be sufficient to provide oscillation over a wide frequency range. Such effects are corrected by adding additional circuitry, such as two tuning diodes (one placed at the base and the other placed at the emitter of the transistor).

Tuning diodes can also impact the performance of a PLL synthesizer. While simple diode tuning circuits are preferred over more complex circuits, a single tuning diode tends to rectify in either positive or negative cycles with increasing voltage, adding to synthesizer harmonic levels and signal instability.

Bias-network time constants for the VCO's active circuitry also affects PLL synthesizer performance. The transistor can be fed from a comparatively-high impedance voltage divider in the base or from a very-low impedance point by having comparatively-high currents through the voltage divider at the base. The collector current behaves differently in both cases. Circuit impedance affects synthesizer performance in terms of output power as well as startup conditions.

In self-limiting sine-wave oscillators (where the feedback loop is closed with a coupling capacitor), it is possible to have an interaction between the time constants of the bias and coupling circuits of the loop and the time constants of the high-frequency tuned circuits of the loop. In this interaction, a self-produced amplitude modulation of the high-frequency oscillation occurs. Such self-modulated behavior is known as "squegging." The low-frequency variations of the envelope may be sinusoidal or exponential.[1]

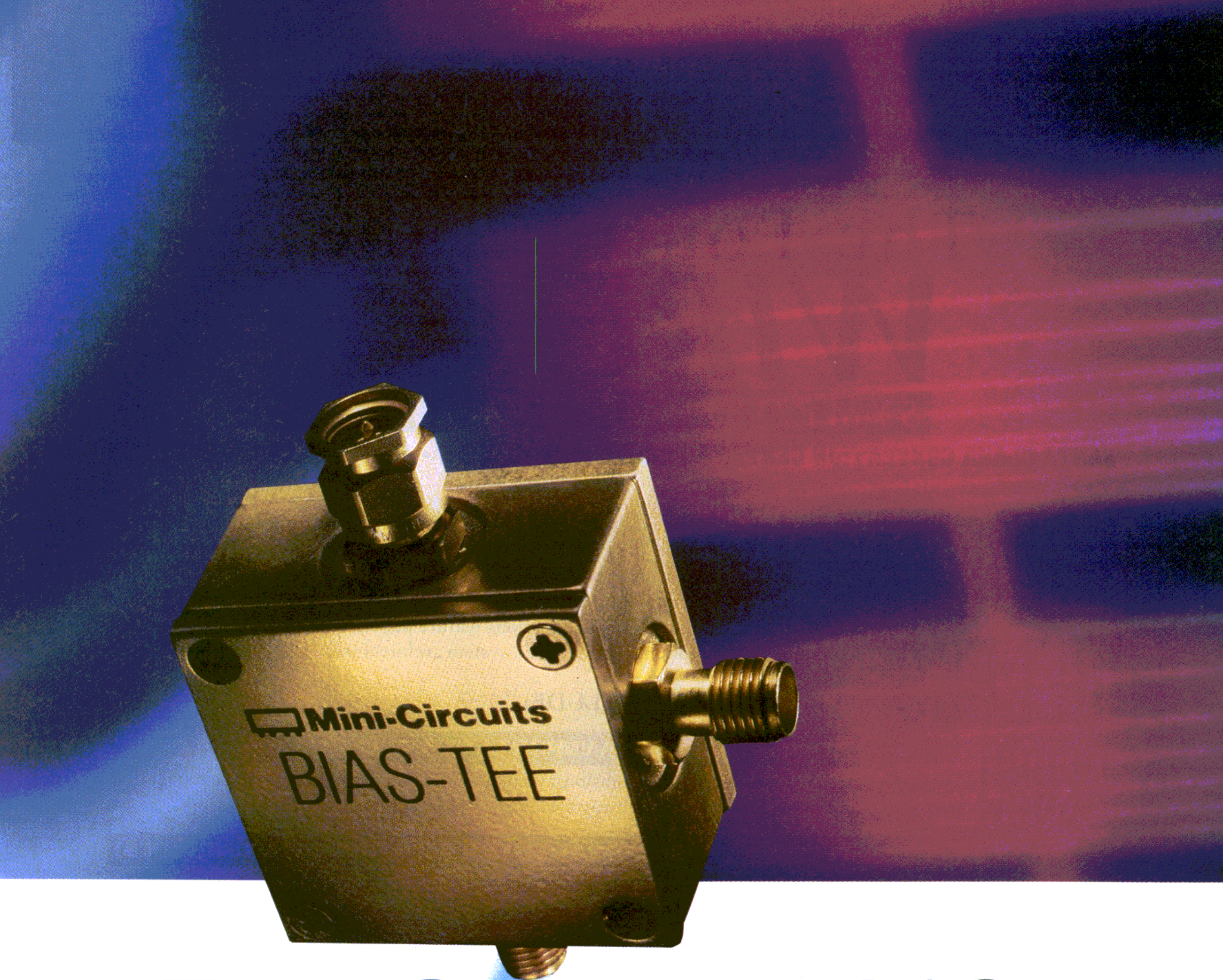


2. This typical VCO circuit, which is useful for wireless applications, is based on a ceramic resonator.

■

The tiny PLL synthesizers at a glance

Frequency range	700 to 1100 MHz
Bandwidth	as wide as 25 MHz
Output level (into 50 Ω)	0 dBm (±3 dB)
Phase noise at 30-kHz offset Typical Minimum	 –117 dBc/Hz –110 dBc/Hz
Spurious reference sidebands at 30 kHz Typical Minimum	 –70 dBc –60 dBc
Spurious non-harmonic levels Typical Minimum	 –70 dBc –60 dBc
Locking time Between channels For any channel	 20 ms maximum 40 ms maximum
Current consumption	35 mA
Signal-to-noise ratio for ±3-kHz deviation	45 dB minimum
Reference-frequency level	1 V peak-to-peak min.



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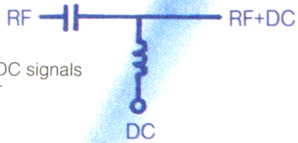

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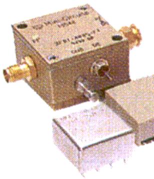

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▲ZFBT-4R2G	10-4200	0.15	0.6	0.6	32	40	50	1.13:1	59.95
▲ZFBT-6G	10-6000	0.15	0.6	1.0	32	40	30	1.13:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
•JEBT-6G	10-6000	0.15	0.7	1.3	32	40	40	-	59.95
•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
•JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	69.95

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CIRCLE NO. 305

PLL SYNTHESIZERS

In a typical VCO circuit for wireless applications (Fig. 2), a ceramic resonator was used for frequency stability centered around 850 MHz. Measured phase noise is about –90 dBc/Hz offset 1 kHz from the carrier and better than –110 dBc/Hz offset 10 kHz from the carrier. The design was based on rough mathematical calculations and optimization performed on the CAE program Microwave Harmonica from Compact Software (Paterson, NJ). A synthesized version of this source design would require either a PLL chip and loop filter or a packaged SPLL synthesizer module from Synergy Microwave Corp.

Synthesizer loop performance is determined by the output filter. CAE tools such as Microwave Harmonica include the equations needed (for damping, number of poles, etc.) for developing higher-order filters. The computer tools are also useful for predicting reference suppression and lock-up time.[2,3] As an example, a fifth-order filter was developed to provide superior reference suppression and lock-up time. The order of five implies that a third-order loop is used within an additional second-order lowpass filter. Predictions performed with the PLL Design Kit software from Compact Software gave estimates of key parameters for the fifth-order PLL, including a reference frequency of 30 kHz (channel spacing), phase-detector gain constant of 1 V/rad, VCO gain constant of 5 MHz/V, a VCO frequency of 900 MHz, and divider ratio of 30,000. Computer design tools such as the PLL Design Kit are also useful for predicting synthesizer lock-up time. In determining the actual time it takes the loop to settle, it is necessary to add the frequency and phase lock-up times. In both simulated and measured step responses, the fifth-order PLL stabilizes in about 1.4 ms following a tuned step.[4]

Noise within a synthesizer's reference source and other components contributes to the ultimate phase noise. The reference oscillator, for example, may be multiplied 30,000 times upward, as in the 850-MHz example synthesizer. In this case, the noise is multiplied with the signal. In a properly-designed synthesizer, the phase noise should be somewhat better overall than the noise of a free-running VCO (Fig. 3). It is also possible to design a PLL synthesizer with such a high division ratio and wide bandwidth that the phase noise is fairly poor compared to the phase noise of a high-Q free-running VCO.

When a frequency synthesizer is used as the local oscillator (LO) in a digitally-modulated signal, the synthesizer translates the frequency of the modulated communications signals upward or downward. Since modulation has been added at another part of the system, the synthesizer need not be modulated, which

800 MHz-1 GHz Surface Mount 4 Way 0° Power Splitter

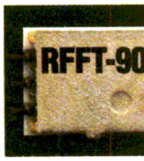
The RFST-4-8 power splitter provides a low cost alternative to conventional power splitters with an extremely low profile of .085", making it compatible with PCMCIA cards and almost any other limited height application. In addition to size, the RFST-4-8 operates over 800 MHz to 1 GHz with 25 dB typical isolation, less than 1 dB Insertion loss, 5° phase unbalance, and 0.4 dB typical amplitude unbalance. This splitter utilizes RF Prime's BLUE CELL™ technology and pricing starts at $21.95 ea. 1–9 qty. **CIRCLE NO. 230**

2.4–2.8 GHz Surface Mount 2 Way 0° Power Splitter

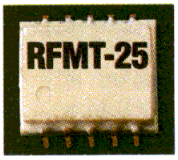
The RFST-25 power splitter provides a low cost alternative to conventional power splitters with an extremely low profile of .085", making it compatible with almost any limited height application. In addition to size, the RFST-25 operates over 2.4 GHz to 2.8 GHz with 30 dB typical isolation, less than 5 phase unbalance and 0.4 dB typical amplitude unbalance. RF Prime's BLUE CELL™ Technology allows pricing for this splitter at $6.95 ea. 1–9 qty.

CIRCLE NO. 229

Surface Mount Low Pass Filter



The RFFT-90 is the first product in a new low cost filter line from RF Prime. The RFFT-90 is designed for the cellular and PCS band of 820–960 MHz. Utilizing RF Prime's BLUE CE Technology, this filter provides less than 1 of insertion loss, as much as 35 dB of s band attenuation at 3.0 GHz; 20 dB at 7.0 G The extremely small size of the leaded sur mount package makes it practical for even smallest PCMCIA applications. (0.290 x .0 x 0.090) Pricing for this low cost filter line st at $5.95 ea. 1–9 qty. **CIRCLE NO. 2**



2.0–3.0 GHz Surface Mount Mixer

PCMCIA applications require the smallest most efficient components available. The RFMT-25 is the first passive mixer of its kind to offer a PCMCIA type 1, 2 and 3 compatible profile, typically less than .085". Thanks to the utilization of RF Prime's BLUE CELL™ Technology, this mixer has a conversion loss of 5.5 dB or less at 2.5 GHz., and guaranteed 7 dB for its entire frequency range. Unlike most mixer designs, this mixer performs at LO powers to 0 dBm, making it very useful for newer power conscious designs.
Prices start at $6.95 ea 1–9 qty. **CIRCLE NO. 231**

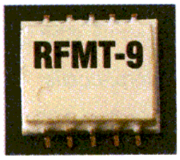
4.4–6.0 GHz Performance Surface Mount Mixer

The RFMT-56 is the latest offering from RF Prime BLUE CELL™ mixer line. Designed for VSAT, WLANs and PCS systems, this mixer is the first of its kind to compete in the ISM Band with expensive high end mixers at a fraction of the cost. Thanks to the utilization of RF Prime's BLUE CELL™ Technology, this mixer has a typical conversion loss of 6.5 dB or less at 5.6 GHz. Prices start at $49.95 ea 1–9 qty.

CIRCLE NO. 232

Low Cost Cellular Band Surface Mount Mixer

Until now, design engineers had to choose between the cost effectiveness of MMIC type mixers or the improved performance of discrete components for the 800 MHz to 1 GHz cellular bands. Now RF Prime introduces the RFMT-9 passive surface mount mixer for emerging high volume commercial designs. With typical performance of 7 dB conversion loss up or down and the reliable FLEX-RAP attachment, the RFMT-9 fits easily into your design. The low profile of this component makes it feasible for use in PCMCIA types 1, 2, 3 and wireless applications, and because it utilizes RF Prime's BLUE CELL™ Technology, the pricing starts at $2.49 ea. 1–999 qty.



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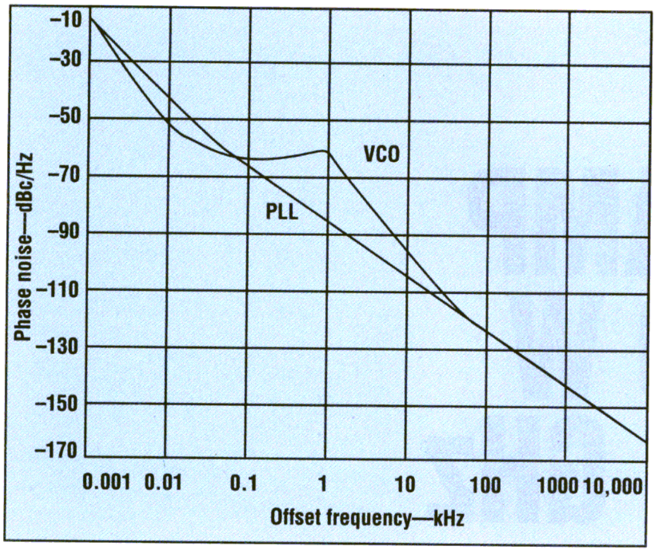
PLL SYNTHESIZERS



3. The phase noise of a free-running oscillator can be stabilized when the same oscillator is part of a closed-loop design.

eases some design constraints since the synthesizer's loop bandwidth determines the maximum allowable modulation frequency.

As a rule of thumb, the loop frequency defines the frequency for modulation applied to the PLL. For example, if an audio bandwidth from 300 to 3000 Hz has its modulation on the PLL, then the loop bandwidth must be 300 Hz or less. For reasons of microphonics and locking time, the bandwidth should be as wide as possible.

Any discussion on PLL synthesizers must also consider control circuitry. Early PLL synthesizers used parallel data, which was latched. This type of data stream is fairly noisy and requires numerous connections. Modern PLL synthesizers use a serial data format for information on the appropriate division ratios concerning the reference divider and the loop divider. Typically, data is transferred into a 15-b latch of the programmable reference divider and into an 18-b latch of the programmable loop divider.

Based on ceramic resonators, the SPLL series of PLL synthesizers offers high performance at low cost. Although standard products cover bandwidths to 25 MHz from 700 to 1100 MHz, custom configurations are also available upon request. **Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (201) 881-8800, FAX: (201) 881-8361.**

CIRCLE NO. 51

References

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2. Ulrich L. Rohde, *Digital PLL Frequency Synthesizers—Theory and Design*, Prentice-Hall, Englewood Cliffs, NJ, 1983.
3. George Vendelin, Anthony M. Pavio, and Ulrich L. Rohde, *Microwave Circuit Design Using Linear and Nonlinear Techniques*, John Wiley & Sons, New York, NY, 1990.
4. Jon Stilwell, Philips Semiconductors, Sunnyvale, CA, personal communications.

HUB-MOUNT AMP DELIVERS 300 W FROM 6 TO 18 GHz

By installing this amplifier on the antenna mount, a costly rotary joint is eliminated.

POWER can be easily wasted through cables, rotary joints, and connections before reaching a transmitting antenna. The dB-4300-618H amplifier avoids such waste by mounting directly on the movable mast or hub of a transmitter antenna, shortening the connecting lines, and decreasing lost power. The rugged hub-mount antenna uses traveling-wave-tube (TWT) technology to produce at least 300-W continuous-wave (CW) output power from 6 to 18 GHz, making it ideal for ground-based threat-emitter applications as well as in commercial satellite-communications transmitters.

The dB-4300-618H amplifier only weighs 88 lbs. (40 kg) and measures 7.0 × 14 × 27 in. (17.78 × 35.56 × 68.58 cm), allowing it to mount on an antenna tower and to rotate with the antenna. In this way, the amplifier can be connected directly to the antenna feed horn without going through an expensive microwave rotary joint. The dB-4300-618H amplifier is housed in a weatherproof enclosure and can be supplied with an optional rack-mountable remote-control unit (see figure). The company also offers environmentally-sealed cables that can be used with the hub-mount amplifier and remote-control unit.

RELIABLE TUBE

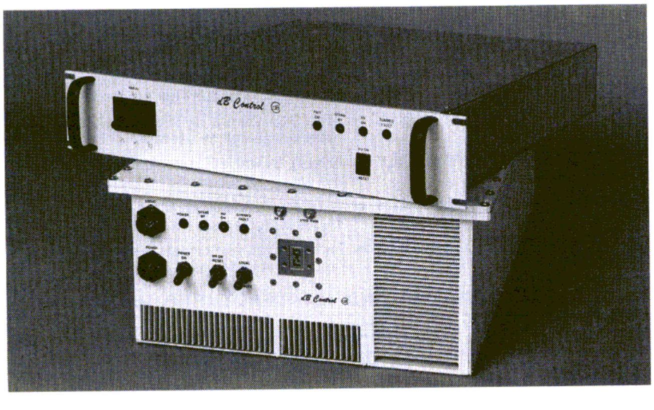
The rugged amplifier incorporates a special TWT manufactured by Teledyne Electronic Technologies (Rancho Cordova, CA), evolving from a design that has been in production for more than nine years. The TWT amplifier offers at least 40-dB gain at its rated output-power level, with minimum noise-power density of –5 dBm/MHz. Optionally, the dB-4300-618H can be equipped with a higher-gain TWT that provides at least 65-dB gain across the frequency range.

The input VSWR is nominally 2.50:1 while the output VSWR is nominally 2.00:1. The dB-4300-618H is supplied with SMA female input connectors and WRD-650 waveguide output connectors. The amplifier features forced-air cooling to dissipate excess heat generated by the TWT (with nominal power consumption of 1875 W).

The dB-4300-618H amplifier is the first in a series of hub-mountable designs intended for applications ranging from military threat emitters to commercial satellite-communications terminals. The hub-mount amplifier is designed for operating temperatures from –40 to +60°C and relative humidity to 100 percent.

The hub-mount component is protected against over-temperature and phase-loss conditions. It will run on 120-VAC three-phase, 208-VAC three-phase, or 230-VAC single-phase supplies. In addition to optional monitors for forward and reverse power readings, the amplifier incorporates various status indicators for monitoring power-on, high-voltage-on, and fault states. P&A: 12 wks. **dB Control, 1120 Auburn St., Fremont, CA 94538; (510) 656-2325, FAX: (510) 656-3214.**

CIRCLE NO. 52



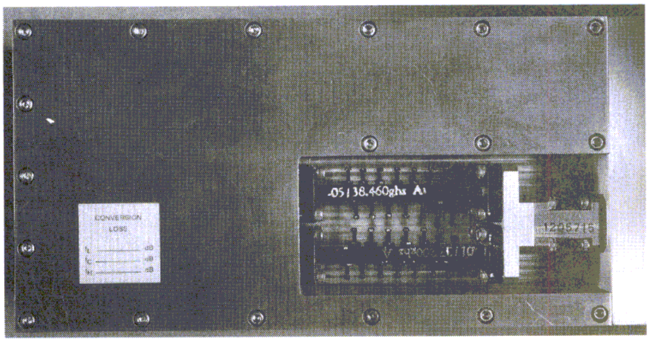
The hub-mountable dB-4300-618H amplifier provides 300-W CW power from 6 to 18 GHz and can be provided with a rack-mountable remote control.

TRANSCEIVER TAKES SIGHT AT 38-GHz LINKS

Designed to be part of a point-to-point microwave radio, a transceiver offers flexibility for system designers.

JACK BROWNE
PUBLISHER/EDITOR

DIGITAL microwave radios have traditionally resided in the 18- and 23-GHz bands. Such radios are invaluable as a means of transmitting video signals and data over line-of-sight distances. Recently, tremendous interest has grown in the 38-GHz band for data transmissions and enhancement of cellular and emerging personal-communications-services (PCS) systems.

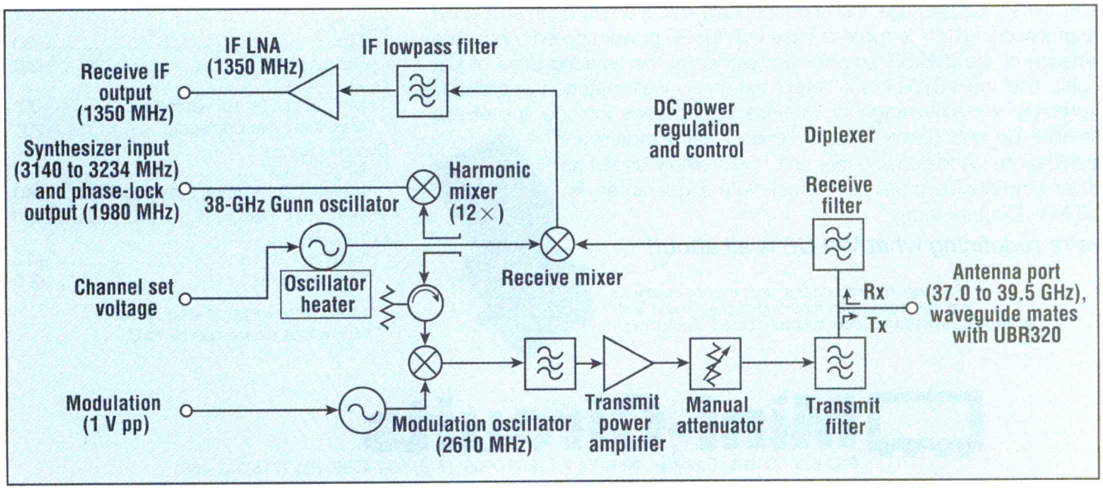


1. The 38-GHz transceiver is based on reliable thin-film components and rugged waveguide assemblies.

In support of this band. the engineers at Litton Solid State (Santa Clara, CA) have developed and continue to evolve a high-performance transceiver for use in 38-GHz digital microwave radios. The transceiver is ideal for radios serving telephone back links as well as video remote locations.

The full-duplex transceiver (Fig. 1) simplifies the task of the digital microwave radio designer. The transceiver includes all of the millimeter-wave components needed for reception and transmission of data-modulated signals. Critical assemblies are custom manufactured for the transceiver using the company's broad base of active and passive design experience.

A receive/transmit diplexer connects to an external millimeter-wave



2. The millimeter-wave transceiver employs a 38-GHz Gunn-diode oscillator with MMIC amplifiers for both receive and transmit modes.

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Model No.	Freq. (GHz)	Insertion Loss ① dB (max.)	1dB Comp. ① dBm (typ.)	In-Out Iso. ① dB (typ.)	Price $ea. (qty.10)
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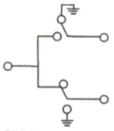
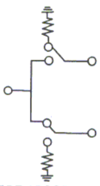
MSWA-2-20 (Absorptive)	DC-2.0	1.3	+27	40	3.45
MSWT-4-20 (Transfer)	DC-2.0	1.8 TX ② 2.0 RX ③	+28 TX ② +27 RX ③	30	3.95

① Midband, 500-1000MHz ② Transmit ③ Receive

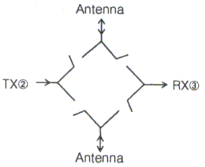
All Units: SOIC 8pin Package Actual Size



SPDT REFLECTIVE



SPDT ABSORPTIVE



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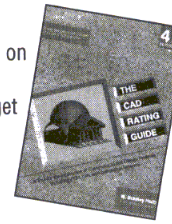

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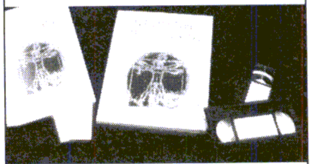

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CIRCLE NO. 221

38-GHz TRANSCEIVER

antenna and separates transmitted and received signals from 37.0 to 39.5 GHz. Received signals from an external antenna are downconverted by means of heterodyne mixing and are screened through a lowpass intermediate-frequency (IF) filter to an IF of 1350 MHz, which can occur through an SMA female connector. The IF bandwidth is ±15 MHz.

The receiver noise figure is 12 dB or less. Millimeter-wave signals are downconverted to the IF with a conversion gain of 20 dB. The receiver handles input signals over a level range of –90 to –20 dBm, providing at least 40-dB image rejection. The receiver phase noise is –85 dBc/Hz offset 1000 kHz from the carrier and –110 dBc/Hz offset 1 MHz from the carrier.

The transceiver uses a proprietary low-phase-noise source based on a Gunn-diode oscillator technology (Fig. 2). The single source is employed for both transmission and reception, and is stabilized by means of an external frequency synthesizer operating from 3140 to 3234 MHz. The Gunn source serves as the local oscillator (LO) in the receive mode to translate received signals to the lower-frequency IF. At that point, system designers must provide some form of demodulation scheme based on the modulation of the received signal.

For direct digital modulation of transmitted signals, the low-noise source is tied to a modulation oscillator with modulation sensitivity of 9 to 15 MHz/V. The linearity of this oscillator is ±5 percent over a ±10-MHz bandwidth. Transmit output power is achieved by using a multistage MMIC power module. Since it shares the same source as the receiver, the transmitter phase noise is similar to that of the receiver. Because of the spectral purity of the Gunn-based source, the transmitter is capable of sending two- or four-level frequency-shift-keying (FSK)-modulated signals at rates to 8 Mb/s. Output levels can be adjusted over a 30-dB range with an integral mechanical attenuator. Transmitter harmonics and spurious content is less than –60 dBc from DC to 21.2 GHz, –30 dBc from 21.2 to 60 GHz, and –20 dBc from 60 to 80 GHz. The transmitter delivers minimum output levels of +15 dBm.

The compact transceiver draws less than 20-W total power from +15-, +5-, and –5-VDC supplies. It measures only 2.5 × 4.0 × 6.5 in. (6.35 × 10.16 × 16.51 cm) and weighs only 2.5 kg. The transceiver is specified for an operating temperature of –40 to +70°C. Versions are also available for use at 18 and 23 GHz. **Litton Solid State, 3251 Olcott St., Santa Clara, CA 95054-3095; (408) 988-1845, FAX: (408) 970-9950.**

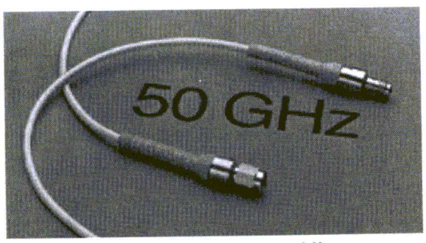
CIRCLE NO. 53

CIRCLE NO. 408

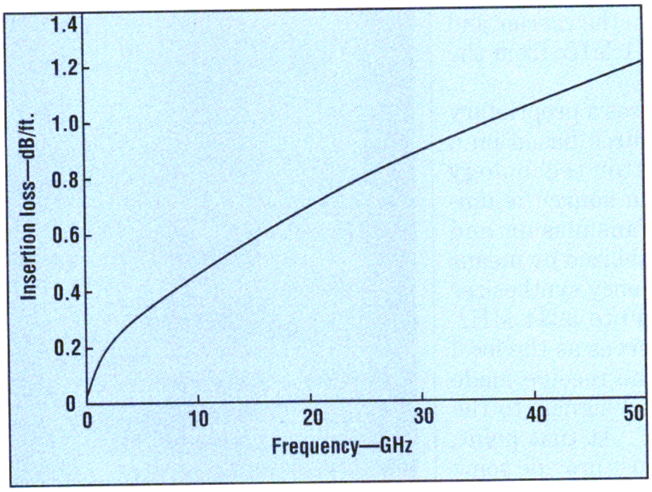
PHASE-STABLE CABLES SERVE USES TO 50 GHz

These cables combine a high degree of flexibility with the phase stability required by network analyzers.

NETWORK analysis places some of the tightest constraints on the design of coaxial test cables and connectors. During the course of a measurement, these cable assemblies are flexed into different shapes to make connections with test fixtures and associated measurement hardware, such as attenuators, bridges, and couplers. Precision cables must undergo this type of flexing while maintaining predictable amplitude and phase behavior. To satisfy all of these requirements in network-analysis measurements to 50 GHz, MICRO-COAX (Collegeville, PA) has introduced its UTiFLEX UFA 125A flexible microwave cable assemblies.



1. Flexible UFA 125A cable assemblies are ideal for commercial and military applications from DC to 50 GHz.



2. Maximum insertion loss of the UFA 125A cable assemblies is extremely low over its specific operating range to 50 GHz.

In addition to their use in vector network analyzers, the UFA 125A cable assemblies (Fig. 1) are well-suited to a wide range of other measurement applications. The assemblies can serve high-speed digital storage oscilloscopes (DSOs), in which changes in phase can degrade the accuracy of timing measurements, and multichannel interferometer receivers that use phase to track target information.

Flexible UFA 125A cable assemblies exhibit minimal change in insertion phase at temperatures from –65 to +165°C. They are rated for at least 10,000 flexures and maintain relatively constant phase when flexed. The minimum dynamic bend radius for the phase-stable UTiFLEX cables is only 1 in. (2.54 cm). Insertion loss is typically less than 0.7 dB/ft. to 20 GHz and typically less than 1.2 dB/ft. to 50 GHz (Fig. 2).

The 50-GHz assemblies are constructed with a solid silver-plated copper center conductor, low-density polytetraflurorethylene (PTFE) dielectric, a silver-plated copper shield, a silver-plated copper braid, and an FEP outer jacket. The rugged UFA 125A cable assemblies also feature crush strengths of better than 450 lbs./ft.

The flexible cables can handle power levels to 25 W CW at frequencies to 50 GHz. In addition, the well-shielded cables offer a high degree of isolation from outside fields (and vice versa), with rated RF leakage of –100 dB. Custom and standard lengths as well as several connector combinations are available. **MICRO-COAX, 245 West 5th Ave., Collegeville, PA 19426-0993; (610) 489-3700, FAX: (610) 489-1103.**

CIRCLE NO. 54

TOUGHER SBL MIXERS

25kHz to 2500MHz
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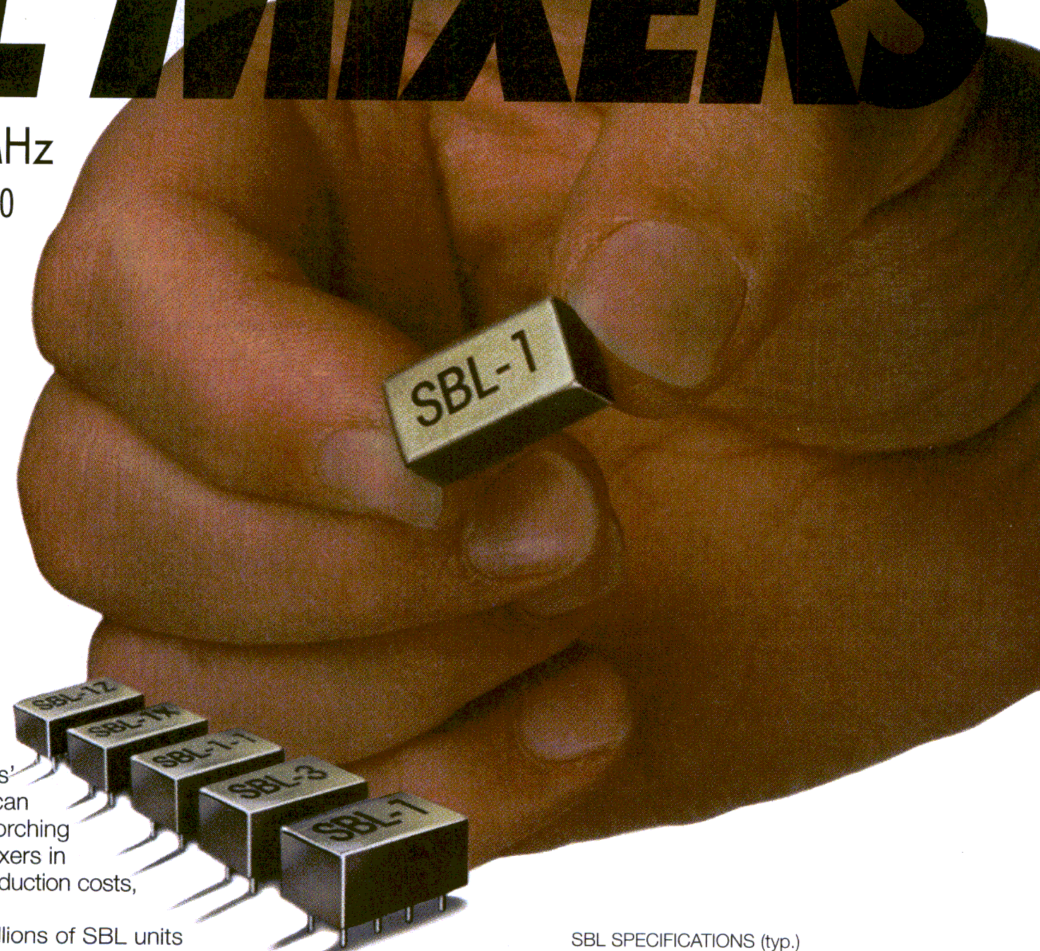

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SBL SPECIFICATIONS (typ.)

Model	Frequency (MHz)	Conv. Loss (dB)	Isolation (dB) L-R	Isolation (dB) L-I	LO Level (dBm)	Price,$ ea. (10qty.)
SBL-1	1-500	5.5	45	40	+7	4.50
• SBL-1X	10-1000	6.0	40	40	+7	6.25
SBL-1Z	10-1000	6.5	35	25	+7	7.25
SBL-1-1	0.1-400	5.5	45	40	+7	7.25
SBL-3	0.025-200	5.5	45	40	+7	7.25
• SBL-11	5-2000	7.0	35	30	+7	18.75
SBL-1LH	2-500	5.8	68	45	+10	5.65
SBL-1-1LH	0.2-400	5.2	64	52	+10	8.20
• SBL-1XLH	10-1000	6.0	40	55	+10	7.25
SBL-2LH	5-1000	5.9	61	54	+10	8.20
SBL-3LH	0.07-250	4.9	60	53	+10	8.20
• SBL-11LH	5-2000	7.0	45	30	+10	19.70
SBL-1MH	1-500	5.5	45	40	+13	9.80
SBL-1ZMH	2-1100	6.5	40	25	+13	11.70
• SBL-2500H	5-2500	6.0	44	44	+17	31.90
• SBL-173SH	5-1200	5.9	35	35	+17	20.65

• IF not DC coupled

**** ULTRA•REL® MIXERS 5 yr. Guarantee***
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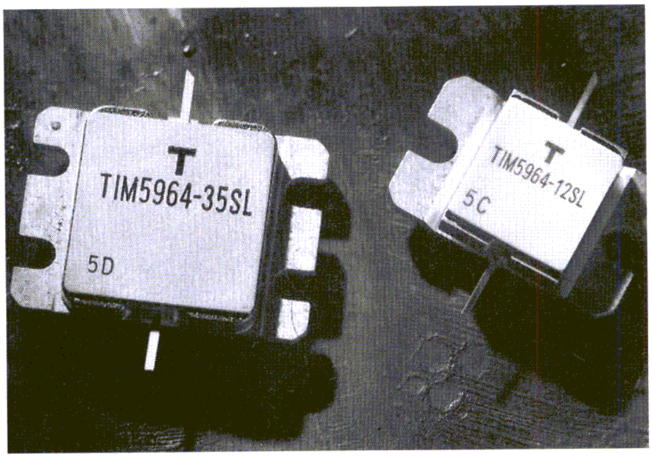
DEVICES REACH NEW POWER LEVELS IN SATELLITE BANDS

These internally-matched GaAs FETs are ideal for radar, line-of-sight, and satellite-communications systems.

JACK BROWNE
PUBLISHER/EDITOR

SOLID-STATE power is the key to long-term reliability in a wide range of communications systems. In both microwave radars and satellite-communications systems that switch from electron tubes to GaAs FET-based amplifiers, the active devices must perform with high efficiency and low power consumption. To meet the needs of these systems, Toshiba America Electronic Components, Inc. (Irvine, CA) has developed a line of internally-matched C-band GaAs FET devices with power-added efficiency as high as 41 percent.

The C-band transistor line includes devices with power-output levels from 4 to 35 W at frequency ranges of 3.7 to 4.2 GHz, 5.9 to 6.4 GHz, 6.4 to 7.2 GHz, and 7.7 to 8.5 GHz (Fig. 1). The 35-W device (+45.5 dBm), model TIM5964-35SL, operates from 5.9 to 6.4 GHz with 8-dB typical gain at 1-dB compression. It features 37-percent power-added efficiency and ±0.8-dB gain flatness.



1. The C-band models TIM5964-12SL and TIM5964-35SL provide 12- and 35-W output power, respectively, in the satellite-communications band from 5.9 to 6.4 GHz.

The C-band GaAs FETs at a glance

Model	Frequency range (GHz)	Output power (dBm)	Gain (dB)	Power-added efficiency (percent)	Typical third-order intermodulation distortion (dBc)
TIM3742-4SL	3.7 to 4.2	+36.5	10.5	37	–45
TIM3742-8SL	3.7 to 4.2	+39.5	10.0	36	–45
TIM3742-16SL	3.7 to 4.2	+42.5	9.5	36	–45
TIM3742-30SL	3.7 to 4.2	+45.0	10.0	41	–45
TIM5964-4SL	5.9 to 6.4	+36.5	9.0	35	–45
TIM5964-8SL	5.9 to 6.4	+39.5	8.5	35	–45
TIM5964-16SL	5.9 to 6.4	+42.5	8.0	34	–45
TIM5964-30SL	5.9 to 6.4	+45.0	8.0	38	–45
TIM6472-4SL	6.4 to 7.2	+36.5	8.0	34	–45
TIM6472-8SL	6.4 to 7.2	+39.5	7.5	33	–45
TIM6472-16SL	6.4 to 7.2	+42.5	7.0	32	–45
TIM7785-4SL	7.7 to 8.5	+36.5	6.5	32	–45
TIM7785-8SL	7.7 to 8.5	+39.5	6.0	30	–45
TIM7785-16SL	7.7 to 8.5	+42.5	5.5	29	–45
TIM7785-30SL	7.7 to 8.5	+45.0	6.0	34	–45

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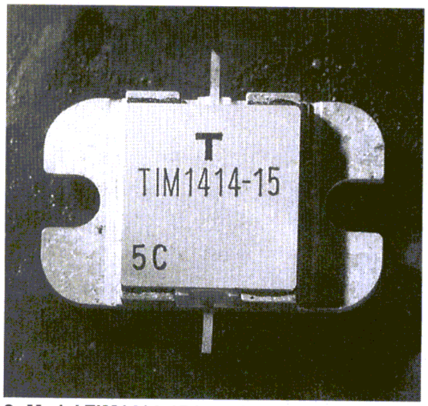
C-BAND GaAs FETs



2. Model TIM1414-15 is an internally-matched GaAs FET device capable of 15-W output power from 14.0 to 14.5 GHz.

Additional transistors in the line include model TIM3742-30SL, with 30-W output power (+45 dBm) from 3.7 to 4.2 GHz. The device achieves 10-dB gain at 1-dB compression with 41-percent power-added efficiency. It draws typical drain-source current of 7 A from a +10-VDC supply. Model TIM5964-30SL operates from 5.9 to 6.4 GHz with 30-W output power (+45 dBm) and 8-dB gain. Similarly, the gain flatness is ±0.8 dB across the band, with slightly less power-added efficiency of 38 percent. It also draws 7-A current from a +10-VDC supply.

At the higher frequencies, models TIM6472-16SL and TIM7785-30SL provide 16-W (+42.5-dBm) and 30-W (+45-dBm) output power from 6.4 to 7.2 GHz and 7.7 to 8.5 GHz, respectively. The former offers 7-dB typical gain at 1-dB compression while the latter achieves 6-dB gain, both with ±0.8-dB fullband gain flatness. The transistors draw 4.4- and 7.0-A current from +10-VDC supplies, respectively, with power-added-efficiency levels of 32 and 34 percent. All of the C-band transistors are rated for typical third-order intermodulation distortion of –45 dBc (see table), making them ideal for use in low-distortion, multicarrier communications applications.

The company has also added the model TIM1414-15 to its family of Ku-band internally-matched GaAs FETs. The device is capable of 15-W output power (+42 dBm) from 14.0 to 14.5 GHz. The flange-packaged transistor (Fig. 2) achieves 6-dB gain at 1-dB compression with power-added efficiency of typically 29 percent and gain flatness of ±0.8 dB. As with the company's other matched GaAs FETs, the third-order intermodulation distortion is typically –45 dBc.

P&A: $380 and up (C-band devices) and $1550 (TIM1414-15) (100 qty.); stock to 30 days. **Toshiba America Electronic Components, Inc., 9775 Toledo Way, Irvine, CA 92718; (800) 879-4963, (714) 455-2000.**

CIRCLE NO. 55

PLLs SERVE PORTABLE WIRELESS SYSTEMS TO 1.1 GHz

These fast-switching PLLs allow designers to create low-power frequency synthesizers for handheld applications.

COST-EFFECTIVE frequency synthesis depends on a low-cost phase-locked loop (PLL) that can lock a free-running source to a reference oscillator quickly and accurately. Three PLLs from the Communications Products Group of Fujitsu Microelectronics, Inc. (San Jose, CA) offer these features with low operating currents at input frequencies to 1.1 GHz.

Models MB15A01 and MB15A02 (see figure), for example, are single-chip solutions to 1.1 GHz (complete with pulse-swallow functions and serial input programmability). The pulse-swallow functions are provided by on-board dual-modulus prescalers that offer a choice of 64/65 or 128/129 divide ratios. The integrated circuits (ICs), which are based on BiCMOS technology, also include an on-chip charge pump which can be bypassed when using an external charge pump for enhanced performance. Both PLL synthesizers include serial-input 18-b programmable dividers and 14-b programmable reference dividers.

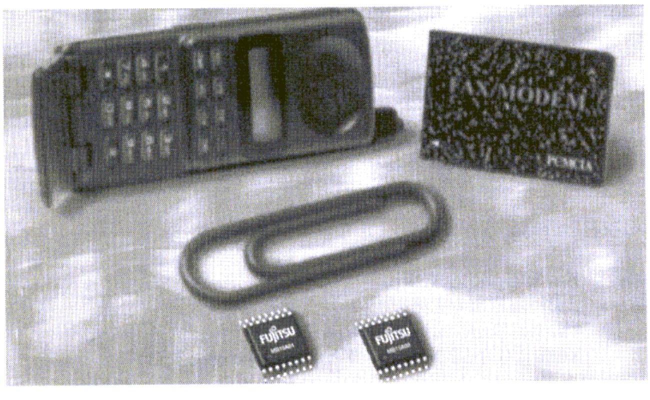
CHOICE OF SUPPLIES

Model MB15A01 is designed for +3.3-VDC supplies while model MB15A02 is for use with +5.0-VDC supplies. The supply current for the former is typically 6.5 mA while the supply current for the latter is 7.0 mA. The ICs are based on the company's earlier, industry-standard MB1501 PLL synthesizer and use the same programming routines as that earlier synthesizer chip, simplifying the upgrade of systems.

Originally designed for use in Global System for Mobile Communications (GSM) circuits, the MB1516A PLL synthesizer can be used in a variety of wireless applications that require low-power consumption to 1.1 GHz. It typically draws only 6.5-mA current from a +3-VDC supply and incorporates a similar architecture as that of the MB15A01 and MB15A02 PLLs, with a pulse-swallow function provided by on-board 64/65 or 128/129 dual-modulus prescalers. The IC also includes charge-pump circuitry with a precision phase comparator, a serial-input 14-b programmable reference divider, and an 18-b programmable divider. The 18-b divider consists of a binary 7-b swallow counter and a binary 11-b programmable counter.

The MB1516A has been developed for low-noise use in wireless transceivers. When tested as part of a frequency synthesizer, the unit exhibits reference-frequency spurious noise of better than –70 dBc/Hz offset 200 kHz from an 825-MHz carrier. The PLL supports charge-pump output voltages of approximately 0 to +5.0 VDC. The output current range is ±10 mA. Like the other PLL ICs, the MB1516A PLL is designed for operating temperatures from –40 to +85°C. All of the ICs are supplied in 16-pin plastic SSOP packages. P&A: $3.18 (MB15A01 and MB15A02) and $3.94 (MB1516A) (10,000 qty.); stock. **Fujitsu Microelectronics, Inc., Communications Products Group, 3545 North First St., San Jose, CA 95134-1804; (408) 922-9000, FAX: (408) 432-9044.**

CIRCLE NO. 56



Models MB15A01 and MB15A02 are serial PLL synthesizers with dual-modulus prescalers designed for applications to 1.1 GHz.

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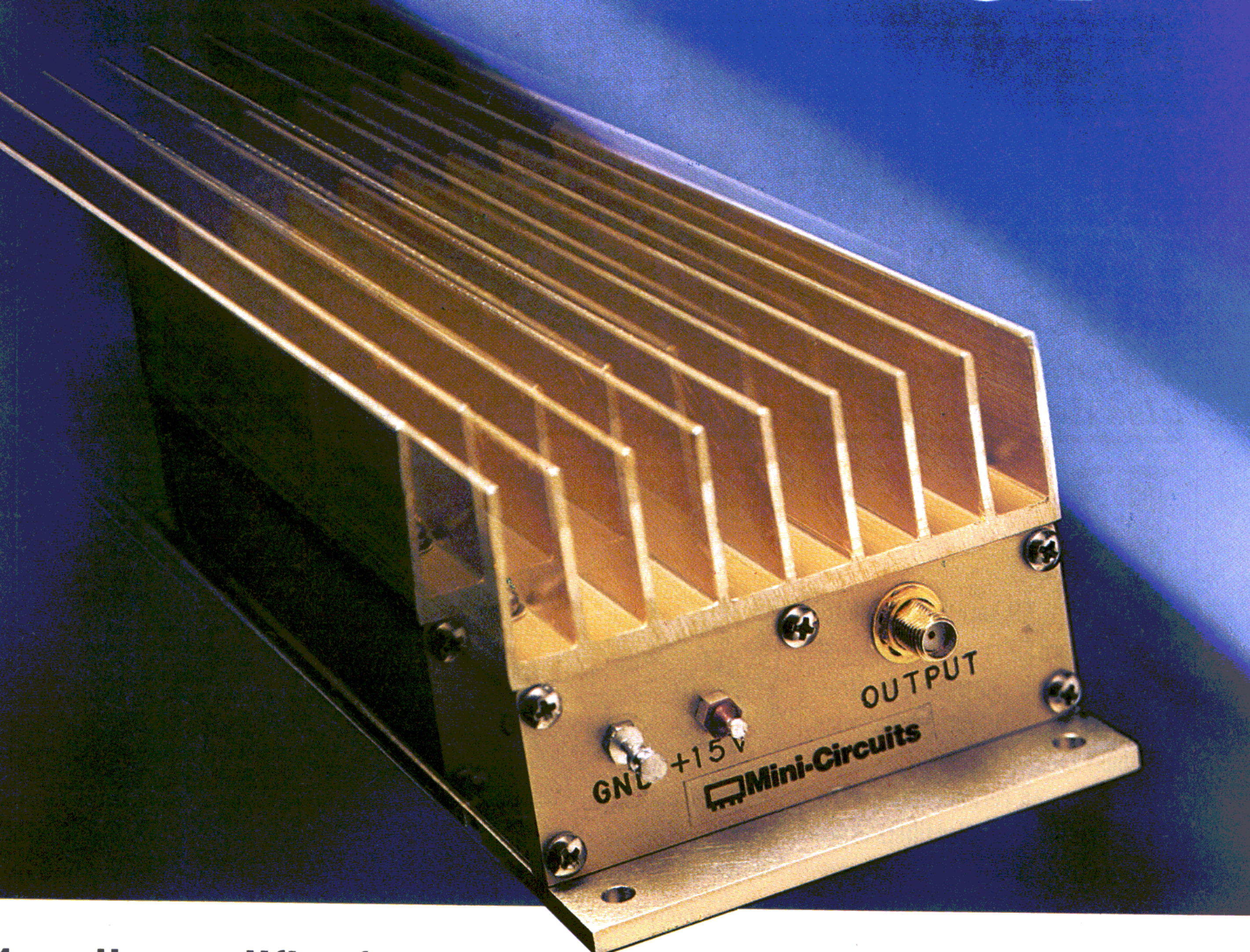

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SPECIFICATIONS	ZHL-42	ZHL-4240	ZHL-42-W	ZHL-4240W
Frequency, GHz	.07 to 4.2	0.7 to 4.2	0.01 to 4.2	0.01 to 4.2
Gain, dB min.	30	40	30	40
Gain Flatness, dB	±1.0	±1.5	±1.5	±1.5
Power Out @ 1 dB CP, dBm min	+29	+29	+29*	+29*
VSWR in/Out, max.	2.5:1	2.5:1	2.5:1	2.5:1
Noise Figure, dB typ	10.0	4.0	8.0**	8.0**
Power Supply, V/ma	+15/690	+15/700	+15/750	+15/850
Third Order Intercept, dBm min.	38	38	38	38
Second Order Intercept, dBm min.	48	48	48	48
Size, in.	7 x 3¼ x 2⅛ h.	7 x 3¼ x 2⅛ h.	7 x 3¼ x 2⅛ h.	7 x 3¼ x 2⅛ h.
Price	**$895.00**	**$1395.00**	**$1095.00**	**$1495.00**

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**Below 100 MHz increases to 15 dB at 10 MHz

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C 97 REV.E

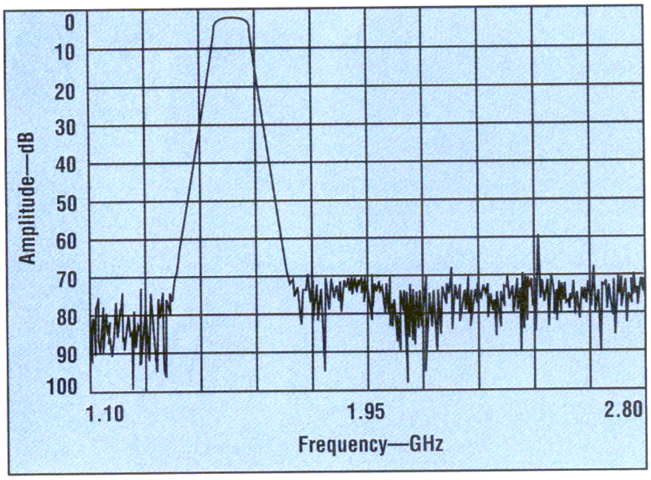
CERAMIC FILTERS AUGMENT COMPANY'S LINE OF PACKAGES

A firm well-known for ceramic packaging materials has also developed temperature-stable microwave filters.

PACKAGES have been the forte of a firm known for processing high-performance ceramic materials. But StratEdge Corp. (San Diego, CA) has also been busy the last several years fabricating filters on ceramic substrates. The company has supplied filters to several military and satellite-communications systems, including the Inmarsat 3 satellite program—the first time the firm has qualified for full space use of a product.

The ceramic filters are designed for versatility. They can be mounted within packages or used in a surface-mount carrier configuration. The filters offer significantly-reduced mass compared to other designs at microwave frequencies (through about 30 GHz) and are fabricated using low-profile planar construction. Because the filters are metallized on thermally-stable ceramic materials, the electrical performance remains consistent over temperature extremes from –60 to +150°C.

The filters can be designed with asymmetrical or symmetrical responses, using interdigital, edge-coupled, and combline designs. These filter designs are developed with the help of a customer's specifications and undergo rigorous simulation on commercial computer-aided-engineering (CAE) tools prior to fabrication. Grounding can be accomplished by means of via holes or wrap-around connections. In addition, the filters can be constructed on multilayer circuit boards, alone or as part of integrated assemblies that also include couplers, power dividers, and diplexers.



An L-band ceramic filter offers flat bandpass characteristics with better than 65-dB out-of-band signal rejection.

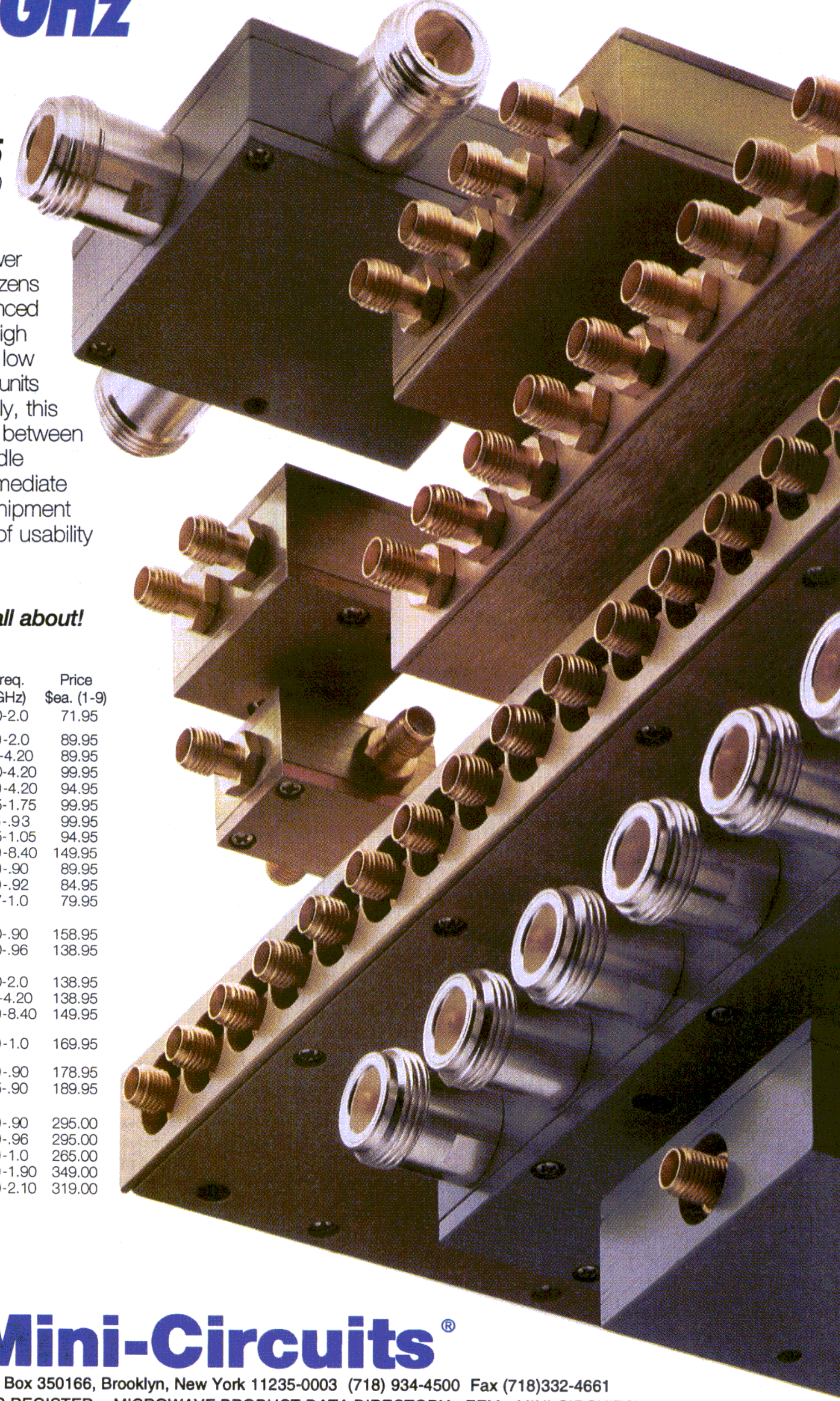
As an example of the technology, a filter developed for L-band satellite communications exhibits better than 65-dB signal rejection at 1.84 GHz, which is approximately 340 MHz from the center frequency. The filter's bandpass response (see figure) reveals a sharp rolloff from the passband region, where insertion loss is less than 2 dB and amplitude ripple is less than ±0.2 dB.

The company continues work on the development of high-performance ceramic packages, such as the SE20-103. With a cavity size of 0.20 × 0.14 in. (5.08 × 2.64 mm), the package accommodates MMICs as well as MICs on thin-film ceramic carriers. The package achieves better than 20-dB return loss from DC to 20 GHz, with less than 0.1-dB insertion loss. The SE20-103 incorporates a 0.015-in.-thick gold-plated copper-tungsten (CuW) base for effective heat dissipation and is designed with six 50-Ω input/output (I/O) ports. The company offers several variations on the package, with different I/O configurations and physical dimensions, including model SE20-200 with three 50-Ω RF ports and four DC ports. **StratEdge Corp., 4393 Viewridge Ave., San Diego, CA 92123; (619) 569-5000, FAX: (619) 560-6877.**

CIRCLE NO. 57

POWER DIVIDERS

500MHz - 8.4GHz



2 to 16 Way from $54.95 (1-9)

When you turn to Mini-Circuits to locate the right power divider for your applications, you can choose from dozens of low cost 2way to 16 way models. Thanks to advanced microstrip design, these units are able to handle high matched power with good VSWR (1.2:1 typ.) and low insertion loss... just 0.1dB (typ., above 3dB) for 2way units to 0.5dB (typ., above 12dB) for 16way. Additionally, this performance packed series features high isolation between ports (30dB typ.) and rugged construction to handle operational temperatures of -55°C to +100°C. Immediate off-the-shelf availability is backed by our 1 week shipment guarantee. So, if you're looking for a better blend of usability and affordability in a power divider...
there's only "1 way" to go...Mini-Circuits !

Mini-Circuits...we're redefining what VALUE is all about!

SPECIFICATIONS

	MODEL	Freq. (GHz)	Price $ea. (1-9)
■	ZC2PD-900	.80-.90	64.95
■	ZN2PD-920	.80-.92	59.95
■	ZN2PD-92OW	.70-1.05	54.95
■	IZY2PD-64	5.80-6.40	89.95
■	IZY2PD-86	7.0-8.60	94.95
■●▼	ZAPD-1	.50-1.0	54.95
■●▼	ZAPD-2	1.0-2.0	54.95
■●	ZAPD-4	2.0-4.20	59.95
■●▼	ZAPD-21	.50-2.0	59.95
●	ZAPD-50	4.4-5.0	54.95
●	ZAPD-50W	4.2-6.0	64.95
■	ZN2PD-1900	1.6-1.9	69.95
■	ZN2PD-1900W	1.5-2.0	64.95
■	ZN3PD-900	.70-1.05	54.95
■	ZN3PD-900W	.65-1.05	69.95
■●	ZA3PD-1	.50-1.0	89.95
■●	ZA3PD-1.5	.75-1.50	89.95
■●	ZA3PD-2	1.0-2.0	89.95
■●	ZA3PD-4	2.0-4.20	89.95
■	ZC6PD-960	.89-.96	124.95
■	ZC6PD-960W	.70-1.0	119.95
■	ZC6PD-1900	1.70-1.90	134.95
■	ZC6PD-1900W	1.50-2.0	129.95
■●	ZB6PD1-900	.80-.90	139.95
■●	ZB6PD1-960	.89-.96	139.95
■●	ZB6PD1-1900	1.70-1.90	149.95
■●	ZAPDQ-2 (90°)	1.0-2.0	79.95
■●	ZAPDQ-4 (90°)	2.0-4.20	79.95

	MODEL	Freq. (GHz)	Price $ea. (1-9)
■●▼	ZAPDJ-2 (180°)	1.0-2.0	71.95
■●	ZA4PD-2	1.0-2.0	89.95
■●	ZA4PD-4	2.0-4.20	89.95
■●	ZB4PD-42	1.70-4.20	99.95
■●	ZB4PD-4	3.70-4.20	94.95
▼	ZB4PD-1750-75	.875-1.75	99.95
■●	ZB4PD1-930	.85-.93	99.95
■●	ZB4PD1-930W	.725-1.05	94.95
●	ZB4PD1-8.4	6.70-8.40	149.95
■	ZC4PD-900	.80-.90	89.95
■	ZN4PD-920	.80-.92	84.95
■	ZN4PD-920W	.67-1.0	79.95
■	ZC8PD-900	.80-.90	158.95
■●	ZB8PD-1	.80-.96	138.95
■●	ZB8PD-2	1.0-2.0	138.95
■●	ZB8PD-4	2.0-4.20	138.95
●	ZB8PD-8.4	7.10-8.40	149.95
■	ZC9PD-1000	.80-1.0	169.95
■	ZC10PD-900	.80-.90	178.95
■	ZC10PD-900W	.75-.90	189.95
■	ZC16PD-900	.80-.90	295.00
■	ZC16PD-960	.89-.96	295.00
■	ZC16PD-960W	.70-1.0	265.00
■	ZC16PD-1900	1.70-1.90	349.00
■	ZC16PD-1900W	1.50-2.10	319.00

For detailed specs refer to Mini-Circuits Short Form Catalog, Trade Directories listed below or consult factory.
Connector Type: ■ SMA ● N ▼ BNC

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For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

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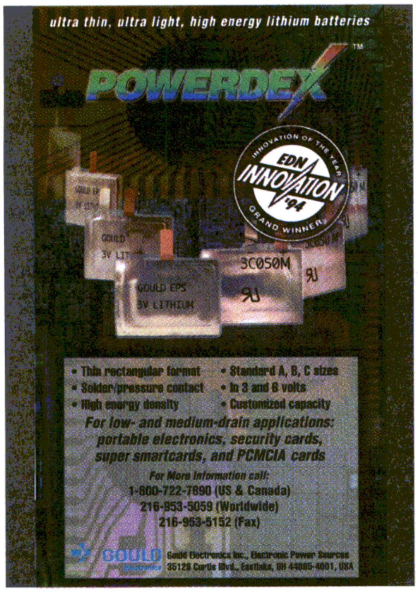
CIRCLE NO. 322

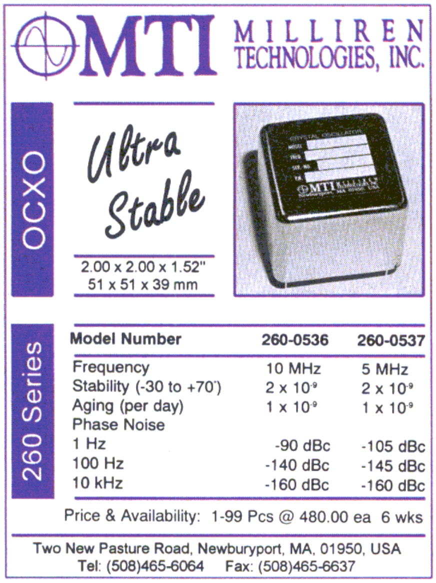
F 177 Rev B



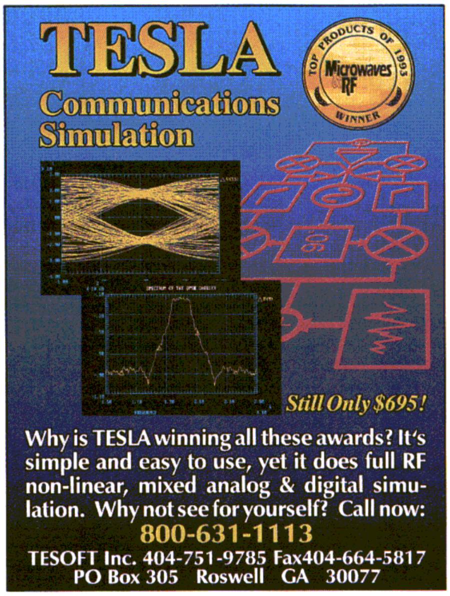
GOULD ELECTRONICS, INC. CIRCLE 555

ETI CIRCLE 554

INTEGRATED COMPONENT SYSTEMS CIRCLE 5



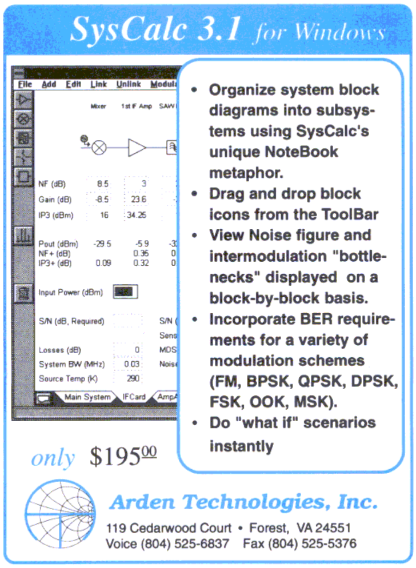
MILLIREN TECHNOLOGIES CIRCLE 560



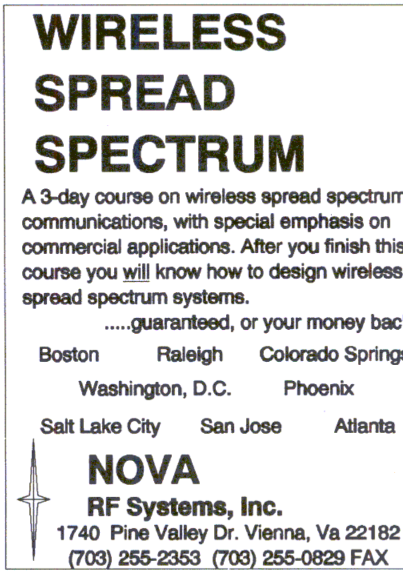
TESOFT INC. CIRCLE 566

MICROWAVE DYNAMICS CIRCLE 5

PENSTOCK CIRCLE 563



ARDEN TECHNOLOGIES CIRCLE 551



NOVA RF SYSTEMS, INC. CIRCLE

Scope offers 100-MHz bandwidth

The THS 720 handheld digital oscilloscope/digital multimeter (DMM) is a portable instrument offering a 100-MHz bandwidth for field-service tests. Featuring two channels for

capturing and comparing signals, the scope digitizes at a rate of 500 MSamples/s for each channel. Offering 21 user-selected automatic measurements, the unit can store up to 10 waveforms and 10 setups in memory. P&A: $2195. **Tektronix Measurement Business, P.O. Box 1520, Pittsfield, MA 01202; (800) 426-2200, FAX: (800) 835-7732.**

CIRCLE NO. 111

Filter targets cellular applications

A bandpass filter designed for cellular transmission applications features an 869-to-894-MHz passband. Demonstrating 0.4-dB insertion loss, the filter has a power rating of 150 W average and 1.5 kW peak. Rejection is 60 dB from 824 to 849 MHz, 35 dB from 790 to 824 MHz, and 35 dB from 920 to 2400 MHz. **Delta Microwave, 840 Via Alondra, Camarillo, CA 93012; (805) 987-6892 ext. 11.**

CIRCLE NO. 112

Transmitter tests PCS systems

The model PCS-20 test transmitter combines a personal-communications-services (PCS) signal generator with a 20-W power amplifier. The transmitter tunes from 1850 to 1990 MHz in 100-kHz steps, with 20-W power output in 1-dB increments. Output phase noise is better than –80 dBc/Hz offset 1 kHz from the carrier while output spurious noise is better than –60 dBc. **Moffet, Larson & Johnson, Inc. (MLJ), 2 Skyline Place, 5203 Leesburg Pike, Suite 800, Falls Church, VA 22041; (800) 523-3117, (703) 824-5660, FAX: (703) 824-5672.**

CIRCLE NO. 113

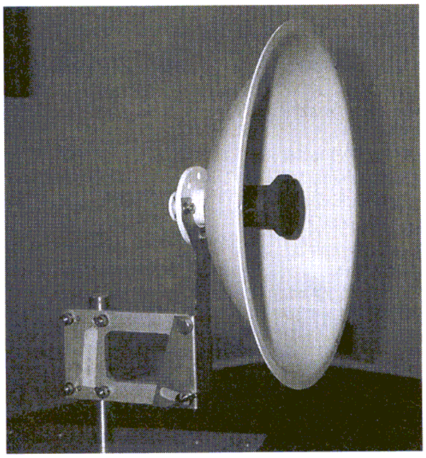
Antenna fills network nulls

Designed to fill nulls in radio-telecommunication networks caused by buildings and natural barriers, a planar antenna covers the 1.7-to-2.5-GHz frequency range in four bands. Tested to military specifications, the antennas are suitable for indoor or outdoor use in concrete buildings, tunnels, and underground systems. **Huber + Suhner, Inc., P.O. Box 400, Essex, VT 05451; (802) 878-0555, FAX: (802) 878-9880.**

CIRCLE NO. 114

Antennas receive 37 to 40 GHz

Cassegrain-type, millimeter-wave receiving antennas are available for 37-to-38.4-GHz and 38.6-to-40-GHz applications. A typical unit, model AR-3938, features 38-dB gain with 3-dB azimuth and elevation beamwidths of approximately 1.6 deg.

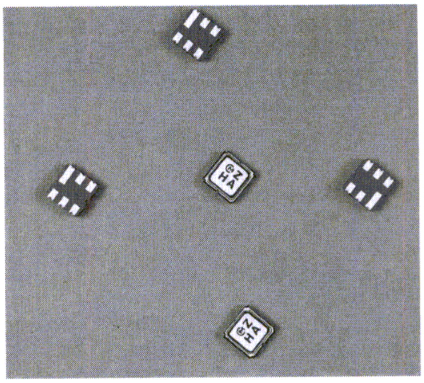


VSWR is better than 1.35:1. The antennas feature 50-W average operating power and 1-kW peak power. P&A: 10 to 12 wks. **Electrodyne Systems Corp., 8 Leuning St., South Hackensack, NJ 07606; (201) 342-4484, FAX: (201) 342-3559.**

CIRCLE NO. 115

SAW filter performs from 1 to 3 GHz

Designed for wireless products, a surface-acoustic-wave (SAW) filter



performs from 1 to 3 GHz. With a base of zinc-oxide printed on a sapphire substrate, the RF filter features a 50-Ω termination and is packaged in a tape-and-reel format. **Murata Electronics North America, 2200 Lake Park Dr., Smyrna, GA 30080; (404) 436-1300.**

CIRCLE NO. 116

Absorbers bond to substrates

A line of flat-sheet radar absorbers offers a pressure-sensitive adhesive backing for fast and easy installation. Providing a permanent bond to most wood, metal, or plastic substrates, the absorbers cover the entire microwave frequency range. Applications include prevention of specular reflection, control of surface currents, modification of the quality factor (Q) of cavities, and antenna pattern adjustment. **Cuming Corp., 230 Bodwell St., Avon, MA 02322; (508) 580-2660, FAX: (508) 580-0960.**

CIRCLE NO. 117

OCXO tunes GSM transceivers

Featuring an SC-cut resonator, an oven-controlled crystal oscillator (OCXO) with a center frequency of 13 MHz is designed for Global System for Mobile Communications (GSM) base transceiver stations. From –10 to +70°C, the oscillator offers a frequency stability and an aging rate of 5×10^{-8}. A 0- to +7-VDC external voltage compensates the aging over a 15-year period. **Thomson Components & Tubes Corp., Special Products Div., 40G Commerce Way, Totowa, NJ 07511; (201) 812-9000, FAX: (201) 812-9050.**

CIRCLE NO. 118

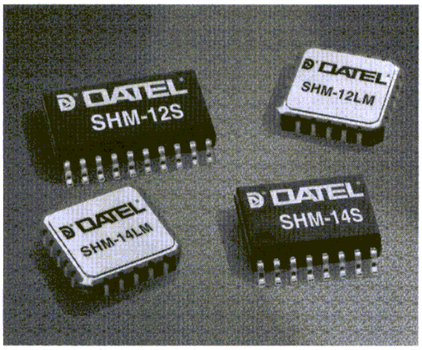
ADC guarantees 41 MSamples/s

The model AD9042 analog-to-digital converter (ADC) guarantees a minimum sampling rate of 41 MSamples/s and a typical rate of 50 MSamples/s. Delivering 12-b performance with an 80-dB spurious-free dynamic range, the ADC achieves 90-dB intermodulation distortion (IMD). The device is housed in a ceramic dual-in-line package (DIP) and is powered by a +5-VDC supply. P&A: $199 (1000 qty.). **Analog Devices, Inc., 181 Ballardvale St., Wilmington, MA 01887; (617) 937-1428, FAX: (617) 821-4273.**

CIRCLE NO. 119

Amplifiers support data acquisitions

The SHM series of monolithic sample-and-hold amplifiers is designed for fast data-acquisition applications, featuring 10-ns acquisition times to accuracies of ±0.1 percent. A typical model, SHM-12, is a 12-b linear am-



plifier with a 55-MHz full-power bandwidth. A 14-b linear amplifier with a 70-MHz full-power bandwidth (model SHM-14) is also available. The amplifiers operate from ±5-VDC supplies with 250-mW power dissipation. P&A: $35 (100 qty.). **DATEL, Inc., 11 Cabot Blvd., Mansfield, MA 02048; (508) 339-3000, FAX: (508) 339-6356.**

CIRCLE NO. 120

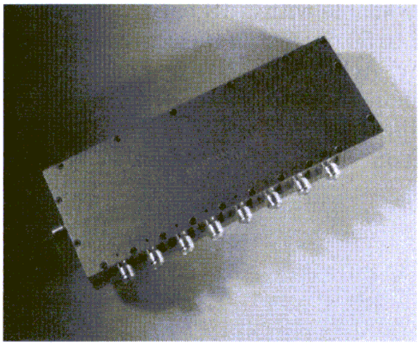
ADC offers 6-μs conversion time

The MAX197 eight-channel analog-to-digital converter (ADC) features a 6-μs conversion time and a 100-kSamples/s sampling rate. Operating from a single +5-VDC supply, the 12-b resolution ADC offers software-selectable inputs of 0 to +5 VDC, 0 to +10 VDC, ±5 VDC, and ±10 VDC. P&A: $9.90 and up (1000 qty.). **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (800) 722-8266, (408) 737-7600 ext. 6087.**

CIRCLE NO. 121

Switch operates from 10 to 1000 MHz

Model SP8T-8011-NR is a single-pole, eight-throw (SP8T) switch operating over the 10-to-1000-MHz bandwidth. Demonstrating 2.5-dB insertion loss, the PIN-diode switch



features minimum isolation of 65 dB. The non-reflective switch contains an integral TTL driver with 3-b decoded logic control and an enable latch. **K&L Microwave Inc., 408 Coles Circle, Salisbury, MD 21801; (410) 749-6774, FAX: (410) 749-6887.**

CIRCLE NO. 122

Isolators range from 4 to 7 GHz

A series of C-band isolators operating across the 4-to-7-GHz frequency range features 20-dB minimum isolation. Offering an optimized 20-percent bandwidth, the isolators demonstrate 0.3-dB insertion loss and 1.25:1 maximum VSWR. The units are packaged in connectorized or drop-in configurations which measure 0.75 × 0.90 × 0.50 in. (1.91 × 2.29 × 1.28 cm). **KW Microwave Corp., 1985 Palomar Oaks Way, Carlsbad, CA 92009; (619) 929-9800, FAX: (619) 929-9899.**

CIRCLE NO. 123

Current meter tests to 110 MHz

The HI-3702 RF induced-current meter functions across the 3-kHz-to-110-MHz frequency range. With a 60-dB dynamic range (1 to 1000 mA), the meter is sized to clamp onto the user's ankle or arm, making measurements possible while walking or climbing. Weighing 5 lbs. (2.25 kg), the unit is powered by a rechargeable NiCd battery with a typical life of 10 hours on full charge. **Holaday Industries, Inc., 14825 Martin Dr., Eden Prairie, MN 55344; (612) 934-4920, FAX: (612) 934-3604.**

CIRCLE NO. 124

Arrays enhance telecommunications

Three new members of the FX series of high-performance gate arrays have a sea-of-gates architecture and a utilization factor of 70 percent. Available with an extended temperature range of 0 to +110°C, the arrays are manufactured with the H-GaAs III™ process. Packaged in a 144 plastic quad flat pack (PQFP), a typical unit, model VGFX20K, features 20,000 raw gates with 90 available input/output signals. The gate arrays are designed to provide the high-performance margins required in the telecommunications industry. **Vitesse Semiconductor Corp., 741 Calle Plano, Camarillo, CA 93012; (805) 388-3700, FAX: (805) 987-5896.**

CIRCLE NO. 125

Signal simulator provides +20 dBm

The model TSS-2000 general-purpose signal simulator is designed for use in test and measurement research applications. Providing +20-dBm maximum output power, the simulator offers multiple modulation formats, narrow and wide-range deviation, and data rates up to 20 MHz.

With sweeping capabilities from 10 to 600 MHz, the unit generates continuous signals in 200-MHz segments from 1400 to 2500 MHz. Doppler simulation can reach up to 100 kHz with triangular or sawtooth patterns. **Microdyne Corp., Telemetry Division, 491 Oak Rd., Ocala, FL 32672; (800) 874-4633, (904) 687-4633, FAX: (904) 687-3392.**

CIRCLE NO. 126

Measurement set targets CATV

Delivering a full set of Federal Communications Commission (FCC) measurements for baseband testing of cable-television (CATV) systems, the model VM100 test set verifies

and monitors composite baseband video signals. Designed to be incorporated in portable equipment packages for characterizing video signals, the unit features small size, simple operation, and automatic reporting. **Tektronix, Inc.; P.O. Box 500, Beaverton, OR 97077-0001; (800) 835-9433, (503) 627-7111, FAX: (503) 690-3959.**

CIRCLE NO. 127

Kits test fiber optics

The FT310 and FT350 fiber-optic test kits provide multimode and single-mode fiber network testing, respectively. While both kits are designed for dual-wavelength testing, the FT310 tests 850- and 1300-nm fiber networks in multimode local-area networks (LANs). The FT350 tests 1300- and 1550-nm fiber networks in single-mode cable-television (CATV) systems. Requiring no additional hardware, the instruments lock in to the proper wavelength and test loss at each wavelength during one measurement. P&A: $2095 (FT310), $3900 (FT350); stock. **Fotec, Inc., 529 Main St., Box 246, Boston, MA 02129; (800) 537-8254, (617) 241-7810, FAX: (617) 241-8616, e-mail: info@fotec.com.**

CIRCLE NO. 128

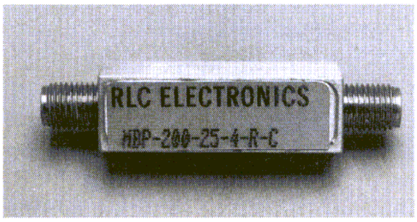
Clock oscillator delivers 10.24 MHz

The model NV93A clock oscillator has a frequency of 10.24 MHz and is designed for master clock applications in telecommunications systems. With a doubly-rotated-cut crystal, the oscillator offers $\pm 1 \times 10^{-10}$/day frequency stability. With 0- to +10-VDC tuning voltage, the oscillator has a minimum mechanical frequency adjustment of $\pm 1 \times 10^{-7}$ and requires a power supply of +24 VDC. **Bliley Electric Co., P.O. Box 3428, Erie, PA 16508-0428; (814) 838-3571, FAX: (814) 833-2715.**

CIRCLE NO. 129

Filters pass 50 MHz to 3 GHz

A series of bandpass filters is available with 3-dB bandwidths from 2 to 50 percent of the center frequency. Achieving a thermal drift of less than 25 PPM/°C, the filters can be specified with center frequencies from 50 MHz to 3 GHz. A typical



unit, model MBP-200-25-4-R-C, operates at a center frequency of 200 MHz with a 3-dB bandwidth of 25 MHz. Insertion loss is less than 2 dB while the total center frequency change over the –55 to +85°C temperature range is less than 0.5 MHz. P&A: $195; 4 to 6 wks. **RLC Electronics, Inc., 83 Radio Circle, Mt. Kisco, NY 10549; (914) 241-1334, FAX: (914) 241-1753.**

CIRCLE NO. 130

Mixer ICs support wireless applications

A family of three integrated-circuit (IC) mixers (package M12P030) features operating frequencies up to 2.5 GHz for wireless-communication applications. Model PMB2331 is a +2.7- to +4.5-VDC, 1.6-mA Gilbert-cell mixer with an 8-dB noise figure. Model PMB2332 adds a low-noise amplifier to the PMB2331 configuration, offering 10-dB gain and a 3.3-dB noise figure at 2.5 GHz. Model PMB-2333 adds a driver amplifier with +10-dBm output power at 1-dB compression to the basic mixer circuit. **Siemens Components, Inc., Integrated Circuits Div., 10950 North Tantau Ave., Cupertino, CA 95014; (800) 777-SIEMENS ext. 280.**

CIRCLE NO. 131

IC recovers 155 and 622 Mb/s

The MAX3270 is a complete clock-recovery and data-retiming integrated circuit (IC) for 155- and 622-Mb/s synchronous-digital-hierarchy (SDH)/Synchronous Optical Network (SONET) and asynchronous-transfer-mode (ATM) applications. Recovered data is phase-aligned using a fully-integrated phase-locked loop (PLL). Meeting the Bellcore and CCITT jitter tolerance specifications, the IC ensures error-free data recovery. The IC operates in the 0- to +70°C temperature range and is supplied in a 44-pin package. P&A: $39.50 and up (1000 qty.). **Maxim Integrated Products, 120 San Gabriel Dr., Sunnyvale, CA 94086; (800) 998-8800, (408) 737-7600 ext. 6087.**

CIRCLE NO. 132

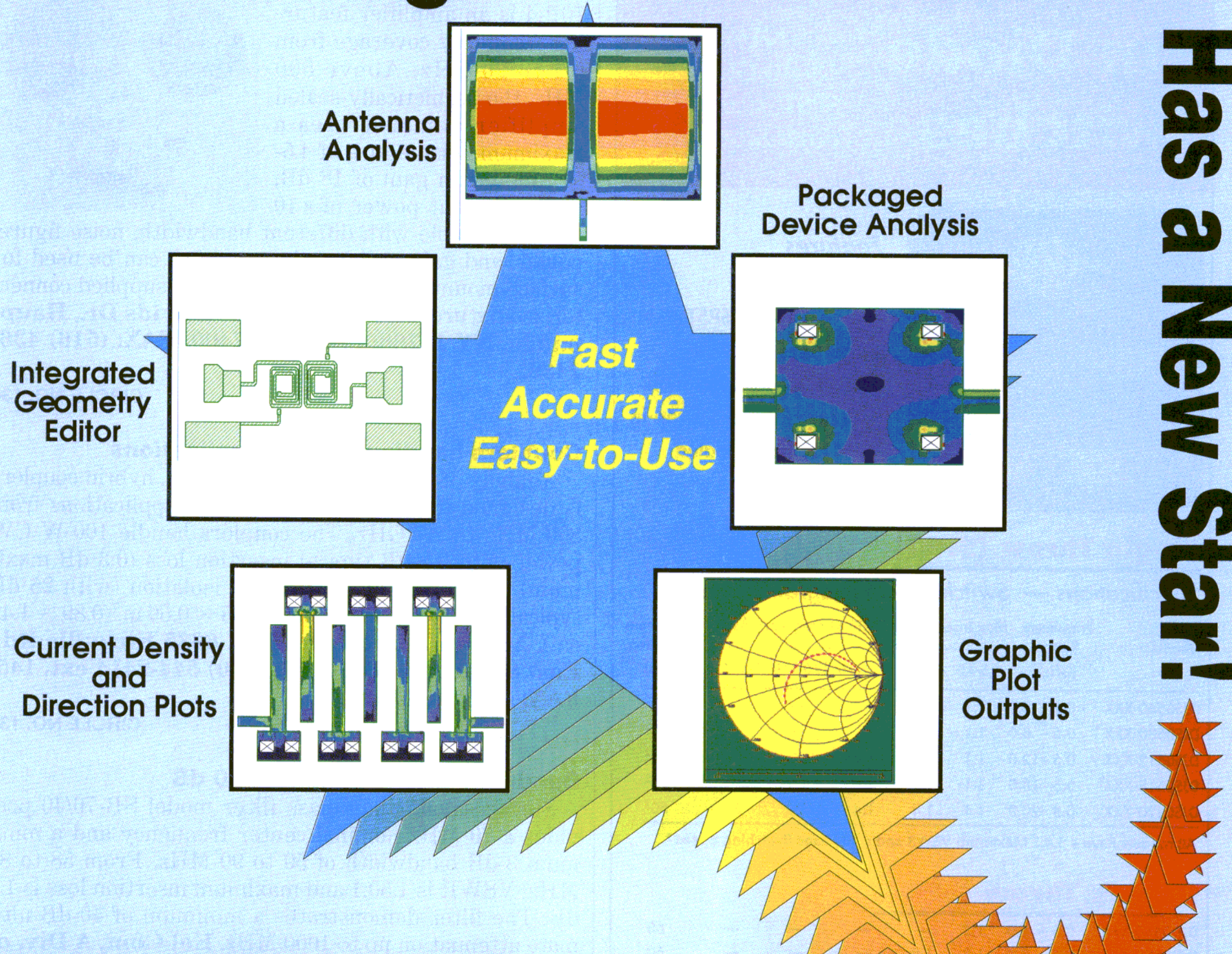
Portable unit analyzes cables

Model RFA-4017-1 is a portable coaxial-cable tester for analyzing BNC male-end cables. Powered by a 9-V battery, the tester indicates whether a cable failed due to a short, open conductor, or open shield.

Adapters enable testing of cables with terminations other than BNC. **RF Industries, Ltd., 7610 Miramar Rd., San Diego, CA 92126-4202; (800) 233-1728, (619) 549-6340, FAX: (619) 549-6345.**

CIRCLE NO. 133

Electromagnetic Simulation Has a New Star!



icrowave Explorer offers superior Electromagnetic Simulation n both open and packaged environments!

ompact Software's Microwave Explorer Electromagnetic Simulator provides superior simulation of EM coupling and diation effects in RF and microwave circuits. Only Microwave Explorer allows designers to model both radiating ructures (antennas) **and** packaged devices using a **single** EM simulation tool!

icrowave Explorer uses the Method of Moments technique to provide accurate 3D analysis of planar circuits in a fraction the time associated with traditional 3D techniques. Advanced simulation techniques require less memory and CPU ne than conventional implementations.

ectromagnetic analysis of complex structures has never been this fast or this easy! The integrated geometry editor cludes GDS II import capability. To find out more about the unique capabilities of Microwave Explorer and to obtain the ame of the Compact Software Sales Representative for your area, please contact:

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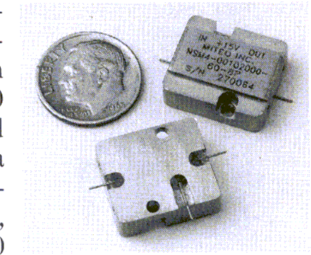
Amplifier covers 0.1 to 20 GHz



Model NSM4-00102000-45-10P-4 is an amplifier featuring frequency coverage from 0.1 to 20 GHz. Above 500 MHz, the hermetically-sealed amplifier demonstrates a maximum noise figure of 4.5-dB, minimum gain of 18 dB, and an output power of +10 dBm. Available with different bandwidth, noise figure, power, and gain options, the amplifier can be used for surface-mount applications or with the supplied connectorized fixture. **MITEQ, Inc., 100 Davids Dr., Hauppauge, NY 11788; (516) 436-7400, FAX: (516) 436-7430.**

CIRCLE NO. 134

Couplers handle wireless applications

A family of six surface-mount, 90-deg. hybrid couplers is designed for cellular and wireless applications from 800 MHz to 2.7 GHz. The couplers handle 100-W CW power with 0.2-dB typical insertion loss (0.3 dB maximum). Featuring at least 22-dB isolation (with 25 dB typical), the couplers measure 0.35 × 0.56 in. (0.89 × 1.42 cm). **Anaren Microwave, Inc., 6635 Kirkville Rd., East Syracuse, NY 13057; (800) 544-2414 ext. 145, FAX: (315) 432-9121.**

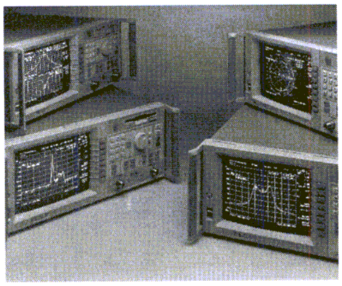
CIRCLE NO. 135

Bandpass filter attenuates 40 dB

Surface-mount bandpass filter model SB-70/40 provides a 70-MHz nominal center frequency and a minimum 3-dB bandwidth of 50 to 90 MHz. From 58 to 82 MHz, VSWR is 1.50:1 and maximum insertion loss is 1.5 dB. The filter demonstrates a minimum of 40-dB ultimate attenuation up to 1000 MHz. **Kel-Com, A Div. of K&L Microwave, Inc., 408 Coles Circle, Salisbury, MD 21801; (410) 749-6774, FAX: (410) 749-6887.**

CIRCLE NO. 136

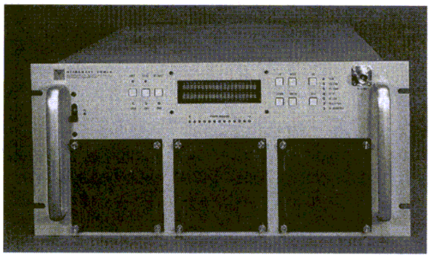
Analyzers test 300 kHz to 3 GHz



A family of network analyzers (HP 8710B) with measurement automation capabilities is designed for testing RF devices in the 300-kHz-to-3-GHz range. Offering real-time sweep speed, the analyzers feature a 100-dB dynamic range and 1-Hz resolution. System directivity is 40 dB with 20-dB test-port match for accurate, repeatable return-loss and impedance measurements. The analyzers provide +16-dBm output power and are available with an optional 60-dB step attenuator. **Hewlett-Packard Co., Direct Marketing Organization, P.O. Box 58059, MS51L-SJ, Santa Clara, CA 95051-8059; (800) 452-4844 ext. 9018.**

CIRCLE NO. 137

Solid-state amp offers 125-W power



Solid-state power amplifier model CJQ-81112 offers 125-W output power from 14.0 to 14.5 GHz. Designed as a direct replacement for traveling-wave tubes, the unit provides gain of 65 dB. The amplifier incorporates a microprocessor for controlling and monitoring functions. **Microwave Power, Inc., 3350 Scott Blvd., Suite 25, Santa Clara, CA 95054; (408) 727-6666, FAX: (408) 727-2246.**

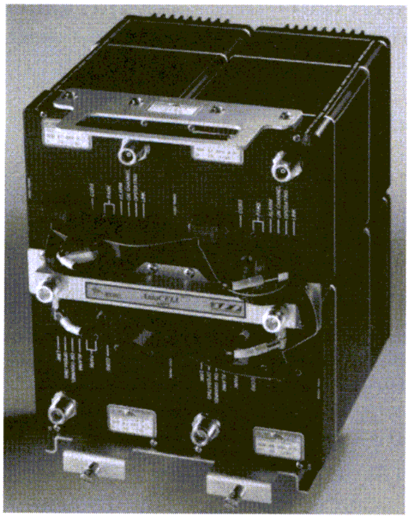
CIRCLE NO. 138

Receiver tests base stations

Designed as a personal-communications-services (PCS) and wireless network-analysis tool, the PathSearch™ system combines a digital power-measuring receiver with Windows-based application software. The receiver tunes from 1840 to 2000 MHz with ±1-PPM accuracy. The system features a 5-dB noise figure and –125-dBm sensitivity in a 25-kHz measurement bandwidth. The control software displays measured signal strength on an optional 486 laptop computer. Capable of making rapid power measurements of multiple channels from a moving vehicle, the system is ideal for PCS cell-site testing. **Moffet, Larson & Johnson, Inc. (MLJ), 2 Skyline Place, 5203 Leesburg Pike, Suite 800, Falls Church, VA 22041; (800) 523-3117, (703) 824-5660, FAX: (703) 824-5672.**

CIRCLE NO. 139

Transmitter/combiner tunes cellular systems

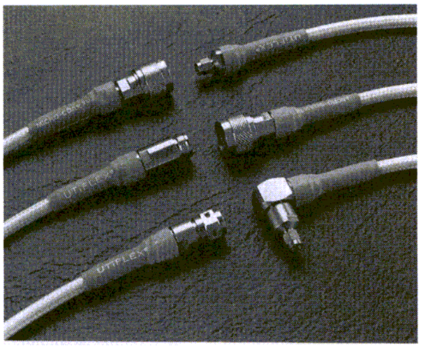


A four-channel autotune ceramic transmitter/combiner, designated AutoCELL™, combines ceramic dielectric-resonator and digital technologies for fine-tuning cellular systems. Six units can be linked together to produce 24 channels that tune to an applied signal within the unit's 30-dB tuning range. Automatic-tuning capability allows cellular carriers to tune re-allocated frequencies where call traffic is heaviest without sending a technician to the cell site. **Allen Telecom Group, Decibel Products Div., 30500 Bruce Industrial Pkwy., Cleveland, OH 44139-3996; (216) 349-8400, FAX: (216) 349-8407.**

CIRCLE NO. 140

Flexible cables feature low loss

The UFB-311A flexible microwave cable assembly features insertion loss of 0.20 dB/ft. at 18 GHz. With a power-handling capacity of 490 W CW at 5 GHz, the cable demonstrates a dynamic bend radius of

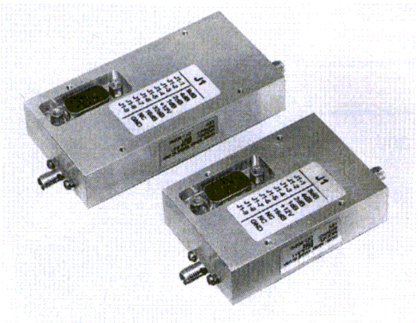


4.75 in. and RF leakage of –100 dB at 1 GHz. Operating over the temperature range of –65 to +165°C, the cable handles frequencies to 18 GHz. P&A: stock. **MICRO-COAX, P.O. Box 993, Collegeville, PA 19426-0993; (610) 489-3700, FAX: (610) 489-1103.**

CIRCLE NO. 141

Attenuators range from DC to 3 GHz

A series of high-performance programmable attenuators operates in the DC-to-3-GHz frequency range with a 1-W power rating. With a 6-ms maximum switching time at +12 VDC, the units offer 1.45:1 maximum



VSWR. A typical unit, model 3215-31, is comprised of five cells and offers a 31-dB attenuation range in 1-dB steps. Demonstrating a maximum 2.5-dB insertion loss, the model 3215 draws 200 mA from a +12-VDC operating current. **Lucas Weinschel, P.O. Box 6001, Gaithersburg, MD 20884-6001; (800) 638-2048, (301) 948-3434, FAX: (301) 948-3625.**

CIRCLE NO. 142

Coupler operates in cellular bands

Performing across the 600-to-1800-MHz band, a dual-directional coupler offers a coupling value of 30 ±2 dB and directivity of better than 25 dB. VSWR is 1.15:1. Large cross-section 7/16 connectors allow input power of up to 2000 W. The coupler measures 5.41 × 2.44 × 1.34 in. (13.74 × 6.20 × 3.40 cm) without connectors. **Sage Laboratories, Inc., 11 Huron Dr., Natick, MA 01760-1338; (508) 653-0844, FAX: (508) 653-5671.**

CIRCLE NO. 143

Oscilloscope traces 20 MHz

Model 6502 is a dual-trace, single time-base oscilloscope with a 20-MHz bandwidth. Featuring ×5 and alternate sweep magnification, the unit allows simultaneous display of

original and magnified traces. The scope requires 35 W of power and weighs 16 lbs. (7.25 kg.). P&A: $499. **HC Protek, 154 Veterans Dr., Northvale, NJ 07647; (201) 767-7242, FAX: (201) 767-7343.**

CIRCLE NO. 144

Synthesizers produce 1 MHz to 18 GHz

Eleven series of frequency-synthesizer families generate output frequencies from 1 MHz to 18 GHz. They are available in any step size from 1 Hz to 100 MHz. Featuring low phase noise and spurious levels to –100 dBc, the components are available in custom or standard designs. **Syntek Corp., 159 Keyland Court, Bohemia, NY 11716; (516) 567-0477, FAX: (516) 567-0726.**

CIRCLE NO. 145

Analyzer tests PDH/SDH signals

The model MP1550A/B compact piesiochronous-digital-hierarchy (PDH)/synchronous-digital-hierarchy (SDH) analyzer incorporates both a transmitter and receiver in one instrument. To test PDH systems, the analyzer utilizes a Mux/Demux function for flexible testing of tributary units from N × 64 kb/s to 139 Mb/s. The unit is suitable for testing SDH add/drop and cross-connect signals at 155 Mb/s and 622 Mb/s. Featuring a built-in printer and an optional disk drive, the analyzer can print and store results from tests conducted in the field. **Anritsu Wiltron, 685 Jarvis Dr., Morgan Hill, CA 95037; (408) 776-8300, FAX: (408) 776-1744.**

CIRCLE NO. 146

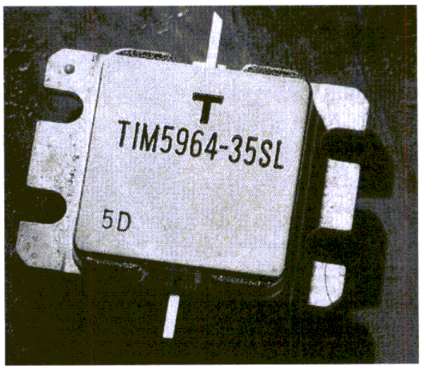
Probe measures current flow

The model IA7 probe mounts onto the company's model 107 spectrum probe to provide spectrum-analyzer RF current measurements from 30 μA to 100 mA. The probe features 60-dB rejection at 60 Hz and a 60-dB dynamic range. P&A: $29; stock. **Smith Design, 207 E. Prospect Ave., North Wales, PA 19454; (215) 661-9107.**

CIRCLE NO. 147

FETs target C-band applications

A family of C-band GaAs field-effect transistors (FETs) is designed for 3.7-to-8.5-GHz applications such as mobile telecom ground stations, satellite uplinks, and digital radio



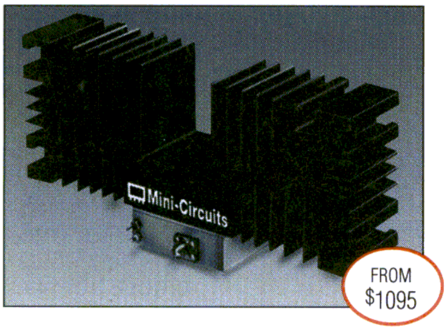
links. A typical 30-W device, model TIM5964-30SL, covers the 5.9-to-6.4-GHz frequency range, offers +45-dBm typical output power at 1-dB compression, and provides 38-percent typical power-added efficiency. P&A: $1350. **Toshiba America Electronic Components, Inc., 9775 Toledo Way, Irvine, CA 92718; (800) 879-4963.**

CIRCLE NO. 148

NEW PRODUCTS

NO. 16

RF/IF MICROWAVE COMPONENTS



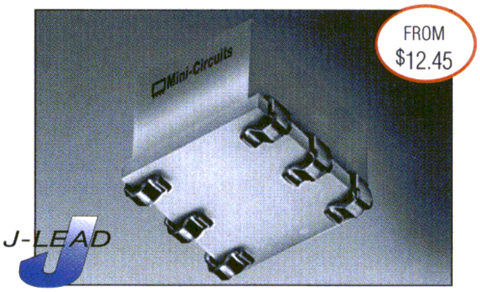
1W MICROWAVE AMPLIFIER HAS WIDE 2-8GHz COVERAGE

Broadband 2 to 8GHz coverage and 31dBm output (typ.at 1dB comp.) enables Mini-Circuits new ZVE-8G microwave amplifier to be used in a wide range of wireless applications, including line-of-site transmit/receive, satellite up/down links, S- and C-Band radars and as an optical transmitter driver amplifier. Unconditionally stable, the unit delivers high 34dB gain (±1.0dB flat) and low VSWR of 1.5 (typ.) at -55°C to +90°C (case temp.). Hermetically sealed package comes with field replaceable SMA connectors.

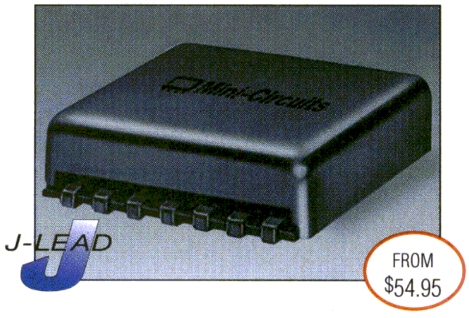
CIRCLE NO. 261

20 TO 1000MHz SM MIXER GUARANTEED 5 YEARS

Cellular and PCN applications are among the primary uses for Mini-Circuits wideband 20 to 1000MHz JMS-2H frequency mixer. This tough, level 17 surface mount mixer features low distortion (25dBm typ.,3rd order IP), high L-R isolation (50dB typ.) and low conversion loss (7.0dB typ.). Rugged, all-welded internal construction withstands reflow up to 240°C for 5 minutes, while the miniature (0.28"X0.31"X0.22") all-ceramic package has solder plated J leads for strain relief. 5 year Ultra-Rel™ guarantee included.



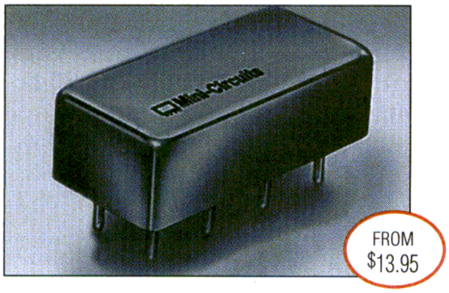
CIRCLE NO. 260



THERMALLY RUGGED I&Q DEMODULATOR WITH J LEADS

Mini-Circuits low-cost JCIQ-176D I&Q demodulator delivers superior shielded performance in a miniature (0.8"X0.87"X0.25") surface mount metal case. It provides a wide 51% bandwidth covering an RF(signal)/ LO(carrier) frequency range of 104 to 176MHz(I&Q DC to 5MHz max.), together with good amplitude (0.15dB typ.) and phase (2 degrees typ.) unbalance, excellent 3rd (-52dBc typ.) and 5th (-65dBc typ.) order harmonic suppression plus solder plated J-leads for excellent solderability and strain relief.

CIRCLE NO. 259

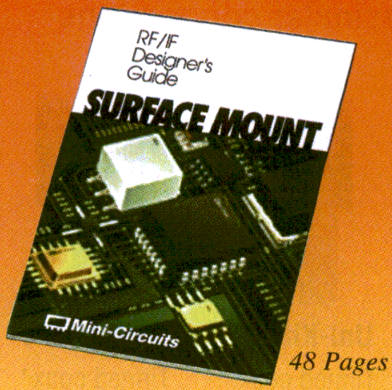


VOLTAGE CONTROLLED OSCILLATOR FOR CATV USE

Mini-Circuits new POS-535 is a low-cost VCO featuring 300 to 525MHz(min.) linear tuning at +12V DC (Vcc) and usable to +15V DC (Vcc). This miniature (0.4"X0.8" board space) plug-in VCO typically provides low SSB phase noise of -93dBc/Hz at 10KHz, -139dBc/Hz at 1MHz and a tuning range of 1.5 to 15V. With an operating temperature range of -55°C to +85°C, the unit is a superior price/performance solution for CATV distribution and set-top converter applications.

CIRCLE NO. 262

DESIGNER'S GUIDE



48 Pages

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CIRCLE NO. 263

2WAY-0° POWER SPLITTER FOR FM, VHF APPLICATIONS

The SYPS-2-1 from Mini-Circuits is a broadband, 2way-0° power splitter covering 2 to 500MHz. Engineered for high performance, this 50 ohm surface mount unit typically has excellent 32dB isolation, low 0.3dB insertion loss and low 1.1:1 VSWR. Housed in a low-cost, plastic surface mount package (on G-10 base), the low profile and small size (only 0.5"X0.375"X0.23") is ideal for miniature and high density designs up to 1W. Tape and reel packaging available.

CIRCLE NO. 264

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For detailed specs on all Mini-Circuits products refer to • THOMAS REGISTER • MICROWAVE PRODUCT DATA DIRECTORY • EEM • MINI-CIRCUITS' 740- pg. HANDBOOK.

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Filter extracts small signals

The model LTC1164-8 low-power filter is an integrated circuit (IC) designed to extract small signals from noisy environments. An eighth-order elliptic bandpass filter, the monolithic device features a –3-dB passband with a –50-dB stopband. Controlled by an external clock, the center frequency can be tuned up to 4 kHz on a single +5-VDC supply and 7.5 kHz with a ±7.5-VDC supply. **Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7487; (408) 432-1900, FAX: (408) 434-0507.**

CIRCLE NO. 149

Generators offer 2-to-20-MHz bandwidths

A series of function generators features bandwidths from 2 to 20 MHz. Sine-wave distortion is less than 1 percent, with better than 0.35-dB flatness across the specified bandwidth. Square-wave rise time is faster than 50 ns while the CMOS output level varies from 4.0 to 14.5 V peak-to-peak. Featuring a 0.2-Hz-to-2.0-MHz bandwidth, model 4010 offers sine, square, and triangle waves; TTL and CMOS outputs; variable waveform symmetry; and variable DC offset. P&A: $229 and up. **BK Precision, Maxtec International Corp., 6470 W. Cortland St., Chicago, IL 60635; (312) 794-9740, FAX: (312) 889-1448.**

CIRCLE NO. 150

OCXO tunes communications

Capable of warming up to a stabilized frequency in less than 2 min., the model FE-101A oven-controlled crystal oscillator (OCX0) demonstrates a temperature stability of 1 $\times$ 10^{-8} across the –55 to +85°C temperature range. The OCXO features low noise under airborne vibration, demonstrating a sensitivity of 3 $\times$ 10^{-10}/G. Requiring 1.75 W of steady-state power at +25°C, the rugged oscillator is designed for portable communications applications. **Frequency Electronics, Inc., 55 Charles Lindbergh Blvd., Mitchel Field, NY 11553; (516) 794-4500, FAX: (516) 794-4340.**

CIRCLE NO. 151

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MARKETING AND ADVERTISING STAFF

PUBLISHER
Jack Browne
(201) 393-6293

ASSISTANT TO THE PUBLISHER
Debbie Cameron
(201) 393-6256

NATIONAL SALES MANAGER
Marc Spector
(201) 393-6225

TRADE SHOW MANAGER
Mary Begley
(201) 393-6289

DIRECT CONNECTION ADS
Joanne Reppas
(201) 666-6698

SENIOR INSIDE SALES REPRESENTATIVE
Loree Poirier
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NORTHERN CA, NORTHWEST
Gene Roberts
Regional Sales Manager
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2025 Gateway Place, Suite 354
San Jose, CA 95110
(408) 441-0550

NEW ENGLAND, NJ
Jerry Bleich
District Sales Manager
611 Route #46 West
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(603) 425-5123
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611 Route #46 West
Hasbrouck Heights, NJ 07604
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MIDDLE ATLANTIC, SOUTHWEST, SOUTHEAST, SOUTHERN CA
Mary Bandfield
District Sales Manager
Penton Publishing
611 Route #46 West
Hasbrouck Heights, NJ 07604
(904) 424-0720

PRODUCTION
Robert D. Scofield
(201) 393-6253

FRANCE
Emmanual Archambeauld
Defense & Communication
10 Rue St. Jean, 75017 Paris, France
Phone: 33-4294-0244
FAX: 33-4387-2729

HONG KONG
Tom Gorman, CCI-Asia Pacific Ltd.
Unit 101, 1/F., Pacific Plaza
410 Des Voeux Road West
Hong Kong
Phone: 852-2858-0789
FAX: 852-2857-6309

TAIWAN, R.O.C.
Charles C.Y. Liu, President
Two-Way Communications Co., Ltd.
12F/1, No. 99, Sec. 2
Tun-Hwa South Road
Taipei, Taiwan, R.O.C.
Phone: 886-2-707-5829
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ISRAEL
Igal Elan, General Manager
Elan Marketing Group
22 Daphna St., Tel Aviv, Israel
Phone: 972-3-6952967
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INDIA
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PORTUGAL
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SPAIN
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Publicidad Internacional
Pza. Descubridor Diego de Ordas, 1
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ITALY
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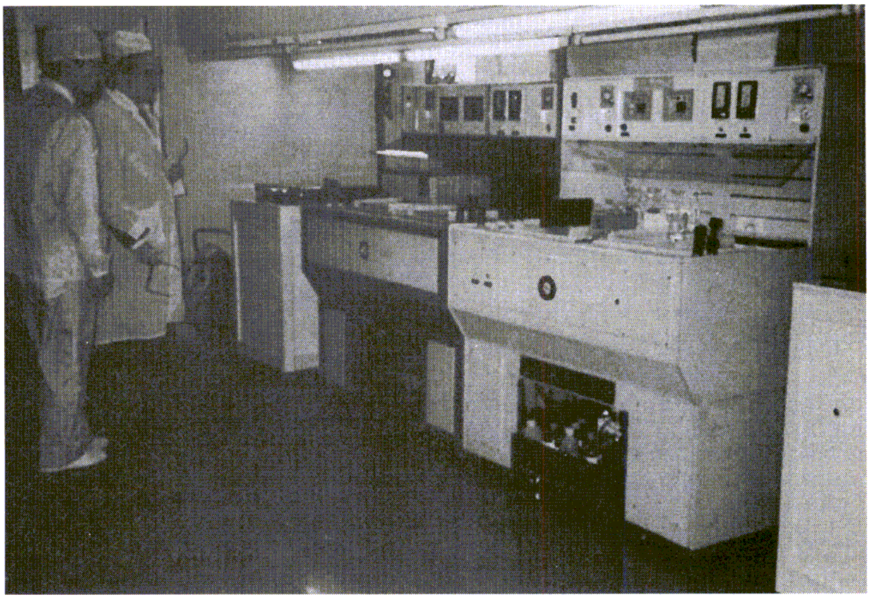

Approximately eight years ago, a Special Report explored emerging markets for electronic equipment in China—markets that are now finally starting to expand. In the photograph above, Harry Rutstein of Dorado Co. (Seattle, WA) was one of the first Americans to establish a cooperative marketing effort with high-frequency electronics firms in China for selling their components in the US.

AUGUST PREVIEW

WIRELESS APPLICATIONS

- **In the news: Exploring export opportunities**
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- **Design a transmit/receive VCO**
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- **How to choose cellular base-station antennas**
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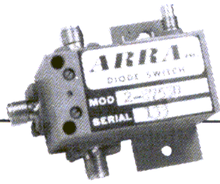

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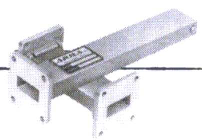

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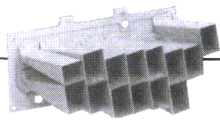

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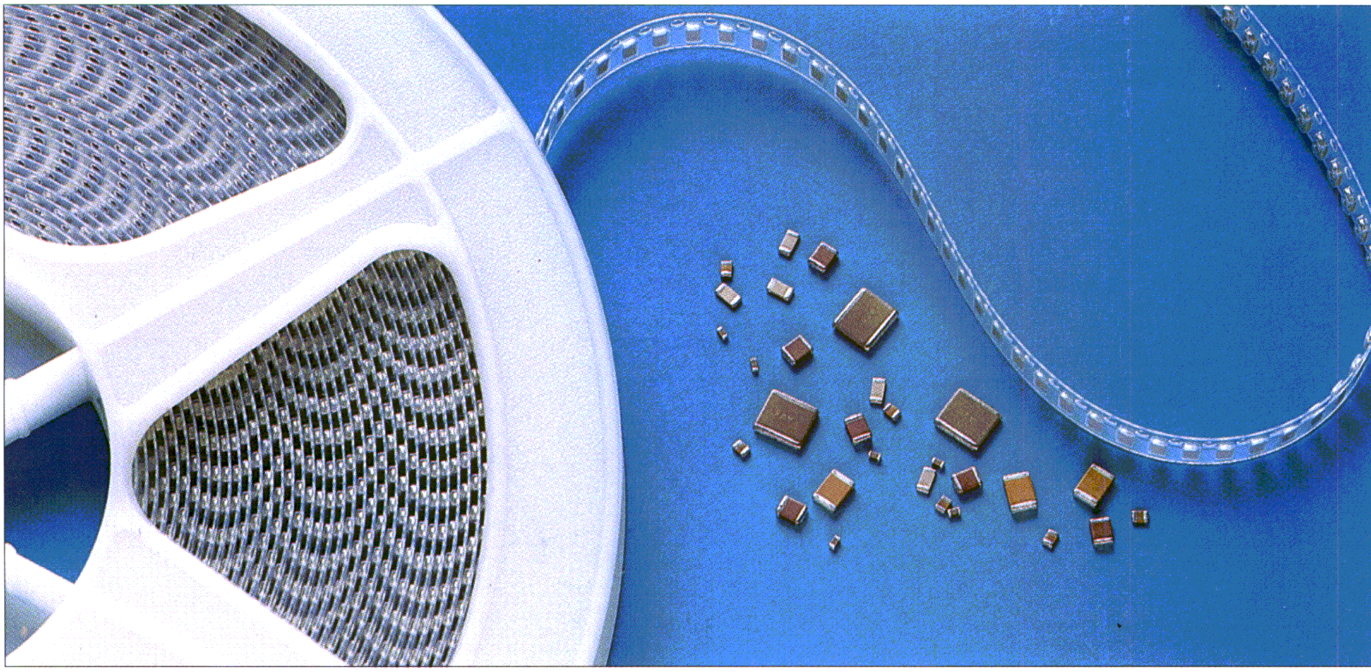
CIRCLE NO. 209

Commercial Line Capacitors



Size	Dielectric	Capacitance Value Range
0603	NPO	1.0 pF to 470 pF
	X7R	470 pF to .022 MFd
	Z5U	.010 MFd to .068 MFd
0805	NPO	1.0 pF to 1000 pF
	X7R	470 pF to .10 MFd
	Z5U	.010 MFd to .22 MFd
1206	NPO	1.0 pF to 4700 pF
	X7R	1000 pF to .22 MFd
	Z5U	.022 MFd to .47 MFd
1210	NPO	220 pF to .010 MFd
	X7R	.010 MFd to .33 MFd
	Z5U	.033 MFd to 1.0 MFd
1812	NPO	470 pF to .018 MFd
	X7R	.022 MFd to 1.0 MFd
	Z5U	.15 MFd to 1.5 MFd
2225	NPO	1200 pF to .047 MFd
	X7R	.033 MFd to 1.5 MFd
	Z5U	1.0 MFd to 4.7 MFd

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