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Microwaves & RF

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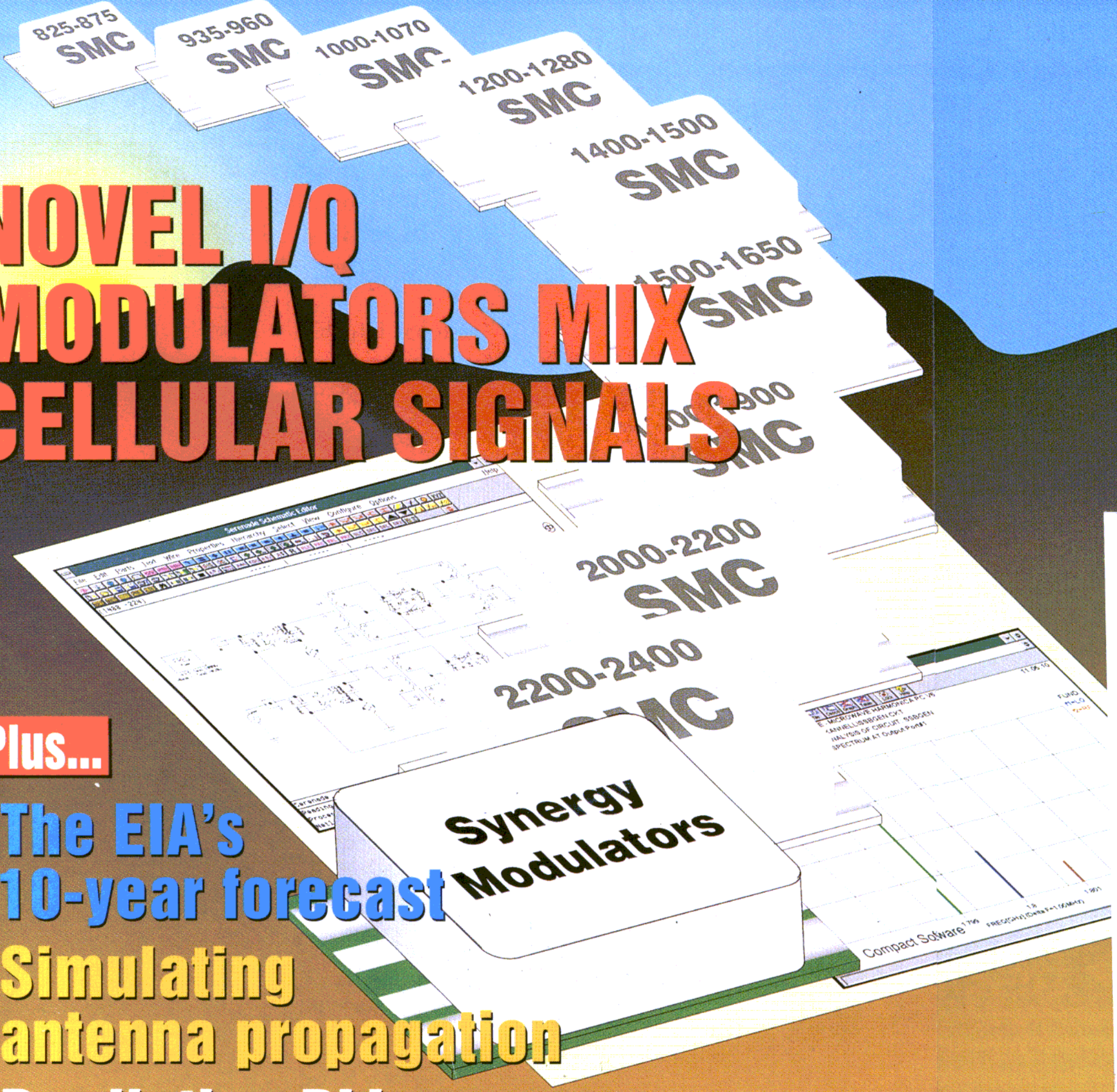

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- The EIA's 10-year forecast
- Simulating antenna propagation
- Predicting PLL phase noise

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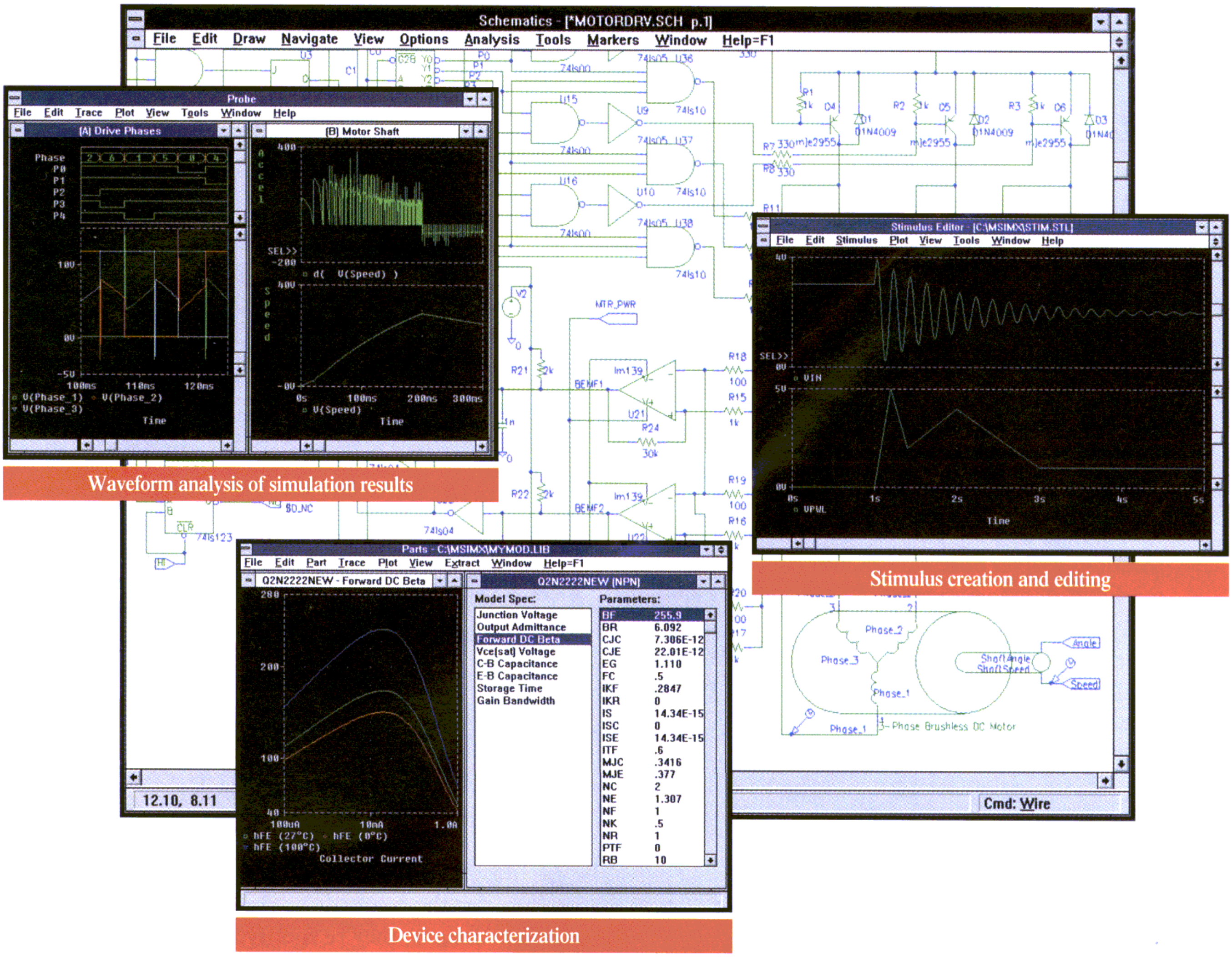

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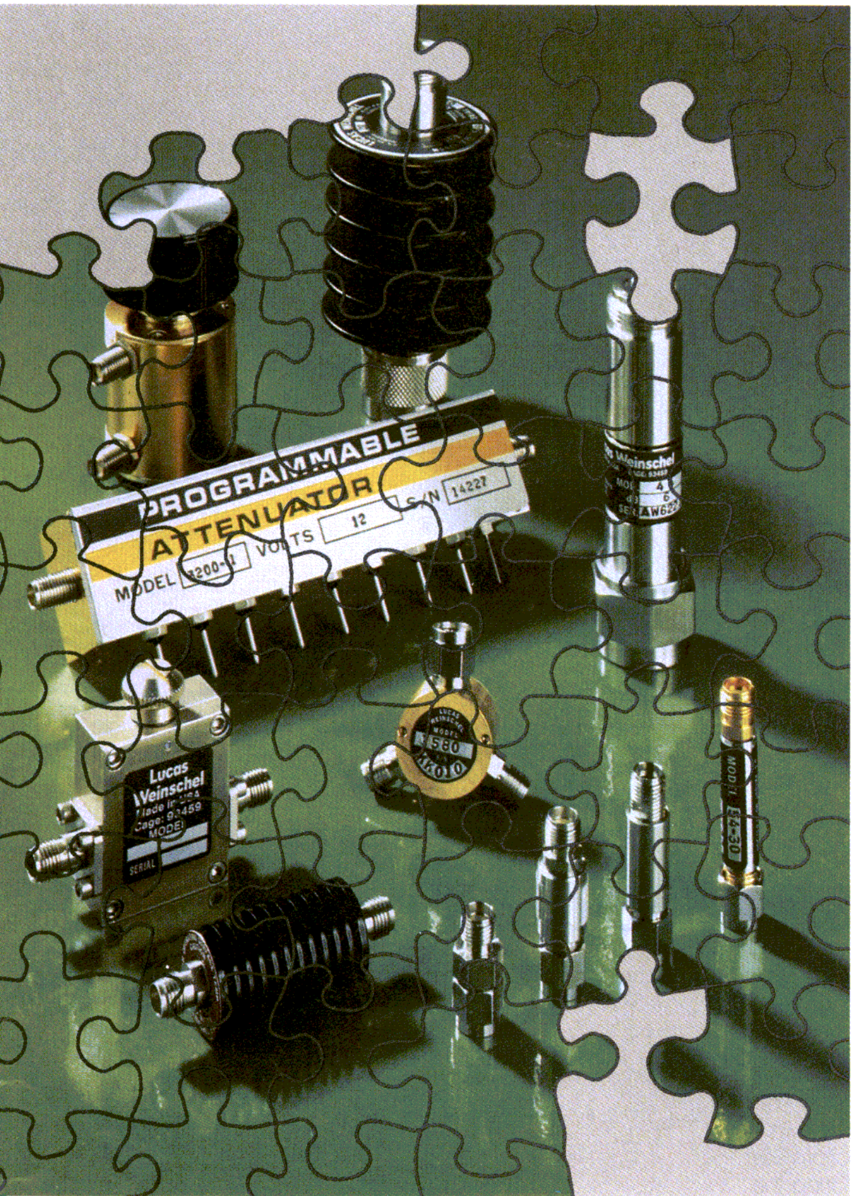

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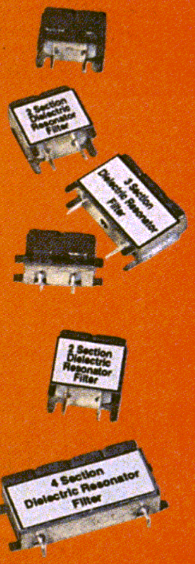

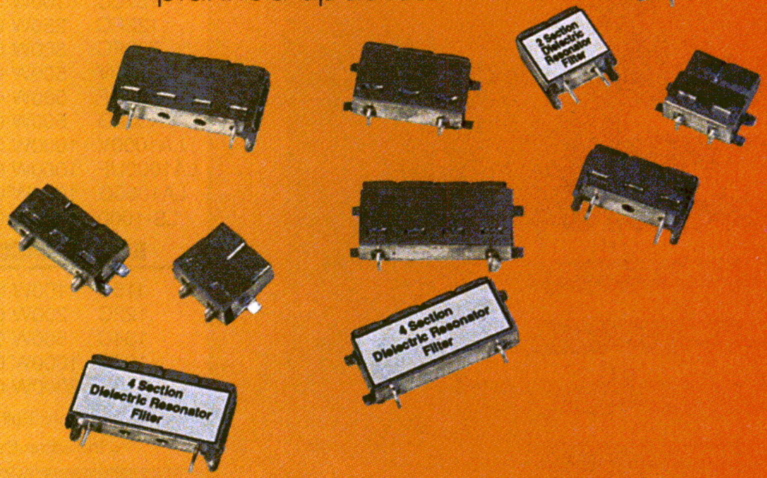

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NOVEMBER 1994 VOL. 33, NO. 11

Microwaves & RF

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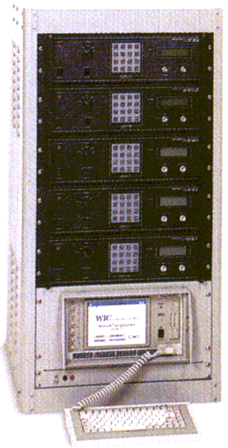
Wireless International Corp. solves tough test problems.

As test engineers and designers, you understand the importance of efficient and effective testing for development and production testing. Poor test methods and inaccurate measurements can bring the production of the best designed equipment to a crawl. Wireless International Corp. (WIC) has answered these problems with plug-in-and-run test systems which provide stimulus, control, and measurement capabilities at your fingertips. Here are just a few of the test solutions.



CDMA Multipath and AWGN test station.

For CDMA testing, WIC's MP-CDMA test system generates multipath and additive noise as specified by IS-98. This system is comprised of the multipath emulator, a precision carrier-to-noise generator, an integrated 486DX/33 computer, and control software with a graphics user interface. The precision carrier-to-noise generator has been designed specifically to operate with extreme accuracy even under the difficult conditions of slow fading for which CDMA systems must be tested. Available frequency ranges are between 800 and 2500 MHz.

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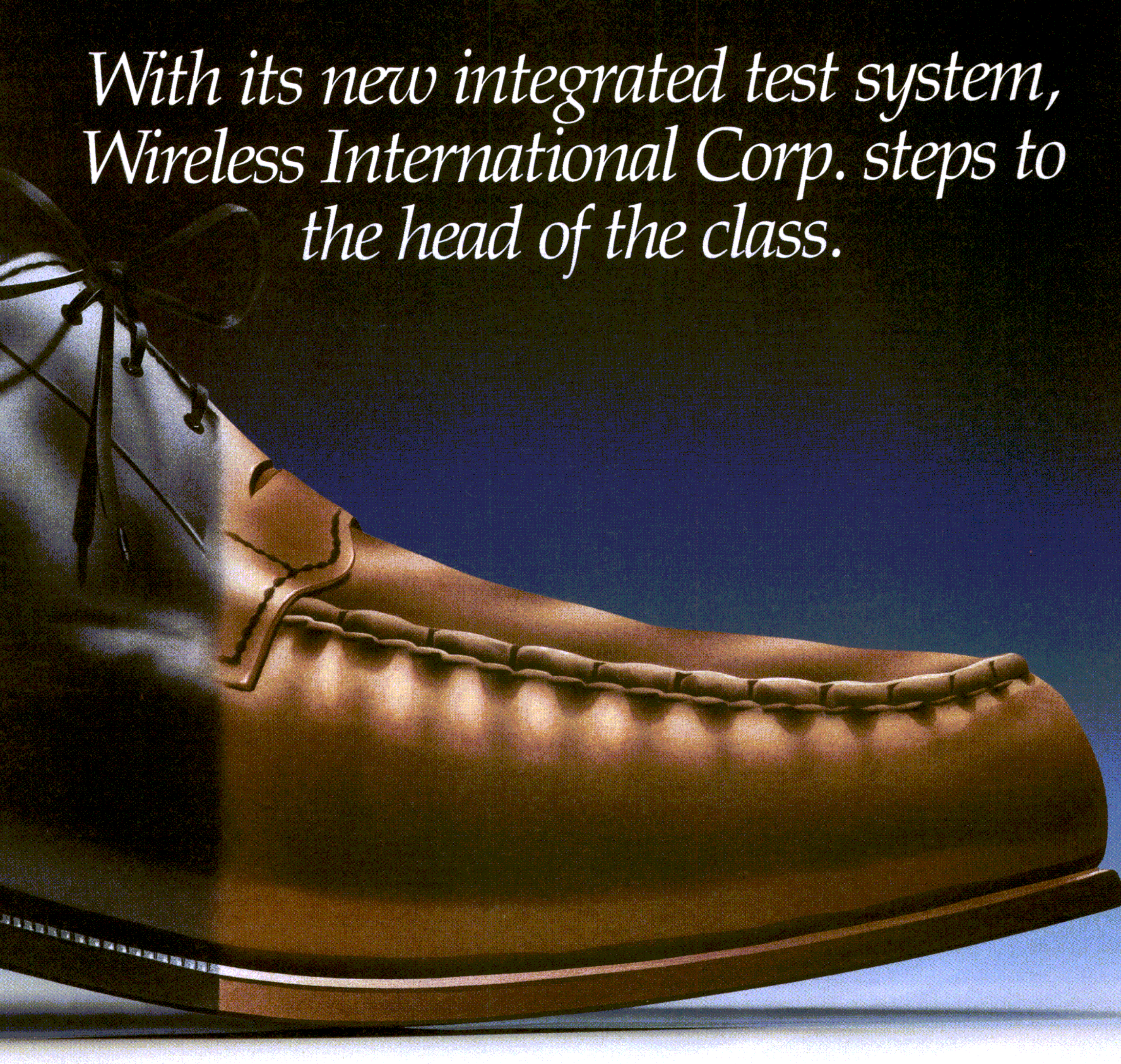
With its new integrated test system, Wireless International Corp. steps to the head of the class.



Multichannel Eb/No versus BER test station.

If you are performing BER versus Eb/No curves for multiple devices simultaneously, then here is your test equipment answer. WIC's Series 800 test stations can generate these curves for up to 8 channels simultaneously, all under the control of a single integrated computer or via the IEEE-488 interface. Each channel contains a precision carrier-to-noise generator and a programmable bit error rate tester. Bit errors and bit error rate data are stored to disk for analysis. Eb/No versus BER curves are generated in both tabular and graphical form for hard-copy output. Data rates up to 8 X 10 MBPS are programmable with error insertion rate, bit slip, and PN code length selections.

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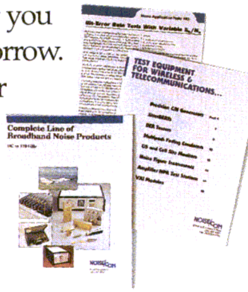
A look into the future.

WIC's products are modular to provide easy upgrading. So the instrument that you buy today won't be obsolete tomorrow.

To receive a FREE copy of our application notes and catalog, contact Bent Hessen Schmidt at Wireless International Corp., E. 49 Midland Ave., Paramus, NJ 07652. Tel: (201) 261-8797. Or fax us at (201) 261-8339.



Wireless Telecom Group INC.

NOISE/COM   WIC Wireless International Corp.

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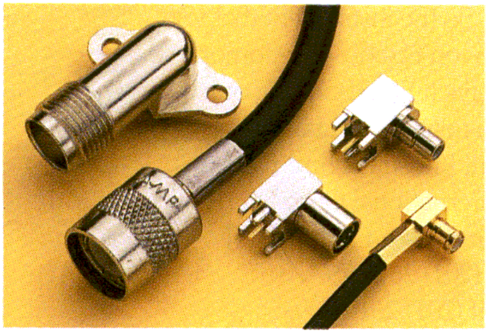
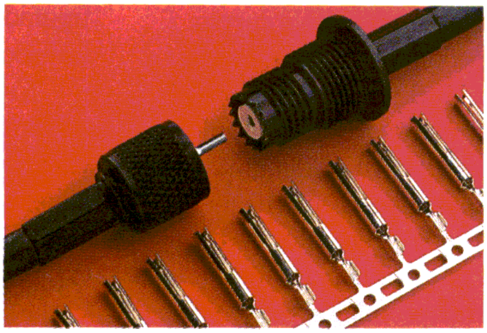
Wherever you may roam, AMP has the RF reach to cover you.





Cellular specials include our conductive black finish versions for antenna mounts. Contacts on strip for mass-production efficiency, available loose-piece for low volume applications.

With its 4GHz top end, our latest RF addition is at home in a range of products, from instrumentation to cellular phones.

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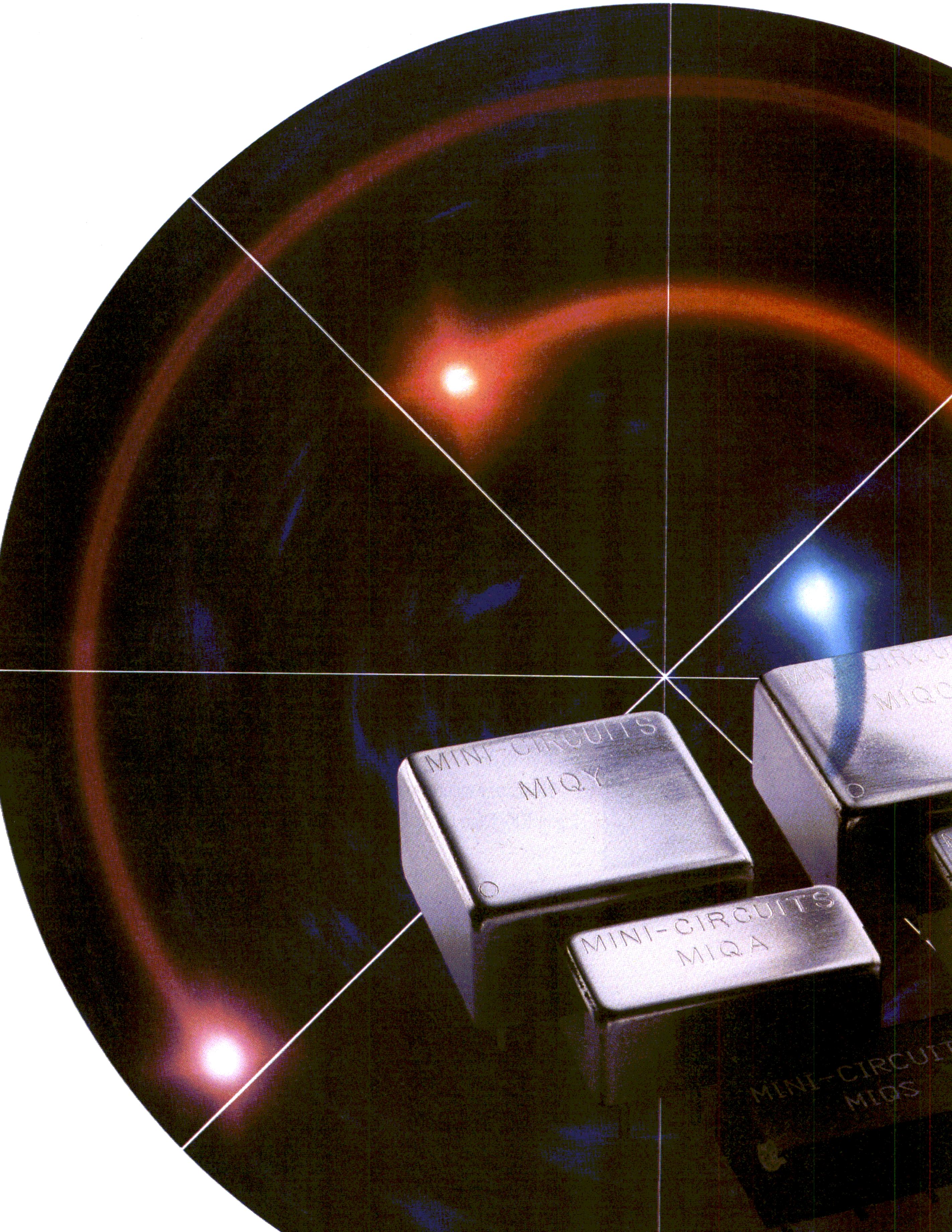
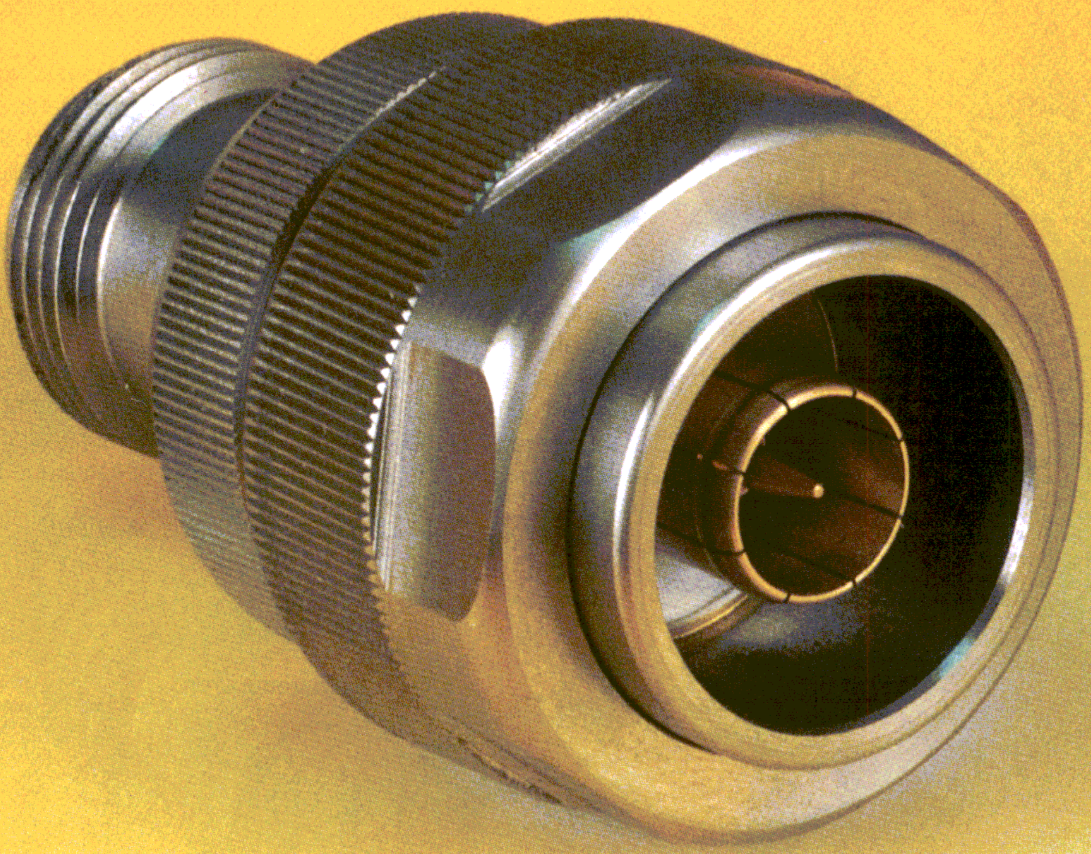


Push-On Connectors

Lock safely to the Standard Thread.   Save Time in Testin



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The 'Connector Saver' consists of the 'Push-On' and the standa
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Noisy effects

To the editor:

The article "Understand the effects of phase noise on ADCs" (June 1994, p. 136) relates the clock phase noise of an analog-to-digital converter (ADC) to an effective number of ADC bits. I have found it more useful to directly compute the effect on the digitized signal. It can be shown that phase-noise sidebands on the ADC's clock appear on the digitized signal, but with relative amplitude reduced by the ratio of signal frequency to clock frequency.

Perhaps there are some problems for which it would be necessary to obtain an effective number of bits corresponding to the Allan Variance. However, it seems that Eq. 3 in the article cannot be correct because it indicates that small fluctuations in sample time or period correspond to large fluctuations in sample frequency, whereas the opposite is true.

Suppose the clock has frequency f_{clock} and is phase-modulated at modulation frequency f_m with an RMS deviation of $\Delta\sigma_{clock}(f_m)$. This might be a discrete modulation component or the phase noise in a narrow band. The modulation results in time jitter at the same f_m with RMS deviation:

$$\Delta T(f_m) = \Delta\sigma_{clock}(f_m)/f_{clock} \quad (1)$$

The time jitter in the clock produces the same change in the ADC's numerical output as would a time jitter of equal magnitude (but opposite sign) in the signal. The numerical output cannot differentiate a delay in the clock from an equal advance in the signal. This time jitter is the same as would be produced by phase modulation on the signal of:

$$\Delta\sigma_{signal}(f_m) = -f_{signal}\Delta T(f_m) = -\Delta\sigma_{clock}(f_m)f_{signal}/f_{clock} \quad (2)$$

Therefore, the amplitude of the apparent phase jitter on the signal equals that of the phase jitter on the clock multiplied by the ratio of the signal frequency to the clock frequency.

Equation 2 holds for all modulation frequencies, so the phase-noise spectrum of the clock is transferred to the signal with the given change in magnitude. Over the region for which the modulation index can be considered small, the apparent spectrum (as indicated by the digitized data) of a clean sinusoid will have the same shape as the spectrum of the noisy sinusoidal clock, except the sidebands will be smaller by [20 dB $\log(f_{clock}/f_{signal})$].

William F. Egan
Cupertino, CA

Company correction

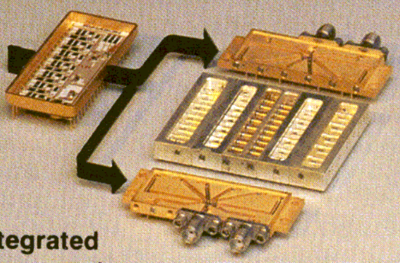
To the editor:

In regard to the article "National telesystems conference focuses on advanced applications" (June 1994, p. 39), engineers at the Fausto Marti Co. were stated as presenting a paper on the airport applications of a radar system. However, the Fausto Marti Co. does not exist. The paper was presented by Gaspare Galati of the TorVergata University of Rome, Mauro Ferri of Oerlikon Contraves Rome, and myself.

Fausto Marti, Ph.D.
TorVergata University of Rome
Rome, Italy

miniature
SWITCH-FILTER BANKS
0.5 to 18.0 GHz

Channel B.W.: 2% to 80%
Up to SP10T
Hermetically Sealed
Switching Speeds to 15 nsec.
Choice of Input Logic
Limiter Protection Option



Miniature filter banks, integrated with PIN-diode switching networks are available from 0.5-18.0 GHz. Customized in performance, these channelizers are user-programmable for channel selection and sequencing.

PRESELECTOR-SWITCH
6.0-18.0 GHz
6-Channels + Filter By-Pass

Frequency Range	6.0-18.0 GHz
Switching speed	100 ns max. 50% TTL to 10/90% RF
Switch Isolation	65 dB min.
TTL Control (3 lines)	3 to 8 Decoder
Power Supply Req.	+5V @ 250 mA, −15V @ 50 mA
Insertion Loss / Variation	7 dB/2dB max. (all passbands)
Reject Band Isolation	60 dB min.

Channel	Passband (GHz)	Reject Bands (GHz)	
#1	6.0- 8.0	2- 4.9	8.9-20
#2	7.6-10.3	2- 6.3	11.4-20
#3	9.8-12.2	2- 8.9	13.2-20
#4	11.8-14.2	2-10.9	15.6-24
#5	13.8-16.2	2-12.8	17.3-24
#6	15.8-18.0	2-15.0	18.9-24
#7	6.0-18.0 Filter By-Pass		

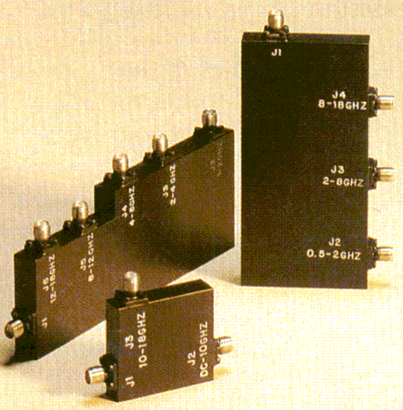
Size	3.85 x 3.50 x .66"
Connectors	SMA Female
Maximum RF Power	250 mW CW
Operating Temp.	− 40°C to +95°C
Storage Temp.	− 55°C to +125°C

CIRCLE NO. 252

0.400" thin LOW PROFILE

0.375" on request and even thinner when supplied with input/output solder pins.

Standard Crossover Frequencies
1 GHz
2 GHz
4 GHz
6 GHz
8 GHz
10 GHz
12 GHz
14 GHz
18 GHz
20 GHz
26 GHz
34 GHz



Custom crossover frequencies anywhere - up to 40.0 GHz

DC to 40.0 GHz
- Diplexers
- Triplexers
- Quadruplexers
- Quintaplexers
- Sextaplexers

Frequency Range:	DC to 40.0 GHz
Crossover Frequencies:	1-2-4-6-8-10-12-14-18-20-26 and 34 GHz
Crossover Regions:	± 4% f_{co} max.
Crossover Insertion Loss:	4.5 dB max.
Passband Insertion Loss:	1.0 dB max. (DC-26 GHz) 1.5 dB max. (26-40 GHz)
Common Port VSWR:	2.0:1 max. (DC-26 GHz) 2.5:1 max. (26-40 GHz)
Selectivity: *	60 dB min., ± 15% f_{co} and band ends when specified
Operating Temperature:	-54°C to +95°C

* **If required, sharper rejection can be provided without compromise in performance.**

DESIGN FLEXIBILITY
The low profile series has the design flexibility of twelve specific crossover frequency choices (from 1.0 to 34.0 GHz) that define the most popular allocated EW-bands from DC to 40.0 GHz. Engineers and system planners may select and specify almost any combination of multiplexed bands to easily satisfy their requirements in a standard Microphase catalog model.

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SUCCESSIVE DETECTION LOG VIDEO AMPLIFIERS

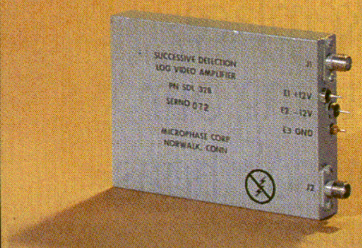
70 dB Dynamic Range

- Exceptional Log Linearity
- Excellent Frequency Flatness

● ABSOLUTE ACCURACY ± 1.75 dB*

Under any combination of frequency, power level and operating over −54°C to +85°C

*for SDL-328



A novel and unusual approach halves the number of successive detection points, thus simplifying gain and frequency compensation vs. temperature. The result is improved linearity, frequency flatness, temperature stability and absolute accuracy.

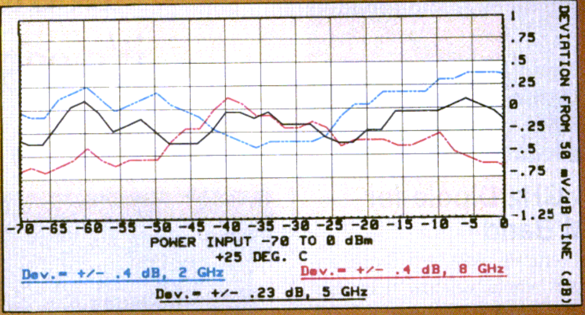
The key component of this design is a proprietary Differential Schottky Detector-Limiter. These devices, operating over narrow portions of their dynamic ranges, provide both low and high level video signals, which are then differentially-coupled to single, low gain video amplifier stages, enabling improved rise time and recovery time.

Model	SDL-328	SDL-3618
Freq. (GHz)	2.0–8.0	6.0–18.0
Freq. Flat.	±1.0 dB	±2.0 dB
VSWR	2.0:1 max.	2.0:1 max.
TSS	−73 dBm	−71 dBm
Log Range	−70 dBm to 0 dBm	−68 dBm to +2 dBm
Log Slope (1)	50 mV/dB	50 mV/dB
Log Lin. (2)	±1.0 dB	±1.5 dB
Recovery	80 ns	60 ns
Absolute Accuracy (3)	±1.75 dB	±3.0 dB

SDL-328/SDL-3618	
P.W. Range	20 ns to C.W.
Rise Time	15 ns
Video Load	93 Ohms
Power	+12V/−12V
Size	3.50 x 2.60 x 0.50"
Op. Temp.	−54°C to +85°C

(1) Other Log Slopes are available.
(2) At any frequency or temperature
(3) Total: Under any combination of frequency, input power level and operating over − 54°C to − 85°C

LOG LINEARITY vs. FREQUENCY



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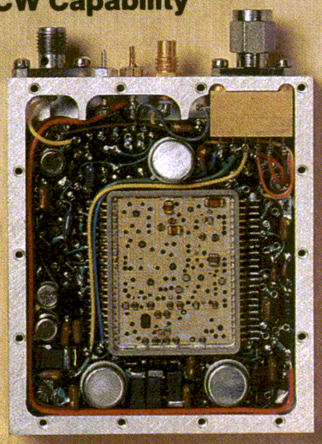
62 dB DYNAMIC RANGE

DC-Coupled DLVA

Extended Dynamic Range −42 dBm to +20 dBm

- **Volume Less than 3 cu. in.**
- **Superior Linearity**
- **Fast Recovery from +15 dBm**
- **+20 dBm CW Capability**



A unique and proprietary "single-diode" detecting circuit overcomes linearity and recovery problems associated with conventional, DC-coupled, extended range dual diode DLVA designs.

2.0–18.0 GHz
Model DSH-3218

Frequency Range	2.0–18.0 GHz
Flatness @ −23 dBm	±1.0 dB
VSWR	3.0:1 max
TSS	−42 dBm min.
Logging Range	−40 dBm to +18 dBm
Log Slope	50 mV/dB
Log Linearity	±0.5 dB (−40 dBm to +18 dBm)
Output Stability (−54°C to +85°C)	±1.0 dB
Pulse Width Range	50 ns to C.W.
Rise Time	20 ns max
Recovery Time (for ±1.5 dB accuracy)	500 ns max (to +15 dBm)
Video Load	100 ohms
Power (No Signal)	+15V ±5%; 190mA max −15V ±5%; 100mA max
Operating Temp	−54°C to +85°C
Size (excl. conn.)	2.70 × 2.30 × 0.47 in.

Available Options:
- Input D.C. bias offset to counter detector R.F. noise rectification
- Other wide-band frequency ranges down to 0.5 GHz or narrow band designs with optimized characteristics.
- Log Slope to 75 mV/dB

CIRCLE NO. 255

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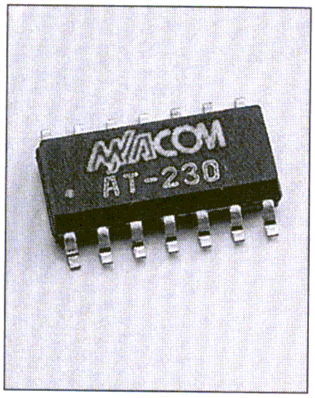

New GaAs MMIC Digital Attenuator

3 bit, 4 dB step in a low cost, SOIC 14 lead, surface mount, plastic package. This digital attenuator covers DC - 2 GHz and has superior attenuation accuracy (0.30 dB $\pm$ 3% of attenuation setting). IP3 $\geq$ 50 dBm at 0.5-2 GHz. Low loss measures 1.5 dB typ.
P/N AT-230

M/A-COM, Inc. 1-800-366-2266

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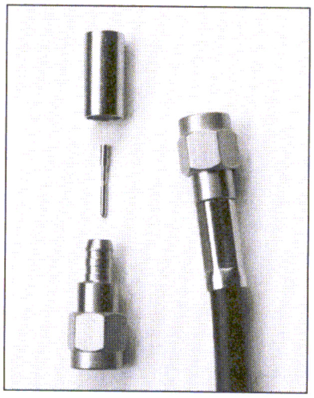

New 3-Piece SMA Connectors

Fewer component piece parts and crimpable center contacts reduce installation costs up to 70%. Stainless steel construction ensures reliable, consistent performance. These connectors are available for flexible RG/U and double braided RD-316 cables . They can be crimped using industry standard tooling.

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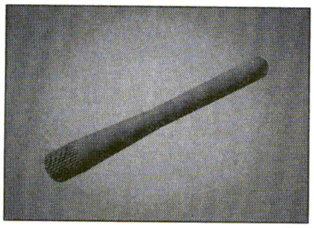

2.4 GHz Dipole for ISM Band

This vertically polarized Dipole antenna is omnidirectional in azimuth and has a frequency range of 2400-2485 MHz. Gain is 2.0 dBi peak and VSWR is 2.0:1. This antenna can be used for a number of ISM applications including wireless LANs and inventory control scanners. Connectors available in SMA female, reverse sex conn. and M/A-COM's OSMT surface mount connector.
P/N AND-C-107

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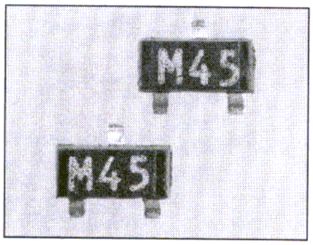

New Low Capacitance Surface Mount Schottky Diodes

These low capacitance (.25 pF max.) Schottky diodes can be used at frequencies through X-band as low cost, sensitive detector and mixer diodes. Designed for commercial applications including RF smart cards, DBS receivers and wireless receivers.
P/N MA4E1245 series

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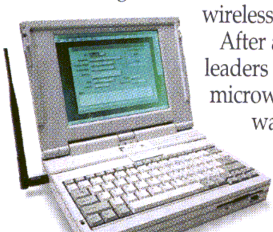
In the race to the marketplace, it's easy to spot people using our wireless data transmission solutions.

In today's intensely competitive wireless environment, the race goes to the swift (and the smart). That's why so many smart companies are turning to M/A-COM to help make their wireless applications a reality.



After all, we've been leaders and innovators in RF, microwave and millimeter wave technology for more than 40 years. Successful companies have learned that M/A-COM has proven, cost-effective solutions that work today—across the spectrum.

You'll find our products are already hard at work around the world in both LANs and WANs. Connecting everything from pen-based computers to bar code scanners to personal communicators. And while today we're helping you with data and voice transmission, we're also ready to take you into the realm of integrated data, voice and video applications.

So if you're looking for more than a supplier, if you're looking for a strategic partner that will help you with product development, innovative solutions and high-volume low-cost manufacturing, look to M/A-COM. We'll give you such a competitive advantage, it'll almost be unfair.

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Please see us at Booth #501 at RF Expo East

CIRCLE NO. 225

MAINTAINING A DEFENSIVE POSTURE

Military contractors and suppliers of electronics components may soon be able to stop holding their collective breaths; the end of the "bloodbath" is in sight. The consolidation of military contractors projected for the end of the Reagan Administration is coming to pass, with a leaner and, hopefully, more efficient defense electronics community surviving throughout the remainder of the 1990s. When the dust settles after 1995, defense business should at least stabilize.

The silver lining to these defense-oriented clouds arises from consistent projections made by the Electronic Industries Association (EIA) in the organization's 10-year forecast of Department of Defense (DOD) and NASA spending. (see Senior Editor Ron Schneiderman's Special Report on the EIA's forecast, pp. 35-41.) Several years ago, the EIA prophesized that 1995 would be a pivotal year for the DOD and its suppliers. In 1995, the organization predicted, cuts in US defense appropriations would reach a steady state, remaining at that reduced level throughout the remainder of the millennium.

Certainly, it is unlikely that companies such as Loral and Martin Marietta are finished with their acquisitions of viable defense-related firms. Still, the process of dividing the defense "pie" has gone on long enough to give a fairly clear picture of who the key remaining defense players will be in the years to come.

Of course, while this is hardly the signal for wild celebration, the leveling of defense cuts does signify stability for firms involved with defense business. Admittedly, military business throughout the remainder of the 1990s will be a mere fraction of the high-water marks enjoyed during the 1980s, but at least the business will be predictable. That is perhaps the most important aspect of the EIA's projections: that defense-based businesses will be able to make their somewhat accurate business projections without trying to guess what programs will be cut by politicians hoping to appease a peace-minded electorate.

Will the defense business ever disappear totally? Probably not, considering the state of mankind and the fact that such things as racial hatred, mistrust, hunger, greed, and megalomania are sure to be with us for a long time.

To perform successfully in this new, leaner, military environment, lessons must be learned from companies that have prospered in commercial pursuits. Even strictly military firms will have to think like commercial houses, using software to develop component and system models to save time, incorporating cell-based manufacturing approaches to cut production time and improve quality, and relying on automated assembly equipment to reduce labor costs. The high profit margins of the 1980s are gone. These newer commercial design/manufacturing strategies may also work quite well in helping remaining military suppliers to achieve profitability.••

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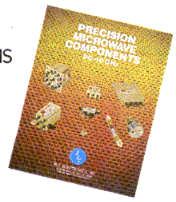

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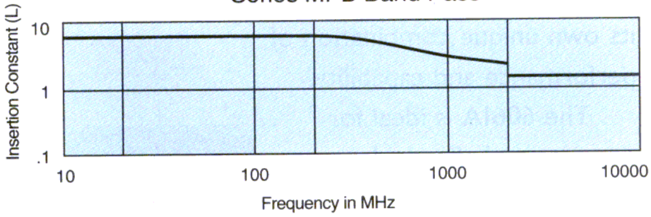

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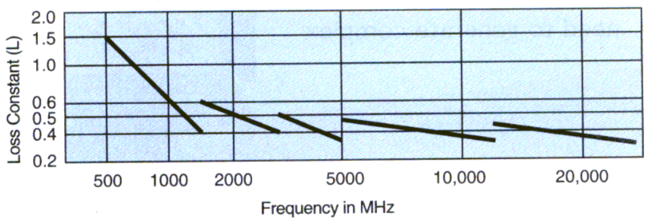

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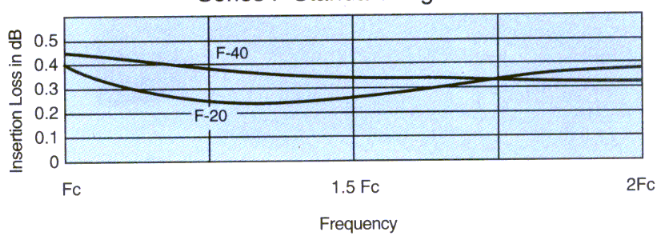

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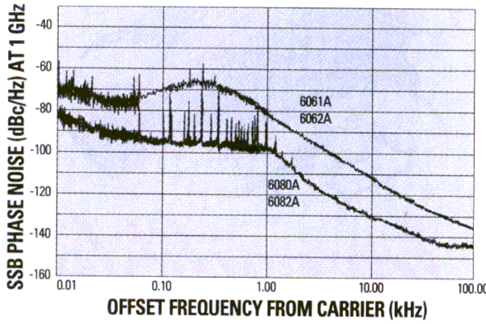

Yes, Giga-tronics is a new name in RF synthesizers.

But this new choice may be your best choice.

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The 6062A adds the modulation capability you need to generate complex signals for communications and radar testing.

And the 6080A and 6082A give you the performance and capability to test sophisticated systems accurately and quickly.

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The John Fluke Manufacturing Company initially developed and introduced this line of synthesized RF signal generators. To date, thousands have performed flawlessly in the field.

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Specifications	Giga-tronics 6061A	Giga-tronics 6062A	Giga-tronics 6080A	Giga-tronics 6082A
Frequency Range Switching speed	.01 to 1050 MHz <100 ms	.1 to 2100 MHz <100 ms	.01 to 1056 MHz <100 ms	.1 to 2112 MHz <100 ms
Spectral Purity* Spurious Subharmonics	<-60 dBc None	<-54 dBc <-45 dBc	<-100 dBc None	<-94 dBc <-45 dBc
Phase Noise* @ 20 kHz offset	<-117 dBc/Hz	<-110 dBc/Hz	<-131 dBc/Hz	<-125 dBc/Hz
Residual FM* (Bandwidth)	<12 Hz (.5 to 3 kHz)	<24 Hz (.5 to 3 kHz)	<1.5 Hz (.3 to 3 kHz)	<3 Hz (.3 to 3 kHz)
Output Range* Accuracy Reverse Power Protection	+13 to -147 dBm ±1 dB >127 dBm 50 Watts/50 Vdc	+13 to -147 dBm ±1.5 dB >-127 dBm 25 Watts/25 Vdc	+17 to -140 dBm ±1 dB >127 dBm 50 Watts/50 Vdc	+13 to -140 dBm ±1 dB >-127 dBm 25 Watts/25 Vdc
Amplitude Modulation Depth Distortion @ 30%	0–99.9% <3%	0–99.9% <3%	0–99.9% <1.5%	0–99.9% <1.5%
Frequency Modulation Max. Deviation* Distortion	100 kHz <1%	400 kHz <1%	4 MHz <1% @ 50% Dev.	8 MHz <1% @ 50% Dev.
Phase Modulation Max. Deviation*	NA	40 Rad.	40/400 Rad.	80/800 Rad.
Pulse Modulation On/off Rise/fall time Minimum Pulse Width	NA	>80 dB <15 ns <2 μs	>40/60 dB <15 ns (Typ 7.5 ns) <30 ns	>80 dB <15 ns (Typ 7.5 ns) <30 ns
Internal Modulation Source Level Range Waveforms Programmable	400, 1000 Hz NA Sine Yes	400, 1000 Hz NA Sine Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes	0.1 Hz to 200 kHz 0 to 4 Vpk Sine/Sq/Tri/Pulse Yes
Memory Locations (NVM)	50 Full Function	50 Full Function	50 Full Function	50 Full Function

*Specifications for the 6061A and 6080A are at 1 GHz, and specifications for the 6062A and 6082A are at 2 GHz. Phase noise is typical for the 6061A and 6062A.

internal diagnostics and modular design for easy fault isolation.

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DOD, agencies talk wireless

WASHINGTON, DC—Looking to save money wherever they can, the DOD and federal civilian agencies are investigating the possibility of joint purchases of cellular phones and services.

The Federal Wireless Policy Committee (FWPC), formed in January to make recommendations on government use of wireless communications technologies, is working with the Defense Information Technology Contracting Office to develop a plan for joint procurements.

A recent study by the Defense Commercial Communications Office (DECCO) indicates that more than 8000 cellular phones are in use in the DOD. The total number of cellular subscribers in the federal government is estimated at more than 20,000.

Eventually, any agreement between the agencies could be extended to include other wireless products.

Army sees mobility limits

FORT MONMOUTH, NJ—What major limitations does the US Army face in its current communications capabilities?

One of the Army's biggest problems, according to Brig. Gen. Michael W. Ackerman, deputy commanding general of the US Army Signal Center (Fort Gordon, GA), is the need for more "fully-mobile" communications equipment. Most current systems, he says, "cannot keep pace with battle tempo."

Another problem, Ackerman said during the IEEE Milcom conference in October, is that the Army is too dependent on terrestrial line-of-sight systems. "We cannot provide command and control (C^2) support over extended ranges." Other problems, he says, include the limited operability of combat radios and networks, limited bandwidth, low throughput, no multimedia capability, and limited support for intelligence and imagery requirements.

GaAs to grow 18 percent/year

LONDON, ENGLAND—Because of their inherent advantage in high-speed and low-power applications, the worldwide market for gallium-arsenide (GaAs) devices will grow at a compound average annual rate of 18 percent from $385 million in 1993 to $878 million in 1998, according to a study by BIS Strategic Decisions.

Growth in device production will increase demand for GaAs wafers to 15 percent per year, but price erosion will lead to only a 7-percent annual growth in value, says the BIS study, *Gallium Arsenide and High Speed Circuits*. The study gives GaAs less than 1 percent of the total semiconductor market.

Market drivers for GaAs devices, according to BIS, are high-speed computing and fiber-optic communications, which are expected to account for more than 80 percent of the merchant market for digital integrated circuits (ICs) by 1998.

BIS says the rapid growth of wireless communications will start to displace military applications as the leading sector for monolithic microwave ICs (MMICs) in 1995. By 1998, wireless communications and consumer applications will represent more than 60 percent of the MMIC market.

According to BIS, the trend to integrate functions within MMICs as well as the pressure on prices, which will affect the value growth, means the merchant market for discrete GaAs FETs will grow at a compound annual rate of only 5 percent over the next five years.

Motorola, Telecom team

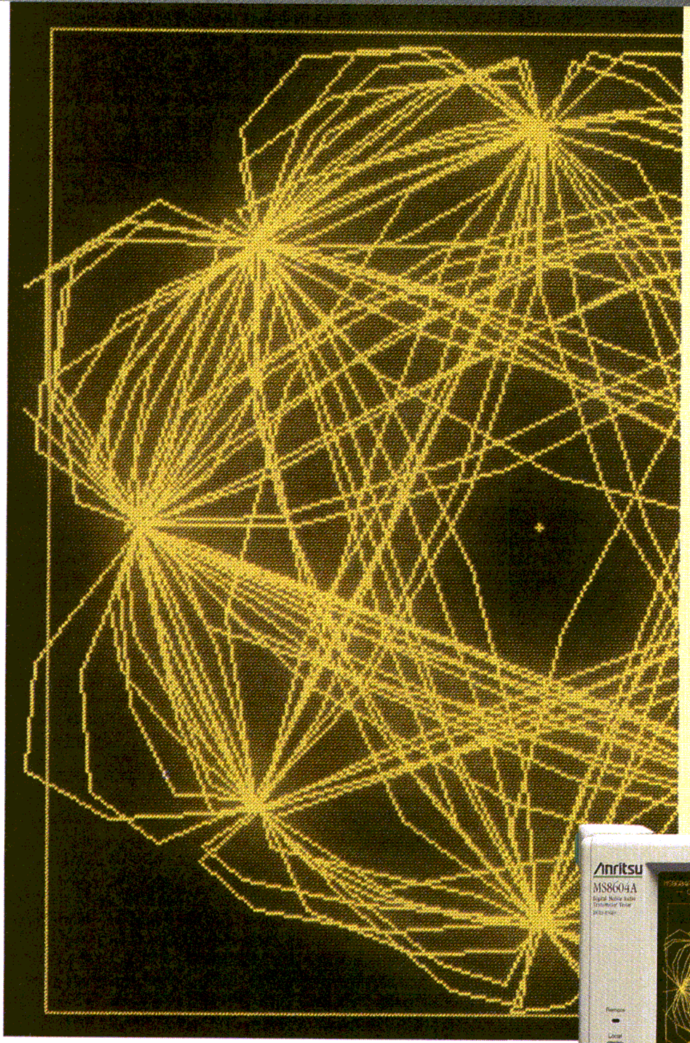
SCHAUMBURG, IL—Motorola, Inc. and Telecom Analysis Systems (TAS) of Eatontown, NJ have agreed to incorporate Motorola's R-2600 communications system analyzer with TAS equipment and software for wireless-communications test applications.

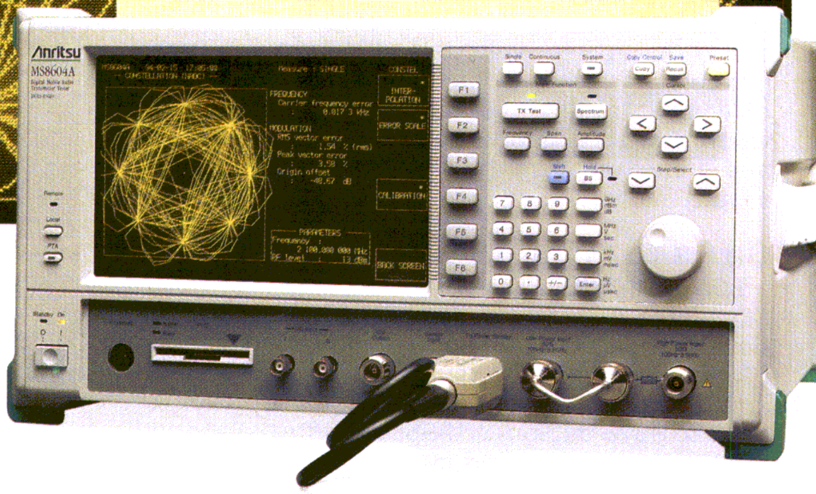
The first such application is the new TAS GT-Cellular, a system for automatic performance testing of cellular modems and cellular fax machines. TAS will OEM the Motorola product and will re-label it the TAS 6600 Wireless Communications Analyzer. The GT-Cellular system models an end-to-end connection from a mobile cellular modem to a land-based modem.

The Motorola/Telecom Analysis Systems 6600 communications system analyzer.

Pricing of the system depends on the specified configuration.

TAS and Motorola are also exploring engineering enhancements to both companies' products to address additional wireless testing applications.





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New PCS software tool

ATLANTA, GA—Engineers at the Georgia Tech Research Institute (GTRI) have developed a software package to predict how radio waves transmit and are reflected inside offices and other buildings.

The patent-pending cell engineering tool (CET) incorporates several distinct analytical methods into a single software package and is based on extensive experimental measurements in a wide range of buildings.

By describing the geometric configuration of a building's walls, ceilings, windows, and doors, telecommunications engineers can use the tool to "make some educated judgments" about where to locate personal-communications-system (PCS) base stations, says Eric Barnhart, a GTRI research engineer. He says the ability to quickly choose the best locations will minimize the number of stations necessary to provide service in a building, thereby reducing the system's cost.

The researchers first applied for and received an experimental license from the Federal Communications Commission (FCC) to characterize how PCS might work when deployed. They focused on the band from 1850 to 2200 MHz—the area of the spectrum the FCC has assigned to PCS.

The research program was sponsored by Hitachi Telecom USA, Inc., but part of the work was carried out in an earlier project supported by BellSouth to characterize indoor propagation of PCS.

Japan's connector market grows

WEST CHICAGO, IL—The Japanese electronic connector market, which totaled $3.4 billion in 1993 and accounted for 1.2 percent of the country's total electronic equipment production, will grow at a compound average growth rate (CAGR) of 5.3 percent over the next five years to $4.4 billion in 1998, according to a market study conducted by Bishop & Associates, Inc.

Bishop says that printed-circuit-board (PCB) connectors were the most commonly-used connectors in Japanese electronic equipment in 1993, totaling $1.5 billion in value. Rectangular input/output (I/O) connectors ranked second in use.

FCC ready to license satcoms

WASHINGTON, DC—The Federal Communications Commission (FCC) has developed a plan that would let up to six companies share frequencies assigned to emerging mobile communications services.

The big winner from the FCC's decision is expected to be Iridium, Inc. (Washington, DC), a consortium that is 27-percent-owned by Motorola, Inc., which plans to begin operating a 66-satellite network by 1998. Proposals for similar systems have been filed by Loral/Qualcomm, a venture of Loral Corp. and QUALCOMM Corp.; TRW, Inc.; Constellation Communications, Inc.; Mobile Communications Holdings, and American Mobile Satellite Corp., which plans to operate a mobile satellite system using a different set of frequencies than the other applicants.

The FCC has required each of the companies to file a revised application by November 16. They have until January 1996 to demonstrate their financial qualifications to develop and launch their satellite networks.

US WEST's new data business

SEATTLE, WA—Noting that customers have different wireless application needs and use a wide variety of computers, cellular phones, modems, and other equipment, US WEST Cellular has launched a new wireless-data business offering an array of products and services across its 13-state service area.

Supporting US WEST Cellular Wireless Data is a growing alliance of software and hardware providers, vendors, distributors, and systems integrators, as well as a line of off-the-shelf cellular data equipment. Charter members of the US WEST Cellular Wireless Data Alliance are MobileData Communications Corp. (Phoenix, AZ), Synergetics International, Inc. (Longmont, CO), Traveling Software, Inc. (Bothell, WA), and U.S. WIRELESS DATA, Inc. (Boulder, CO).

The products being offered by US WEST include a line of data-capable cellular phones by Audiovox, Motorola, and Nokia; cellular modems produced by AT&T and Microcom; and cellular fax machines by Mitsubishi. As new products are tested, US WEST will add them to its equipment list.

Proxim, Intermec enhance deal

MOUNTAIN VIEW, CA—Proxim, Inc. has expanded its relationship with Intermec (Everett, WA), calling for Intermec, a manufacturer of bar-code-based data-collection hardware and software, to integrate Proxim's 2.4-GHz frequency-hopping RangeLAN2 system into Intermec's JANUS handheld data-collection product family.

The agreement also enables Intermec to market customized versions of the RangeLAN2/PCMCIA, RangeLAN2/ISA, and RangeLAN2/Access Point products through Intermec's worldwide distribution channels.

Intermec already offers a range of RF data-collection products in the US using Proxim's 902-MHz direct-sequence spread-spectrum technology. Intermec plans to integrate an OEM version of the RangeLAN2/PCMCIA product into the JANUS PC-compatible handheld units with built-in scanners and keypads.

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CIRCLE NO. 248

Recommendations for 900 MHz

WASHINGTON, DC—Ten manufacturers and systems integrators of electronic-toll and traffic-management systems have jointly recommended that the Federal Communications Commission (FCC) reserve portions of the 902-to-928-MHz frequency band for use by automatic vehicle-identification (AVI) systems.

The action, under consideration in FCC Docket 93-61, is aimed at eliminating interference in AVI systems used to collect tolls and traffic data electronically. Several hundred thousand motorists are already using AVI equipment in the 902-to-928-MHz band.

The recommendations came in the form of a letter to FCC Chairman Reed Hundt. It was signed by representatives of Amtech Corp., Delco Electronics Corp., Intellitag Products, Mark IV Industries, Motorola, AT/Comm, Hughes Transportation Management Systems, Lockheed IMS, MFS Network Technologies, and Texas Instruments.

Several states have issued requests for proposals (RFPs) seeking AVI systems operating at 2.45 GHz rather than 902 to 928 MHz, but none of these states have yet implemented a system at the higher frequency. Among the group's arguments is that a jump to the 2.45-GHz band would require substantial industry investment in research and development (R&D) and production with no operational or functional benefit.

Varian to sell division

PALO ALTO, CA—Varian Associates, Inc. is looking for a buyer for its electron devices operations, the smallest and oldest of its four core businesses.

J. Tracy O'Rourke, Varian's chairman and CEO, estimated the value of the business at close to $150 million. In Fiscal Year 1994, Varian posted sales of $275 million and had pretax earnings of $18 million.

Varian's electron devices organization produces vacuum tubes, power supplies, amplifiers, and other products largely for communications, medical, and defense markets. It employs 1700 workers primarily at plants in Palo Alto, San Carlos, and Santa Clara, CA; Beverly, MA; and Georgetown, Canada.

O'Rourke says the decision to sell the business allows the company to exit what is essentially a components business and intensify its focus on faster-growing equipment segments serving the health-care, semiconductor-equipment, and instruments markets. However, he says the sale is dependent on getting a price that recognizes the improving value of the electron devices operation.

The investment banking firm of Morgan Stanley & Co. has been retained to identify potential buyers and assist in the sale.

EC adopts satcom plan

WASHINGTON, DC—The European Community (EC) has adopted a liberalized satellite-communications (satcom) equipment and services policy for the European Union (EU) that is expected to yield a 10-fold increase in satcom revenues in the region by the year 2000. Studies estimate that as many as 80,000 very-small-aperture-terminal (VSAT) satellite dishes may be deployed across the EU by that time. "The major users are expected to be in retailing, distribution, and financial sectors," the EC says. "Many similar potential users in the European Union have pan-European requirements and few suppliers can offer credible, fully-supported pan-European service in the present environment."

Features of the EC's new Satellite Directive include a reduction in costs of deploying and operating satellite networks, a harmonized regulatory environment to help establish pan-European satellite networks, the removal of prohibitions on service and interconnections, and simplification of licensing equipment registration and installation.

The directive is effective immediately.

ITS America adds telecom group

WASHINGTON, DC—The Intelligent Transportation Society of America (ITS America) has established a Telecommunications Committee out of its predecessor, the Communications Spectrum Task Force.

The committee's responsibility is to formulate and recommend ITS America's position on wireless and wireline communications and communications integration issues.

The committee is divided into Wireless Communications and Wireline Communications Subcommittees. The Wireless Communications Subcommittee will work on spectrum management, RF communication systems, and electromagnetic-compatibility issues.

Another subcommittee focusing on communications integration will be established by the end of the year, according to Jerry Marsh, ITS America's director of standards and telecommunications.

Kudos...

Several industry companies have been ISO 9000 certified in the past month, including AstroLab, Inc. (ISO 9001), Andrew Corp. (ISO 9001), Magnavox Electronic Systems Co. (ISO 9001), and Littlefuse, Inc. (ISO 9002) for specific product lines and facilities...ANADIGICS (Warren, NJ) has been named as a state designee in the 1994 Blue Chip Enterprise Initiative, sponsored by Connecticut Mutual, the US Chamber of Commerce, and Nation's Business, for small businesses that have overcome challenges and emerged stronger.

Accomplish you

You can rely on HP's complete line of standard 6-18 GHz Avantek amplifiers to always deliver a winning edge.

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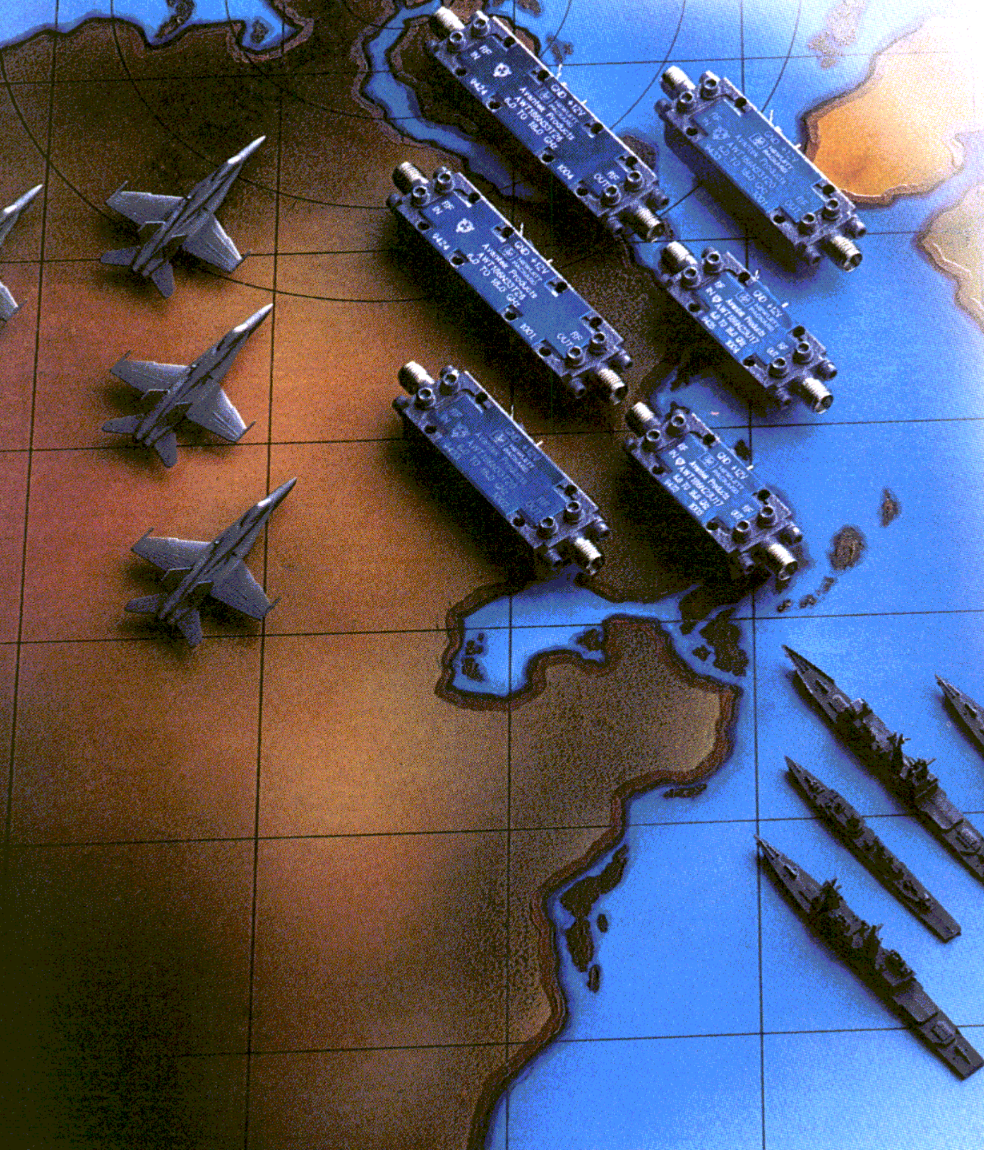

First off, HP's new family of amplifiers exhibit outstanding overall electrical performance. Using PHEMT GaAs technology, these amplifiers provide industry leading noise figures, higher gain and low current consumption. And because HP guarantees more specifications, there are no surprises. Gain (min and max), Peak-to-Peak Gain Variation (max), Noise Figure (max), P1dB (min), PSAT (min), Third Order Intercept Point (min), VSWR (max) and Current (max) are all specified, so you're assured of guaranteed performance.

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AFT General Purpose Series @ 25°C

57 NEW MODELS

Model	Gain (dB) Min.	Gain (dB) Max.	Gain Variation (dB) Max. (P–P)	Noise Figure (dB) Max.	Power Output for 1 dB Gain Compression (dBm) Minimum	PSAT (dBm) Min.
Low Noise Amplifiers						
AFT 186 N 40 U 18	18.0	22.0	3.0	4.0	10.0	12.0
AFT 186 N 40 U 23	23.0	28.0	3.0	4.0	10.0	12.0
AFT 186 N 40 U 33	33.0	39.0	4.0	4.0	10.0	12.0
AFT 186 N 40 U 48	48.0	56.0	5.0	4.0	10.0	12.0
Low Noise Medium Power Amplifiers						
AFT 186 N 50 U 21	21.0	27.0	3.0	5.0	18.0	20.0
AFT 186 N 50 U 24	24.0	30.0	3.0	5.0	18.0	20.0
AFT 186 N 50 U 35	35.0	42.0	4.0	5.0	18.0	20.0
AFT 186 N 50 U 45	45.0	52.0	5.0	5.0	18.0	20.0

AWT Premium Performance Series @ 25°C

Model	Gain (dB) Min.	Gain (dB) Max.	Gain Variation (dB) Max. (P–P)	Noise Figure (dB) Max.	Power Output for 1 dB Gain Compression (dBm) Minimum	Third Order Intercept Point (dBm) Minimum
Low Noise Amplifiers						
AWT 186 N 23 U 17	17.0	20.0	2.0	2.3	7.0	15.0
AWT 186 N 23 U 20	20.0	23.0	2.0	2.3	4.5	12.5
AWT 186 N 23 U 28	28.0	32.0	3.0	2.3	6.5	14.5
AWT 186 N 23 U 40	40.0	45.0	4.0	2.3	13.0	21.0
Low Noise Medium Power Amplifiers						
AWT 186 N 27 U 23	23.0	26.0	2.0	2.7	14.5	22.5
AWT 186 N 27 U 31	31.0	35.0	3.0	2.7	17.0	25.0
AWT 186 N 27 U 42	42.0	47.0	4.0	2.7	18.0	26.0
100 mW Amplifiers						
AWT 186 P 20 U 22	22.0	25.0	2.0	4.5	20.0	28.0
AWT 186 P 20 U 29	29.0	33.0	3.0	4.5	20.0	28.0
AWT 186 P 20 U 39	39.0	44.0	4.0	4.0	20.0	28.0

AWT Premium Performance Temperature Compensated @ -54 to +100°C

Model	Gain (dB) Min.	Gain (dB) Max.	Gain Variation (dB) Max. (P–P)	Noise Figure (dB) Max.	Power Output for 1 dB Gain Compression (dBm) Minimum	Third Order Intercept Point (dBm) Minimum
Low Noise Amplifiers						
AWT 186 N 30 T 21	21.0	24.0	2.0	3.0	5.0	13.0
AWT 186 N 30 T 23	23.0	26.0	2.0	3.0	6.0	14.0
AWT 186 N 30 T 28	28.0	32.0	3.0	3.0	8.0	16.0
AWT 186 N 30 T 38	38.0	43.0	4.0	3.0	11.5	19.5
Low Noise Medium Power Amplifiers						
AWT 186 N 33 T 20	20.0	23.0	2.0	3.3	8.5	16.5
AWT 186 N 33 T 29	29.0	33.0	3.0	3.3	16.0	24.0
AWT 186 N 33 T 40	40.0	45.0	4.0	3.3	17.0	25.0
Medium Power Amplifiers						
AWT 186 P 18 T 20	20.0	23.0	2.0	5.5	18.0	26.0
AWT 186 P 18 T 28	28.0	31.0	3.0	5.5	18.0	26.0
AWT 186 P 18 T 38	38.0	43.0	4.0	4.5	18.0	26.0

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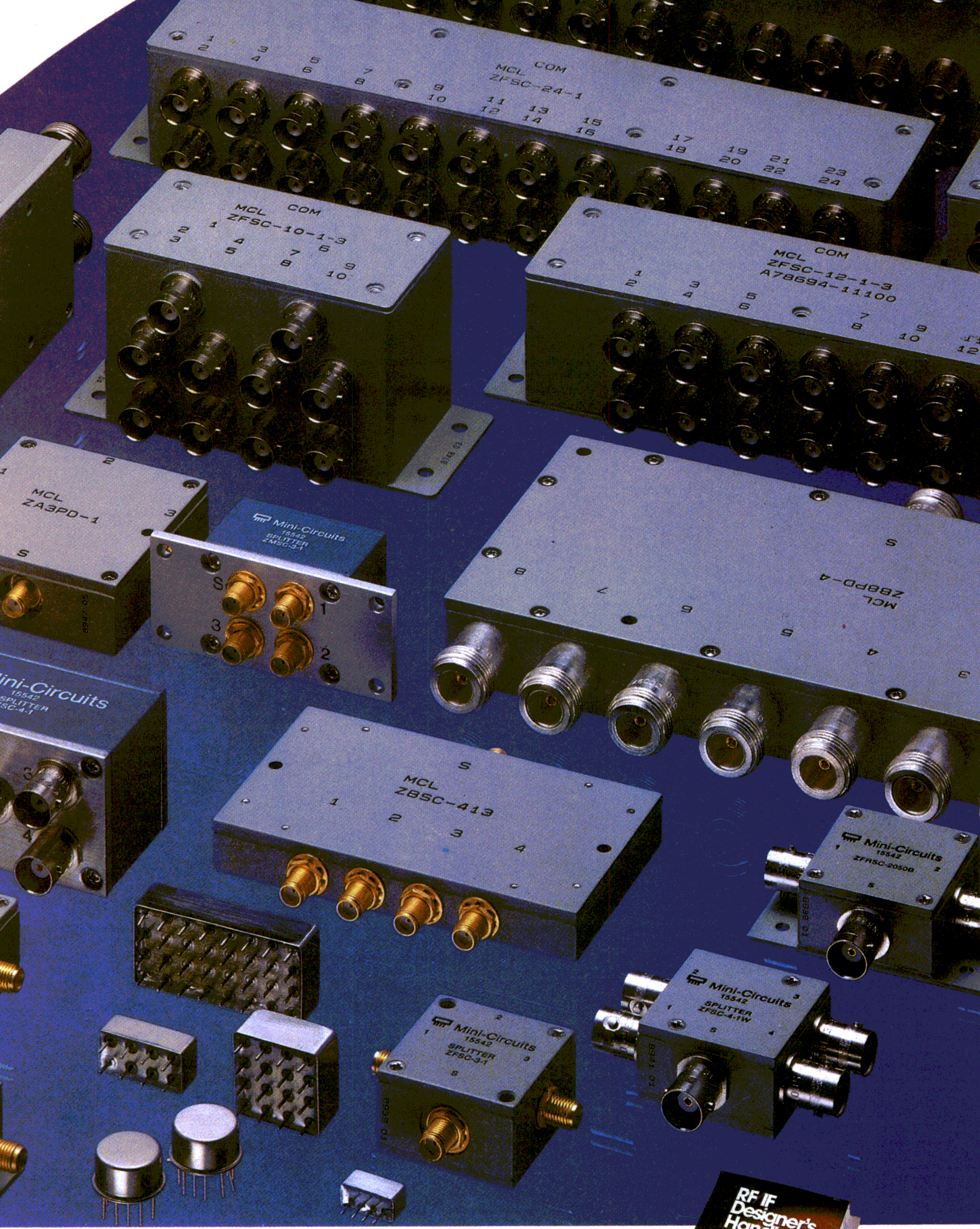


CIRCLE NO. 284

F134 Rev

EIA's 10-Year Forecast

DOD SPENDING SLIDES, BUT ELECTRONICS IS SAFE

The DOD is just beginning to come to grips with declines in its budget, although upgrades offer some opportunities.

RON SCHNEIDERMAN
SENIOR EDITOR/NEWS

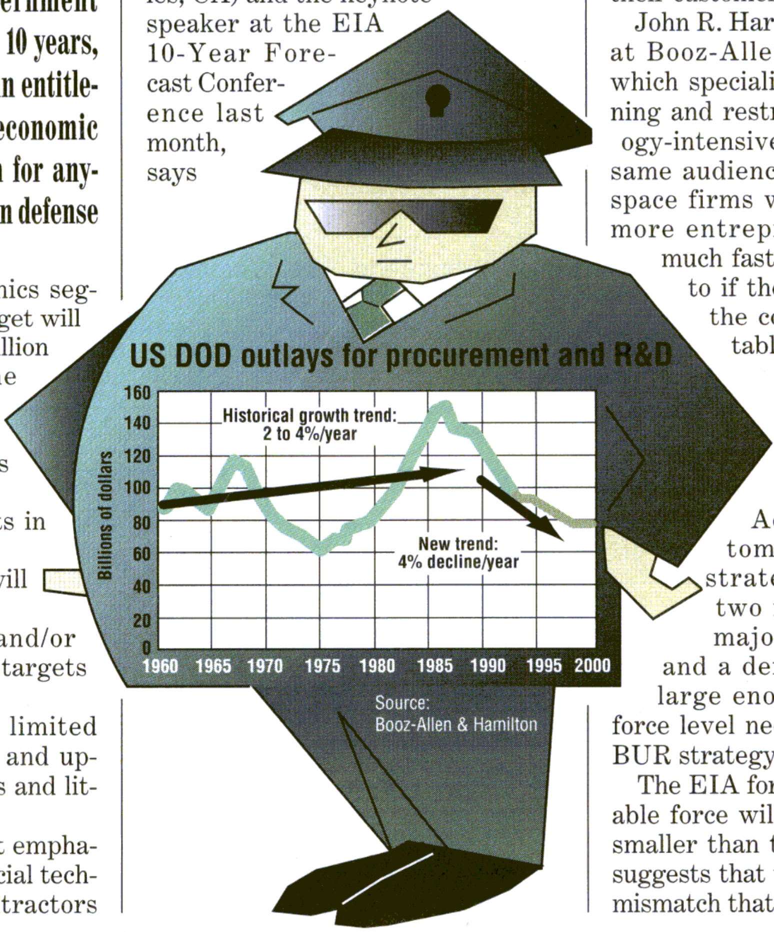
THE electronics industry has dodged another bullet. Government spending trends over the next 10 years, with projections of increases in entitlement spending and slower economic growth, will leave little room for anything but a continued decline in defense spending.

Fortunately, the electronics segment of the US defense budget will remain fairly stable at $37 billion annually, according to the 10-year forecast of DOD and related opportunities by the Electronic Industries Association (EIA).

There are several caveats in the forecast, however:

- Planned procurements will be cut.
- Programs with cost and/or schedule problems will be targets for cancellation.
- Opportunities will be limited primarily to modifications and upgrades, with few new starts and little full-scale development.
- There will be significant emphasis on dual-use and commercial technologies, with defense contractors losing business to commercial suppliers. At the same time, the EIA believes DOD acquisition reforms will provide new opportunities for commercial electronics firms at the component and subsystem levels.

C. Michael Armstrong, chairman and CEO of Hughes Aircraft Co. and GM Hughes Electronics (Los Angeles, CA) and the keynote speaker at the EIA 10-Year Forecast Conference last month, says that could hurt companies imbued in a military culture, "Companies in the defense sector tend to measure themselves against each other and that could be a mistake. Companies making commercial products know how to cut costs and keep consumers happy. These are companies that would love to add the Pentagon to their customer list."



John R. Harbison, a vice president at Booz-Allen & Hamilton, Inc., which specializes in strategic planning and restructuring for technology-intensive companies, told the same audience that defense/aerospace firms will have to be much more entrepreneurial and move much faster than they are used to if they hope to succeed in the commercial world (see table).

Another concern of defense/aerospace companies is the affordability gap between the Clinton Administration's Bottom-Up Review (BUR) strategy to "fight to win two nearly simultaneous major regional conflicts" and a defense budget that is large enough to maintain the force level necessary to uphold the BUR strategy.

The EIA forecasts that the affordable force will be about 15 percent smaller than the BUR force, which suggests that there is a plans/reality mismatch that will require a rethink-

EIA FORECAST

ing of national security objectives and strategies.

"In any event," says Ed Waesche, director of strategic and market planning at Grumman Corp. (Bethpage, NY) and chairman of the EIA 10-Year Forecast Committee, "emphasis for the foreseeable future will be on affordability, affordability, and affordability."

The EIA believes that shrinking the DOD's immense infrastructure, which takes up to about 50 percent of the budget, is essential to free up funds if the force is to be modernized. The association expects the procurement budget, which is forecasted to bottom out in 1995 at $44.5 billion, will rise to only $48.5 billion in 10 years. At the same time, research and development (R&D) and engineering funds will drop about 35 percent in real terms, with very few major new program starts.

The EIA says it believes this slowdown in equipment modernization will cause the defense/aerospace industry to lose a significant number of jobs over the next 10 years, with the final figure mainly dependent on how fast the DOD's infrastructure is reduced. Those infrastructure cuts would allow defense dollars to be earmarked for force modernization. However, Waesche says continued emphasis on modifications and upgrades of so-called "sunset" systems means there will be ample opportunities for electronics suppliers and integrators.

"With a fairly stable electronics segment, electronics suppliers will be cushioned somewhat from the continuing downturn in the defense business," notes Waesche.

The EIA's forecast, which covers Fiscal Years 1995-2004, is based on analyses prepared by EIA-member defense/aerospace company representatives and are supported by extensive interviews with defense experts in Congress, the Administration, the DOD, think tanks, and Wall Street.

The EIA values the market for modifications, retrofits, and maintenance (MRM) in excess of $20 billion for defense electronics firms over the next 10 years.

"To keep aging platforms in the field, budget appropriators will favor modifications and retrofits required to maintain or increase readiness and provide service life extension, such as the recently-awarded Navy P-3C upgrades program," says Bob Lusardi, the MRM market study leader. Lusardi says this should serve as an incentive for the military services to keep their modifications and retrofits budgets at about the Fiscal Year 1995 levels throughout the forecast period.

There are a large number of players, both in the government and industry, who are competing in the MRM market. According to Lusardi, the DOD is emphasizing the use of commercial off-the-shelf (COTS) components in MRM applications.

In aircraft, EIA forecasters note that significant adjustments have already been made to procurement plans. B-2 bomber buys have been cut from 132 aircraft to 20; the C-17 from 210 to 40; and Lockheed's new F-22 fighter from 750 to 442, although the entire F-22 program is now in question and could seriously slip from its current design review and production schedule. However, the electronic content of aircraft continues to grow (it will account for about 55 percent of the cost of the F-22)—from about $5 billion this year to more than $7 billion in 2004, according to EIA projections.

In missiles, the EIA says that modifications and upgrades will outpace new program starts. The emphasis will be on affordability. Missile electronic procurements will amount to

Comparison of defense and commercial process capabilities

Process	Defense	Commercial
Innovation		
Market strategy	Threat-driven/reactive	Opportunistic
Program definition	Technology-driven	Market-driven/driving
Source and role definitions	Overlapping/short-term	Lean/strategic
Product/process design	Independent/sequential	Integrated/simultaneous
Delivery		
Sales capture	Monopsonistic	Entrepreneurial
Purchasing/material flows	"Just in case"	"Just in time"
Manufacturing and assembly	Lengthy/fat	Rapid/lean
Distribution and support	Direct	Channel-specific
Management and control		
Supply chain	Adversarial/complex	Trusting/streamlined
Internal capabilities	Incremental/continuous	Block change
Customer relationships		Trusting/lean

Source: Booz-Allen & Hamilton

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SPECIFICATIONS	ZHL-42	ZHL-4240	ZHL-42-W	ZHL-424OW
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.
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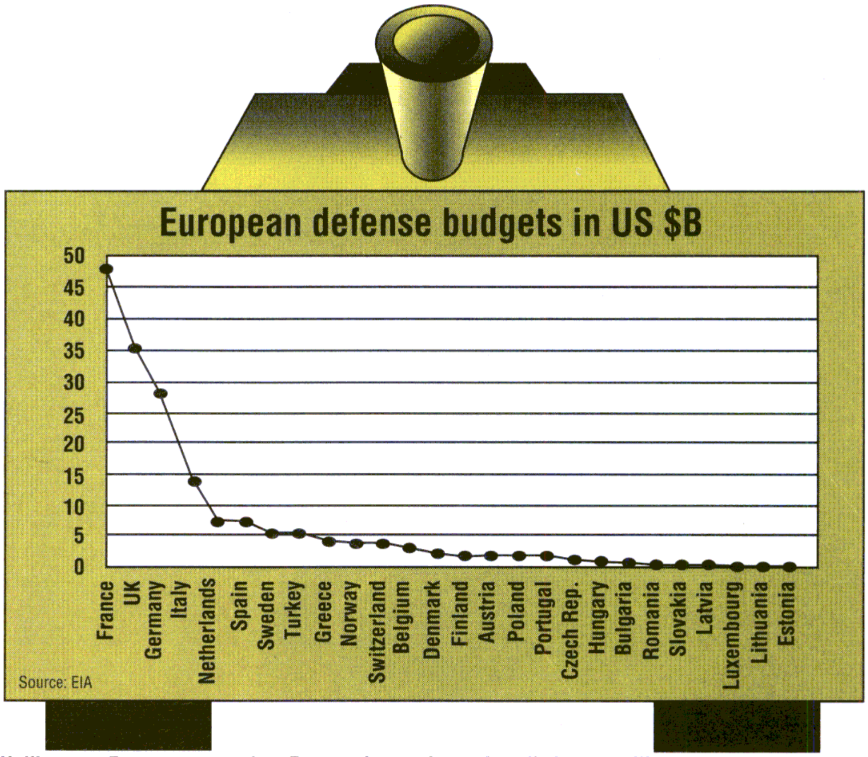
about $2 billion this year and will climb very slightly over the forecast period.

The market for space electronics is basically flat over the forecast period, at about $1.5 billion annually in procurements, with the few proposed new program opportunities yet to be committed over the long term. These include military satellite-communications and global-positioning-system (GPS) follow-ons. However, the EIA says the need for next-generation spacecraft late in the decade will result in a resurgence of business for electronics.

Ship electronic procurements are expected to climb from just over $1 billion this year to something over $2 billion in 2004. There will be fewer ships in the fleet, but those still operating will have a higher electronic content.

Ordnance and weapons will continue to be another opportunity for industry companies, if only a small



Unlike most European countries, France plans to invest heavily in new military programs.

EIA FORECAST

one in DOD buying terms. The electronics content of this market this year is about $300 million, but the EIA expects it to grow steadily to about $600 million over the next 10 years. There will be fewer quantities, but the emphasis on smart weapons will mean more electronics and a growing market for upgrades.

New initiatives in vehicle electronics stem from "lessons learned" from Desert Storm. The EIA sees this market almost doubling from $200 million this year to just over $400 million in 2004, partly due to the development of new automated crew functions and safety enhancements.

NASA, meanwhile, has its own problems. A year ago, the EIA's forecast group reported that NASA had no direction, no clear long-range mission plan, and little support in the White House. This year's report on the space agency indicates that little has changed.

NASA has absorbed a 30-percent cut in its five-year program in the past two years. Virtually all NASA programs are being squeezed and no major new program starts are planned. Key sectors such as communications, tracking and data systems, and space science are expected to barely maintain their budgets over the next several years. Everything in the EIA's forecast for NASA says smaller and cheaper—smaller missions, some of which will require international partnering, and controlled spending, along with some program restructuring and improved productivity.

According to EIA forecasters, NASA's budget will hit bottom in 2001/2002, then level out toward the end of the forecast period in 2004.

OPPORTUNITIES IN EUROPE

The European defense electronics market is not much better than the US; it, too, is shrinking. But an emphasis on upgrades means that a higher proportion of the money will be spent on electronics. Since many of these will be upgrades of US platforms, a lot of money should come to US firms. "However, US defense electronics wins in Europe during the next five years will not make up for losses in traditional US markets," says Robert Martin of Motorola and chairman of the EIA Requirements Council International Committee. "There are opportunities for US defense electronics firms in Europe, but technical competition is fierce and political/industrial factors weigh heavily."

Martin says that except where US firms have a clear niche, and those cases are few, US companies can expect stiff European competition and a selection approach in which technological superiority and low cost will not necessarily win. "Local industrial benefit, technology transfer, and reciprocal access to the US market—factors that affect jobs—weigh

EIA FORECAST

more heavily than ever in European selections," notes Martin.

The trend in Europe is toward technological sufficiency instead of technological superiority. Quality standards, such as ISO 9000, are also becoming increasingly important.

The combined defense budgets of the 26 European nations covered in the study totals less than 60 percent of the US defense budget, and the budgets of four countries—France, the United Kingdom, Germany, and Italy—comprise 66 percent of the combined European total.

According to Martin, five of the seven most-recently-approved new NATO Infrastructure Capability Packages are for command, control, and communications (C^3) systems, in contrast to a historical predominance of construction projects. Other major NATO programs on the horizon include NATO ground surveillance and NATO Airborne Warning and Control System (AWACS) upgrades—all of which have a high electronics content.

"France, a notable exception to the falling trend of most European defense budgets, is instead investing heavily in defense with the view of becoming the premier arms supplier of Europe," says Debi Davis, deputy director of international marketing at Martin Marietta Corp. (Bethesda, MD) and vice chair of the international study. France has the largest European defense budget and, unlike other countries which are focusing on upgrades, is building new air and naval platforms to carry it into the next century. "Opportunities for US firms are few," says Davis, "and are focused on niche markets where US firms have a clear technological edge."

The UK, says Davis, is facing difficult choices about which of the 20 major approved programs will receive funding from a budget projected to support only 10 of these programs. "The good news is that US firms are competitive for virtually all UK requirements, especially if they can provide UK industrial participation."

Germany is a long shot, says Davis, because of US government technology-transfer obstacles and inconsistencies. "Germany will look first to local firms, second to France, third to the rest of Europe, fourth to others, and fifth to the US."

Meanwhile, Davis notes, "Italy's new 10-year defense plan will need to be reviewed for US opportunities when it is finished near the end of the year." Best bets are expected to be in theater missile defense, a "mini-AWACS," and C^3 programs.

In the southern-tier countries—Greece, Portugal, Spain, and Turkey—upgrades of US platforms dominate US opportunities. Most of the procurement money will go to programs already underway or identified, only a few of which are still open to competition.

The Nordic region (Denmark, Finland, Norway, and Sweden) is a small but significant market that favors US industry, says Motorola's Martin. Sweden has the sixth largest defense procurement budget in Europe which, in contrast to the general trend, is projected to grow due to the Gripen fighter aircraft (US industry produces 35 percent of the Gripen). The Gripen and US F-16 and F-18 programs consume the major portions of the Nordic defense-procurement budget.

In other Western European countries, such as Austria, Belgium, the Netherlands, Luxembourg, and Switzerland, the Netherlands—with Europe's fifth largest defense budget—represents the most significant defense market, according to the EIA study.

In Central Europe, Martin says that Poland, the Czech Republic, Hungary, and Romania offer the greatest potential, but competition from Western Europe and Israel is tough. The top priority in Central Europe is to achieve compatibility with NATO. However, upgrades are more likely in the region than new system procurements.

Back in the US, the DOD is expected to begin focusing more of its science and technology (S&T) spending on supporting its ability to fight two major regional conflicts (MRCs) simultaneously and to support dual-use technologies. To do that, the Pentagon has replaced its seven thrust-based S&T strategies with 22 so-called DOD Technology Area Teams, which could be expanded to as many as 25 or 27 teams. Currently, the teams cover a broad base of technologies—from C^3, electronic devices, and electronic warfare to human-systems-interfaces materials processing.

Almost two-thirds of Advanced Research Projects Agency (ARPA) programs are now dedicated to dual use, with electronics getting the lion's share of funding. Key programs include application-specific electronic modules (ASEMs), multichip modules (MCMs), high-density microwave packaging, and low-cost radars.

The ARPA-managed Technology Reinvestment Program (TRP) lists seven technology focus areas; the 1995 list and solicitation, scheduled to be published by the end of October, will be expanded, according to EIA forecasters.••

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IEDM CONFERENCE SUPPORTS TUBES AND SEMICONDUCTORS

This respected technical conference documents the state of the art in both electron devices and solid-state semiconductors.

JACK BROWNE
ASSOCIATE PUBLISHER/EDITOR

MARKING its 40th year, the International Electron Devices Meeting (IEDM) remains perhaps the most significant forum for important advances in electron devices and semiconductors. This year is no different, with more than 200 invited papers from around the world falling into 36 technical sessions. The 40th Annual IEDM is scheduled for December 11-14, 1994 at the San Francisco Hilton (San Francisco, CA).

The IEDM will commence with a luncheon keynote address by Simon Sze concerning "Four Decades of Semiconductor Device Developments: Achievements and Challenges." Sze, formerly with AT&T Bell Laboratories, is now Director of the Microelectronics and Information Systems Research Center at National Chiao Tung University in the People's Republic of China. Sze was also known for his time as Editor of *IEEE Electron Device Letters.*

In the area of vacuum electronics, A. Kasugai and fellow researchers from the Japan Atomic Energy Research Institute at the Naka Fusion Research Establishment (Ibaraki-ken, Japan) will describe the development of a high-power, long-pulse gyrotron with a collector-potential depression system. When operated in the $TE_{22,2}$ whispering gallery mode (WGM) at 110 GHz, the tube produced better than 500-kW output power for pulses of longer than 1 s. Using a water-cooled collector, the tube achieved about 30-percent efficiency. The longest pulse duration of 5 s resulted in 350-kW output power with overall efficiency of 48 percent. The beam current was 17 A with accelerating voltage of 77 kV.

Researchers D.B. Lyon and A.J. Theiss from the Electron Devices Div. of Litton Industries (San Carlos, CA) will offer details on a new class of permanent-periodic-magnet (PPM)-focused, high-power traveling-wave tubes (TWTs) with a novel integral-pole-piece, folded-waveguide circuit. The latest TWT developed with this architecture generated 10-dB/in. gain with a bandwidth of about 350 MHz at Ka-band. The output power ranged between 800 and 1400 W with total efficiency between 20 and 28 percent.

H. Wang and co-workers from the Electronic Systems and Technology Div. of TRW (Redondo Beach, CA) will present information on a 140-GHz monolithic low-noise amplifier (LNA). The amplifier, the highest-frequency MMIC amplifier reported so far with three-terminal devices, demonstrated 9-dB gain at 142 GHz for a two-stage design. Based on 0.1-μm InAlAs/InGaAs/InP pseudomorphic high-electron-mobility transistors (HEMTs) with transition frequency of 240 GHz and maximum frequency of oscillation of 400 GHz, the amplifier features input return loss of better than 10 dB and output return loss of more than 5 dB when measured from 139 to 145 GHz.

K.E. Kreischer and co-workers from the Plasma Fusion Center at the Massachusetts Institute of Technology (Cambridge, MA) will detail attempts to build a 1-MW, 100-GHz gyrotron with an internal-mode converter. Using a $TE_{22,6,1}$ operating mode with a standard tapered cavity, a power level of 840 kW was achieved with 23-percent efficiency at 113.2 GHz. The addition of an internal-mode converter reduces window reflections, provides better pumping conductance within the vacuum tube, and improves mode stability. The tube operates with 83 kV and 34 A.

T. Bemis and associates from the Electron Devices Div. of Litton Industries present information on a "beamstick" developed for a 95-GHz harmonic gyroklystron. The tube, being developed as part of ARPA's High-Power Millimeter-Wave Amplifier Program, aids the generation and focus of a hollow, axis-encircling electron beam.

Work performed at the Naval Research Laboratory (Washington, DC) by G.S. Park *et al.* focuses on a two-stage gyro-TWT amplifier with tapered input and output waveguide. Designed for Ka-band operation, the tube exhibited linear gain of 30 dB and saturated gain of 25 dB when operating in the TE_{10} rectangular tapered-waveguide mode over a 20-percent bandwidth. The efficiency was measured at 16 percent for a power supply of 33 kV and 1.5 A.

A.N. Curran and the team from the NASA Lewis Research Center (Cleveland, OH), in conjunction with C.E. Weeder and Z.A. Zacher from Hughes Aircraft Co. (Torrance, CA) and W.L. Harvey from the Jet Propulsion Laboratory (Pasadena, CA), will describe results for a Ka-band TWT developed and space-qualified for NASA's Cassini Mission to Saturn (scheduled for 1997). The low-power TWT has demonstrated an overall saturated efficiency of better than 40 percent, incorporating computer-aided designs of the helix and multistage depressed collector.

G. Groshart from Northrop Grumman (Rolling Meadows, IL) will explain the design of a microwave power module for phased-array radars. The module is a complete 100-W transmitter operating from 6 to 18 GHz. The unit includes a power booster TWT, a MMIC driver amplifier, power-conditioning circuitry, and a modulator in a package measuring only 7.5 in.^{3}. The modules can be stacked in an array with one-half-wavelength spacing at 18 GHz.

M.A. Kodis and associates from the Electronics Science and Technology Division of the Naval Research Laboratory, along with B. Goplen and D.N. Smithe from Mission Research Corp. (Newington, VA), will provide the results from experiments to determine the saturation behavior and maximum conversion efficiency of emission-gated electron beams in slow-wave circuits. Computer simulations have shown that single-pass conversion efficiencies of better than 50 percent may be attained with moderately-tight electron bunches in a properly tapered helix. The results compare tapered and untapered helix designs.

D. Sprehn and co-workers from the Stanford Linear Acceleration Center (Stanford, CA) will discuss the design and performance of 150-MW S-band klystrons. These pulsed klystrons operate at 2.998 GHz with 3-μs pulses using 535 kV and 700 A.

HEMTs ON SILICON

In solid-state design developments, H. Suehiro and co-workers from Fujitsu Laboratories, Inc. (Atsugi, Japan) will reveal one of the more significant advances in semiconductor technology: a 3.6-GHz dual-modulus prescaler fabricated with pseudomorphic HEMT technology on silicon substrates. While HEMT structures have traditionally been formed on GaAs substrates, these researchers note that devices on silicon can be mass-produced in far larger numbers than on GaAs because of the larger sizes of silicon wafers. The technology was used to create a 51-stage ring oscillator with 0.35-μm gate-length HEMTs that achieved propagation delays of only 22.3 ps.

Ming-Yih Kao and researchers at Martin Marietta Laboratories (Syracuse, NY) will highlight a low-noise, InP-based HEMT device with silicon-nitride passivation. The transistor has shown less than 1-dB noise figure at 63 GHz with associated gain of about 7.6 dB.

Kohju Matsunaga and associates at the Kansai Electronics Research Laboratories of NEC (Shiga, Japan) will examine a very-efficient heterojunction FET developed for 12-GHz amplification. The 8.4-mm-periphery device has delivered +37.5-dBm (5.6-W) output power with 13-dB linear gain and 56-percent power-added efficiency at 12 GHz with a drain bias of 7 V.

Yasushi Amamiya *et al.* at NEC Corp. will unveil work on power heterojunction bipolar transistors (HBTs) for microwave and millimeter-wave applications. A single-emitter HBT achieved a maximum frequency of oscillation (f_{max}) of 143 GHz. A common-base HBT with six emitter fingers produced maximum CW output power of 365 mW at 25.2 GHz with 9.1-dB linear gain.

Exploring the potential capabilities of silicon-germanium (SiGe) technology, A. Schuppen and co-workers at the Ulm Research Center of Daimler Benz AG (Ulm, Germany) will provide information on multi-emitter-finger SiGe HBTs with different collector designs. The devices have achieved f_{max} values to 120 GHz with 20-dB linear gain at 10 GHz.

Also working with SiGe, D. Harame and associates from IBM (Yorktown Heights, NY), along with C. Kermarrec, T. Tewksbury, and T. Tice from Analog Devices (Wilmington, MA) and J. Cressler from Auburn University, will explain a 200-mm SiGe HBT technology for use in wireless and mixed-signal applications. The production-line technology, which is aimed at applications to 2 GHz and higher, boasts f_{max} of greater than 45 GHz and power-added efficiency of 66 percent.

This year's IEDM follows a trend of increasing software presentations, as researchers explore new ways to model both semiconductors and tube components. In a presentation that should impact mixed-signal simulations, T. Skotnicki and co-workers from CNET-CNS (Meylan, France) will report on a new analog/digital model for sub-half-micron MOSFETs. The model features 34 parameters, six of which are devoted to device optimization.

In noting that recent 0.1-μm-gate-length MOSFET developments have resulted in unit-current-gain frequencies as high as 110 GHz, R.R.J. Vanoppen and co-workers from Philips Research Laboratories (Eindhoven, The Netherlands) will offer a technique for accurately characterizing these devices. Such characterizations of Y-parameters, current, voltage, and power gain can be used to improve the parameters of high-frequency, high-speed MOSFETs.

The 40th Annual IEDM also features a wide range of papers on digital and optical devices. For more information about the conference, contact Melissa Widerkehr, IEDM, Suite 610, 1545 18th St. N.W., Washington, DC 20036; (202) 986-1137, FAX: (202) 986-1139.••

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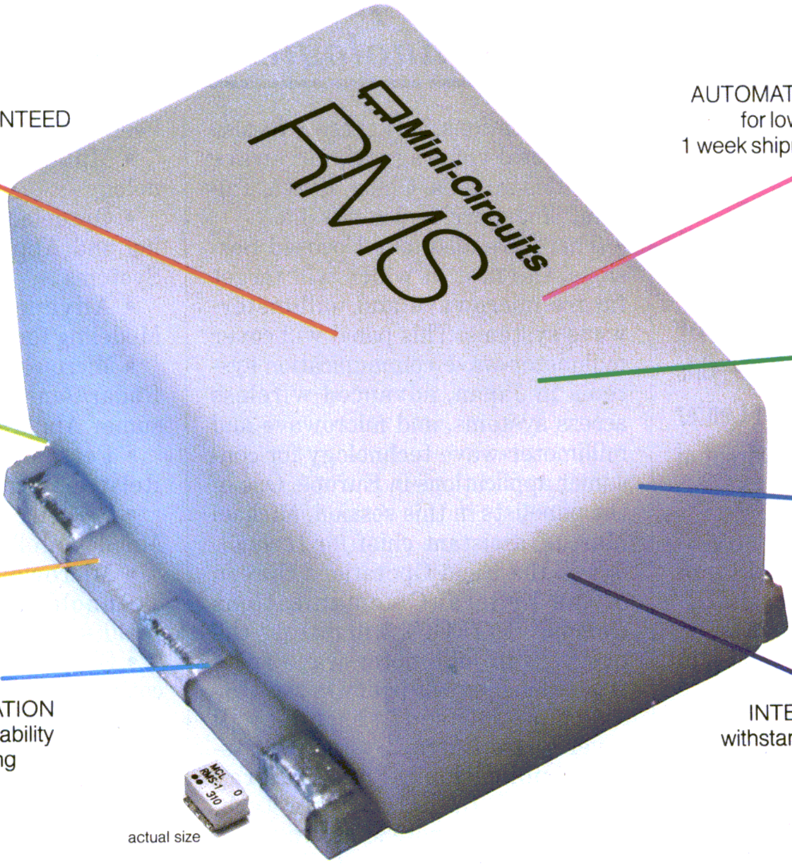

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CIRCLE NO. 301

F166 REV. ORIG.

Asia-Pacific Microwave Conference

APMC '94 SHOWCASES MICROWAVE ADVANCES

In Japan, much of the talk is on future applications for emerging technologies.

FOR only the second time in its history, the Asia-Pacific Microwave Conference will be held in Japan—this time at the Nippon Convention Center (Makuhari Messe) on the waterfront of Tokyo Bay in Chiba, December 6-9.

Sponsored by the Institute of Electronics, Information, and Communications, along with the IEEE MTT-S and URSI, the 9th Annual APMC '94 has targeted advances in microwave and millimeter-wave technologies in commercial and consumer electronic applications—from the initial design phase through advanced development processes and test and measurement issues—with a series of technical panels, tutorials, and workshops. In several of the sessions, additional time has been scheduled for discussion of the presented material.

Reviewers have selected 264 papers for the meeting from the 452 papers submitted from 28 countries. In addition, 25 invited papers will be presented in two Asia-Pacific Sessions and European Sessions.

The technical sessions are heavy on applications and the use of monolithic microwave integrated circuits (MMICs), particularly in personal communications, but there will also be general coverage of microwave activities in India, China, Korea, Taiwan, Singapore, and Australia.

There are also four Focused Sessions, the first of which will target future microwave and millimeter-wave systems. This panel will cover millimeter-wave communication systems in Japan, advanced wireless access systems, and microwave and millimeter-wave technology for consumer applications in Europe. One of the panelists in this session, Michael Marcus, assistant chief for technology in the Field Operations Bureau of the Federal Communications Commission (FCC), will discuss the progress in millimeter-wave spectrum-management policy in the US.

Other "focused" sessions will cover Phased Array Systems I: System Applications, Phased Array Systems II: Basic Hardware Techniques, and Ultimate Microwave and Millimeter-Wave Technologies.

Advances in millimeter-wave technology have major implications for the industry, with the advent of potential mass-product applications such as vehicle collision-avoidance radar and other short-range sensing systems. Wireless local-area networks (WLANs) is another prospective application gaining attention. These applications require wide frequency bandwidths to meet the need for high spatial resolution and large transmission data rates.

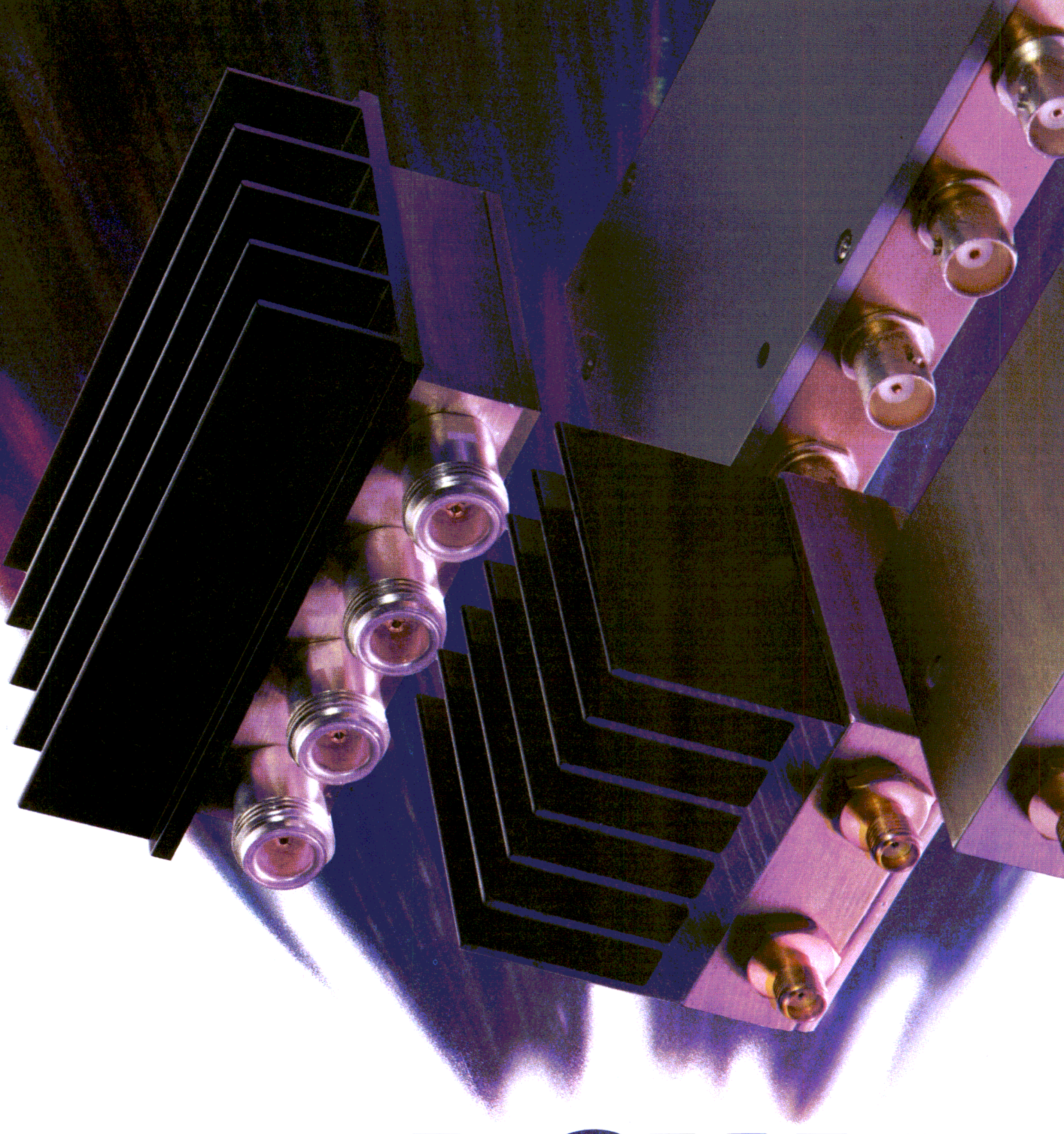
The final day of the conference has been dedicated to eight workshops:

- Millimeter-Wave MMIC Technology
- Optoelectronic Signal Processing and Applications to Microwave Systems
- Advanced Nonlinear Device Modeling for Circuit Simulations
- Microwave and Millimeter-Wave Radar/Sensor Technology for Consumer Applications
- Personal Communications and Related Technologies
- Present Status and Trends for Mobile/Satellite Communications
- Microwave Circuit-Simulation Technology by Electromagnetic Field Analysis
- Superconducting Device Applications to Microwave and Millimeter-Wave Circuits

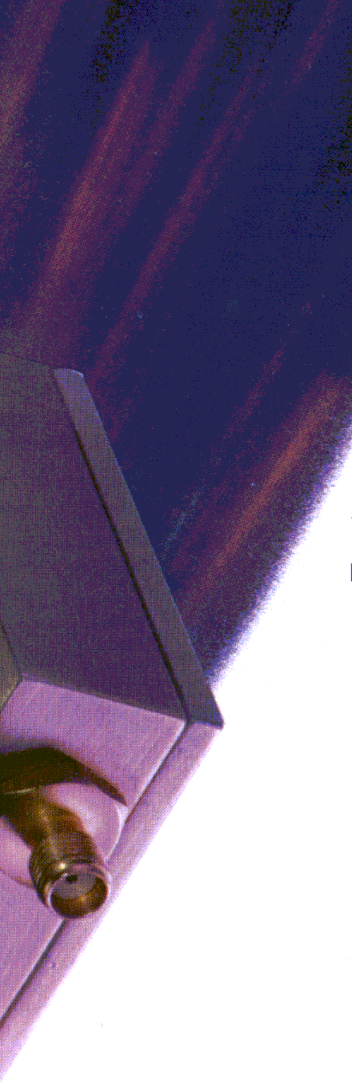
The keynote speaker, T. Okoshi, director-general of the National Institute for Advanced Interdisciplinary Research in Japan, is expected to address the evolution of microwave and optical-wave techniques along with their integration in future systems for the infrastructure of information and communications.

More than 240 companies are scheduled to exhibit products at the 1994 conference. In addition, 20 technical seminars will be presented by exhibitors.

To register for APMC '94, contact the APMC '94 Secretariat, c/o REALIZE, Inc., 4-1-4 Hongo, Bunkyo-ku, Tokyo 113, Japan; FAX: 81-3-3815-8939. ••



POWER



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PSC-2-960-1W	2	300-960	1	0.5	0.5 above 3.0	27	25.95	①
PSC-2-500-1W	2	225-500	1	0.5	0.2 above 3.0	27	21.95	①
ZA2CS-500-15W	2	200-500	15	7.5	0.3 above 3.0	31	74.95	②
ZA2CS-600-10W	2	100-600	10	5.0	0.4 above 3.0	27	74.95	②
ZA3CS-400-3W	3	2-400	3	1.0	0.5 above 4.8	25	59.95	③
ZA3CS-450-9W	3	100-450	9	3.0	0.9 above 4.8	22	99.95	③
ZB4CS-440-12W	4	100-440	12	3.0	0.6 above 6.0	27	134.95	④
ZB6CS-150-12W	6	50-150	12	2.0	0.5 above 7.8	32	159.95	⑤
ZB8CS-950-32W	8	800-950	32	4.0	0.4 above 9.0	30	199.95	⑥

† Over −55°C to +55°C. Above 55°C, derate Linearly to 20% of Rating at 90°C.
① Pin Connections ② BNC Std. for Type N or SMA add $5 to unit price
③ BNC Std. for Type N or SMA add $10 to unit price ④ BNC Std. for Type N or SMA add $15 to unit price
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MSW-2-20 (Reflective)	DC-2.0	1.0	+24	34	2.95
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

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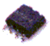
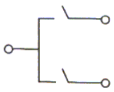
All Units: SOIC 8pin Package  Actual Size



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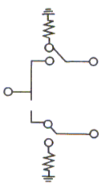
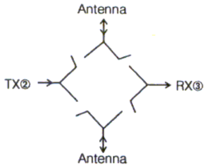


SPDT ABSORPTIVE



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F 174 Rev O

CROSSTALK

Norman Spector *is president of Norsal Industries, Inc. (Islip, NY), a manufacturer of microwave components and subsystems for the military market.*

MRF: *What are your roots in this business?*

Spector: I started at Sperry, which I thought was an absolutely great place to learn the technology. All the knowledgeable players had come from there, including Seymour Cohen, the founders of Narda, and the Varian brothers (who had left prior to my working there).

I was employed in the components group endearingly called by our mail station as "D-40." Until the building was demolished, all of Sperry's radars came from D-40. Two months out of school, I was given the assignment of designing the waveguide components for an L-band, 10-MW radar, which was twice the power output of the state of the art at that time. That was in 1954.

Frank Klausnick, my section head, told me that Sperry had never been at that power level, that no one employed there had any experience at 10 MW, and that I had 18 months to complete the program. It was my indoctrination to the real world.

In 1955, I made an IR&D proposal to develop stripline technology for Sperry, and I was funded (Sanders Associates had just come out with their Tri-Plate product). One of the first products that I designed was a stripline variable attenuator with coaxial connectors. The only source of microwave power was the klystron, but when you varied the voltage to vary the power, the frequency changed. Meanwhile, the tube department was making high-power klystrons.

When I asked about attending WESCON, Klausnick said that I had to write and present a paper. By the time everyone edited my paper on high power in stripline, WESCON was gone. However, I did make the National Electronics Conference in Chicago. One year later, I joined two engineers from the antenna group to found ARRA (Bayshore, NY).

MRF: *Who else was involved in that operation?*

Spector: The founders were Harold Isaacson, Bill Bauer, and myself. The company nearly failed in the antenna business. When it was decided that the company should do something else, I suggested we build attenuators. About 40 years later, ARRA is still a leader in the attenuator field.

I left ARRA in 1964 and made a proposal to Tore Anderson, a vice president at Budd Stanley (a manufacturer of waveguide products), to manufacture a line of miniature microwave components using the new "OSM" connectors. I was turned down because Tore did not see a future in this type of product. By 1965, Budd Stanley was out of business.

Soon after, I started working at Loral in The Bronx. There were 800 employees at the time. I later became a program manager.

In 1967, I went to work for Automatic Metal Products as chief engineer. I was there for two and a half years under four different presidents. Then I went to work for Ben Friedman at Solitron in Long Island City. Completely unannounced, Friedman loaded up a truck one Saturday and moved part of the company to Florida and the rest of the corporate headquarters to Tappan, NY. In 24

CROSSTALK

hours, he moved prints, parts and machines. Management (Bob Latin and myself) and some of the engineering staff were fired only the day before. Sal Ammoratti, one of the engineers, and I founded Norsal Industries the following Tuesday.

MRF: *When was that?*

Spector: On April Fools Day in 1971. We had false starts in both the manufacturing of microwave connectors and chip resistors. When all of the dust finally settled, we focused on the manufacturing of broadband passive microwave devices. Our introduction of directional couplers, 0.5-to-18-GHz power dividers, and hybrids featured bandwidths that were unheard of at the time. These products had no competition for many years until Narda entered the field.

MRF: *Was everything in waveguide bands before that?*

Spector: No, they were in octave bands, but the ECM [electronic-countermeasures] market had yet to mature. I had a sole-source product that didn't have a very big market because the market wasn't ready. When the market was finally ready, buyers went to Narda to develop these same products. The marketing lesson I learned was that, at that point in time, price wasn't everything, image was what counted.

MRF: *How much of your business is offshore?*

Spector: Forty percent of our business is overseas. That's the way it has been for the last 10 years.

We wound up doing business with Japan, which is very good, and we are trying to do the same thing with the Chinese market. We are starting to see activity in these markets.

I found out that the Japanese will copy a design if they need large volumes, otherwise, they will specify products. That arrangement is very good for us.

MRF: *Norsal is still largely military-oriented. Are you doing any commercial work?*

Spector: I got myself involved in the commercial field through the Small Business Innovation Research (SBIR) program. I did a proposal on a noise-canceling cockpit communication system. Then I did a noise-canceling stethoscope. I lost both. Next I did a proposal for a noise-canceling hearing aid. I lost that, too, but I decided to make the hearing aid anyway. I did some patent research in my library and, as a result, I filed a patent on noise canceling this year.

MRF: *What does that have to do with microwaves?*

Spector: Nothing. But it has a lot to do with the technology we have learned over the years. You are not selling couplers to K-Mart. There is no market for that.

MRF: *What do you mean by noise cancellation?*

Spector: Everybody seems to be in the noise-cancellation business nowadays. They raise the highs and lower the lows, but that is not noise cancellation. That may be good for a passenger in an airplane, but it is not good in a car phone or in a hearing aid because you lose fidelity.

> **"Everybody seems to be in the noise-cancellation business."**

Automatic gain control (AGC) is often used, but that is not noise canceling. Undesired continuous sound is noise. Undesired speech is babble.

MRF: *What applications are covered in your patent?*

Spector: It covers the telephone (including wireless), the stethoscope, cockpit communications, and hearing aids. But to me, the simplest and cheapest way of getting into this area was in the hearing-aid business.

I was reviewed at the SBIR by a doctor who said, "Why do we need a noise-canceling stethoscope?" My wife works in a nursing home, so I asked the head nurse what she thought about noise and stethoscopes. She said, "You can't hear a thing. I wish I had something to suppress noise."

MRF: *Hasn't General Microwave benefited from state programs to support programs such as this?*

Spector: Yes, under a LILCO (Long Island Lighting Company) program.

There are three key options. You have the SBIR at the federal level; in New York you have got the Industrial Effectiveness, Diversification Program; and in Long Island you have got LILCO's program. All three are available to me. It is important to realize that you have got to have initial funds because all they give you is matching funds.

I got involved with the Industrial Effectiveness Program in 1992, but I couldn't afford to put up the funds because at that time I went into Chapter 11. We are coming out of that by December 5, 1994.

MRF: *Do you think there will be a movement of people who were microwave types who see opportunities in other areas?*

Spector: The government says a lot of people are employed now, but I don't see that in my business.

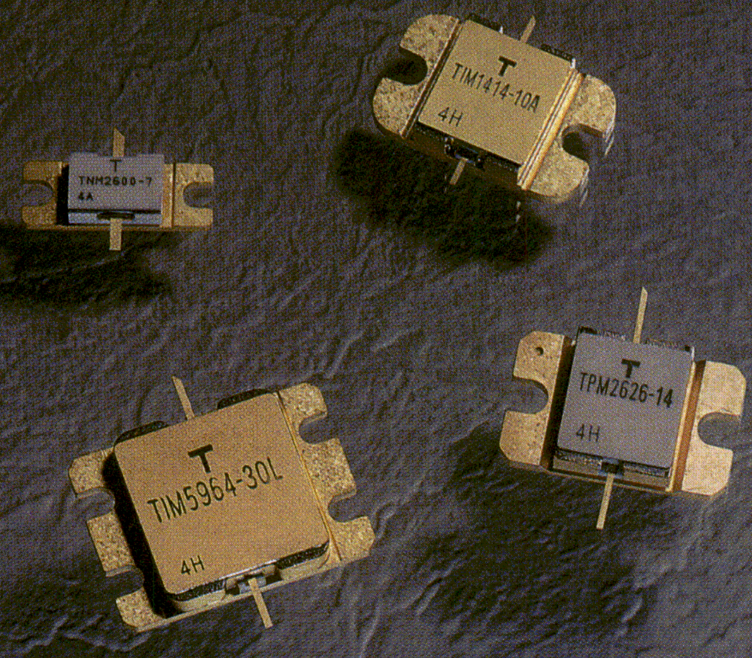
I have an application for a design opening from a guy who has been out of work for a year. He is no longer a statistic. If I hire him, he will not be removed from the unemployment roll—he will be added to the employment rolls.

MRF: *As a new hire?*

Spector: Yes, but from where? It sounds like employment is up. All these companies leaving the business are laying people off and the unemployment numbers don't change. Where do they go? I don't know, but there are an awful lot of people that are no longer statistics.

I hired someone for two years as a consultant. When he worked for me, he didn't become employed. When he stopped working for me, he didn't become unemployed. Now, he's writing a book on geography. This is a graduate engineer.

This engineer is about 45 or 50 years old. He's got 15 or 20 working years left, and he's ready for a career change. But if you are in your mid-50's or later, it is too late; you can't change.••



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New wireless alliances formed

It was tough enough trying to distinguish the players without a program; now try keeping up with the teams.

Last month, two groups of companies agreed to form alliances in order to provide nationally-branded wireless communications products and services and to jointly bid for personal-communications-services (PCS) licenses to be auctioned by the Federal Communications Commission (FCC) in December.

Bell Atlantic and NYNEX, which have already teamed, have joined AirTouch Communications and US WEST to create a common "look and feel" for services for both cellular and PCS customers.

At the same time, Sprint (the third-largest long-distance telephone carrier in the US) and Tele-Communications, Inc. (TCI), Comcast Corp., and Cox Cable, three of the country's largest cable-television companies, announced they would cross-promote a variety of wireless and cable services using the Sprint brand.

"The venture already possesses considerable wireless experience and expertise, and wireless is an essential component of the venture's package of services," says Brian L. Roberts, president of Comcast. Nevertheless, Roberts says the partnership will seek affiliations with additional cable companies.

The joint venture will be owned 40 percent by Sprint, 30 percent by TCI, and 15 percent each by Comcast and Cox.

Teleport Communications Group, which is owned by TCI, Cox, Comcast, and Continental Cablevision, Inc., will also participate in the venture, providing local access for long-distance services and local exchange companies.

The Bell Atlantic/NYNEX/AirTouch/US WEST venture will be governed by a board made up of three members from the Bell Atlantic/NYNEX partnership and three from the AirTouch/US WEST joint venture. However, the cellular properties of Bell Atlantic/NYNEX will not be merged with AirTouch/US WEST. These will be managed as separate operations.

Meanwhile, MCI Communications, Inc. has decided to go it alone in wireless, at least for the time being. The company had been negotiating to form alliances with several wireless communications organizations (among them, Bell Atlantic and NYNEX).

MCI says it now intends to participate in the wireless market by buying excess wireless capacity from existing cellular companies and emerging PCS providers. MCI has already abandoned plans to invest $1.4 billion in Nextel Communications, which is building a network based on specialized-mobile-radio (SMR) systems. ●●

Contracts

Raytheon Co.—$18.4 million to a consortium led by Raytheon's Electromagnetic Systems Division from the US Air Force Wright Laboratory to develop broadband signal-processing telecommunications technology. The program comes under the DOD Advanced Research Projects Agency (ARPA)-led Technology Reinvestment Project (TRP). Also, $18 million from the German Aviation Authority to supply the nucleus of a next-generation air-traffic-control center.

Aydin Corp.—$3.9 million from the US Army to supply wideband telemetry systems designed to transmit missile-seeker video and data over a single RF link.

Telephonics Corp.—$10 million from the Civil Aviation Administration of China to supply an air-traffic-control system for Zhuhai International Airport in southeast China.

Fairchild Data Corp.—$400,000 from Inteltrade, the purchasing arm of the Hungarian Telecommunications Corp., for antennas, modems, and network-management equipment for the Hungarian Railway System.

TRL Microwave Technology, Inc.—$250,000 from WharfCATV in Hong Kong to supply multi-channel microwave distribution system (MMDS) downconverters and antennas.

Fresh Starts

Oak Industries, Inc.—Has signed a letter of intent to purchase AT&T's frequency-control product line unit (North Andover, MA) The unit's average annual sales are $50 million and it is profitable. The operation is part of AT&T's Advanced Integrated Modules business unit—one of six business units that make up AT&T Microelectronics.

TERRASAT, Inc.—Has been formed to develop and manufacture components and subsystems for terrestrial microwave radios and satellite equipment. The company is located at 7017-B Realm Dr., San Jose, CA 95119; (408) 225-4700.

Nokia Mobile Phones—Will establish a support center for the Americas at its existing Melbourne, FL facility. The new organization will be responsible for Nokia's OEM relationships, accessory business, after-sales service, and technical support.

Penstock, Inc.—Signed a distribution agreement with Motorola to distribute Motorola's entire line of RF/microwave products. Also, Penstock signed an agreement with Comlinear Corp., making Penstock a nationwide distributor of Comlinear products.

Ericsson Radio Access AB—Has agreed to a non-exclusive OEM arrangement with Tellabs International, Inc. in which Ericsson will integrate Tellabs' Martis DXX networking system in a cellular transport network that Ericsson will market worldwide. Tellabs and Ericsson have also agreed to collaborate on the development of future enhancements to the Martis product.

P-Com, Inc.—Has signed an OEM agreement with Harris Corp.'s Farinon Division enabling Harris Farinon to expand its current microwave radio product line into the 38-GHz market by offering P-Com's Tel-Link Series radio systems for the emerging personal-communications-services (PCS) market.

ANADIGICS—Has completed a 10,000-sq.-ft. expansion of its headquarters facility in Warren, NJ. The expansion brings the facility to 75,000 sq. ft.

Wavetek Corp.—Has acquired the assets of the Schlumberger Communications Test Division, which includes the radio-communications test-equipment (Ismaning, Germany) and the telecommunications test-equipment business (Saint Etienne, France). Last year, the Schlumberger division's worldwide revenues were in excess of $50 million. Schlumberger will retain a minority interest in the business. With this acquisition, Wavetek's annual sales will be approximately $150 million.

Teknekron Communications Systems, Inc.—Has entered into an agreement with AT&T Wireless Services (formerly McCaw Cellular Communications) to develop specifications for personal communications products based on the IS-136 standard for time-division multiple access (TDMA). TCSI is a software products and services firm.

Parker Hannifin Corp.—Has acquired Chomerics, Inc., a manufacturer of electromagnetic-interference (EMI)-shielding materials and thermal interface products, from W.R. Grace & Co. for about $40 million in cash. Chomerics sales totaled $55 million in 1993.

AVX Corp.—Has opened a southwest regional sales office in Scottsdale, AZ. The office will serve Arizona, southern California, and southern Nevada.

Varian Associates—Has begun a $4 million expansion of its Tempe, AZ electronic center which will double the facility's size.

Herschel Shosteck Associates, Ltd.—Has moved to Wheaton Plaza, South Office Building, 11160 Viers Mill Rd., Suite 709, Wheaton, MD 20902; (301) 589-2259.

National Instruments—Has opened four new international offices—in Mexico, Singapore, Taiwan, and Scotland.

Q-bit Corp.—Has relocated to 2144 Franklin Dr. N.E., Palm Bay, FL 32905; (407) 727-1838.

Wireless Spectrum Technology, Inc.—Has licensed its radio-telephone technology to Ericsson Radio Systems A.B. (Stockholm, Sweden). The non-exclusive license covers spectrum-optimization techniques to increase spectrum capacity.

TELECOM Denmark A/S—Has been divided into two units—Tele Denmark International and TELECOM Denmark.

Sprague-Goodman Electronics, Inc.—Has moved to 1700 Shames Dr., Westbury, NY 11590; (516) 334-8700.

Electronic Industries Association (EIA)—Has established a Sensor Manufacturers' Division within the EIA Components Group. Founding companies include AMP, Honeywell, Murata Electronics North America, Eaton Corp., and Motorola.

Personal Communications Industry Association (PCIA)—Has approved the merger with the National Association of Business and Educational Radio (NABER). The new organization will be known as the Personal Communications Industry Association.

University of California—Has established a Center for Wireless Communications at its San Diego campus School of Engineering.

QUALCOMM, Inc.—Thom F. Degnan to vice president of sales and marketing of satellite-based networks for the Communications Systems Division; formerly Paris, France-based managing director of Scientific-Atlanta's European VSAT business.

Lockheed Corp.—John McMahon to assist Lockheed's top management with the government's anti-trust review of the merger of Lockheed and Martin Marietta; formerly head of Lockheed's Missiles and Space Group. Also, Vance Coffman to head of the Missiles and Space Group until joint operations begin with Martin Marietta; formerly executive vice president at Lockheed.

Penstock—John Windhol to product manager for the M/A-COM and RF Prime lines; formerly a field engineer.

Amplica, Inc.—Paul O. Daughenbaugh, Jr. to general manager; formerly senior vice president of operations and engineering. Also, Prem K. Sood to vice president of thin-film technology; formerly manager of thin-film operations for Lucas Aerospace's Microwave Technologies Division.

Litton Industries—Peter Sahjani to director of international sales and marketing for the Litton Solid State Division; formerly director of marketing and applications at Loral-FSI.


SAHJANI


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Rogers Corp.—Aarno A. Hassell to vice president of market and venture development; formerly vice president of circuit materials.

Sciteq Electronics, Inc.—Wayne W. Warden to western regional sales manager; formerly sales manager of Western Microwave.

Loral Corp.—Richard A. Inciardi to executive director of its Space Systems/Loral subsidiary to handle satellite-systems business developments; formerly senior director of business development for Fairchild Space & Defense Corp.

Meta-Software, Inc.—Richard N. Lanham to director of international sales in Asia; formerly strategic account manager for Cadence Design Systems.

Interstate Electronics Corp.—Bradford S. Anderson to vice president of business development; formerly director of marketing for Stanford Telecom.


ANDERSON


BEATTIE

Aerovox, Inc.—Paul S. Beattie to national sales manager; formerly area sales manager for southern California, the mid-Atlantic states, Canada, and the Middle East.

Andrew Corp.—Floyd L. English to chairman of the board; he retains the president and CEO titles.

GHz Technologies, Inc.—John Devlin to marketing and sales manager; formerly sales manager for wireless products at K&L Microwave.

MRC Telecommunications, Inc.—Craig Stapel to vice president of sales; formerly senior manager for MCI in Des Moines, IA.

Electro-Metrics, Inc.—David R. Cook to manager of marketing and sales; formerly director of sales for Electro-Mechanics Co.

AVX Corp.—Donald Coppinger to southwestern regional sales manager; formerly western regional manager at Vitramon.

C-COR Electronics, Inc.—David J. Eng to vice president of sales and service; formerly regional sales manager for Sprint Corp.

GO Communications Corp. (formerly Columbia PCS, Inc.)—Michaela Barnes to director of marketing; formerly director of market planning and analysis for Concert Communications Corp., the new global joint venture between MCI and British Telecom.

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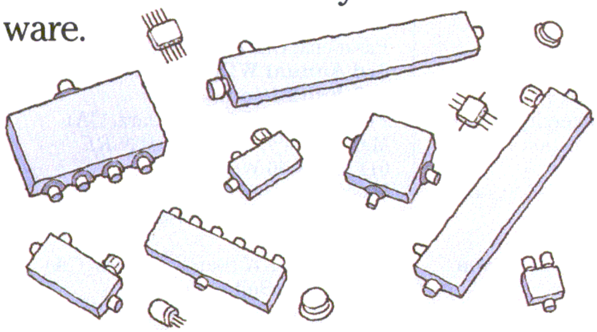
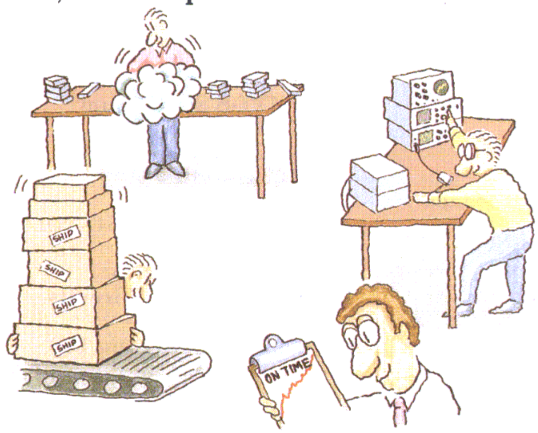
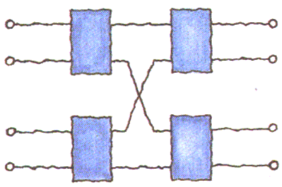


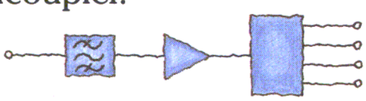
Now, we put it all together for you, test it, and ship it...on time!



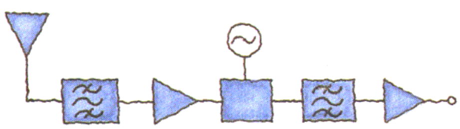
What is "it"? A Beamformer.



A Multicoupler.



A low noise receiver.



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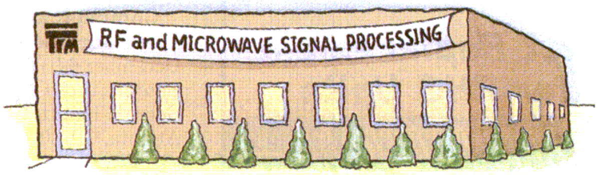

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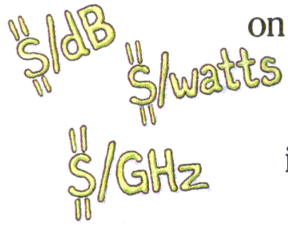

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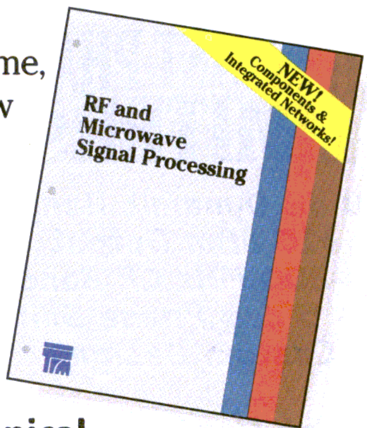

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Short Courses

Microwave Measurements
November 29-30 (Boulder, CO)
MTT-S Automatic RF Techniques Group/National Institute of Standards and Technology (NIST)
Ray Tucker
Rome Laboratory/ERST-A
525 Brooks Rd.
Griffiss AFB, NY 13441

Analog and Digital Cellular Networks: CDMA vs. TDMA
December 5-7 (Washington, DC)
The George Washington University
Continuing Engineering Education Program
School of Engineering and Applied Science
(202) 994-6106

Far-Field, Anechoic-Chamber, Compact, and Near-Field Antenna Measurements
December 6-9 (Atlanta, GA)
Georgia Tech Continuing Education
Georgia Institute of Technology
Atlanta, GA 30332; (404) 894-2547

Meetings

The Automatic RF Techniques Group
Fall 1994 Conference
December 1-2 (Boulder, CO)
Ronald Ginley
NIST, Mail Stop 813.06
325 Broadway
Boulder, CO 80303; (303) 497-3634

Asia-Pacific Microwave Conference (APMC '94)
December 6-9 (Tokyo, Japan)
Prof. Masami Akaike
Technical Program Committee
c/o REALIZE, INC.
2-16-13 Yushimi
Bunkyo-ku, Tokyo 113, Japan
+81-3-3815-8590

IEEE International Electron Devices Meeting
December 11-14 (San Francisco, CA)
Melissa Widerkehr
IEDM
1545 18th St., N.W.
Suite 610
Washington, DC 20036; (202) 986-1137

1995

AFCEA & US Naval Institute Western Conference & Exposition
January 18-20 (San Diego, CA)
AFCEA International Programs Office
4400 Fair Lakes Court
Fairfax, VA 22033; FAX: (703) 818-9177

EMI/EMC Metrology Challenges for Industry
January 25-26 (Boulder, CO)
National Institute of Standards and Technology (NIST)
Ms. Ann Bradford
NIST, Mail Stop 813.07
325 Broadway
Boulder, CO 80303; (303) 497-3321

RF Expo West
January 29-February 1 (San Diego, CA)
6300 S. Syracuse Way, Suite 650
Englewood, CO 80111; (800) 828-0420

Wireless '95
February 1-3 (New Orleans, LA)
Cellular Telecommunications Industry Association (CTIA)
1250 Connecticut Ave., N.W.
Washington, DC 20036; (202) 785-0081

16th Annual IEEE Aerospace Applications Conference
February 4-11 (Aspen, CO)
Sohrab Mobasser, Program Chairman
Jet Propulsion Lab
MS 198-235
4800 Oak Grove Dr.
Pasadena, CA 91109; (818) 354-4466

3rd Annual WIRELESS Symposium & Exhibition
February 13-15 (Santa Clara, CA)
Mary Begley, *Microwaves & RF*
611 Route 46 West
Hasbrouck Hts., NJ 07604; (201) 393-6289

International Solid-State Circuits Conference
February 15-17 (San Francisco, CA)
Attn: Diane Suiters
655 15th St. N.W., Suite 300
Washington, DC 20005
FAX: (202) 347-6109

US Conference on GaAs Manufacturing Technology
May 7-11 (New Orleans, LA)
Tom Cordner, Conference Chair
Texas Instruments
(214) 995-5511

IEEE MTT-S Symposium
May 15-16 (Orlando, FL)
Mahesh Kumar
c/o LRW Associates
1218 Balfour Dr.
Arnold, MD 21012; (410) 647-1591

Call for Papers

Custom Integrated Circuits Conference
May 1-4, 1995 (Santa Clara, CA)
Melissa Widerkehr
CICC
1545 18th St., N.W., Suite 610
Washington, DC 20036; (202) 986-2166
Deadline for papers: December 14, 1994

5th International Symposium on Recent Advances in Microwave Technology
September 11-16, 1995 (Kiev, Ukraine)
Banmali Rawat
Technical Program Co-Chair
Dept. of Electrical Engineering
University of Nevada
Reno, NV 89557; (702) 784-6927
Deadline for abstracts: January 30, 1995

Asia-Pacific Microwave Conference (APMC '95)
October 10-13, 1995 (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
Deadline for papers: March 10, 1995

IEEE Military Communications Conference
November 5-8, 1995 (San Diego, CA)
Joe M. Straus
Electronics Systems Division
The Aerospace Corp.
M4/933
P.O. Box 92650
Los Angeles, CA 90009
Deadline for abstracts: February 3, 1995

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AFS3-01000200-08-ULN	1–2	34	1.0	**0.8**	2.0:1	+10	**$1150**
AFS3-02000400-10-ULN	2–4	28	1.0	**1.0**	2.0:1	+10	**$ 950**
AFS3-02000600-12-ULN	2–6	24	1.0	**1.2**	2.0:1	+10	**$ 950**
AFS3-04000800-10-ULN	4–8	24	1.0	**1.0**	2.0:1	+10	**$ 950**
AFS3-08001200-14-ULN	8–12	22	1.0	**1.4**	2.0:1	+10	**$1050**
AFS3-02000800-18-ULN	2–8	20	1.5	**1.8**	2.0:1	+10	**$1050**
AFS4-12001800-28-ULN	12–18	20	1.5	**2.8**	2.0:1	+10	**$1150**
AFS4-08001800-30-ULN	8–18	20	1.75	**3.0**	2.0:1	+10	**$1150**
AFS4-06001800-35-ULN	6–18	18	2.0	**3.5**	2.0:1	+10	**$1150**
AFS4-02001800-35-ULN	2–18	18	2.5	**3.5**	2.0:1	+10	**$1150**
AFS3-00100200-15-ULN	0.1–2	36	1.0	**1.5**	2.0:1	+10	**$ 950**
AFS3-00100400-18-ULN	0.1–4	28	1.3	**1.8**	2.0:1	+10	**$ 950**
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AFS3-00100800-25-ULN	0.1–8	24	1.5	**2.5**	2.0:1	+10	**$ 950**
AFS3-00101000-32-ULN	0.1–10	20	1.5	**3.2**	2.0:1	+10	**$ 950**
AFS3-00101200-35-ULN	0.1–12	20	1.75	**3.5***	2.0:1	+10	**$ 950**
AFS4-00101800-40-ULN	0.1–18	18	2.5	**4.0***	2.5:1	+10	**$1150**
AFS4-00102000-50-ULN	0.1–20	16	2.8	**5.0***	2.5:1	+10	**$1150**

* Noise figure increases below 500 MHz

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CIRCLE NO. 220

Editorial call!

The editors of *Microwaves & RF* invite you to submit design features and new product information addressing the themes of our 1995 issues. Each issue is dedicated to a particular area, highlighting recent advances in RF and microwave technologies. Design features should demonstrate innovation and practical applications of new devices, materials, and techniques to the challenges facing engineers in the RF and microwave industry. The length of design features should be limited to about 18 double-spaced typewritten pages with four to eight illustrations and must reach us at least 60 days prior to the targeted month. Articles not fitting an issue theme are also considered.

Issue themes:

February.................**Devices & ICs**
March ....**Wireless Technology/ WIRELESS Show Wrap-Up**
April...................**Communications/ MTT-S Show Preview**
May...................**Radar & Antennas**
June..............**Military Electronics**
July........**Modulation Techniques**
August.......**Wireless Applications**
September.......................**Dual-Use Technologies**
October.................**GaAs & Silicon**
November...........**Computer-Aided Engineering**
December...............**Wireless Show Preview/Top Products of 1995**

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NEWS UPDATE

TRACKING STORIES PREVIOUSLY REPORTED IN MICROWAVES & RF

TOUGH TALK FOR THE MILITARY MICROWAVE MARKET. Microwave manufacturers must employ every cost-saving measure, every market analysis tactic, and every business structuring strategy they can to compete in the world market, according to a new market study by Frost & Sullivan (Mountain View, CA). The study also notes that many industry companies are not doing what is necessary to succeed in the market, such as controlling their overhead, incorporating commercial technologies into their product development plans, integrating MMIC technologies into their products, and improving company/supplier relations. Although microwave components are critical to military systems, the F&S study, *World Military Microwave Components & Assembly Markets*, projects the market will reach a low of $1.11 billion in 1996. However, F&S says the market has some promising areas; namely, high-end microwave hybrids, which may increase their market share of total microwave component revenues from 19.2 percent in 1991 to 30.6 percent in 1999. F&S says the Pacific Rim and Middle East continue to offer opportunities as defense spending in those regions increases. Nevertheless, F&S believes revenues for the world microwave assemblies market will fall 10 percent between 1993 and 1996, "Several military microwave assembly manufacturers may leave the market during that time unless they are able to offer commercial products that can sustain them until defense spending increases." The F&S also says that many companies lack an overall understanding of how market requirements are changing and are unsure about the changes that are necessary in managing their businesses.

NEXT: COMMERCIAL APPLICATIONS ABOVE 40 GHz. The Federal Communications Commission (FCC) now plans to release its proposal for allocating frequency bands above 40 GHz for commercial applications in mid-October. (The proposal was to have been released in mid-July but was delayed, in part, by the arrival of two new commissioners.) Release of the FCC proposal will be followed by a period of public comment. Michael Marcus, assistant chief of the commission's Field Operations Bureau, says the allocation of bands from 40 through 150 GHz could be announced by mid-1995.

SIGN OF THE TIMES. In keeping with the times, the Electronic Industries Association (EIA) will dedicate much of its 24th annual Research & Development (R&D) and Budget Conference (March 28-29, 1995 in Washington, DC) to commercial topics. Sessions will cover civil research, business and investment strategies, dual-use technologies, and worldwide avionics markets. Presentations on emerging market opportunities will also be made by the Departments of Commerce, Transportation, and Energy.

IRIDIUM FILES ITS FLIGHT PLAN. Iridium, Inc. (Washington, DC), the group organized by Motorola to develop and operate a global 66-satellite wireless personal communications network, says it expects to take delivery of its first satellites in late 1996. These satellites will be launched in January 1997 and Iridium plans to begin commercial service in October 1998. The system is designed to permit virtually any type of telephone transmission, including voice, data, fax, and paging.

—RON SCHNEIDERMAN

W-band mixers feature 12.8-dB conversion loss

Field-effect-transistor (FET) mixers feature better intermodulation and compression performance than their diode counterparts, making them desirable for millimeter-wave applications. K.W. Chang *et al.* at the TRW Space and Electronics Group (Redondo Beach, CA) and W.H. Ku at the University of California at San Diego present a single-balanced, W-band mixer realized with 0.1-μm pseudomorphic GaAs high-electron-mobility-transistor (HEMT) technology. The mixer delivers a minimum conversion loss of 12.8 dB at 93 GHz for an +8-dBm local-oscillator (LO) drive level; this represents a 10-dB improvement over previously-reported performance. See "A W-Band Monolithic, Singly-Balanced Resistive Mixer With Low Conversion Loss," *IEEE Microwave and Guided Wave Letters*, Vol. 4, No. 9, September 1994, p. 301.

BiCMOS process produces high-speed devices

The trend toward greater functionality in high-speed digital circuits is increasing the importance of integrating high-density complementary-metal-oxide-semiconductor (CMOS) and bipolar emitter-coupled-logic (ECL) functions. This integration is challenging due to the conflicting fabrication-process requirements of CMOS and bipolar devices. T.M. Liu *et al.* at AT&T Bell Laboratories (Holmdel, NJ) outline a silicon fillet self-aligned contact (SIFT) process that permits integration between CMOS and bipolar devices while reducing parasitic capacitances. The bipolar CMOS (BiCMOS) process was used to build a frequency divider providing 13.5-GHz operation and optical preamplifiers operating at 2.5 and 5.0 Gb/s. See "An Ultra-High-Speed ECL-BiCMOS Technology With Silicon Fillet Self-Aligned Contacts," *IEEE Transactions on Electron Devices*, Vol. 41, No. 9, September 1994, p. 1546.

Transitions link slotline with CPW at Ka-band

The development of optoelectronic integrated circuits (OEICs) on indium phosphide (InP) is being sought for high-speed communications applications. Coplanar waveguide (CPW) is especially suitable as a transmission medium for radio circuits on InP at frequencies up to W-band. D. Mirshekar-Syahkal at the University of Essex (Essex, United Kingdom) and D.J. Newson, D. Wake, and I.D. Henning at BT Labs (Suffolk, United Kingdom) discuss three different CPW-to-slotline transitions for 30-GHz operation. Two of the transitions provide a direct connection between the CPW and slotline, exhibiting bandwidths as large as 35 GHz. The third transition design is a balun circuit which provides a return loss of –15 dB at 30 GHz. See "Wideband Transitions for Applications in MMICs and OEICs," *IEEE Microwave and Guided Wave Letters*, Vol. 4, No. 9, September 1994, p. 299.

MESFET design reduces parasitic-coupling effects

The increasing complexity and decreasing size of multifunction monolithic microwave integrated circuits (MMICs) used in state-of-the-art communications systems is making them more vulnerable to coupling between circuit elements. In response to this problem, A.D. Yarbrough and S.S. Osofsky at the Aerospace Corp. (Los Angeles, CA) present the concentric metal-semiconductor field-effect transistor (CMESFET), which is less vulnerable to coupling and crosstalk than conventional devices while being compatible with standard planar circuitry. The transistor features a grounded source electrode that surrounds the gate and drain electrodes, shielding them from electromagnetic fields. Simulation results indicate a bandwidth of 17 GHz for a gate length of 2 μm. See "Design and Analysis of a Traveling-Wave MESFET With Enhanced Shielding Capabilities," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, No. 9, September 1994, p. 1610.

Power MESFET uses 2.9-V drain bias

Because the number of battery cells in handheld phones affects the overall system size and weight, these systems must employ highly-efficient transistors requiring low operating power. J.-L. Lee at the Electronics and Telecommunications Research Institute (Taejon, Korea) outlines a power GaAs metal-semiconductor field-effect transistor (MESFET) that delivers 31.5-dBm output power at 900 MHz while utilizing a 2.9-V drain bias. The corresponding gain and power-added efficiency are 11.5 dB and 64 percent, respectively. See "2.9-V-Operation GaAs Power MESFET With 31.5-dBm Output Power and 64-Percent Power-Added Efficiency," *IEEE Electron Device Letters*, Vol. 15, No. 9, September 1994, p. 324.

IMAGE REJECTION MIXERS

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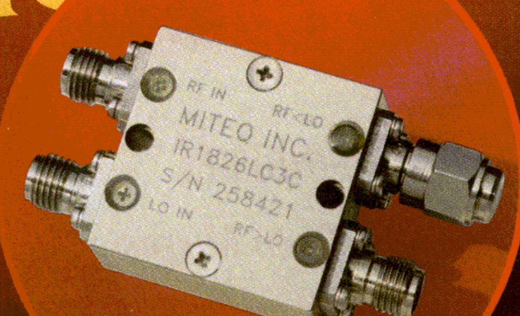

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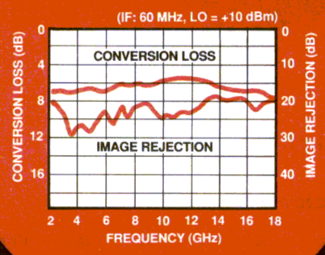

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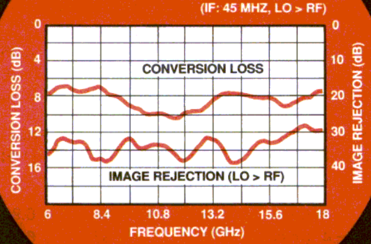

IMAGE REJECTION MIXERS AND I/Q PHASE DETECTORS

Model Number	Frequency Range RF (GHz)	Frequency Range IF* (MHz)	LO Power (Nominal) (dBm)	Conversion Loss (Typ./Max.) (dB)	Image Rejection (Typ./Min.) (dB)	LO-RF Isolation (Typ./Min.) (dB)	Input IP^3 (Typ.) (dBm)
IR0502LC1	.5 to 2	DC to 100	10 to 13	8.5 / 9.5	18 / 15	20 / 18	15
IR0104LC1	1 to 4	DC to 200	10 to 13	8.0 / 9.0	20 / 18	20 / 18	15
IR0208LC2	2 to 8	DC to 500	10 to 13	8.0 / 9.0	20 / 18	20 / 18	15
IR0618LC3	6 to 18	DC to 500	10 to 13	8.0 / 10.0	20 / 18	20 / 18	15
IR0218LC1	2 to 18	DC to 500	10 to 13	9.5 / 11.0	18 / 15	20 / 18	15
IR0226LC1	2 to 26	DC to 500	10 to 13	12.0 / 14.5	18 / 15	18 / 15	15
IRE0104LI1	1 to 4	DC to 200	10 to 13	8.5 / 9.5	40 / 28	30 / 24	15
IRE0208LI1	2 to 8	DC to 500	10 to 13	8.5 / 9.5	40 / 28	30 / 24	15
IRE0618LI1	6 to 18	DC to 500	10 to 13	9.0 / 10.0	40 / 28	35 / 24	15
IRB0104LC1	1 to 4	DC to 200	–10 to +10	8.0 / 9.5	20 / 18	23 / 20	0
IRB0208LC1	2 to 8	DC to 500	–10 to +10	8.0 / 9.5	20 / 18	23 / 20	0
IRB0618LC1	6 to 18	DC to 500	–10 to +10	9.0 / 10.0	20 / 18	23 / 20	0
IR0501LC1	.5 to 1	DC to 100	10 to 13	8.0 / 9.0	20 / 18	23 / 20	15
IR0102LC1	1 to 2	DC to 200	10 to 13	7.0 / 8.0	20 / 18	23 / 20	15
IR0204LC2	2 to 4	DC to 500	10 to 13	6.5 / 7.5	20 / 18	23 / 20	15
IR0408LC2	4 to 8	DC to 500	10 to 13	7.0 / 8.0	20 / 18	23 / 20	15
IR0812LC2	8 to 12	DC to 500	10 to 13	8.0 / 9.0	20 / 18	23 / 20	15
IR1218LC3	12 to 18	DC to 500	10 to 13	8.0 / 9.5	18 / 15	23 / 20	15
IR1826LC3	18 to 26	DC to 500	10 to 13	9.0 / 12.0	18 / 15	23 / 20	15
IRN0304LC2	3.7 to 4.2	DC to 100	7 to 13	5.5 / 8.0	20 / 18	23 / 20	15
IRN0506LC2	5.4 to 5.9	DC to 500	7 to 13	5.5 / 8.0	20 / 18	23 / 20	15
IRN0910LC2	8.5 to 9.6	DC to 1000	7 to 13	7.0 / 9.5	20 / 18	23 / 20	15
IRN1416LC3	14 to 16	DC to 1000	7 to 13	7.0 / 9.5	20 / 18	23 / 20	15
IRF0102	1.2 to 1.7	10 to 100	20 to 25	8.0 / 10.0	20 / 18	25 / 20	33
IRF0304	3.7 to 4.2	10 to 500	20 to 25	8.0 / 10.0	20 / 18	25 / 20	33
IRF0506	5.4 to 5.9	DC to 500	20 to 25	8.0 / 10.0	20 / 18	25 / 20	33
IRF0910	8.5 to 9.6	DC to 1000	20 to 25	8.0 / 10.0	20 / 18	25 / 20	33
IRF1416	14 to 16	DC to 1000	20 to 25	8.0 / 10.0	20 / 18	25 / 20	33

*Standard models provided with octave IF bandwidths, custom designs are available with multioctave IF coverage

For additional technical information, custom design requirements or descriptive literature, please contact Ted Heil, Marketing Manager, at (516) 436-7400, extension 315.

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CIRCLE NO. 228

SOFTWARE SIMULATES ANTENNA PROPAGATION IN WIRELESS SYSTEMS

Once used for military simulations, these powerful antenna design tools can now be applied to commercial applications.

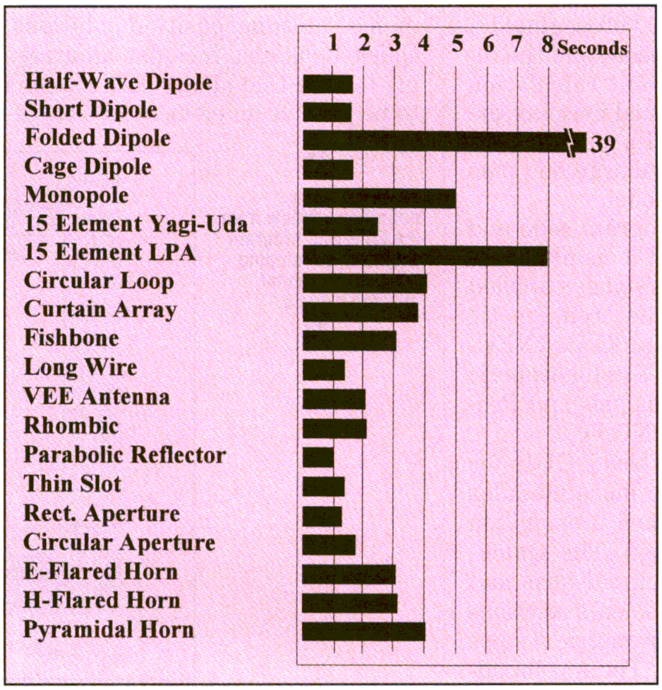
ANTENNAS remain one of the most difficult of all high-frequency components to model. Because they radiate into free space, equations governing radiators with boundaries do not truly apply. Commercial electromagnetic (EM) simulators have begun to attack antenna simulations, but many of these applications are still experimental. Fortunately, years of research performed at the Communication Engineering Laboratory (CEL) of the Science Applications International Corp. (SAIC) (Marlborough, MA) have recently been transformed into powerful design tools for antenna analysis.

The software tools can be used on workstations as well as on 486-level personal computers. Three of these software modules provide antenna analysis of designs from low frequencies (LFs) through super-high frequencies (SHFs) using closed-form solutions, method of moments, and Geometric Theory of Diffraction techniques. Two software propagation modules provide analysis of medium-frequency (MF) ground-wave, MF sky-wave, and high-frequency (HF) sky-wave communication links.

MALCOLM PACKER, Senior Engineer, Science Applications International Corp., Communication Engineering Laboratory, 300 Nickerson Rd., Marlborough, MA 01752; (508) 460-9500, FAX: (508) 460-8100.

The software programs simplify antenna and propagation modeling with modern graphical-user-interface (GUI) tools. The flexibility of these modules matches modeling sophistication to the capability of the user. This "matching" not only shortens the "learning curve" but also reduces the time required to produce useful results. Faced with reduced government spending and available manpower, these modules provide extensive analysis capabilities appropriate for modern work forces faced with the pressures of increased competition and decreased time to market.

Most graphically-based EM software is for analysis of closed systems. Typical closed systems are confined within well-defined boundary conditions (i.e., filters and wave-



1. The execution time for the Quick-Look antenna-analysis program module was plotted for a typical personal computer.

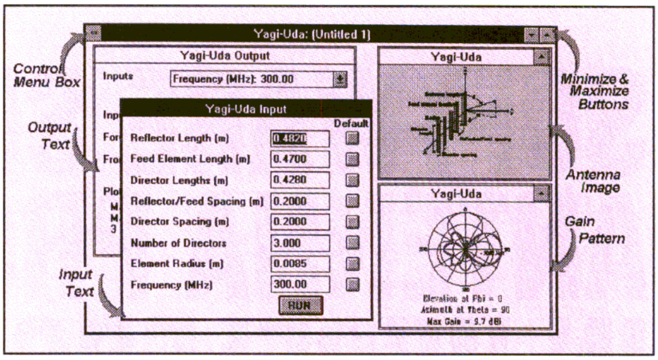
guide structures). Even for these simple structures, resulting EM-field solutions are often only electrostatic fields. Open systems, such as EM radiation in free space, are defined by infinite boundary conditions, which makes discrete spatial stepping solutions unmanageable. Rigorous codes that solve open systems can be extremely difficult to use. For example, the Numerical Electromagnetic Code (NEC)[1,2] is a well-established and validated code that provides accurate antenna-characteristic predictions based on method-of-moments solutions.[3]

METHOD OF MOMENTS

The method-of-moments solution is a matrix solution where each antenna wire must be divided into small pieces called segments. Every segment and its relationship to every other segment is represented in a square matrix for inversion and solution. Each wire is defined by its Cartesian endpoints, radius, number of segments, and an assigned tag number. For a single-wire dipole antenna, the NEC definition is a simple task with or without a GUI. When the quantity of wires approaches 100, calculation of endpoint coordinates becomes difficult. The GUI makes it possible, however, to handle antenna and platform models with as many as 10,000 segments. The GUI frees the user from the tedious task of endpoint calculation while providing a visual image of the wire model from all aspect angles, with the ability to enlarge one particular part of the model.

The linking of program code and complementary GUI used in the NEC software has also been applied to the Numerical Electromagnetic Code-Basic Scattering Code (NEC-BSC) program[4] and the Ionospheric Communications Analysis and Prediction Program (IONCAP).[5]

Along with these three GUIs for rigorous codes, two more modules for antenna design and propagation have been developed. The Quick-Look module uses closed-form and simple method-of-moments solutions to perform quick parametric studies of 20 antenna types.[6] The AM-broadcast module is a comprehensive system for modeling MF communication links. The module is composed of three individual submodules for antenna analysis, ground-wave analysis, and sky-wave analysis.



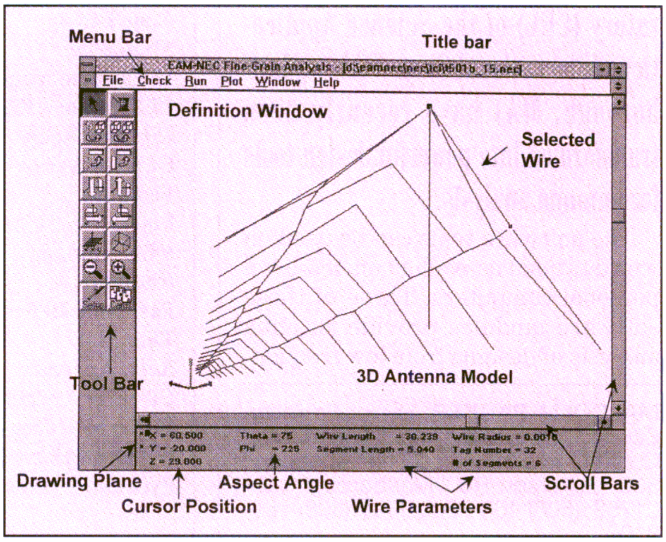
2. This is the typical computer display screen for a Yagi antenna analyzed with the Quick-Look antenna-analysis program module.

The GUI in the Quick-Look module allows for quick specification of each antenna's physical dimensions for parametric studies. The principal advantage of the Quick-Look module derives from the rapid central-processing-unit (CPU) time required for each antenna analysis. These CPU-time requirements vary from nearly instantaneous to 39 seconds on a 33-MHz, 80486-based personal computer (Fig. 1).

The numerical antenna-analysis approach depends on the particular antenna type under study, with all 20 algorithms described as either closed-form, simple method-of-moments, or superposition solutions. Quick-Look also includes an arraying feature that allows each antenna to be used as an element in a three-dimensional antenna array.

Each antenna type within the Quick-Look module has four windows used for input and output information (Fig. 2). Tailored to each antenna type, the input window allows the user to describe physical dimensions, excitation characteristics, and other measured quantities. The user can enter a specific value or use a default option. Defaults appear for each parameter and can be used as a guide or tutorial for a "typical" antenna. An additional "user-friendly" feature is instant error checking. If an out-of-range or invalid value is entered, the GUI will alert the user to this error and provide assistance in choosing acceptable values. All functions in this window can be performed with either mouse or keyboard control.

An antenna diagram serves as a useful reference for all required physical input parameters such as length, height, and radius. If a user is unfamiliar with an antenna, its dia-



3. The antenna-definition window from the EAM-NEC program assists in developing three-dimensional antenna models.

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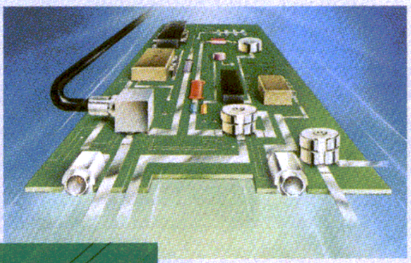

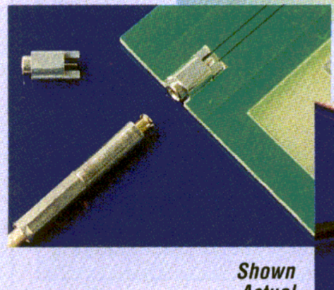

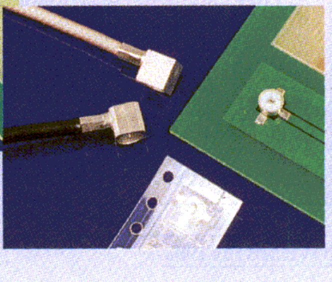

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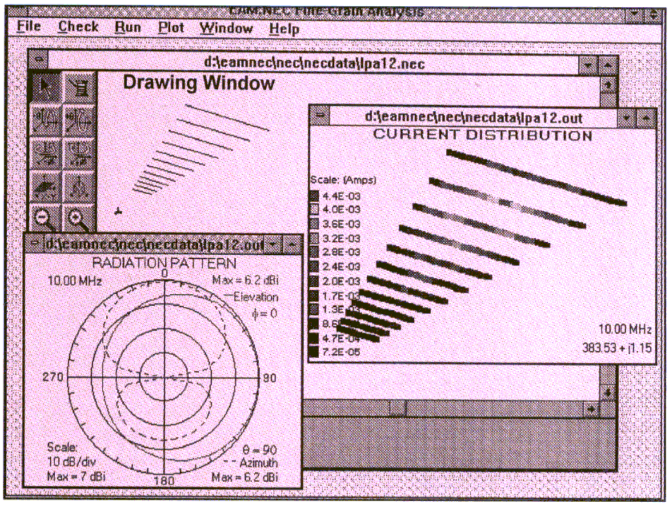
CIRCLE NO. 204



4. Current distributions are displayed using color coding to differentiate between areas of high and low current density.

gram can be enlarged to show greater detail or reduced to create more workspace. Calculated results are displayed in two separate windows: one with specific calculated quantities, the other with a radiation-pattern plot.

A text output window displays calculated parameters, such as maximum gain, half-power beamwidth, and radiation resistance, as well as reviewing the input parameters. The radiation-pattern window contains calculated pattern data for any user-specified plane of view. Users can view an elevation pattern, azimuth pattern, or both. Plots can also be displayed in either Cartesian or polar coordinate systems. As with the antenna diagram, a radiation pattern can be enlarged or reduced to suit an operator.

ANTENNA ANALYSIS

The EAM (Electromagnetic Analysis Module)-NEC module provides complete wire and patch antenna analysis.[7] Core computations are based on the current distribution on a segmented wire and patch model. Computational time is directly related to the electrical size and segmentation of the antenna model. The module includes a three-dimensional antenna-definition package to help users visualize the antenna model, check for input errors, and specify NEC execution-control parameters. The module executes NEC from within the GUI so that the user never has to leave the Windows user interface in order to run a DOS-based code.

The EAM-NEC module includes a menu bar, tool bar, drawing window, and model statistics (Fig. 3). The menu bar allows access to file-management operations, executes NEC, displays output plots, manipulates windows, and provides help information.

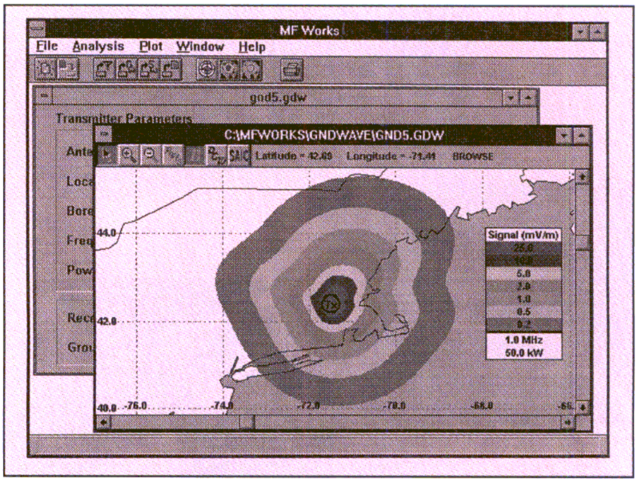
A key feature of the EAM-NEC module is the antenna-definition window. The window is much like a typical Windows vector-based drawing package with additional features for displaying three-dimensional images. This three-dimensional drawing package automates the tedious work of defining and typing wire coordinates in a DOS text file by providing full three-dimensional mouse movement.

An important feature of the EAM-NEC GUI is the method employed for wire definition. Defining a wire is similar to drawing a line in a commercial graphics software package. Wires are drawn simply by "clicking" the left-hand mouse button at the wire start point (coordinate), then "rubber banding" the wire to the desired wire end coordinate and releasing the mouse button. The wire is displayed on the screen and its start and end coordinates are stored in memory for subsequent creation of an NEC input file. Existing wires are easily edited.

Connecting two wires requires that the connecting ends have identical three-dimensional floating-point coordinate values. This connection is not easily accomplished when converting mouse-cursor screen coordinates to three-dimensional coordinates because the distance between screen pixels is much larger than the resolution of a floating-point number. The antenna-definition window provides four functions in order to guarantee precise wire connections: "Snap to Grid," "Wire-Segment Find," "Wire-End Find," and "Display Segmentation."

The first function restricts the cursor movement to a user-defined three-dimensional grid resolution. The second function sets the three-dimensional cursor coordinates to match those of the closest wire-segment with a simple keystroke. The third function sets the three-dimensional cursor coordinates to that of the closest wire end. The last function shows the segmentation of the entire model or selected portions.

5. The IONWIN and AM-broadcast modules can produce color contour plots of polar radiation.



The EAM-NEC's GUI enables an antenna model to be quickly viewed from any point specified in spherical coordinates. This feature is accomplished using "scroll bars," "zoom buttons," and "orientation buttons." Scroll bars are used to change the location of the three-dimensional origin on the screen. Zoom buttons enable a user to enlarge a portion of a model in order to show more detail or shrink the display in order to show more of the model. Coordinate-system-orientation buttons allow a user to view a model from any aspect angle. Each time a button is pressed, positional values are incremented or decremented by a user-specified amount.

After definition of model wires, NEC-execution "control lines" for excitation, frequency, and desired output must be specified. The EAM-NEC program includes a control-line editor that simplifies specification of most NEC-execution parameters. A "miscellaneous" line allows the use of control lines not recognized by the control-line editor, such as "upper medium," "dielectric sheath," and "print control." The experienced user can use the "miscellaneous" line to create any desired execution control line.

DENSITY PATTERNS

Using the EAM-NEC GUI, elevation and azimuth patterns can be displayed individually or together on a single polar plot (Fig. 4). On screen, the two patterns are differentiated by both color and thickness. Color-coded current-density diagrams graphically display current flow, using the convention of blue (cold) for lowest current density and red (hot) for highest current density. The value associated with each color can be determined automatically or specified by the user.

The EAM-BSC module[8] provides predictions of EM scattering from electrically-large objects using a GUI that executes NEC-BSC. As with the EAM-NEC module, this GUI includes a three-dimensional drawing package, user-friendly dialog boxes, NEC-BSC-execution interface, and the capability to rapidly reduce and display NEC-BSC output data.

NEC-BSC, developed at Ohio State University, is based on a uniform asymptotic technique formulated with the uniform geometrical theory of diffraction (UTD). Electrically-large structures, greater than three wavelengths in diameter, are simulated using structures such as plates, cylinders, ellipsoids, and cones. The software's principal output data includes electric-field and magnetic-field strengths as well as radiation patterns. Although NEC-BSC is capable of frequency sweeps, the module does not calculate surface currents, so impedance data is unavailable. The NEC-BSC module employs military-critical code and must be obtained from the Electro-Science Laboratory of Ohio State University.

The IONWIN (for Ionospheric Windows) module provides complete HF sky-wave propagation analysis. It uses a specially-designed GUI that employs the Ionospheric Communications Analysis and Prediction Program (IONCAP). IONCAP predicts propagation characteristics of HF sky-wave channels. A user specifies node parameters (such as transmitter and receiver locations, antenna characteristics, multipath delay, power, noise, frequencies, time of day and month, sunspot number, and required reliability) by means of an input window. A map window based on the Defense Mapping Agency's (DMA) highest-resolution map database assists in specifying geographical coordinates of nodes.

For accurate performance predictions on an HF communication link, antenna radiation-pattern data must also be supplied. This can be accomplished through internal antenna-performance prediction algorithms or by supplying a file that contains IONWIN-compatible pattern data in binary form. Binary antenna data can be created from an HF antenna modeled with EAM-NEC.

The AM-broadcast module provides a comprehensive system for modeling MF frequency antennas and propagation.

Output data can be plotted or stored as an output file. Output plots include signal-to-noise ratio (SNR) versus time of day, frequency versus time of day, required power versus frequency, reliability versus frequency, and polar radiation patterns. Output plots can be displayed as typical x-y plots or as a color contour plot (Fig. 5).

AM PREDICTIONS

The AM-broadcast module provides a comprehensive system for modeling MF frequency antennas and propagation. The module itself is composed of three individual submodules: antenna analysis, ground-wave analysis, and sky-wave analysis. Predictions made with the antenna-analysis submodule serve as the input information for the other submodules.

ANTENNA ANALYSIS

The antenna analysis consists of two stages: performance prediction and output-data visualization. Input parameters are specified with a customized input dialog while outputs are displayed in polar radiation plots. The polar radiation plots consist of azimuth cuts of the antenna's three-dimensional power-gain pattern from a user-defined elevation angle.

As with the antenna analysis, the ground-wave analysis consists of two stages: performance prediction and output-data visualization. Input parameters are specified using a customized input dialog and a transmitter-location input map, while output information is displayed in color contours superimposed on a map. Once an analysis is performed, the results can be stored on disk. The saved file can then be re-opened by the input dialog and by the contour map window.

The input parameters necessary for ground-wave analysis include the antenna-analysis file name, the antenna bore-site angle, the location of the transmitter, the operating frequency, the transmitter power, and the desired receiver grid size. The receive-grid center coincides with the transmitter location. The receive-grid dimensions specify a rectangular area over which predictions are performed. Required receive-grid inputs include width, height, and resolution—all in units of geographical degrees. Ground-wave propagation predictions are accomplished with either homogeneous or varying ground electrical parameters. The sky-wave analysis is performed in the same two-step manner as the ground-wave analysis, with similar input and output parameters. The options between the two submodules are similar.

This collection of antenna and propagation codes is written in C++ or Pascal languages for Windows. The modules are designed for personal computers with 4 MB of random-access memory (RAM), 5 MB of available hard-disk space, MS-DOS 5.0 or higher, and Windows 3.1 or higher operating system working in enhanced mode. An optional map database requires an additional 115 MB of hard-disk storage space. ●●

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LabVIEW GRAPHICAL PROGRAMMING

Gary W. Johnson

Computer control of test equipment has been vital in minimizing the time needed to perform electronic measurements. Early computer-based test systems, however, required tedious programming to perform even simple measurement routines. The demand for user-friendly instrumentation software led to the development of virtual-instrument tools such as LabVIEW from National Instruments (Austin, TX). In *LabVIEW Graphical Programming*, author Gary Johnson outlines programming techniques and provides useful tips for obtaining the maximum benefits from this popular instrumentation software tool.

As the author explains, data acquisition begins with a physical phenomenon to be measured, which may be electrical, optical, or mechanical. A sensor is used to transform the phenomenon into a signal that is easier to transmit and analyze, such as a voltage or current. Signal conditioning is then used to amplify and/or filter the raw data and prepare it for analog-to-digital conversion.

A chapter is dedicated to LabVIEW programming techniques. As Johnson mentions, LabVIEW is a dataflow language which allows different nodes (objects that accept inputs and process them into outputs) to execute in parallel. In fact, all programming is done with the use of block diagrams, which are directly compiled to executable code. Among the programming tools outlined are "for" and "while" loops, shift registers, strings, arrays, and clusters (which are equivalent to records in Pascal and structs in C).

The development of an application in LabVIEW involves a series of steps: defining the problem, specifying the input/output (I/O) hardware, and prototyping the user interface, followed by designing, writing, testing, and debugging the program. As Johnson explains, the addition of thorough documentation will prove indispensable to the users of any LabVIEW application program.

Instrument drivers are collections of virtual instruments used to control a programmable instrument. The instruments used in conjunction with LabVIEW are generally interfaced using serial (RS-232C or RS-422A), GPIB, or VXI standards. Among the functions supported by most instrument drivers are communications, data transfer, configuration management, and basic controls.

Considerable attention is given to applications of LabVIEW in process control, physics, data visualization, and automated testing. For instance, LabVIEW can be used in conjunction with a waveform digitizer to gauge pulsed signals. A test sequencer (or test executive) facilitates automated tests by scheduling tests based upon pass/fail status, providing an operator interface, and organizing test results.

The textbook includes a diskette containing example programs and libraries of utility, circular-buffer, and data-acquisition virtual instruments. Johnson does not assume that readers have a software engineering background or utilize a particular operating platform. (1994, 522 pp., hardcover, ISBN: 0-07-032692-4, $45.00). **McGraw-Hill, Inc., 11 W. 19th St., New York, NY 10011; (800) 2-MCGRAW.**

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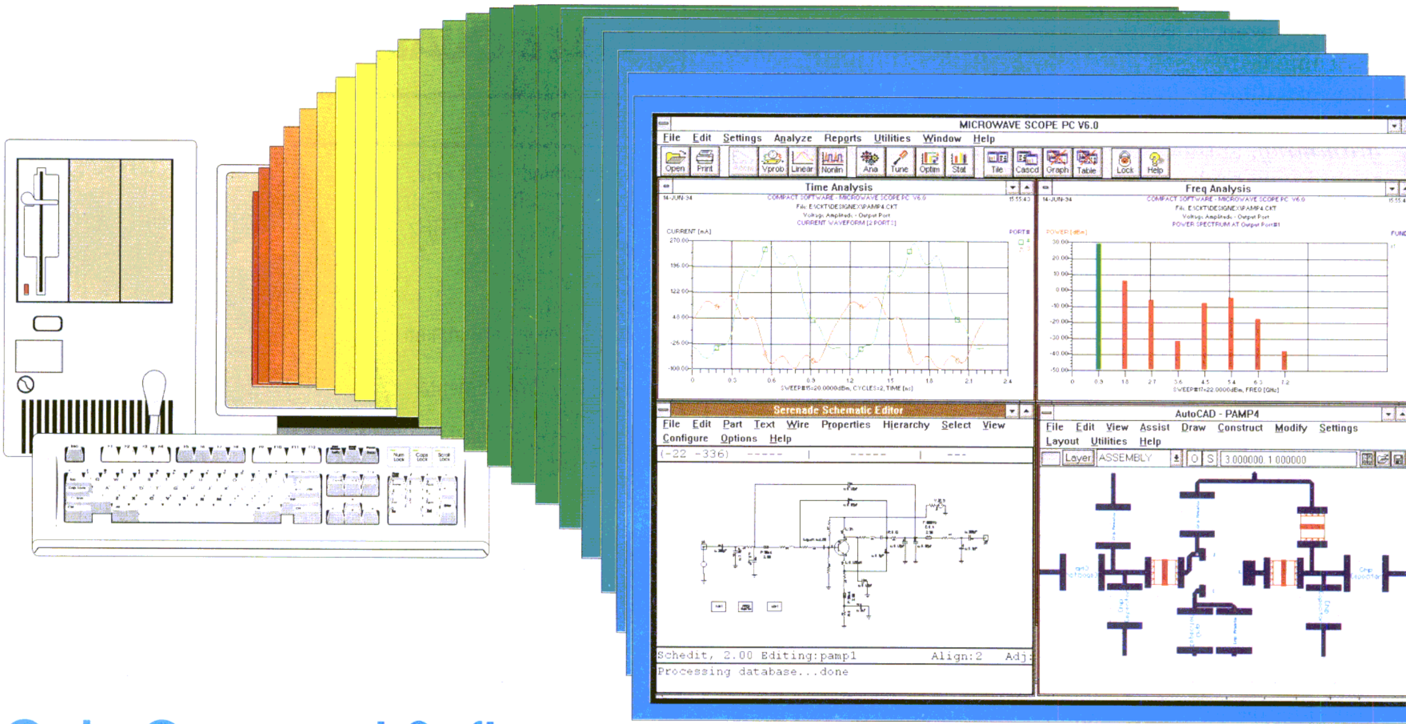

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CIRCLE NO. 218

Penstock Acquired by Avnet, Inc.

Leading RF/Microwave distributor joins Electronics Marketing Group, retains name, independence, market focus.

By DOUGLAS R. DREW

GREAT NECK, N.Y. — Solidifying its position in the rapidly growing wireless communications market, Avnet, Inc. announced today that it has completed the acquisition of Penstock, Inc.

Penstock, the 39th largest industrial distributor in North America, is the United States' leading technical specialist distributor of microwave and radio frequency products and related value-added services.

Under the terms of the acquisition, the Sunnyvale, California-based Penstock will retain its name and remain a separate company, as part of Avnet's Electronics Marketing Group (EMG), currently the world's largest electronics distributor, with sales of more than $2.3 billion.

Sustained Sales Growth

Penstock's sales reached $45 million in the fiscal year ending this past March, an increase of 32% over the previous year, and were projected to exceed $57 million this year. But the privately-held company "wouldn't be able to reach the next level of growth" on its own, according to Bruce White, Penstock's founder and president.

"Avnet has presented Penstock with a golden opportunity," White said. "We'll be able to maintain our individual presence in the industry while having access to additional financial resources to grow the company in such a way as to benefit our customers, suppliers and employees.

"This alliance will allow us to stay focused in our niche communications market," he added, "using strong technical field sales engineers and providing significant inventory levels of quality products to our customers."

White remains president of Penstock, reporting to Roy Vallee, Avnet's president and chief operating officer.

Opportunities For Penstock

"The RF/Microwave market continues to grow dramatically," Vallee said. "We are excited about the potential opportunities for Penstock. They're as committed to quality as we are, so we're especially pleased to welcome them to the Avnet family."

Prior to the acquisition, Avnet EMG was comprised of five sales and marketing divisions; Allied Electronics, Time Electronics, Avnet International, Avnet Computer Group and Hamilton Hallmark.

The alliance represents a major opportunity for both distributors.

By significantly expanding the support network of Penstock, the acquisition will enable both companies to offer more extensive services to their respective clients, according to industry analysts.

A Shared Priority

"Both Penstock and Avnet have always made their customers the number one priority and credit much of their success to this," Vallee said. "The proposed structure of this merger strongly reinforces that philosophy and neither company anticipates any 'shakedown' period since the fit is a perfectly logical one on all levels."

Sources familiar with the deal confirmed that no management changes are planned.

Traditionally a military supplier, Penstock entered the commercial arena six years ago and has increased its revenue by at least 30% every year since then. Although the company still generates about $11 million worth of military business annually, approximately 75% of its business now comes from commercial sales.

$2 Billion Commercial Market

In recent years, the military market has remained essentially static, while analysts estimate that the mushrooming commercial market for RF/microwave components has reached $2 billion.

Founded in 1975 and incorporated in 1984, Penstock's specialized product lines include such principal suppliers as Avantek, Comlinear, Hewlett-Packard, M/A-Com, QMI, Sawtek, SGS-Thomson, Siemens, Star Micronics and Toko America.

Financial terms of the acquisition, which was completed in just over four weeks, were not disclosed.

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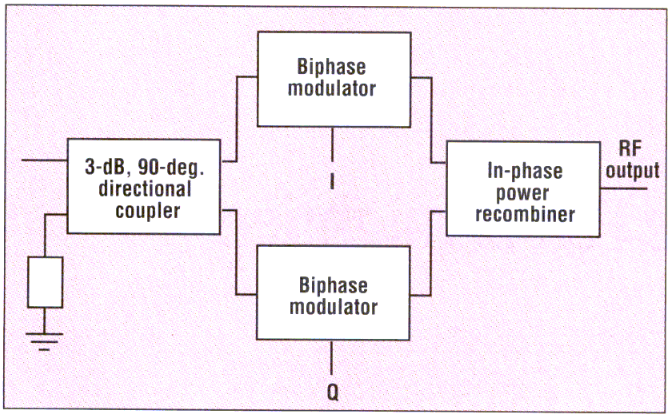
BALANCED DESIGN DELIVERS C-BAND VECTOR MODULATION

This microstrip-based circuit employs common-source MESFETs without the need for input-matching networks.

VECTOR modulators are used to control the amplitude and phase of signals in such applications as microwave communications and instrumentation. These components can be configured for a variety of modulation schemes, including binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), quadrature amplitude modulation (QAM), and even radar chirps. One such modulator employs metal-semiconductor field-effect transistors (MESFETs) in a balanced design to provide C-band operation without the need for input-matching networks.

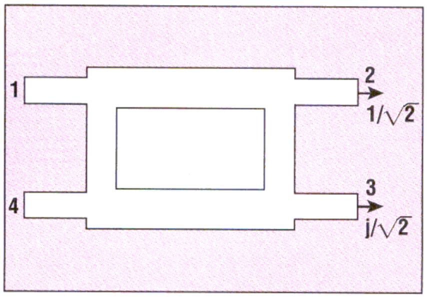
The principle of vector modulation is the quadrature phase recombination of two signals, denoted by I (in-phase) and Q (quadrature). The signals in the I-Q plane represent the signal amplitude and phase with respect to the carrier frequency.[1]

SONIA DASSONVILLE, ENST de Bretagne, BP 832, 29285 Brest Cedex, France; (33) 38-00-14-00, and **FRANCOIS BEAUREGARD** and **FADHEL M. GHANNOUCHI,** Ecole Polytechnique de Montreal, Electrical and Computer Engineering Dept., Case Postale 6079, Succursale A, Montreal, Quebec H3C 3A7, Canada; (514) 340-4671, FAX: (514) 340-5892.



1. The standard vector-modulator circuit splits the input signal into two quadrature signals, which are then combined.

The vector modulator is designed to provide a predictable and unambiguous phase shift between 0 and 360 deg. via the control of MESFET gate bias voltages. The output amplitude is independent of the phase shift but can be varied by using MESFET control voltages.[2]



2. A branchline structure was used for the 3-dB coupler because of its simplicity and good narrowband performance.

In principle, the signal modulated at a carrier frequency ω_c (in rad/s) can be described by the following equation:

$$S(t) = A(t)\ \sin\ [\omega_c t + \phi(t)] \quad (1)$$

where:

A(t), ϕ(t) = the amplitude and phase shift of the modulated signal, respectively.

Ideally, the relationship between the modulated signal and baseband signals [i(t) and q(t)] is given by:

$$A(t) = [i^2(t) + q^2(t)]^{0.5} \quad (2)$$

$$\phi(t) = tan^{-1}\ [q(t)/i(t)] \quad (3)$$

These equations are used to model the vector-modulator operation, but require some tuning due to the nonideal behavior of the different vector-modulator components.[3]

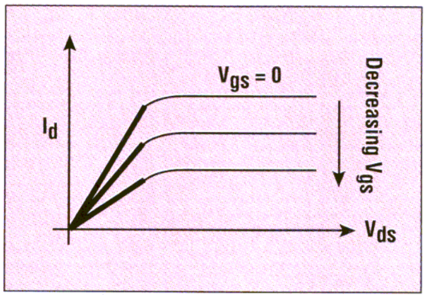
In the standard vector-modulator configuration (Fig. 1), the incoming RF signal is split into two paths

which have a quadrature phase relationship and are used to feed two biphase modulators. Each biphase modulator creates a linear change in the signal's amplitude and phase by performing a multiplication by an arbitrary real number between –1 and +1. The two signals in quadrature phase at the outputs of the two biphase modulators are added via a power combiner.

Each element of the C-band modulator circuit[4] was optimized using Microwave Design System (MDS) software from Hewlett-Packard Co. (Palo Alto, CA) in order to preserve the phase quadrature between the two paths over the entire operating bandwidth.

A branchline configuration was used for the 3-dB hybrid coupler because of its simplicity and good performance over a narrow bandwidth. The input power is split equally between ports 2 and 3 into two quadrature-phase paths. The remaining port is isolated (Fig. 2).

The power combiner was realized with a 180-deg. hybrid ring (rat-race circuit). Power applied at any port of the hybrid ring is divided equally between the two adjacent ports. The remaining port is isolated since the input signal travels over one half wavelength in one direction and one wavelength in the other direction. The longer path introduces a phase reversal that cancels the voltage at the isolated port and creates a virtual ground at that port. In this circuit



4. This I-V characteristic plot illustrates the variation in V_{ds}/I_d ratio with V_{gs}. This variation influences the MESFET output resistance.

design, two signals enter ports 1 and 2 and are recombined at port 3, while port 4 is connected to a 50-Ω resistor (Fig. 3).

In general, PIN diodes are used to achieve the control signals. However, the capacitive and inductive elements used to ensure bias isolation are critical for PIN diodes but are not necessary for MESFETs. For this reason, MESFETs were preferred to PIN diodes.

MESFET CONTROL

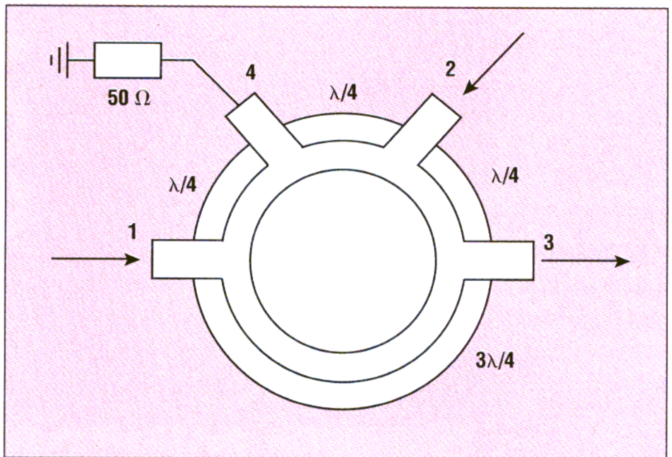
Each MESFET is biased by a voltage source which controls the gate-source voltage (V_{gs}). The variation of V_{gs} changes the V_{ds}/I_d ratio (where V_{ds} and I_d are the drain-source voltage and drain current, respectively) in the MESFET's ohmic region, resulting in a transistor output resistance that varies as shown in Fig. 4. This DC control voltage at the gate produces the required variable attenuation.[5]

With this bias control, the FETs can be modeled as a one-port RLC series circuit that introduces parasitics which may generate variation of the output impedance with frequency. To eliminate these effects, the biphase modulator is designed with a balanced structure (Fig. 5), which is realized with four 3-dB directional couplers.

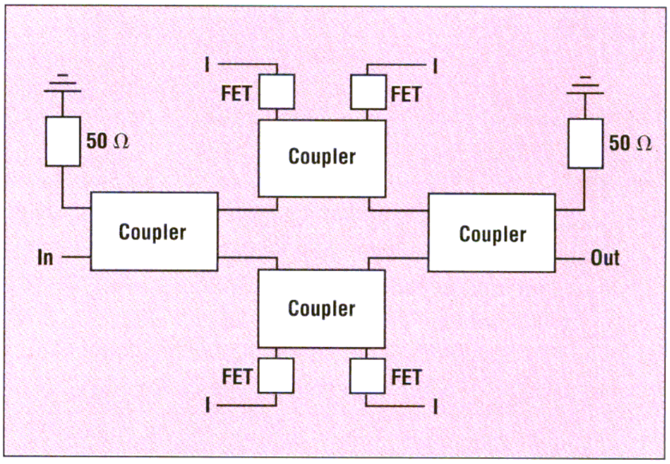
The biphase modulator controlled by the Q signal has the same design as that of the I signal, but the signal variations will be in quadrature with those of the I component. The modulator exhibited a simulated maximum phase error of 5 deg. over the entire operating frequency range.

The vector modulator was realized with a PTFE substrate having a relative permittivity (ϵ_r) of 2.33 and thickness of 20 mils (0.508 mm). The circuit dimensions are 5 × 6 in. (12.7 × 15.2 cm).

To ensure good bias isolation, a capacitance and an inductance were added to each FET. The circuit was then manufactured in microstrip and tested from 3.7 to 4.2 GHz while varying the control voltages. As the test results (Fig. 6) illustrate, the I and Q vectors are not exactly quadrature in phase. However, as long as the FETs are used in their linear ranges, the variations of both vectors will also be linear over the entire operating bandwidth. It is then possible to determine the I and Q voltages needed to synthesize a given amplitude and phase.



3. In the 180-deg. hybrid ring, input signals at ports 2 and 3 are recombined at port 3, with port 4 being isolated.



5. The biphase modulator is realized with this balanced configuration, which features four 3-dB directional couplers.

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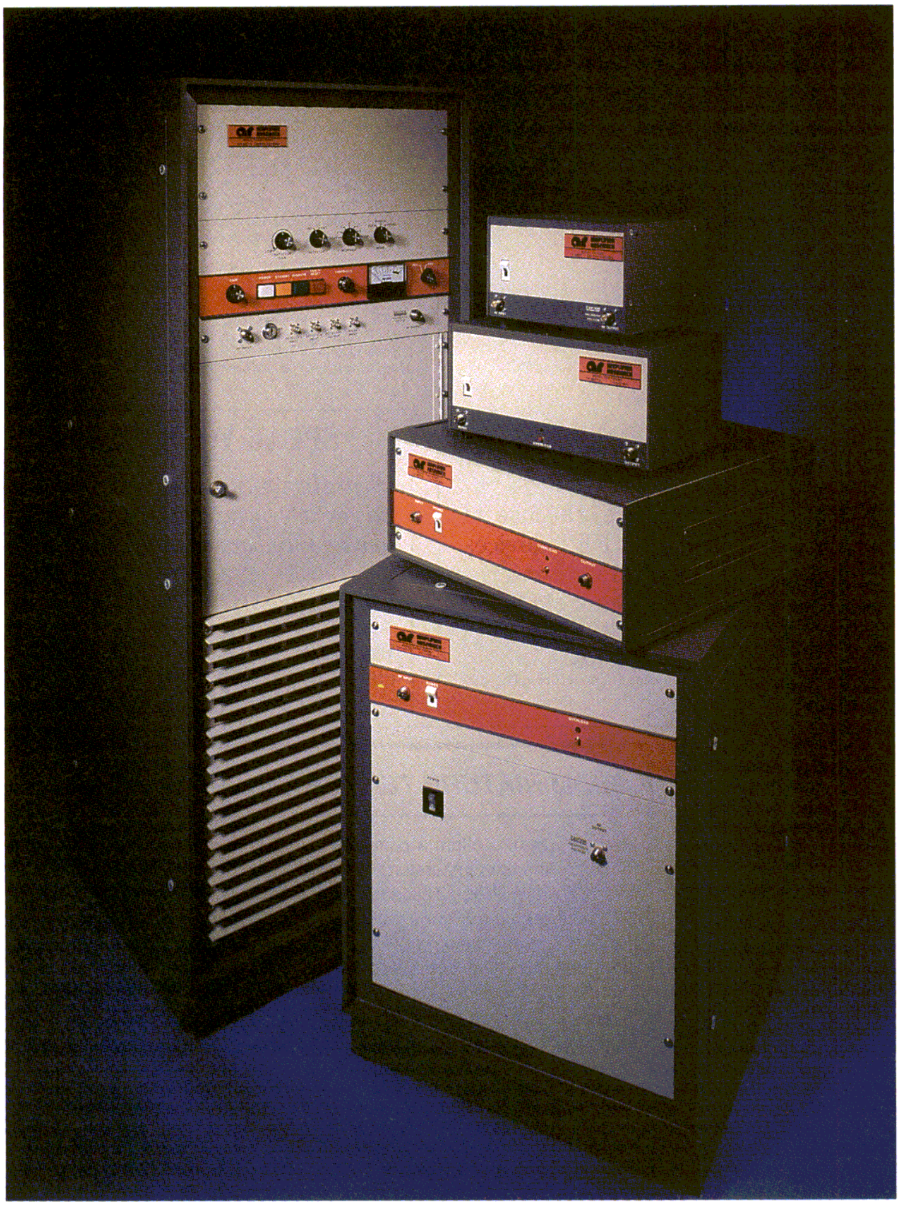

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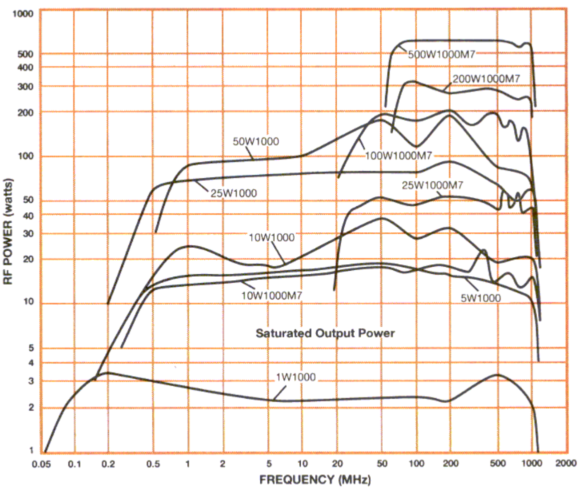

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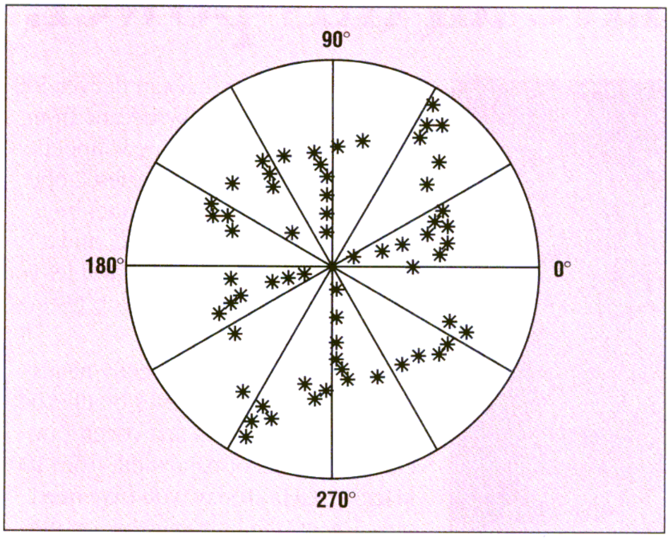
VECTOR MODULATOR



6. The vector-modulator output was measured for varying control voltages from 3.7 to 4.2 GHz.

It is expected that direct modulation at microwave frequencies will produce a better bit error rate (BER) than heterodyne modulation.[6] The proposed configuration is more appropriate for digital modulation schemes and communication systems. Furthermore, the use of planar technology and FET devices easily permits monolithic-microwave-integrated-circuit (MMIC) realization. ●●

Acknowledgments

The authors thank J. Gauthier for manufacturing the vector modulator and the NSER

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For further reading

A. Truitt, J. Cerney, and J.S. Mason, "A 0.3-to-3-GHz Monolithic Vector Modulator for Adaptive Array Systems," *IEEE MTT-S Symposium Digest*, 1989, pp. 421-422.

R. Pyndiah, R. Leblanc, and P. Ballage, "GaAs MMIC Direct Linear Vector Modulators in Digital Radio Links," *Microwave Journal*, March 1990, pp. 136-144.

TECHNIQUE MODELS MILLIMETER-WAVE DIODE DETECTORS

A Schottky-barrier diode mounted across a unilateral finline provides high sensitivity at millimeter-wave frequencies.

THE application of millimeter-wave technology in satellite and terrestrial communications systems demands high-performance detectors operating at those frequencies. A simple, repeatable technique for modeling and designing millimeter-wave detectors employs a Schottky-barrier diode in conjunction with a unilateral finline structure.

Among the typical requirements for millimeter-wave detectors are broadband operation, high sensitivity [tangential signal sensitivity (TSS) < –35 dBm], good resolution (>500 mV/mW), and low return loss (<10 dB).

In order to achieve these RF and DC characteristics, a Schottky-barrier diode mounted across a unilateral finline was employed as the millimeter-wave sensor. Schottky-barrier diodes were utilized for a number of reasons. In particular, high-power sources are not needed to achieve noise-free operation and good linearity in Schottky-barrier diodes (unlike the case with bolometers and thermistors). In addition, the stability of Schottky-barrier diodes is superior to that of other types of semiconductor diodes. A unilateral finline was chosen for the guiding medium because of its performance advantages (such as low cutoff frequencies for higher-order modes) over other transmission media. Unilateral finline is the simplest form of finline structure and is well-suited for fabrication of millimeter-wave components.

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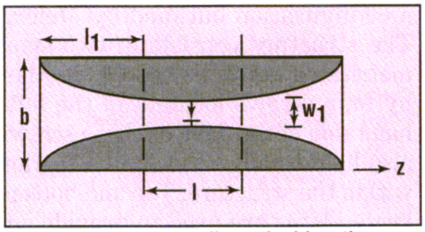
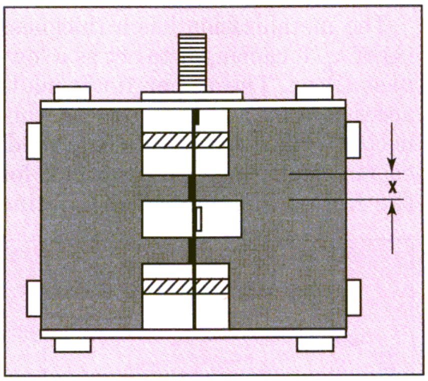
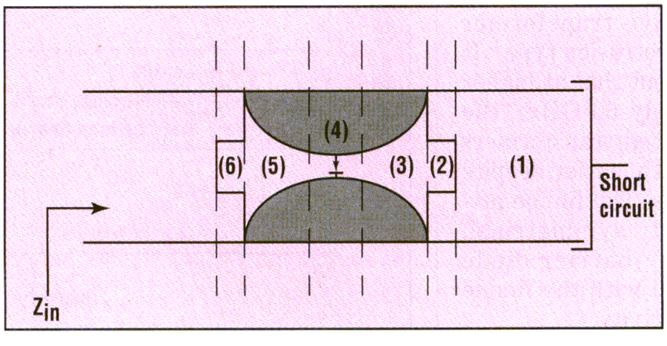


1. In order to minimize discontinuities, the finline's slot width (w_1) is set equal to the diode diameter.

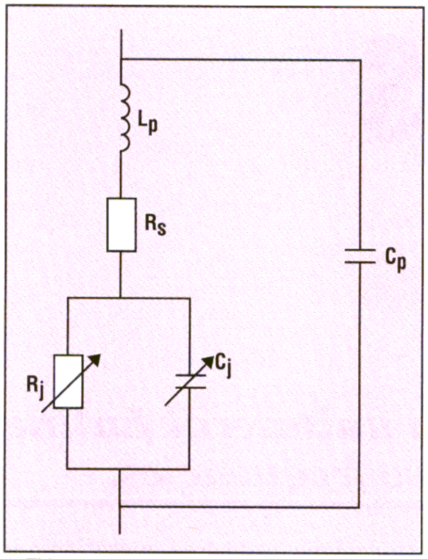


2. The finline detector's upper fin is accessed with a standard SMA connector, while the lower finline is grounded via the detector casing.

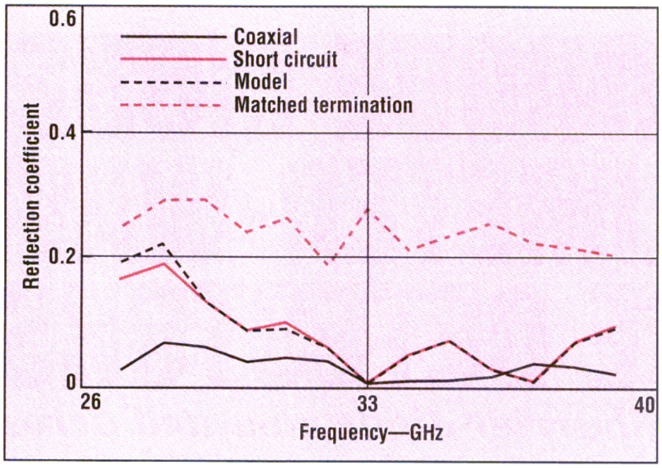
Figure 1 shows a schematic of the finline artwork. The slot width (w_1) is chosen to equal the diode diameter. This is done to minimize the effect of the physical discontinuity due to the mounting of the diode in the finline environment. This was deemed more important than attempting to match the finline impedance to that of the Schottky-barrier diode since an accurate means of determining the diode impedance in



3. The finline detector is modeled by dividing it into discrete subsections. The input impedance of section 1 is the load impedance of section 2, and so on.



4. This simple circuit was used to characterize the Schottky-barrier diode. The effects of package and mounting parasitics (L_p and C_p) can be minimized by using beam-lead devices.



5. Detector measurements show that a variable short-circuit termination provides a much better reflection coefficient than a matched termination. The plot also shows good agreement between measurement and simulation results.

a finline structure was not available.

To negate the discontinuity effects at the beginning of each taper, the fin length (l) was chosen to be $3\lambda_g/4$ (where λ_g is the guide wavelength). Although the signal attenuation and likelihood of higher-order interference increase with the finline length, the discontinuity effect was thought to be the most crucial factor in the finline design. To match the finline realization to the rectangular waveguide, a tapered finline and a series of quarter-wave transformers were included in the design. The taper has a typical profile described by the equation:[1]

$$w(z) = b - (b - w_1)\sin^2(\pi z / 2l_1)$$
$$for\ 0 < z < l$$

where:

b = the waveguide height, and

l_1 = the taper length.

The quarter-wave transformer was a first-order protrusion type.[2] It should be pointed out that at higher frequencies (namely 60 GHz), the fabrication of printed transformers becomes significantly easier despite a larger return loss. The finline artwork is completely symmetrical, with the Schottky-barrier diode mounted in parallel with the finline for maximum sensitivity.

The casing structure was based on a configuration outlined by Meier.[3] The structure consists of two symmetrical brass sections held together by four screws located on the left-hand side of the device. These screws also help to align the finline section within the structure. Top and bottom brass plates are used to provide additional detector stability, while thin Teflon sheets are employed to insulate the conductive surface of the fin from the brass casing (Fig. 2).

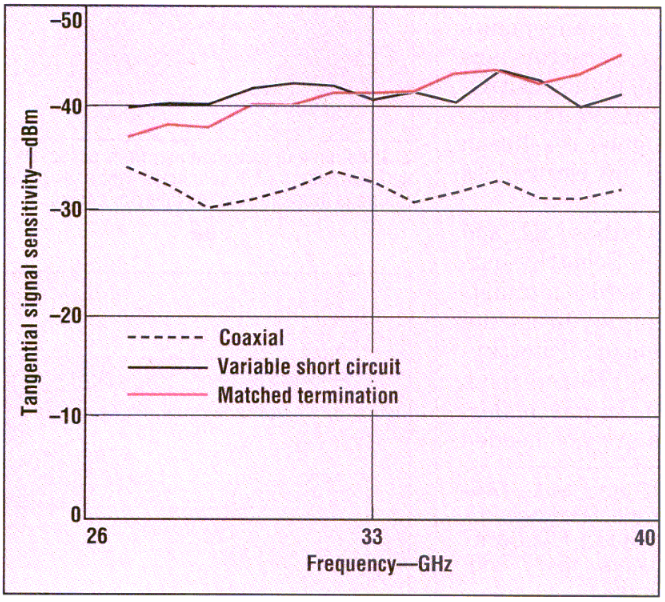
The metallization has a thickness (x) of $\lambda_g/4$, causing it to act as a low-pass filter. The upper fin is made accessible by a standard SMA connector while the lower fin is grounded via the casing. An allowance for the finite thickness of the finline section was made in the casing in order to ensure a smooth transition between the waveguide and finline as well as to minimize structural discontinuities.

The detector may be terminated with a variable short circuit (although this approach only gives improved performance at a particular frequency). For broadband applications, a matched termination can be used.

DETECTOR MODELING

A W-band (75-to-110-GHz) shunt finline Schottky-barrier detector was designed and implemented using the aforementioned technique.

Perhaps the best means of explaining the finline-detector modeling is

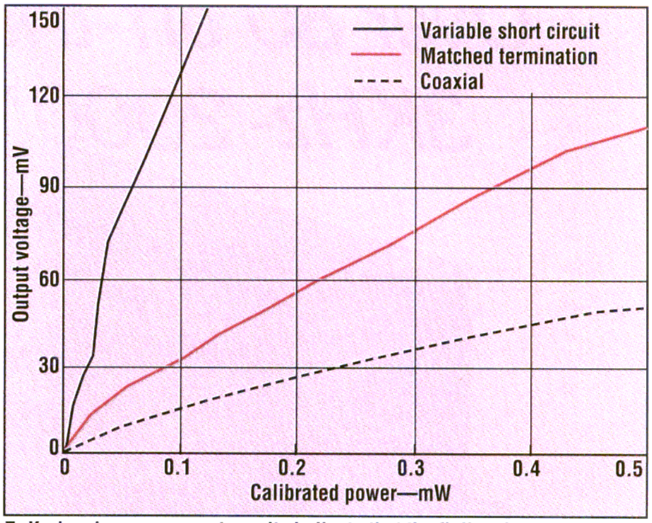


6. The finline detector provides much better tangential signal sensitivity than the coaxial detector, regardless of the termination employed.

to refer to the simplified RF circuit of Fig. 3. This diagram shows how the detector was divided into discrete sections. The input impedance seen at each section was then calculated using well-known transmission-line techniques.

The input impedance of the first section with the known termination (denoted as section 1 in Fig. 3) was initially determined. This value became the load impedance of section 2, whose input impedance was then calculated. This procedure was repeated until the impedance at the device's input terminals (section 6) was found.

Closed-form empirical expressions proposed by Pramanick and Bhartia[4] were used to model the unilateral finline. These formulas effectively "curve-fit" to results obtained with the spectral-domain technique and are accurate to within 2 percent over the entire range of finline dimensions. The finline tapers were modeled by dividing the continuous taper into finite discrete sections (typically 10 to 20 sections). The impedance seen at each step was determined from the input impedance of the previous stage, the length of the step, and the impedance of the finline for that particular gap width. The quarter-wave transformers were modeled using the homogenous waveguide approximation and perturbation theory given by Verver and Hoefer.



7. Ka-band measurement results indicate that the finline detector provides much greater resolution than a coaxial design.

The Schottky-barrier diode can be modeled by using the equivalent circuit of Fig. 4, where R_s represents the spreading resistance, R_j denotes the junction resistance, and C_j designates the junction capacitance. These parameters can be determined either experimentally or analytically.[5]

An important issue must be addressed when modeling the package and mounting parasitics (represented by L_p and C_p). Estimates of the parasitics associated with the diode package and mounting typically given by manufacturers are of limited use for broadband modeling of these devices. This is due to the parasitic elements representing finite lengths and gaps associated with the package and bond wires. Consequently, a distributed LC network was used to model these parasitics accurately. The overall effect of the diode package and mounting parasitics can be minimized by employing beam-lead devices.

MEASUREMENT RESULTS

To measure the return loss or reflection coefficient of the detectors, a scalar network analyzer (similar to that proposed by Knorr[6]) was developed. TSS measurements were made by internally-modulating the millimeter-wave source with a 10-kHz square wave and observing the resultant waveform on a cathode-ray oscilloscope.

The reflection coefficient of a Ka-band finline detector with a matched termination was compared to that of the same device with a variable short-circuit termination (Fig. 5). The performance improvement obtained with the tuned detector is quite evident. The same plot shows the simulation results obtained with the aforementioned modeling technique (a six-element LC ladder network was used to represent the package parasitics).

Good agreement was obtained between experimental and theoretical results. To put these results (and subsequent measurements) into perspective, the characteristics of a commercially-available detector [a matched

coaxial detector from Wiltron Co. (Morgan Hill, CA)] were also evaluated and displayed.

Figure 6 shows the measured TSS of the Ka-band finline detector with matched and variable short-circuit terminations, as well as the TSS of the commercial coaxial detector. As the plot illustrates, the TSS of the finline detector with either termination option is significantly greater than that of the coaxial detector (with more than 10-dB improvement at some frequencies).

The resolution of these detectors at 33 GHz was also measured (Fig. 7), with the results clearly demonstrating the enhanced performance of the finline detector. The resolution of the finline detector with the short-circuit termination is significantly greater than that obtained with the matched termination. Both resolution and TSS are important detector performance parameters in a wide range of applications (such as reflectometer systems), and the finline detector clearly shows advantages in this regard.••

Note

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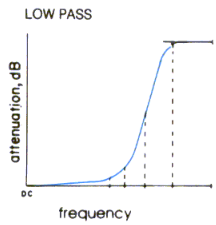

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★LP-5	DC-5	8-10	10-200	★LP-250	DC-225	320-400	400-1200
★LP-10.7	DC-11	19-24	24-200	★LP-300	DC-270	410-550	550-1200
★LP-21.4	DC-22	32-41	41-200	★LP-450	DC-400	580-750	750-1800
★LP-30	DC-32	47-61	61-200	★LP-550	DC-520	750-920	920-2000
★LP-50	DC-48	70-90	90-200	★LP-600	DC-680	840-1120	1120-2000
★LP-70	DC-60	90-117	117-300	★LP-750	DC-700	1000-1300	1300-2000
★P-90	DC-81	121-137	167-400	★LP-800	DC-720	1080-1400	1400-2000
★LP-100	DC-98	146-189	189-400	★LP-850	DC-760	1100-1400	1400-2000
★LP-150	DC-140	210-300	300-600	★LP-1000	DC-900	1340-1750	1750-2000
★LP-200	DC-190	290-390	390-800	★LP-1200	DC-1000	1620-2100	2100-2500

Price, (1-9 qty), all models: plug-in $14.95, BNC $32.95, SMA $34.95, Type N $35.95

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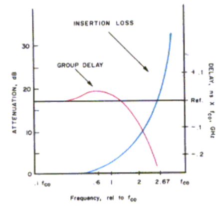
Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB	Model No.	Passband MHz loss < 1dB	Stopband, MHz loss > 20dB	Stopband, MHz loss > 40dB
SCLF-21.4	DC-22	32-41	41-200	SCLF-190	DC-190	290-390	390-800
SCLF-30	DC-30	47-61	61-200	SCLF-380	DC-380	580-750	750-1800
SCLF-45	DC-45	70-90	90-200	SCLF-420	DC-420	750-920	920-2000
SCLF-135	DC-135	210-300	300-600				

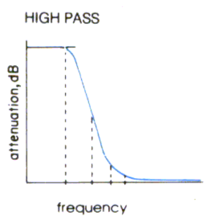
Price, (1-9 qty), all models: $11.45



Flat Time Delay, dc to 1870MHz

Model No.	Passband MHz loss < 1.2dB	Stopband MHz loss > 10dB	Stopband MHz loss > 20dB	VSWR Freq. Range, DC thru 0.2fco X̄	VSWR Freq. Range, DC thru 0.6fco X̄	Group Delay Variations, ns Freq. Range, DC thru fco X̄	2fco X̄	2.67fco X̄
★BLP-39	DC-23	78-117	117	1.3:1	2.3:1	0.7	4.0	5.0
★BLP-117	DC-65	234-312	312	1.3:1	2.4:1	0.35	1.4	1.9
★BLP-156	DC-94	312-416	416	0.3:1	1.1:1	0.3	1.1	1.5
★BLP-200	DC-120	400-534	534	1.6:1	1.9:1	0.4	1.3	1.6
★BLP-300	DC-180	600-801	801	1.25:1	2.2:1	0.2	0.6	0.8
★BLP-467	DC-280	934-1246	1246	1.25:1	2.2:1	0.15	0.4	0.55
▲BLP-933	DC-560	1866-2490	2490	1.3:1	2.2:1	0.09	0.2	0.28
▲BLP-1870	DC-850	3740-6000	5000	1.45:1	2.9:1	0.05	0.1	0.15

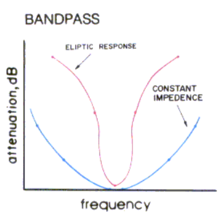
Price, (1-9 qty), all models: plug-in $19.95, BNC $36.95, SMA $38.95, Type N $39.95
NOTE: ▲: -933 and -1870 only with connectors, at additional $2 above other connector models.



high pass, Plug-in, 27.5 to 2200MHz

Model No.	Stopband MHz loss < 40dB	Stopband MHz loss < 20dB	Passband, MHz loss < 1dB	VSWR Pass-band Typ.	Model No.	Stopband MHz loss < 40dB	Stopband MHz loss < 20dB	Passband, MHz loss < 1dB	VSWR Pass-band Typ.
★HP-25	DC-13	13-19	27.5-200	1.8:1	★HP-400	DC-210	210-290	395-1600	1.7:1
★HP-50	DC-20	20-26	41-200	1.5:1	★HP-500	DC-280	280-365	500-1600	1.8:1
★HP-100	DC-40	40-55	90-400	1.8:1	★HP-600	DC-350	350-440	600-1600	2.0:1
★HP-150	DC-70	70-95	133-600	1.8:1	★HP-700	DC-400	400-520	700-1800	1.6:1
★HP-175	DC-70	70-105	160-800	1.5:1	★HP-800	DC-445	445-570	780-2000	2.1:1
★HP-200	DC-90	90-116	185-800	1.6:1	★HP-900	DC-520	520-660	910-2100	1.8:1
★HP-250	DC-100	100-150	225-1200	1.3:1	★HP-1000	DC-550	550-720	1000-2200	1.9:1
★HP-300	DC-145	145-170	290-1200	1.7:1					

Price, (1-9 qty), all models: plug-in $14.95, BNC $36.95, SMA $38.95, Type N $39.95



bandpass, Elliptic Response, 10.7 to 70MHz

Model No.	Center Freq. (MHz)	Passband I.L. 1.5 dB Max. (MHz)	3 dB Bandwidth Typ. (MHz)	Stopbands I.L. > 20dB at MHz	Stopbands I.L. > 35dB at MHz
★BP-10.7	10.7	9.6-11.5	8.9-12.7	7.5 & 15	0.6 & 50-1000
★BP-21.4	21.4	19.2-23.6	17.9-25.3	15.5 & 29	3.0 & 80-1000
★BP-30	30.0	27.0-33.0	25-35	22 & 40	3.2 & 99-1000
★BP-60	60.0	55.0-67.0	49.5-70.5	44 & 79	4.6 & 190-1000
★BP-70	70.0	63.0-77.0	68.0-82.0	51 & 94	6.0 & 193-1000

Price, (1-9 qty), all models: plug-in $18.95, BNC $40.95, SMA $42.95, Type N $43.95

Constant Impedance, 21.4 to 70MHz

Model No.	Center Freq. MHz	Passband MHz loss < 1dB	Stopband loss > 20dB at MHz	VSWR 1.3:1 Total Banc MHz
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★IF-30	30	25-35	1.9 & 210	DC-330
★IF-40	42	35-49	2.6 & 300	DC-400
★IF-50	50	41-58	3.1 & 350	DC-440
★IF-60	60	50-70	3.8 & 400	DC-500
★IF-70	70	58-82	4.4 & 490	DC-550

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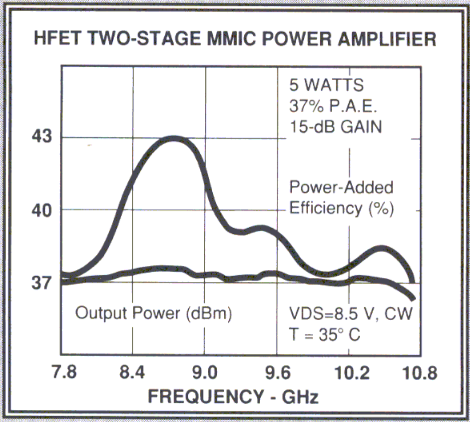

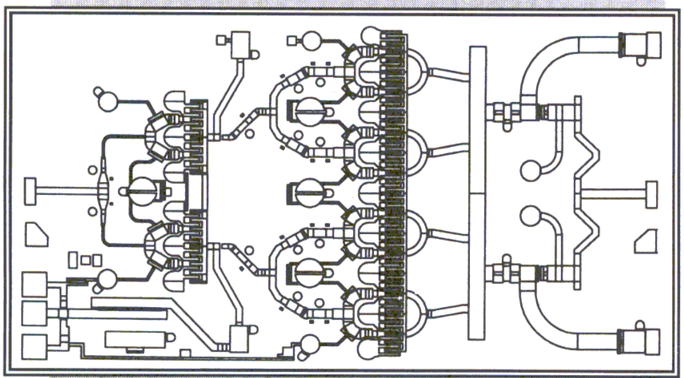

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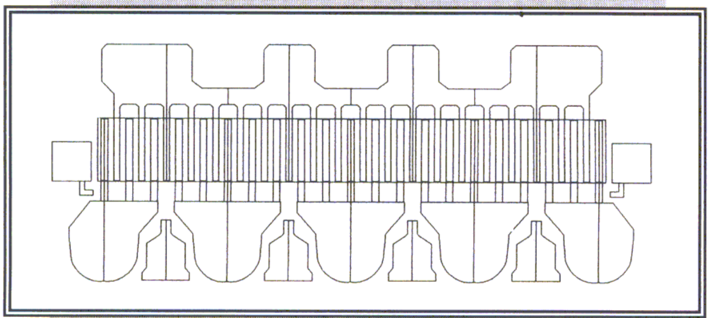

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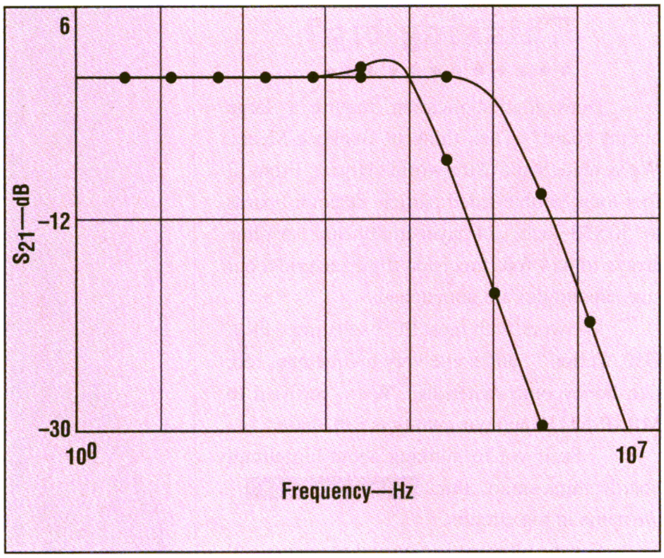
CAE SOFTWARE PREDICTS PLL PHASE NOISE

The output phase noise of a PLL is determined by examining the contribution of all PLL building blocks.

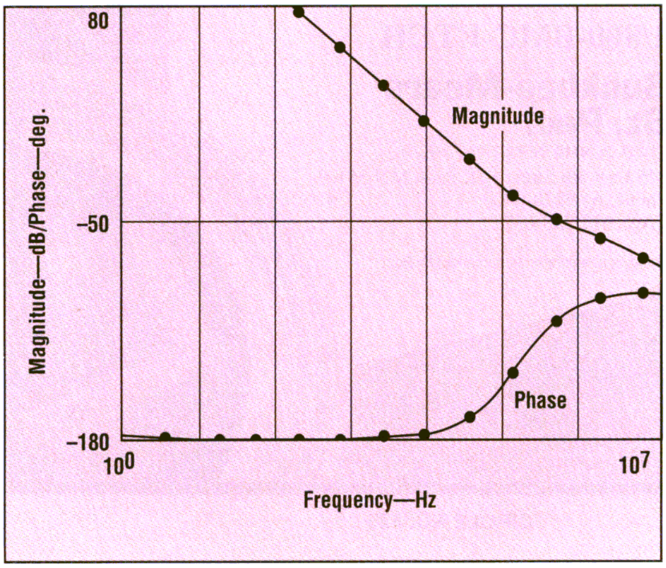
PHASE noise is a key parameter used to characterize the performance of phase-locked loops (PLLs). By employing the gain-block function included in the popular Touchstone linear simulation program from HP-EEsof, Inc. (Westlake Village, CA), the noise density of each PLL building block can be determined and used to derive the phase noise at the PLL output.

A previous article (see *Microwaves & RF*, September 1994, p. 87) outlined the development of a Touchstone simulation circuit for PLL synthesizers. The PLL components—including the loop amplifier, phase detector, voltage-controlled oscillator (VCO), and prescaler—were de-

ALEX HODISAN, Chief Engineer, Microkim Ltd., Scientific Industries Center, P.O. Box 1797, Haifa, Israel 31016; (972) 4-551211, **ZIV HELLMAN,** Project Engineer, Misat Ltd., P.O. Box 35, Tirat-Ha'Carmel, Israel 30200; (972) 4-573208, and **AVI BRILLANT,** Systems Engineer, MTI Technology and Engineering (1993) Ltd., Atidim Industrial Park, Building 3, P.O. Box 43066, Tel-Aviv, Israel 61430; (972) 3-6487901, FAX: (972) 3-6487940.



1. The PLL simulation program was used to determine the ideal closed-loop response for the PLL synthesizer.



2. The unstable open-loop response determined with the simulation program indicates a phase margin of 5 deg.

fined and combined to form a complete PLL simulation circuit.

An optimized stable system was obtained through interactive variations of the synthesizer's gain and phase plots until the best design was achieved. This was illustrated using the analysis of the F-111 attacking-radar synthesizer, operating from 850 to 1150 MHz in 5-MHz steps.

The synthesizer's ideal closed-loop response (Fig. 1) was obtained. This response does not include the effect of the elliptic filter. Without the loop-amplifier input lowpass filter (which smooths the phase-detector current pulses), all delays are neglected.

In addition, the ideal loop response was compared to that of the optimized practical loop. The phase margin was 90 deg. for the ideal loop. The optimized practical loop (with resistance $R_{1/2}$ = 10 kΩ) exhibited a phase margin of 63 deg., which is an adequate value.

The unstable open-loop response (Fig. 2) was also obtained. This response exhibited a phase margin of 5 deg. A Smith chart used as a Nyquist plot (Fig. 3) shows the effect of all added parasitics on the ideal-loop response. Here, the phase margin is 35 deg.

The results obtained with the Touchstone simulation circuit (Fig. 4) exhibited good agreement with PLL measurements.

PLL PHASE NOISE

In general, the phase noise within the loop bandwidth is a function of the reference source's noise density, while the phase noise outside the loop bandwidth is represented by the VCO's noise density.

Since the synthesizer is a frequency multiplier, the phase noise at a certain offset frequency from the carrier (within the loop bandwidth) is given by:

$$P_n = 20 \log (f_o / f_r) + P_{n/ref} + M \qquad (1)$$

where:

f_o = the output frequency,

f_r = the frequency of the reference source ,

f_o/f_r = the division ratio (also given by N),

$P_{n/ref}$ = the reference phase noise, and

M = the error factor (note that M can vary from 0 to 4 dB).

The ideal loop-bandwidth selection for best noise performance has a 3-dB cutoff frequency (f_{3dB}) that satisfies the condition of equality between the $P_{n/ref}$ and the VCO phase noise. Consequently, when the loop is locked, the total output phase noise is the lower of the two values.

In reality, there are several contributors to the total PLL phase noise. These noise sources are the

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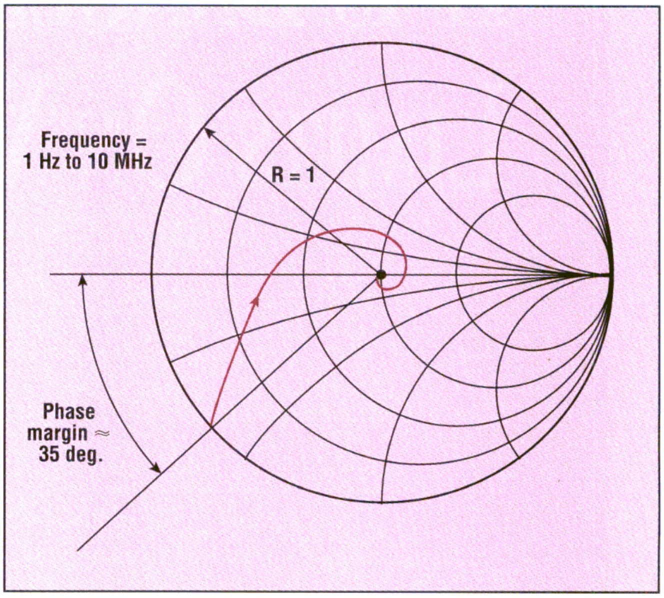
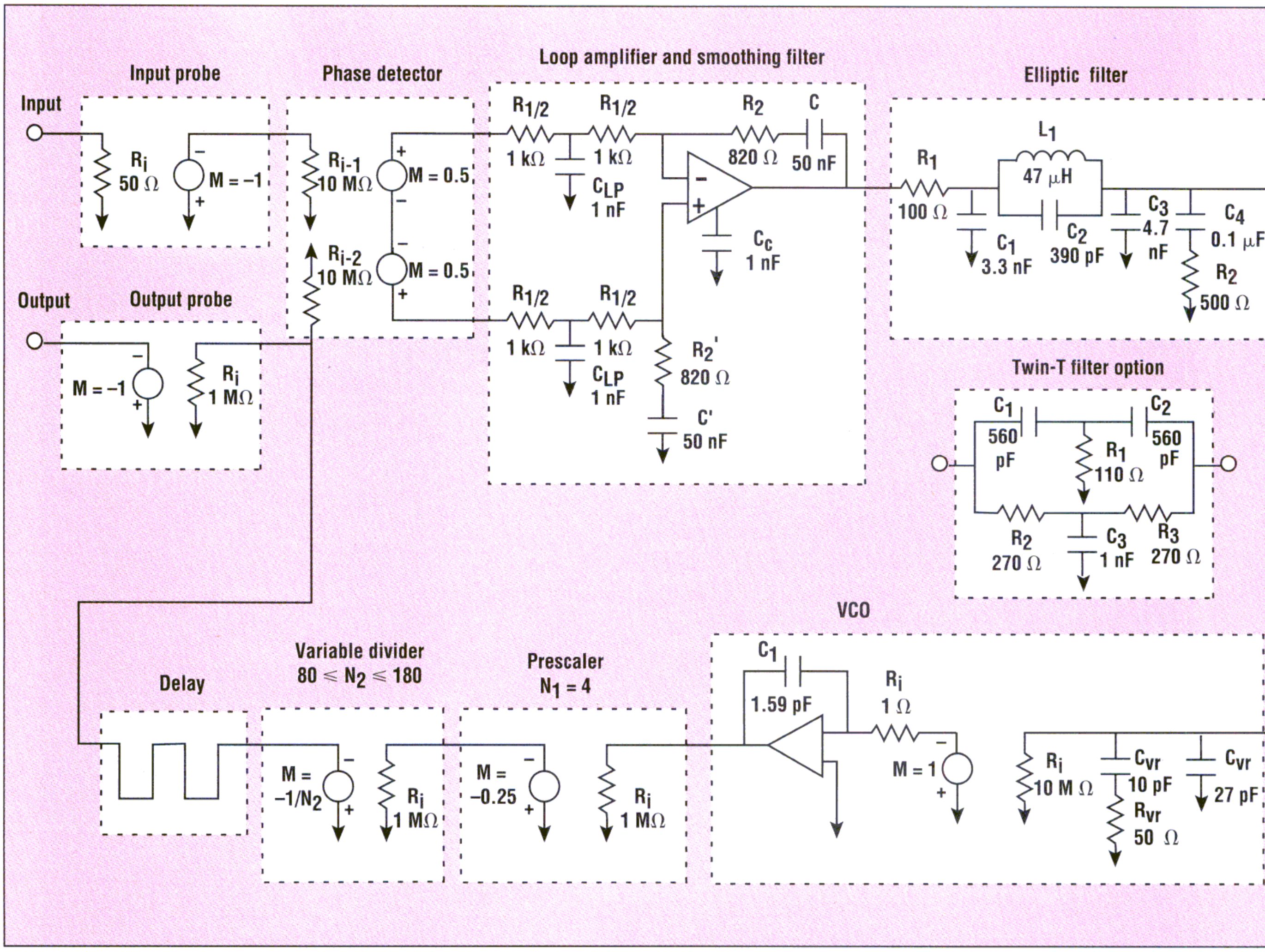
reference crystal source, phase detector, loop amplifier (active integrator), VCO, and dividers. Each noise source is characterized by its own noise density function [Sϕ(f)].

The Sϕ(f) data can be taken from catalogs for the loop amplifier, reference source, and VCO or, alternatively, can be calculated using the Kroupa Theory[1] and Manassewitsch's method[2] for obtaining the noise density of the phase detector and dividers.

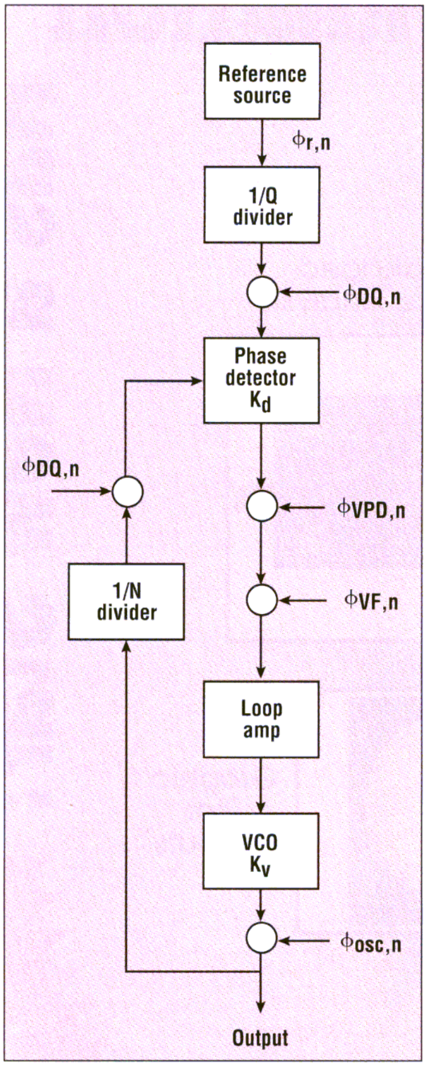
By using the Touchstone gain-block option, each Sϕ term can be specified and injected into its proper point in the simulated circuit. The analysis of the F-111 attacking-radar synthesizer can be used as a practical example. The synthesizer-simula-



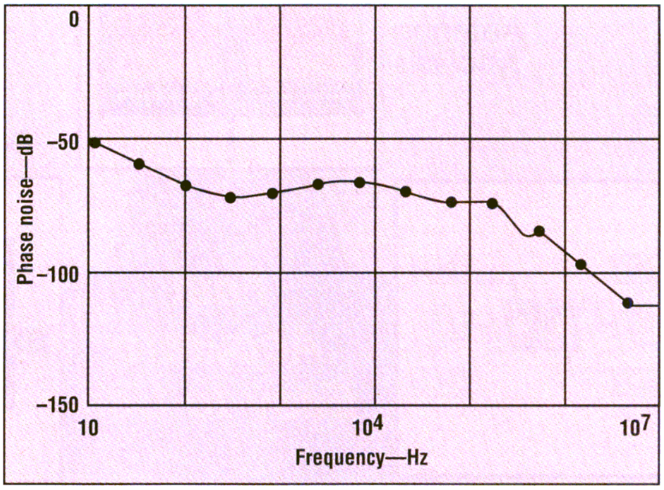
3. This Smith-chart plot includes the effects of all added parasitics on the ideal open-loop response. A phase margin of 35 deg. is determined.



4. After defining all the PLL building blocks, this circuit was developed for computer simulation of the PLL response.



5. As this block diagram illustrates, the PLL noise is simulated by taking the noise densities of the PLL components injected into different points of the PLL circuit.



7. This plot represents the phase-noise performance of the entire PLL simulation circuit.

tion block diagram is given in Fig. 5.

The output phase noise within the loop bandwidth is given by Kroupa:

$$\phi_{o,n} \approx \phi_{r,n}(M + N/Q) + [\phi_{DQ,n} - \phi_{DN,n} + (V_{PD,n} + V_{Fn})/K_d]N \quad (2)$$

where:

$\phi_{r,n}$ = the reference-source output phase noise,

$\phi_{DQ,n}$ = 1/Q divider phase noise,

$\phi_{DN,n}$ = 1/N divider phase noise,

$V_{PD,n}$ = the noise voltage at the phase-detector output,

V_{Fn} = the noise voltage at the loop amplifier/filter input,

K_d = the phase-detector gain, and

N and Q = the divider ratios.

The spectral densities are given in the following expression from Kroupa [refer to Fig. 1 in Kroupa's article for more information]:

$$S\phi_{o,n}(f) = S\phi_{r,n}(f)[M + N/Q]^2 + \{S\phi_{DQ,n}(f) + S\phi_{DN,n}(f) + [S_{VPD,n}(f) + S_{VF,n}(f)]/K_d^{\,2}\}N^2 \quad (3)$$

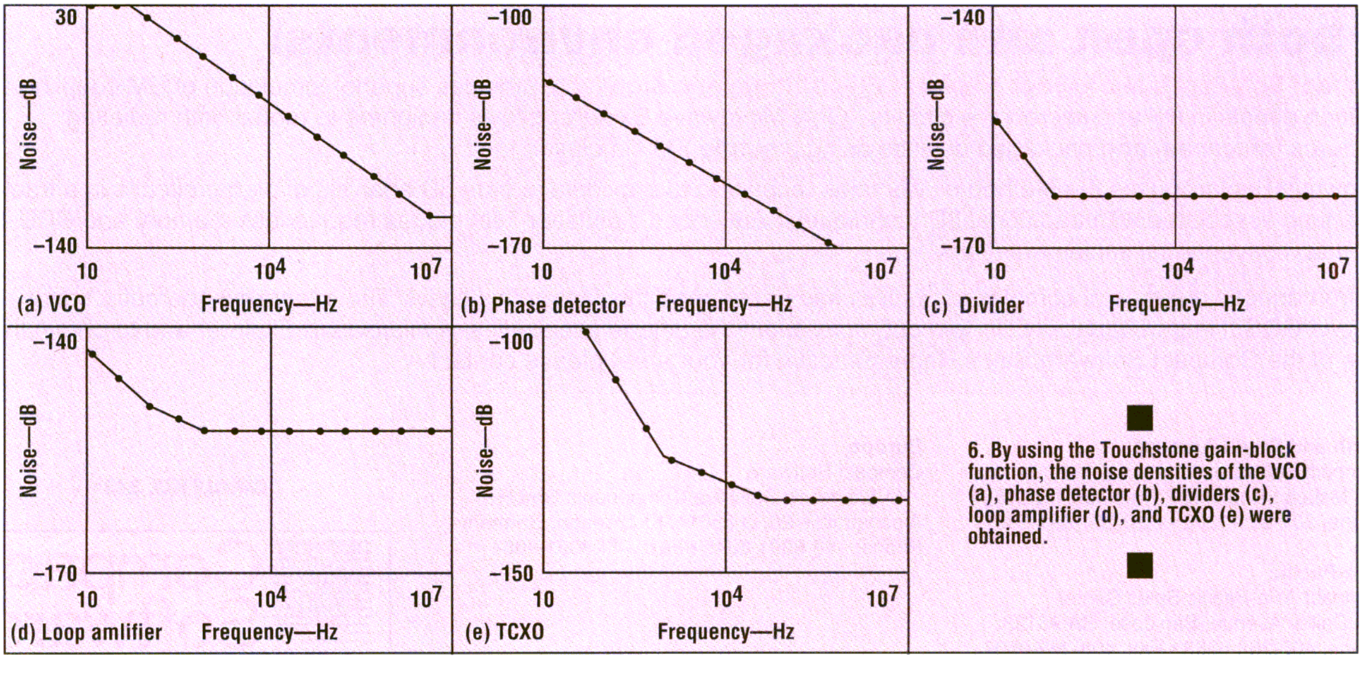
where:

$S\phi_{r,n}$ = the reference-source noise spectral density,

$S\phi_{DQ,n}$ = the 1/Q divider noise spectral density,

$S\phi_{DN,n}$ = the 1/N divider noise spectral density,

$S\phi_{VPD,n}$ = the phase-detector



6. By using the Touchstone gain-block function, the noise densities of the VCO (a), phase detector (b), dividers (c), loop amplifier (d), and TCXO (e) were obtained.

noise spectral density,

$S\phi_{VF,n}$ = the loop-amplifier/filter noise spectral density, and

f = the offset frequency.

The quantities in the above equations describe the individual loop components' spectral densities. For instance, the noise spectral density of the digital phase detector is:

$$S\phi(f)\ (in\ rad^2/Hz) = 10^{-10.6 \pm 0.3}/f \qquad (4)$$

where:

$S\phi(f) = S_{VPD,n}(f)/K_d^2$.

Since $K_d < 1$:

$$S_{VPD,n}(f) < S\phi(f) \qquad (5)$$

and

$$10\ \log\ [S_{VPD,n}(f)] = 10\ \log\ [S\phi(f)] + 10\ (\log\ K_d^2) \qquad (6)$$

Furthermore, phase detectors built of emitter-coupled logic (ECL) or complementary metal-oxide semiconductor (CMOS) logic exhibit better noise behavior—nearly –22 dB in the flicker-noise region.

The digital-divider noise spectral density can be described by:

$$S\phi_{D,n}(f) = S\phi_{in}(f)/N^2 + 10^{-14.7}/f + 10^{-16.5} \qquad (7)$$

where:

$S\phi_{in}$ = the input noise spectral density.

The last two terms of the above expression can be expressed as:

$$S\phi add \approx 10^{-14.7}/f + 10^{-16.5} \quad (8)$$

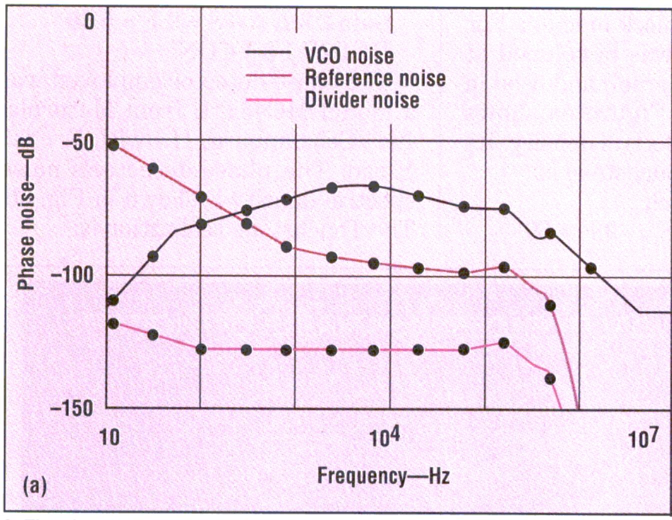
For divider output frequencies higher than 1 MHz, $S\phi$add is approximately –280 dB. This indicates that the input noise predominates. The expression $S\phi$add is referred to in this discussion since the output frequency of the dividers is higher than 1 MHz; consequently, $S\phi_{in}(f)/N^2$ is negligible.

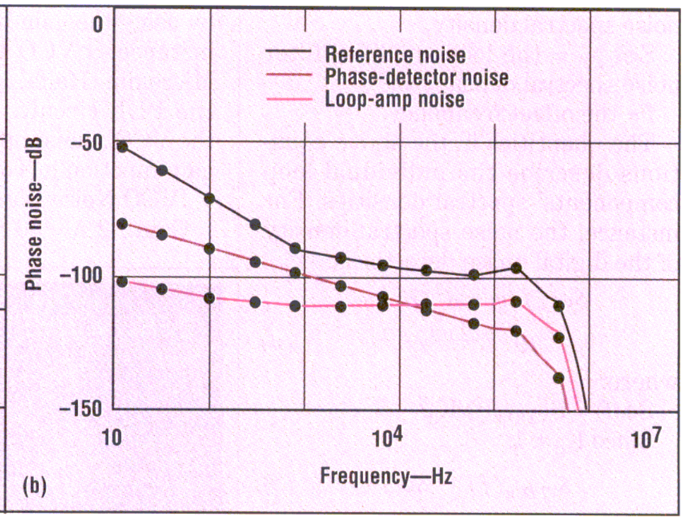
Note that the values for reference noise and VCO noise were taken from a catalog, while the loop-amplifier noise was calculated from data sheets.

Each component's noise contribution was calculated and represented by using the gain-block function. For instance, a VCO was developed at Microkim (Haifa, Israel) and used in the PLL circuit. Figure 6a shows the VCO's noise spectral density. Its gain function in Touchstone is:

```
!VCO Noise Block
Gain 1 2 A = 30 S = –9 F = 50
Gain 2 3 A = 0 S = 9 F = 5E6
DEF2P 1 3 VCON
```

The phase detector employed was a model MC4344L from Motorola, Inc. (Schaumburg, IL) with K = 0.5 V/rad. The phase detector's noise spectral density is shown in Fig. 6b. The Touchstone realization is:





8. The phase-noise contributions of the VCO, dividers, phase detector, loop amplifier, and TCXO reference source were obtained using the simulation program.

```
!Phase Detector Noise Block
Gain 1 2 A = –129 S = –3 F = 50
DEF2P 1 2 PDN
```

The dividers used were models SP8611AC (a 1/4 divider) and SP-8743AC (an 8/9 divider) from Plessey (Swindon, Wiltshire, United Kingdom). The divider noise block is:

```
!Divider Noise Block
Gain 1 2 A = –147 S = –3 F = 1
Gain 2 3 A = 0 S = +3 F = 100
DEF2P 1 3 DIVN
```

Figure 6c shows the divider noise spectral density.

The loop amplifier used was a model HA2-2620-8 from Harris Semiconductor (Melbourne, FL). Its noise parameters were obtained from data sheets. The noise density at the loop-amplifier input is shown in Fig. 6d. The Touchstone gain block for the loop amplifier is given by:

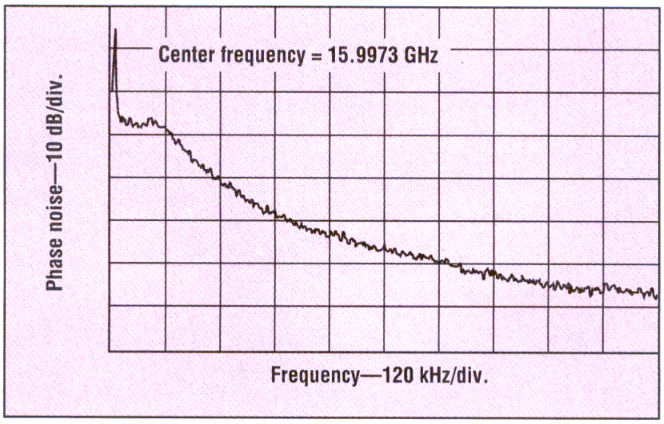
```
!Loop Amp Noise Block
Gain 1 2 A = –146 S = –21 F = 10
Gain 2 3 A = 0 S = +1.2 F = 100
Gain 3 4 A = 0 S = +0.9 F = 1E3
DEF2P 1 4 AMPN
```

The temperature-controlled crystal oscillator (TCXO) was a model 254Y0389, a 120-MHz component from Vectron Labs (Norwalk, CT). Its noise density (Fig. 6e) was obtained from data sheets. The corresponding Touchstone noise block is:

```
!TXCO Noise Block
Gain 1 2 A = –90 S = –6 F = 10
Gain 2 3 A = 0 S = 4.5 F = 1E3
Gain 3 4 A = 0 S = 1.5 F = 50E3
DEF2P 1 4 TCXON
```

The simulated synthesizer phase noise is shown in Figs. 7 and 8, while the measured phase noise is displayed in Fig. 9. It can be seen that the spectral purity within the loop bandwidth is 27 dB + 10 log 3000 = –62 dBc/Hz, while the simulation prediction was –70 to –65 dBc/Hz (Note that the synthesizer analysis was performed at approximately 1 GHz and upconverted to X-band by an injection-locked dielectric-resonator oscillator using the same reference source, hence the –6-dB difference).

As Fig. 8 illustrates, the VCO phase noise within the loop bandwidth behaves like a highpass filter, while the phase responses of the TCXO, phase detector, loop amplifier, and dividers behave like a lowpass filter. The noise contribution of the dividers and loop amplifier is negligible; the noise contribution of the phase detector is nearly the same as that of the reference source.●●



9. The measured phase noise within the loop bandwidth is approximately –62 dBc/Hz. This agrees well with the simulated result of –70 to –65 dBc/Hz.

Editor's note

Because of limited space, the complete Touchstone program code could not be included. This information can be obtained by contacting Dawn Prior, *Microwave & RF*, 611 Route 46 West, Hasbrouck Heights, NJ 07604.

References

1. V.F. Kroupa, "Noise Properties of PLL Systems," *IEEE Transactions on Communications*, October 1982, pp. 2244-2251.
2. V. Manassewitsch, *Frequency Synthesizer Theory and Design*, 2nd ed., John Wiley & Sons, 1980.

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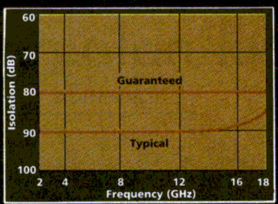

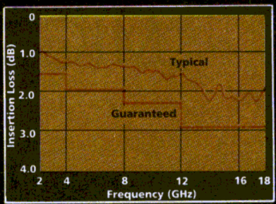

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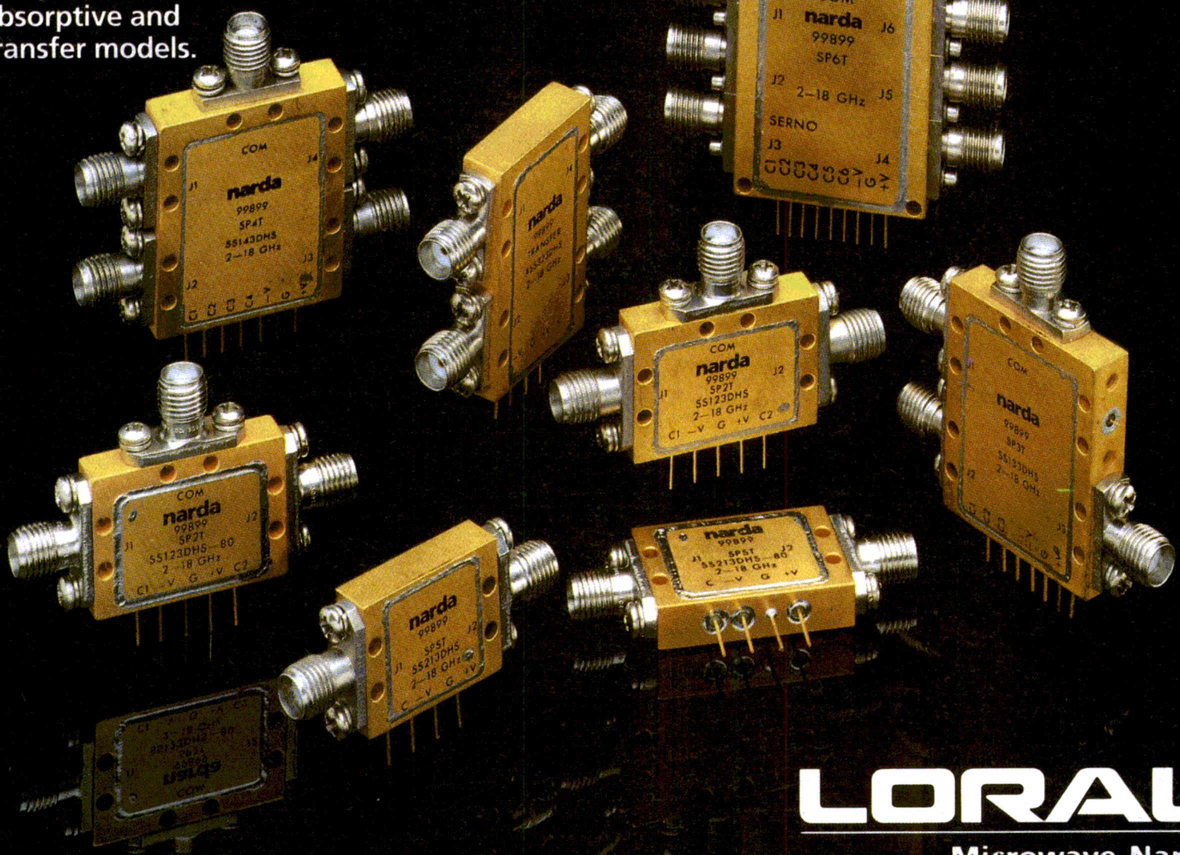

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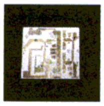

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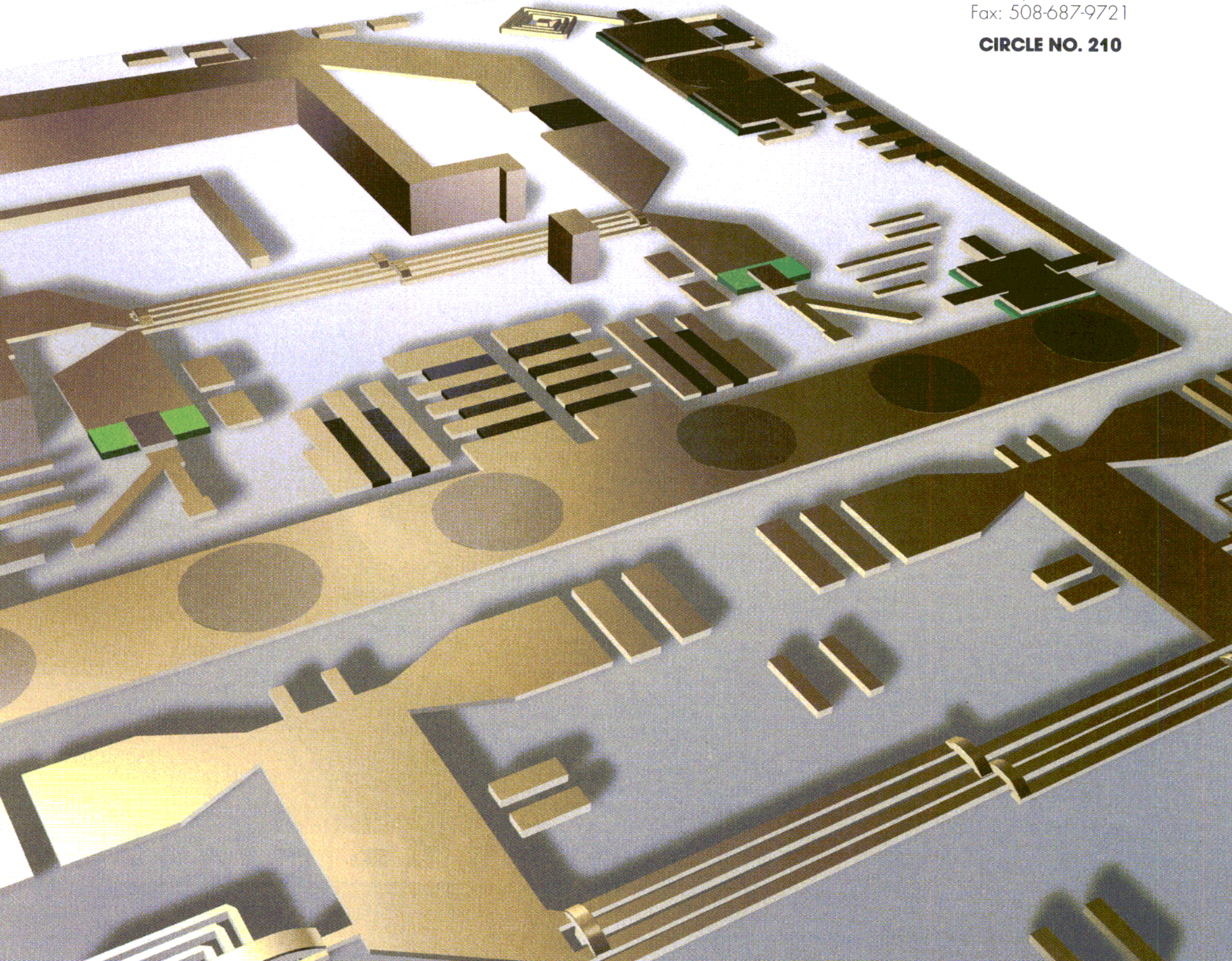

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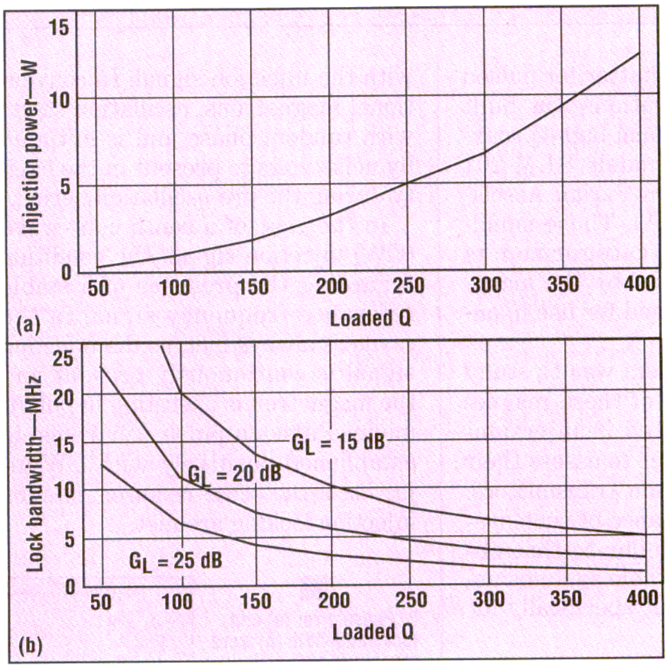
Injection locking of magnetrons is utilized to realize the performance requirements of coherent transmitters. To gain the advantages of high locking gain and wide lock bandwidth (LBW), the magnetron Q must be low. This requires that the magnetron cavity be heavily loaded. For injection-locking applications, magnetrons must be specially built with low-Q characteristics and designed for low magnetic-field operation, which is a determining factor of preoscillation noise.[1]

M.V. GOPALAKRISHNA, Engineer SF, and **C.S. HARISH,** Engineer SD, Vikram Sarabhai Space Center, Electronics Division, Indian Space Research Organization, Trivandrum 695 022, India; (91) 56-2444, (91) 56-2555, FAX: (91) 471-79795.



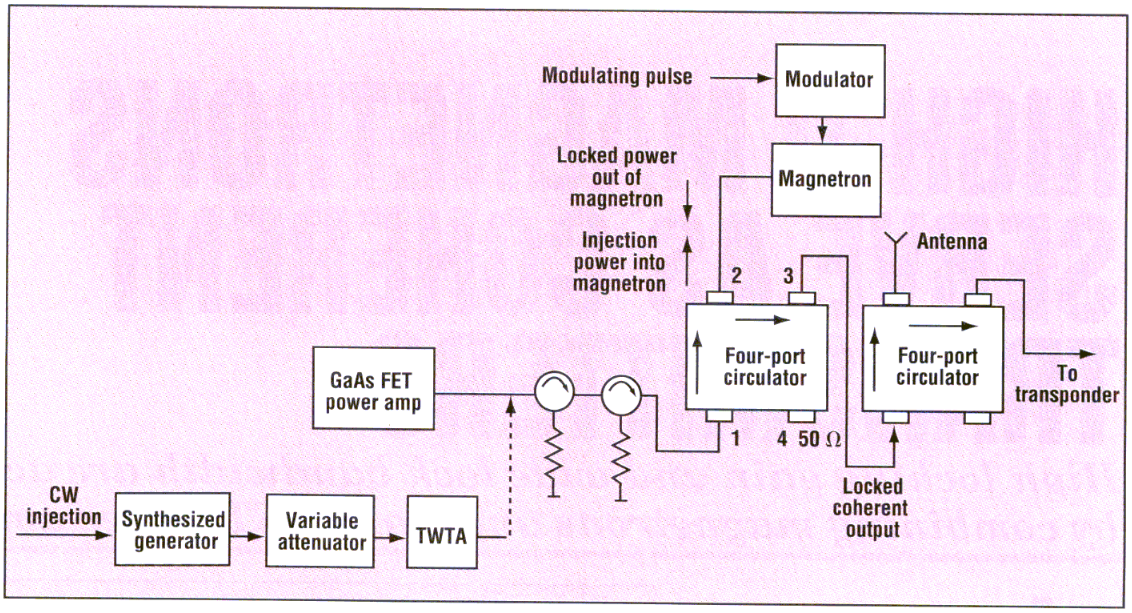
1. The required injection power (a) and obtainable lock bandwidth (b) were plotted versus the magnetron's loaded Q.

The number of resonators used in these low-Q magnetrons is generally greater than that of conventional devices. This aids the low-field operation and depresses the operating voltage. In addition, an integral circulator/isolator is employed to facilitate injection couplings and improve the pulling range of the magnetron, thus reducing the pulling figure.

Other types of magnetrons offering this low-Q property are voltage-tunable magnetrons, which are potential candidates for injection. However, the voltage-tunability and frequency-agility characteristics inherent in these magnetrons go unused. Furthermore, the availability of such magnetrons is limited since they must be custom-built for specific applications, making them very expensive.

Where such high cost is restrictive, the solution lies in using conventional high-Q coaxial magnetrons for injection locking. This is dependent on meeting the system LBW requirement and on the affordability of comparatively-higher injection powers. This is especially true for fixed-frequency applications such as pulsed coherent transponders.

2. The magnetron's operating configuration produces a fixed load condition for a load isolation of 40 dB and antenna VSWR of 1.50:1.



A coherent transmitter for pulsed transponder applications was built using two conventional high-Q coaxial magnetrons—models BLM 201 and VMC 1180 from Varian Associates (Palo Alto, CA). These small-size magnetrons (categorized as "beacon magnetrons" by the manufacturer) are designed for use in on-board applications.

The design problem was to study the characteristics of these magnetrons when operated in injection-locked mode in order to assess their suitability as coherent transmitters. The phase performance of such systems should be similar to that obtained from comparable systems using magnetrons built specifically for injection locking.

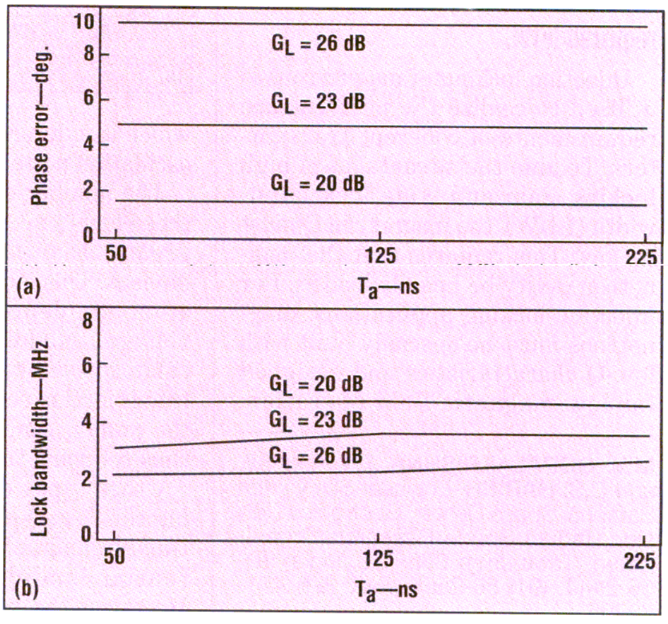
LOCKING REQUIREMENTS

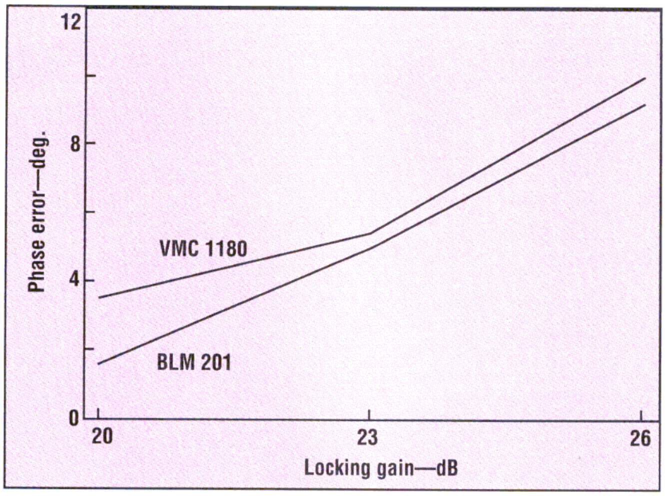
Injection locking involves the insertion of a highly-stable external reference frequency [which is close to the magnetron's natural resonant frequency (f_o)] via a circulator. When the injected signal has sufficient magnitude, pulsed oscillations of the magnetron are forced to synchronize (or lock) to the phase of the injected signal. The basic requirement for locking is that the injection signal be present (with sufficient amplitude) in the magnetron's anode circuit before the onset of oscillation. When this condition is satisfied, oscillation is triggered and initiated in phase with the injection signal. In conventional magnetrons, oscillation starts with random phase and is initiated by noise voltage present in the cavity during the pre-oscillation period.

In the case of a continuous-wave (CW) injection signal, the condition regarding the presence of a stable reference-frequency signal in the cavity is always met, as the injection signal is continuously present and the magnetron is operating in pulsed mode. Pulse-to-pulse coherence is established positively with CW injection if the other requirements for injection locking are met.

If the injection signal is in the form of an RF pulse, it is very important that the injected RF pulse leads the magnetron's modulating pulse by a period equal to or greater than the magnetron pre-oscillation period (which depends upon the Q and the angular frequency at which the magnetron oscillates). Precision timing circuits are employed to maintain this pulse positioning so that locking is achieved and sustained throughout the length of the pulse. This locking must be maintained across the entire range of environmental conditions faced by the system.

3. Phase error (a) and lock bandwidth (b) were measured as functions of the "time ahead" for the BLM 201 magnetron.





4. The phase errors for the BLM 201 and VMC 1180 magnetrons were measured for three different injection-drive (or locking-gain) levels.

There are two modes of injection locking—"priming" and "locking." In priming mode, high locking gain [G_L, defined as the ratio of the magnetron output power (P_o) to the injection-signal power (P_i)] on the order of 40 to 60 dB is achievable while the injection-signal frequency differs from f_o by about 10 to 20 MHz.

In locking mode, however, high locking gains are not possible. A reasonably-high practical locking gain is on the order of 20 dB while the injection frequency (f_{inj}) is much closer (about 2 to 3 MHz) to f_o. Regardless of the locking mode, injection locking is governed by Adler's equations.[2]

The basic Adler equation for injection locking[3] is given by:

$$P_i / P_o \geq Q_L(\Delta f / f_o) \qquad (1)$$

where:

Q_L = the loaded Q of the magnetron.

The LBW is defined as:

$$LBW = 2\Delta f = f_u - f_L \qquad (2)$$

where:

f_L = the lower lock frequency, and
f_u = the upper lock frequency.

Note that f_L and f_u are symmetrical to f_o while f_{inj} is located between f_L and f_u. In addition:

$$P_i \geq P_o(Q_L \times \Delta f / f_o)^2 \qquad (3)$$

$$LBW = 2\Delta f = (2f_o / Q_L)(P_i / P_o)^{0.5} \qquad (4)$$

LBW can also be described as:

$$LBW = 2f_o /(Q_L G_L)^{0.5} \qquad (5)$$

where:

$G_L = P_o/P_i$.

The required P_i and obtainable LBW for a system are calculated from Eqs. 3 and 4, which are derived from Eq. 1.

Plots of Eqs. 3 and 4 were obtained for the magnetron design problem. Figure 1a shows the P_i requirement as a function of Q_L for a fixed P_o and LBW. Figure 1b presents the obtainable LBW as a function of Q_L for different G_L values.

The advantages of using low-Q magnetrons for injection locking (as seen from Adler's equations) are high G_L and wider LBW. It is also evident that the two modes of injection locking are characterized with reference to Adler's equations. Locking mode is possible only with high-Q_L magnetrons, while priming mode can only be achieved with low-Q_L magnetrons.

DESIGN SPECIFICATIONS

The design objective was to realize a coherent transmitter by making use of conventional high-Q coaxial magnetrons operating in pulsed injection-locked mode. The following specifications were to be met:

Magnetron to be used: Model BLM 201 or VMC 1180

Application: Pulsed coherent C-band transponder

Frequency of operation: Any fixed frequency in the 5.4-to-5.9-GHz band (5660 MHz was selected)

Coherent power required: 400 W (peak)

Coherent injection source: Interrogating RF pulse from a precision C-band monopulse coherent (PCMC) radar, received and coherently processed in the transponder as a reply pulse

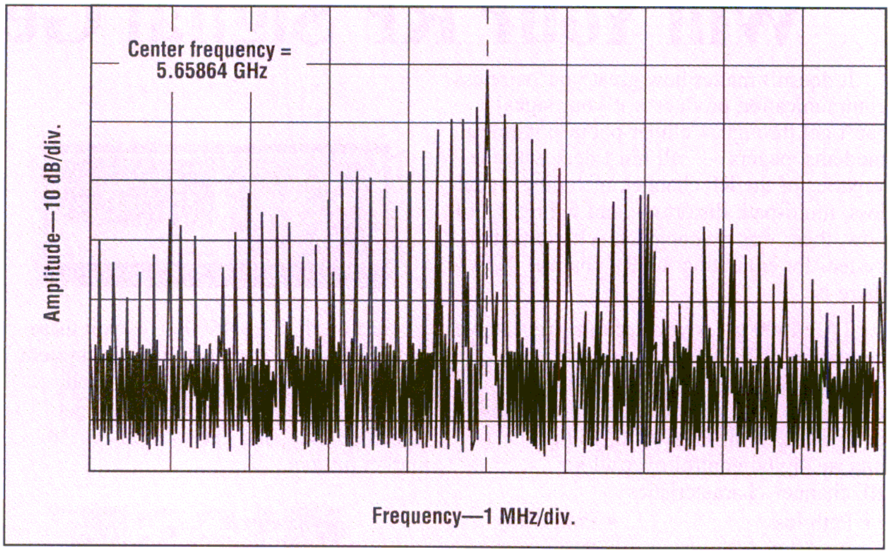
Available coherent signal power: –5 dBm (fixed output from a limiting amplifier at 60 MHz, upconverted to 5660 MHz in the transponder)

RF pulse width: 1 µs

Duty factor: 0.002 (maximum)

Temperature range: +8 to +70°C

Phase error: Less than 10-deg.



5. The pulsed RF output of the locked BLM 201 magnetron was obtained for a CW injection power of +36 dBm.

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.01–500	AU-1332	45	0.5	2.0:1	1.3	1.4	1.5	10	$350
.01–1000	AM-1300	25	0.75	2.0:1	1.4	1.6	1.8	6	$375
1–100	AU-2A-0110	30	0.5	2.0:1	1.2	1.2	1.3	3	$275
1–100	AU-3A-0110	50	0.5	2.0:1	1.2	1.2	1.3	10	$300
1–500	AU-1A-0150	14	0.5	2.0:1	2.7	2.8	2.9	10	$200
1–500	AU-2A-0150	30	0.5	2.0:1	1.3	1.4	1.5	8	$275
1–500	AU-3A-0150	45	0.5	2.0:1	1.3	1.4	1.5	10	$300
1–500	AU-4A-0150	60	0.5	2.0:1	1.3	1.4	1.5	10	$325
1–1000	AM-2A-000110	25	0.75	2.0:1	1.4	1.6	1.8	8	$300
1–1000	AM-3A-000110	35	0.75	2.0:1	1.4	1.6	1.8	9	$350
20–200	AU-1158	30	0.5	2.0:1	2.7	2.7	2.7	17	$275
50–90	AU-1001	14	0.25	1.3:1	5.0	5.0	5.0	18	$200
50–90	AU-2A-1158	30	0.25	1.3:1	2.7	2.7	2.7	20	$275
50–90	AU-3A-1263	43	0.25	1.3:1	1.5	1.5	1.5	20	$325
50–350	AU-1210	18	0.5	2.0:1	2.6	2.7	2.8	10	$200
100–1000	AM-1331	35	0.75	2.0:1	1.4	1.6	1.8	15	$400
100–2000	AMMIC-1348	14	1	2.2:1	5.0	4.3	4.6	14	$395
100–2000	AMMIC-1318	6	1	2.2:1	4.5	4.0	4.0	12	$350
500–1000	AMMIC-1141	10	0.5	1.5:1	6.0	6.0	6.0	10	$200
500–1000	AM-2A-0510	24	0.5	2.0:1	1.4	1.5	1.6	0	$300
500–1000	AM-3A-0510	37	0.5	2.0:1	1.4	1.5	1.6	9	$350
500–1500	AM-3A-0515	30	0.5	2.0:1	1.5	1.8	2.2	4	$375
500–2000	AM-2A-0520	19	0.75	2.0:1	1.4	1.9	2.4	-4	$350
500–2000	AM-3A-0520	30	0.75	2.0:1	1.4	1.9	2.4	5	$400
500–2000	AM-4A-0520	40	1	2.0:1	1.4	1.9	2.4	5	$450
1000–2000	AM-2A-1020	19	0.5	2.0:1	1.8	2.1	2.4	4	$325
1000–2000	AM-3A-1020	30	0.5	2.0:1	1.8	2.1	2.4	10	$375
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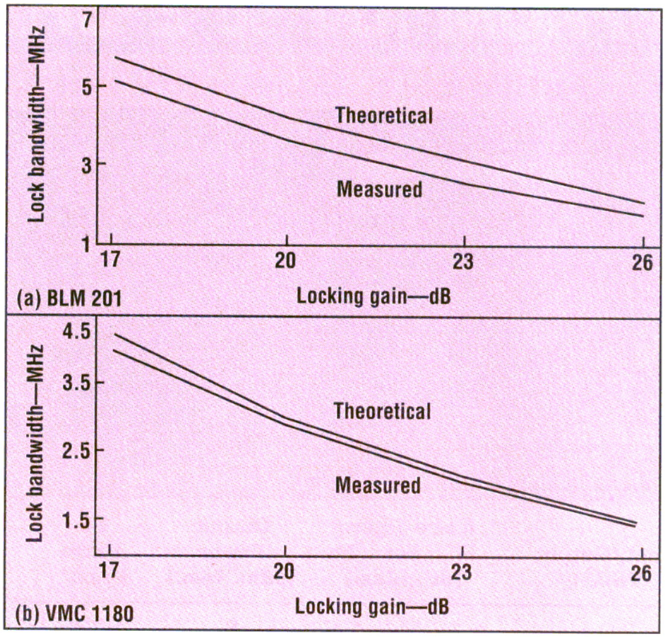


6. Measured and theoretical lock bandwidth are plotted versus locking gain for the BLM 201 and VMC 1180 magnetrons.

root-mean-square (RMS)

Note that the BLM 201 magnetron was available during the initial phases of the work but was later discontinued by the manufacturer. However, the design was completed using the VMC 1180.

A number of design factors come into play when determining the required LBW. The LBW should be wide enough to accommodate the frequency changes due to the following factors:

(1) An f_o drift is generated by temperature extremes encountered during operation. This depends upon the magnetron's temperature-coefficient (T_c) specification. The magnetrons used in the experiment are temperature-compensated to provide better frequency stability over a wide thermal range of –65 to +90°C. The frequency drift for the required temperature range can be estimated from the magnetron's T_c specification.

The frequency drift calculated in this manner is often higher than the actual result, since the T_c parameters given in manufacturer data sheets are generally the maximum values. Hence, the frequency drift measured during magnetron thermal-cycling tests can be used to find T_c with some allowance for practical applications.

(2) Another source of frequency drift is extremes in load VSWR, which depend upon the magnetron pulling factor. Magnetrons specifically designed for injection locking usually have a built-in circulator to couple injection power and extract locked power. Apart from this, a circulator helps to maintain a magnetron's load VSWR below a specified level to reduce the pulling effect. In the present case where the circulator is not an integral part, an external circulator can be employed for this function.

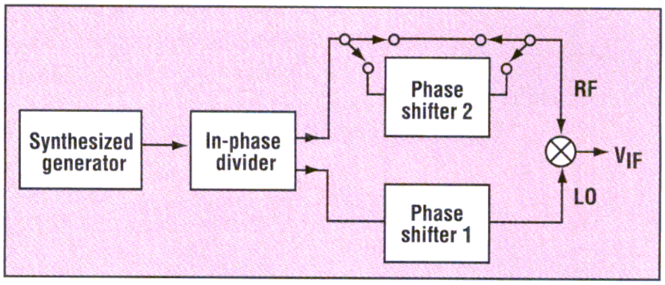
Although the magnetron sees a fixed load condition (an antenna with a VSWR of 1.50:1 is used), an estimation of the frequency change is essential since the load VSWR can vary with temperature. The isolation in the circulator presents a constant reflection to magnetrons only at constant room temperature. As the temperature varies, the isolator's input VSWR changes. Slight phase change can also occur. Thus, frequency variations due to the change in VSWR must be taken into account.

(3) The magnetron pushing figure also generates frequency drift. Frequency pushing depends on the rate of rising current at the start of the pulse and the rate of falling current at the end of the pulse. These rates depend upon the magnetron's rate-of-rising-voltage (RRV) specification. The time periods in which the frequency pushing is prominent are negligible compared to the pulse length. The frequency drift due to pushing is mainly generated by the modulator, which causes a change in pulse current. Hence, care is taken in the modulator design to reduce this effect. A flat-top modulator pulse is desirable and its operation should be at peak-current value, where minimum frequency pushing occurs.

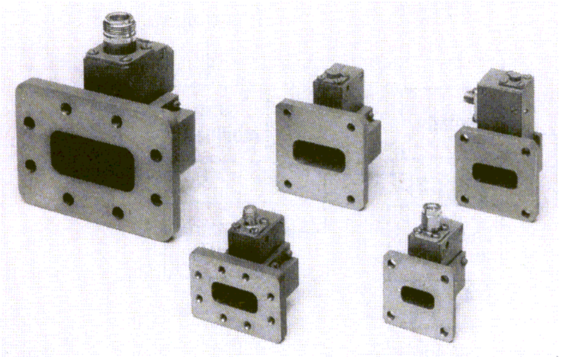
(4) Frequency change due to duty-cycle variation must also be considered. Since the operating pulse width is constant, the pulse-repetition frequency (PRF) is varied gradually and the frequency variation is recorded. Since the transponder operates in conjunction with two or more radars, the PRF in a practical case varies in steps (such as single, double, or triple PRFs) depending upon the number of radars interrogating the transponder at a given time. Taking the maximum case for three-radar interrogation, the frequency changes for single to triple PRFs were recorded. The maximum measured variation was 400 kHz.

(5) Finally, the one-way Doppler frequency must be accounted for. This frequency depends upon the velocity at which the magnetron (transponder) moves with respect to the radar. Taking a maximum velocity of 15 km/s for the design, the one-way Doppler excursion is 283 kHz for an operating frequency of 5660 MHz.

7. This circuit sets the phase quadrature between the LO and RF signals, thus calibrating the double-balanced mixer.



Iso-Adaptors WR-284 thru WR-62



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WR 137	6.8 - 7.2 GHz	CMR, CPR, U/G	SMA,N
WR 112	7.0 - 8.5 GHz	CMR, CPR, U/G	SMA,N
WR 90	8.5 - 9.6 GHz	CMR. CPR, U/G	SMA
WR 75	10.7 - 12.7 GHz	CPR-F/G, U/G	SMA
WR 62	14.0 - 14.5 GHz	CPR-F/G, U/G	SMA

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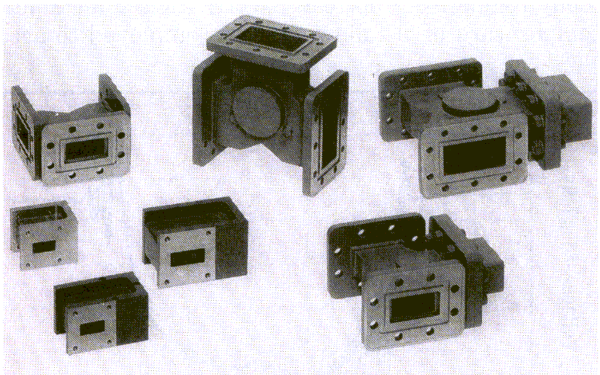
WR 137	6. 8 - 7. 2 GHz	CMR, CPR, U/G
WR 112	7. 1 - 7. 7 GHz	CMR, CPR, U/G
WR 90	8. 5 - 9. 6 GHz	CMR, CPR. U/G
WR 75	10. 7 - 12. 7 GHz	CMR, U/G
WR 62	14. 0 - 14. 5 GHz	CPR, U/G



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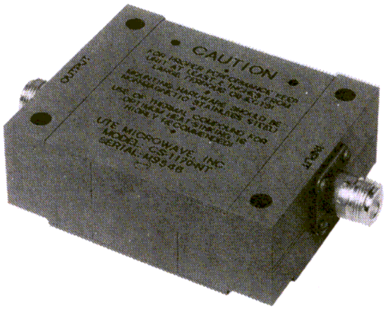

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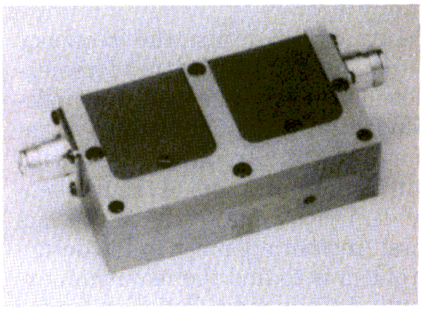

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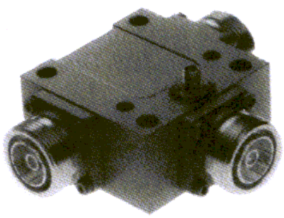

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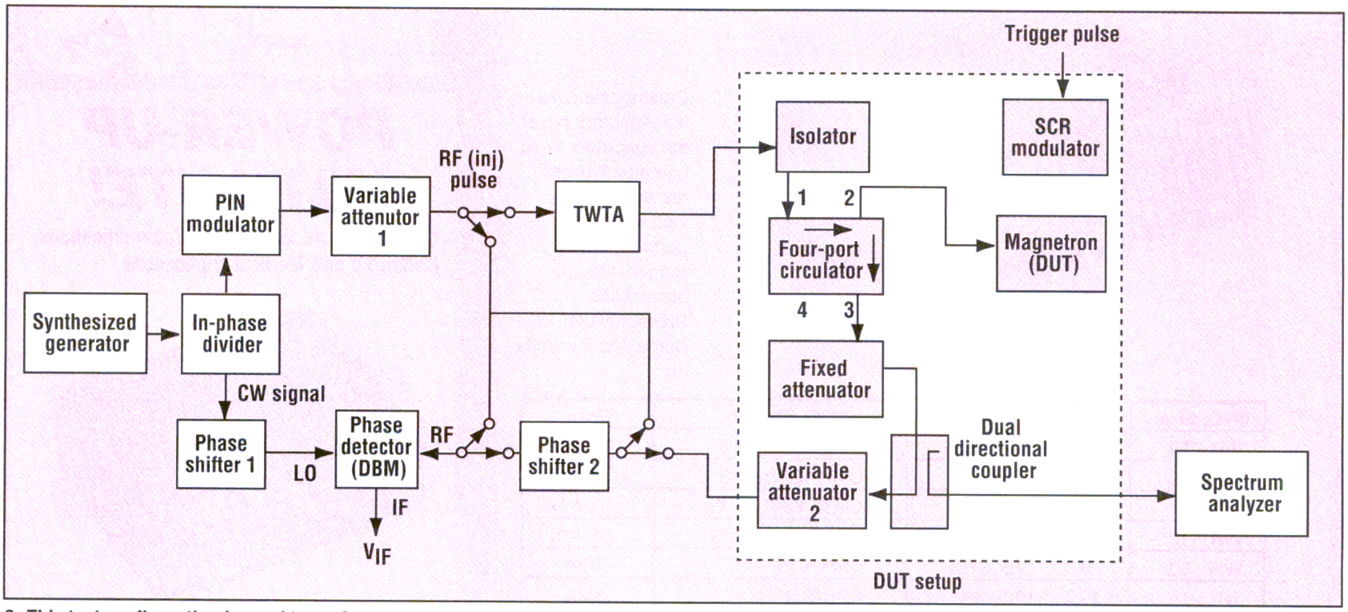


8. This test configuration is used to perform magnetron phase measurements. The pulsed injection signal is obtained by modulating a signal from a synthesized source.

In a system design, the frequency deviations due to all of the aforementioned factors can be estimated independently. In the worst-case situation, the total frequency deviation will be the worst sum of the frequency deviations due to the above factors. Another approach to the design problem is to find the maximum extent of frequency deviation under simulated conditions in which all of the factors come into play.

DRIFT MEASUREMENT

A practical approach was adopted to measure the temperature coefficient that characterizes the frequency drift due to f_o drift, load VSWR extremes caused by frequency pulling, and frequency pushing.

The BLM 201 can be used as an example. The magnetron, along with its associated circulators and modulator (Fig. 2), was subjected to hot and cold soak tests. The procedure adopted for the tests was to soak the magnetron system at both temperature extremes (+8 and +70°C) for 5 hours each. At the end of soaking, the magnetron was energized, with the frequency measurement made after half an hour of stabilization.

A 1-MHz decrease in f_o was observed for a 45°C increase in ambient temperature (from +25 to +70°C). This yields a T_c of –22 kHz/°C. In addition, a decrease in frequency of 0.6 MHz was observed for a 17°C decrease in ambient temperature (from +25 to +8°C). This corresponds to a T_c of +35 kHz/°C.

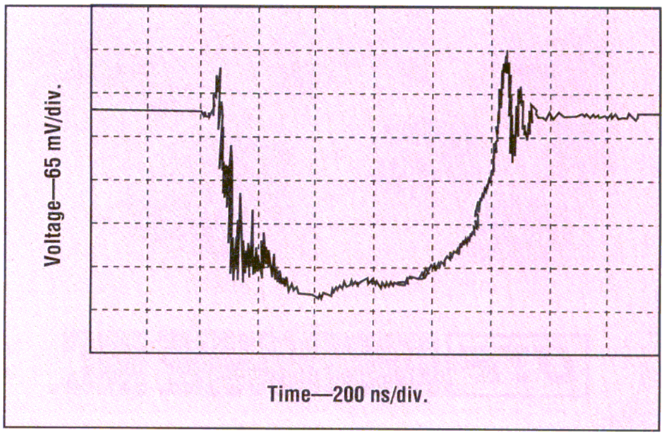
For the VMC 1180 magnetron, the maximum T_c value measured in the same manner was –35 kHz/°C (for both increasing and decreasing temperature).

Even though T_c describes a magnetron's frequency variation with body temperature, the T_c measurements were made with respect to ambient temperature. The T_c value based on ambient air is much higher than the T_c based on body temperature since the body temperature of a magnetron operating at its rated power is much higher than the ambient temperature. By using the measured T_c value based on ambient air, a built-in allowance is provided for the frequency drift.

Based on this measurement, a maximum operational T_c value of –35 kHz/°C was used to calculate the maximum frequency drift. Taking a 50°C variation in temperature on either side with respect to room temperature, the corresponding frequency drift is 1.75 MHz. The corresponding minimum required LBW is 2Δf (or 3.5 MHz).

Apart from the built-in allowance for this 3.5-GHz figure, an additional allowance was employed to account

9. The detected phase appears as a video pulse, in this case for an injection-drive level of +33 dBm.



for duty-cycle variation and one-way Doppler frequency. With a small guard band, the LBW is fixed at 5 MHz.

Having arrived at the LBW, the required injection power must be calculated. For an LBW of 5 MHz and a peak locked-power output of 400 W, the P_i calculated by Eq. 3 is 8.24 W for the BLM 201 magnetron and 11.26 W for the VMC 1180.

INJECTION TIMING

One of the requirements for pulsed injection locking is the "timing" of the modulating pulse with respect to the injection RF pulse (where both pulses are of the same width). This timing should be adjusted in such a way that by the time the magnetron's anode voltage builds up from start to threshold, the injection signal will already be present at its full power in the anode cavity. In other words, the pulse injection signal should lead the anode-voltage pulse by a time period termed the "time ahead" (t_a). The minimum t_a required to achieve injection locking is equal to the pre-oscillation period (t_p) of the magnetron. This period is the time taken for the growth of oscillation ($t = t_p$) and is given by the expression:[4,5]

$$t = 2Q_L / \omega_o \qquad (6)$$

where ω_o equals $2\pi f_o$.

For an operating frequency of 5660 MHz, t works out to be 21.38 ns for the VMC 1180 ($Q_L = 380$) and 13.50 ns for the BLM 201 ($Q_L = 240$). The t_a must be found which will ensure positive injection locking under all conditions (particularly all temperature environments). Any variation in t_a caused by temperature extremes should not make it less than the required minimum, in which case loss of lock will occur and the magnetron will go into free-running mode. Care was taken in the system design to derive the timing pulses from a clock oscillator suitable for the required temperature range. In general, a t_a of 10 times the time constant ($t_a = 10t_p$) is considered satisfactory.

The minimum and maximum limits for t_a depend upon the following:

- The t_a value should not be too low or too high, as this can cause deterioration of the magnetron's phase performance.
- It should not cause any other variations in injection-locking parameters which would be detrimental to the system performance.

The greater the t_a value, the longer the absence of the injection signal during the modulating-pulse period. This is due to the injection pulse ending before the end of the modulating pulse.

To determine the effect of t_a on phase performance, the phase error introduced by the magnetron was measured as a function of t_a for both magnetron models. The t_a was varied from 50 to 225 ns (a little over $2t_p$ to $10t_p$, respectively). A plot of phase error versus function of t_a for the BLM 201 magnetron (Fig. 3a) shows no change in phase error for t_a values up to $10t_p$. This dismisses the initial concern that the phase performance deteriorates with increasing t_a.

The other important parameter—LBW—was also measured as a function of t_a. A slight increase in LBW was observed with rising t_a. This will not cause any deterioration of the system. A plot of LBW versus t_a was obtained for the BLM 201 (Fig. 3b), with similar performance observed in the VMC 1180 case.

The phase errors introduced by the BLM 201 and VMC 1180 magnetrons for three injection-drive levels of +30, +33, and +36 dBm were also measured and plotted (Fig. 4). Based on the aforementioned observations, t_a values of 100 and 125 ns were used for the BLM 201 and VMC 1180 magnetrons, respectively. This equals about $7t_p$ for both cases. In addition, the minimum t_a causing phase deterioration was measured and found to be about 20 to 25 ns for both magnetron models.

SYSTEM CONFIGURATION

In the configuration adopted for pulsed injection locking of the magnetron in a coherent transponder (shown in Fig. 2), the injection signal is the received interrogation pulse coherently processed in the transponder, with a power level of about –5 dBm. This power is amplified to a level required for locking by means of a GaAs FET pulsed-power amplifier specifically designed for this application. The amplified power is injected into the magnetron via a four-port circulator. Two more isolators included in the path provide reverse isolation (in addition to that provided by the circulator).

The total isolation provided is much higher than the directivity requirements of the coherent source to the magnetron. The coherent output power is directed to the antenna through another four-port circulator (the antenna circulator), which serves as a duplexer. The magnetron operating with 40-dB load isolation and an antenna VSWR of 1.50:1 thus sees a fixed load condition.

The magnetron's basic injection-locking parameters (including LBW and P_i) were measured from +8 to +70°C. The actual system operating-temperature requirement is +13 to +60°C.

Experiments were conducted initially with a CW injection source. The injection signal is obtained from a synthesized generator, with the test configuration being the one adopted for pulsed injection locking. A fixed-gain (40-dB) traveling-wave-tube amplifier (TWTA) was used in place of a GaAs FET power amplifier to magnify the injection signal (illustrated in Fig. 2 by the dotted-line connection). The variable-attenuator setting of the synthesized signal generator is used to obtain the required injection-drive levels.

The LBW was measured as a function of injection power for a fixed magnetron output of 400 W. This measurement was realized by finding the lower and upper frequencies of the band in which the magnetron goes out of lock. In the case of locking with CW injection, the CW signal seen on the spectrum analyzer (superimposed on the magnetron's RF spectra) coincides with the center of the main lobe when in lock. It moves together with the RF spectra when the injection-signal frequency is varied within the LBW. When out of lock, the variation of the CW signal frequency cannot make pulsed spectra move with it.

PULSED INJECTION

In case of a pulsed injection signal, the superimposed injection-signal spectra cannot be seen as clearly, but the movement of RF spectra can be viewed clearly when the frequency of the injected pulsed signal is varied within the LBW. No hysteresis effect was found for a back-and-forth variation of injection frequency to check the accuracy of lower and upper lock frequencies. This is due to the frequency locking occuring on a pulse-to-pulse basis. Spectrum displays were recorded while conducting the above experiments on BLM 201 magnetrons (Fig. 5).

The magnetron operating in injection-locked mode (along with the associated circulators and modulator setup) was subjected to temperature soak tests. All measurements were taken at room temperature in hot and cold soak conditions. The procedure adopted was the same one used to measure T_c; the magnetron system was soaked at both temperature extremes (+8 and +70°C) for 5 hours each. At the end of soaking, the magnetron was energized, and after half an hour of stabilization, measurements were taken. The measured LBW was plotted against locking gain and compared with the theoretically-estimated LBW for the BLM 201 and VMC 1180 (Fig. 6).

Phase errors introduced by the magnetron were measured for various injection-drive levels using a double-balanced mixer (DBM) as a phase detector,[6,7] along with a set of variable phase shifters.

Phase measurement is made on the principle that the application of two identical-frequency, constant-amplitude signals to a mixer produces a DC output which is proportional to the phase difference between the signals. The signals to be compared are the inputs to the phase detector. At quadrature, the output of the phase detector is 0 Hz, with an average output voltage (V_{IF}) of 0 V at the IF port.[8,9]

The DBM was initially calibrated by measuring its V_{IF} as a function of the phase introduced between two identical-frequency, constant-amplitude signals applied to the local-oscillator (LO) and RF ports. In the DBM calibration setup (Fig. 7), a signal from a synthesized source is split by an in-phase power divider to produce two identical-frequency signals which are applied to the LO and RF ports at the appropriate power levels. The "PS 1" signal is initially excluded, while the "PS 2" setting is adjusted for a null (V_{IF} = 0). This sets the phase quadrature between the LO and RF input signals. PS 2 is then introduced into the circuit and the V_{IF} readings are recorded against known amounts of phase introduced through the signal. A plot of V_{IF} as a function of phase serves as a DBM calibration chart.

TEST SETUP

In the setup for magnetron phase measurement (Fig. 8), pulsed injection signals are obtained by modulating a signal from a synthesized source. A CW sample of the injection signal is taken through an in-phase power divider and applied to the DBM's LO port through PS 1. This signal serves as a reference for the phase measurement.

The pulsed RF signal is amplified in a fixed-gain TWTA and injected into the magnetron via an isolator and four-port circulator. Variable attenuator 1 (VA 1) is adjusted to get the required power levels to the magnetron. The locked output is applied to the DBM RF port through a precalibrated phase shifter (PS 2). For all phase measurements made with the CW reference, the pulsed signals applied to the DBM LO and RF ports are at the appropriate power levels for optimal DBM operation as a phase detector. The two signals to be compared are in CW and pulsed form, respectively. Hence, the detected phase is in the form of a video pulse whose amplitude is proportional to the phase difference between the signals. The phase readings (which are in the form of V_{IF}) are taken from the DBM calibration chart.

The oscilloscope plots of detected phase were obtained for injection-drive levels of +30, +33, and +36 dBm. Errors other than DC offset (such as mixer-introduced phase shift) were compensated by adjusting the length of the cables. In addition, the deviation from quadrature was monitored each time a phase measurement was made. After initial calibration, the mixer's DC offset was limited to a minimum of 2 to 3 deg. Only this term can be treated as an error in the phase measurement.

The phase error introduced by the magnetron in locking becomes smaller with increasing injection power (i.e., with a decrease in locking gain). Referring to the plot of Fig. 4, the phase error is measured up to an injection power of 4 W. At 10 to 12 W of injection power (where the system is designed to operate), the phase error is indiscernible with this phase-measurement setup. The detected phase plot for the BLM 201 (Fig. 9) shows a noisy phase transient at the start of the pulse, followed by a steady-state phase.[10] The noise content in the phase transient becomes smaller as the injection power is increased.

Experimental results are in close agreement with the theoretical estimates. The deviation with estimated LBW is due to the difference between the magnetron's actual loaded Q and the specified value. State-of-the-art technology provides GaAs FET power amplifiers with output levels on the order of 30 W at C-band. For pulsed injection-locking applications, the amplifier must be turned on only during the period in which the injection pulse appears at the input. Hence, the amplifier can be operated with TTL pulses, which are synchronized with the injection pulse. TTL operation drastically reduces the amplifier power drain. With emerging MMIC technology, a 10-to-12-W pulsed-power amplifier with a TTL driver can be realized.

Conventional high-Q magnetrons operated in injection-locked mode thus offer a viable alternative to the relatively-expensive, specialized magnetrons used in coherent-transmitter applications.••

Acknowledgments

The authors thank U.S. Singh, Group Director, Electronics Group; N.K. Agarwal, Head, Electromagnetics Division; R.M. Vasagam, Director, AVN; Dr. S.C. Gupta, former Director, and P.P. Kale, current Director, Vikram Sarabhai Space Centre, for their encouragement and support of this work. The authors also express their gratitude to Prof. R.V.S. Sitaram, Adviser, SAMEER (Bombay, India) for the valuable suggestions given during the course of this work. Thanks are also due to V.K. Garg of SAC (Ahmedabad, India) for providing a GaAs FET power amplifier and to G. Vinod for the assistance given in carrying out this work.

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For further reading

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Simulating chirp signals

Chirp signals are employed to enhance the performance of radar systems. A typical chirp radar pulse requires the generation of a pulsed RF signal whose carrier frequency is swept by several megahertz over a time interval of 10 to 100 μs. Publication No. 46889-472, titled "Generating Radar Chirp Signals," overviews the testing and simulation of these signals.

Signal generators in the 2050 series contain a wideband FM (WBFM) input which provides a 1-dB bandwidth of greater than 10 MHz and deviations of at least 1 percent of the carrier frequency. A chirp signal can be created by connecting a ramp generator to the WBFM port (to sweep the carrier frequency) and then introducing a pulse input.

To minimize distortion of the ramp linearity caused by the finite WBFM bandwidth, the ramp generator should be set to provide the sweep before the RF pulse. This allows any transient effects to decay before the start of the RF pulse.

For better accuracy (at the expense of increased cost), FM chirp signals can be generated using in-phase/quadrature (I/Q) modulation signals. In this case, the I/Q modulator must be configured in single-sideband form. An applied tone produces a carrier frequency equal to the modulator input frequency plus or minus the modulating tone. An arbitrary waveform generator with two outputs is useful for providing the required I and Q signals.

A potential source of chirp-signal error is a lack of phase quadrature between the I and Q signals. This problem can be corrected by introducing delay compensation to match the I and Q channels.

The four-page application note also outlines rise/fall-time control and frequency-range extension. A copy of the note can be obtained by contacting: **Marconi Instruments, Inc., 3 Pearl Court, Allendale, NJ 07401; (201) 934-9050, FAX: (201) 934-9229.**

CIRCLE NO. 194

Optimizing PCB layouts

Surface-acoustic-wave (SAW) filters feature a low physical profile and amenability to automated assembly, rendering them useful in high-volume commercial applications. In order to achieve optimal performance from a SAW filter and its associated matching components, printed-circuit boards (PCBs) must be properly configured. This performance optimization is discussed in an application note titled "Optimizing PC Board Layouts," which is included in the Summer 1994 issue of SAW Scene.

Among the circuit effects that must be minimized is feedthrough, which is unwanted transmission due to coupling (such as capacitive coupling). In the frequency domain, feedthrough degrades the SAW filter rejection and causes a periodic ripple in the output amplitude, phase, and group delay.

Typical system requirements demand 30 to 60 dB of rejection from SAW filters. To achieve this level of performance, it is imperative that the input and output ports be isolated from each other. One method of minimizing crosstalk between the input- and output-matching components is to place a metal shield or septum between the components.

The note outlines several other layout guidelines for optimizing PCB performance. For instance, a ground plane should be present on both the top and bottom of the PCB. In addition, a plated-through slot may be included to further isolate the filter's input and output ports and minimize RF leakage through the PCB dielectric layer.

To receive a copy of the note, contact: **Sawtek, Inc., P.O. Box 609501, Orlando, FL 32860-9501; (407) 886-8860.**

CIRCLE NO. 195

Measuring laser pulses

Laser pulses are characterized by a low repetition rate and high bandwidth, which makes them difficult to monitor on a conventional analog oscilloscope. Application note ITI-018, titled "Characterizing Lasers with Digital Oscilloscopes," outlines the testing of these signals with digital oscilloscopes.

The laser-pulse test setup simply involves connecting the laser synch signal to the trigger source and properly adjusting the trigger delay and timebase setting. A high-speed photodetector is used to capture the laser beam. To ensure accuracy, the photodetector should have a fast rise time (< 200 ps).

Low synch-to-pulse jitter is especially important when using the synch signal as a measurement reference. With the model 9360 digital oscilloscope, the delay between the trigger point and the laser pulse is automatically measured and used to correct further measurements.

Two types of pulse-width measurements can be made with the 9360 scope. The pulse under test can be measured at full-width/half-maximum (i.e., at 50 percent of the pulse amplitude) or at $1/e^2$ (i.e., 13.53 percent of the pulse amplitude).

Since laser applications often require a precise and steady level of energy, measurement of energy stability is a useful capability. This measurement can be performed by employing the scope's integration function. The integration of the pulse over time is proportional to the energy contained in it.

In order to minimize the occurrence of missed pulses, a tolerance mask can be generated around a critical pulse. This data is then used to perform a pass/fail test on received waveforms.

A copy of the note is available from: **LeCroy Corp., 700 Chestnut Ridge Rd., Chestnut Ridge, NY 10977-6499; (800) 4-LECROY, (914) 425-2000, FAX: (914) 425-8967.**

CIRCLE NO. 196

COVER FEATURE

NOVEL I/Q MODULATORS MIX CELLULAR SIGNALS

By employing subharmonic mixing techniques, these SSB modulators provide good performance and system cost savings.

SINGLE-SIDEBAND (SSB) or in-phase (I)/quadrature (Q) modulators are used extensively in communications systems, including cellular and personal-communications-systems (PCS) networks. Although the basic design is fairly mature, it has been completely revamped thanks to an innovative technique developed by Synergy Microwave Corp. (Paterson, NJ). The novel approach is based on subharmonic mixing techniques and is applicable from about 500 to 3000 MHz.

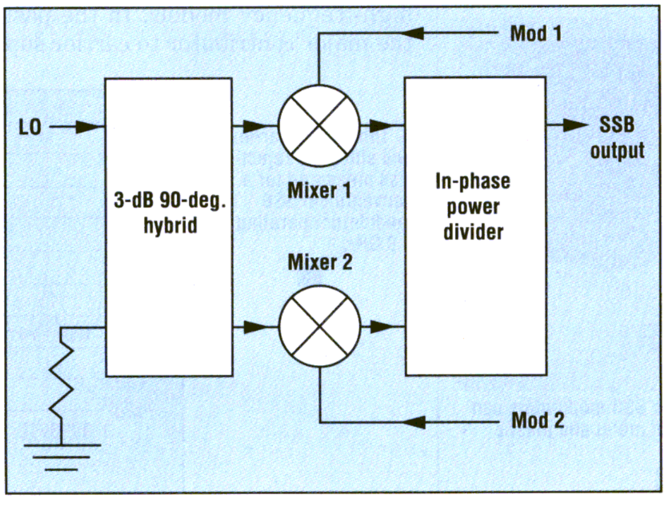
In a communications receiver, SSB or I/Q modulators are useful in discriminating and removing the lower sideband (LSB) or upper sideband (USB) generated during frequency conversion, especially when the sidebands are very close in frequency and attenuation of one of the sidebands cannot be achieved with filtering. This is the case with audio and video modulation, where signals from DC to 10 MHz must be converted to a higher frequency that is appropriate for transmission. In such cases, both sidebands will be very close in frequency to the carrier frequency. With an I/Q modulator, one of the sidebands is easily canceled or attenuated along with its carrier.

Attenuation of the carrier has been the most troublesome aspect in the design of passive I/Q modulators. Isolation between the local-oscillator (LO) port and the RF port of the mixers, which is the main parameter in determining carrier rejection, is usually insufficient at frequencies above 200 MHz.

Previous I/Q modulator designs were basically comprised of two double-balanced mixers (Fig. 1). The mixers are fed at the LO ports by a carrier phase-shifted through a 90-deg. hybrid. Thus, the carrier signal's relative phase is 0 deg. to one mixer and 90 deg. to the other mixer. Modulation signals are fed externally in phase quadrature to the two mixers' IF ports. The mixers' modulated output signals are combined through a two-way, in-phase power divider/combiner.

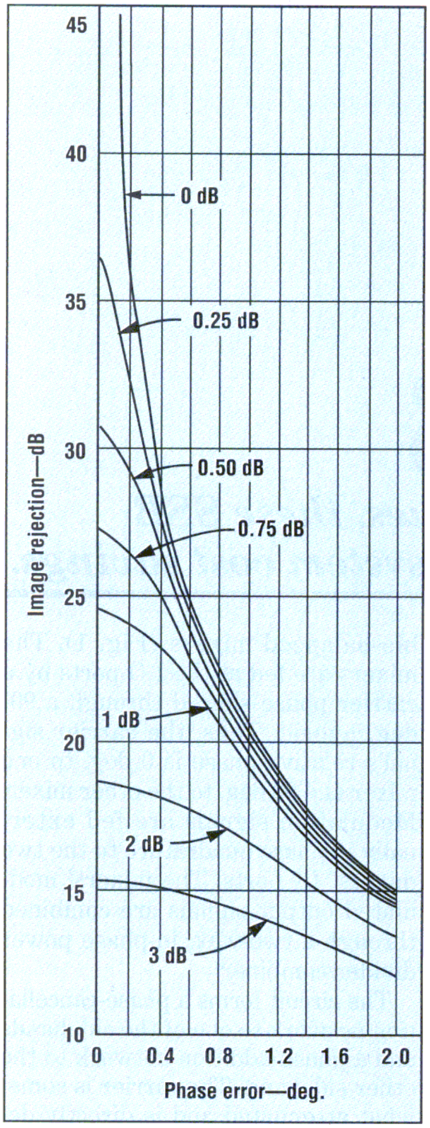
The circuit forms a phase-cancellation network to one of the sidebands and a phase-addition network to the other sideband. The carrier is somewhat attenuated and is directly dependent on the inherent LO-to-RF isolation of the mixers and the modulating signal level. In a standard

SHANKAR R. JOSHI, Chief Engineer, Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (201) 881-8800, FAX: (201) 881-8361.

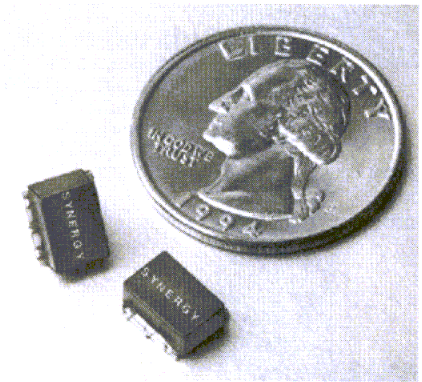


1. An SSB modulator matches two high-frequency mixers, a 90-deg. hybrid, and an in-phase power combiner to produce an SSB output signal.

I/Q MODULATORS



2. The level of SSB rejection improves as the phase- and amplitude-imbalance performance of an SSB modulator improves.



3. The novel subharmonic SSB modulators can be supplied in a variety of metal and plastic packages.

line of I/Q modulators from Synergy, USB suppression results when the first modulation port (MOD 1) is fed with a signal that is 90 deg. in advance of the signal feeding the second modulation port (MOD 2). Opposite phasing can be arranged by changing the internal phase polarity of the mixers or by interchanging the 90-deg. hybrid output ports to the LO ports of the mixers.

The phase and amplitude imbalances between the various components used in the manufacturing of the I/Q modulators must be tightly maintained for optimum SSB rejection. Matching of the two mixers for conversion loss and insertion phase is extremely critical, since differences in these parameters will add to amplitude- and phase-imbalance errors. The 90-deg. hybrid in the LO port must be in nearly perfect phase quadrature.

Phase- and amplitude-imbalance errors adversely affect sideband suppression (Fig. 2). In most cases, a typical passive I/Q modulator operates with a carrier input level of +10 dBm, which is required to drive the diodes in the mixers to operate in the linear range. The dynamic range of these mixers can be significantly improved by using diodes with a higher barrier height. The LO signal in this case must be increased in order to drive these diodes into conduction in their linear range.

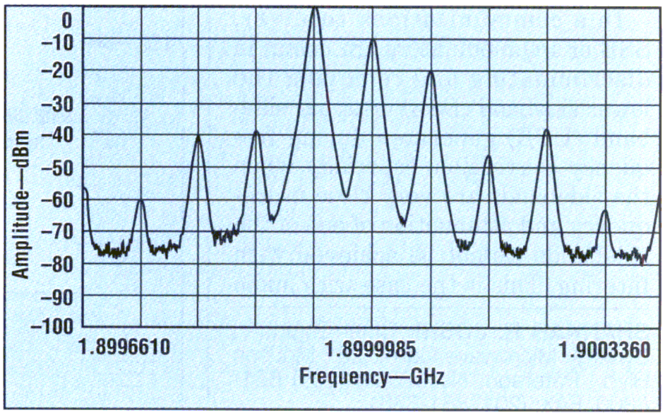
Carrier rejection is also a problem when designing an SSB modulator, since only a few decibels of suppression can be achieved in standard high-frequency models. In the past, the major contributor to carrier suppression was the inherent LO-to-RF isolation through the mixers. Unfortunately, this isolation is usually poor at cellular frequencies (800 to 1000 MHz), where at least 25-dB carrier rejection is necessary. In some cases, designers feed a small amount of DC into the IF ports to control the carrier rejection, which complicates the driver circuitry and calls for temperature compensation when operating at different temperatures.

As an example, an SSB modulator is assumed to operate with +10-dBm LO drive with each modulating signal at –10 dBm and in phase quadrature to each other when applied to the modulating ports (MOD 1 and MOD 2). The result will be a modulated signal at –16 dBm, assuming 6-dB conversion loss. For 20-dB carrier rejection with respect to the desired modulated signal, the carrier must be at –36 dBm, which translates to LO-to-RF isolation of 46 dB.

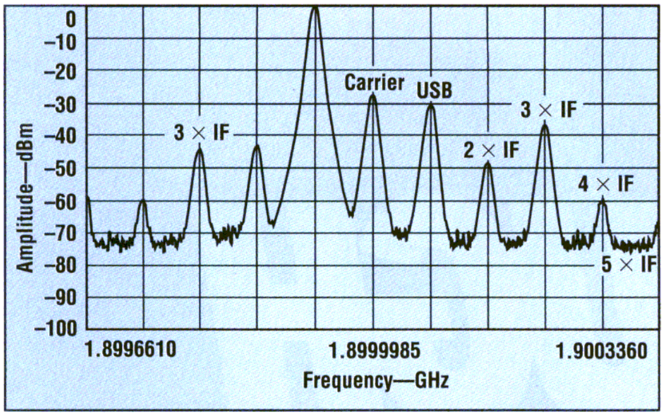
By employing a novel approach (patent pending), the engineers at Synergy have extended the performance of SSB modulators beyond the limits of conventional designs. The approach is based on the use of subharmonic mixers in place of fundamental-frequency mixers. Subharmonic mixers use anti-parallel diode pairs in their construction.[1-3] Matched anti-parallel diode pairs used in single-ended or single-balanced mixer configurations cancel even-order intermodulation products (such as 2LO × 2RF, 3LO × 3RF, etc.) at all ports.

Single-ended mixers lack the port-to-port isolation needed for SSB-modulator applications. Odd-order

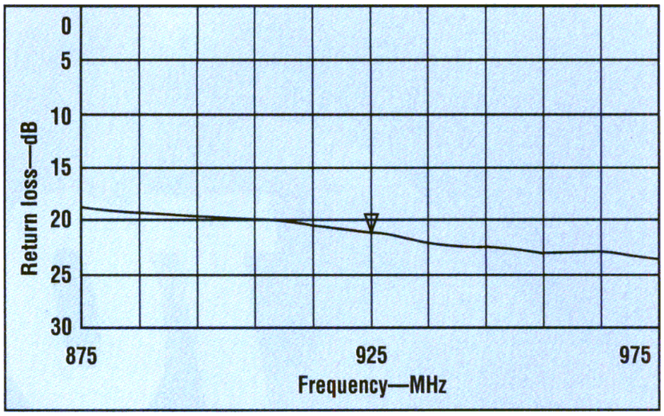
4. This plot of carrier and sideband rejection was measured for a conventional SSB modulator operating at 1.9 GHz.



I/Q MODULATORS



5. This plot of carrier and sideband rejection was measured for a novel harmonic SSB modulator operating at 1.9 GHz.



6. The SSB modulator's return loss was measured at the local-oscillator (LO) port.

products of the RF and LO frequencies (even LO × odd RF) and (odd LO × even RF) appear on all ports, requiring extensive filtering for satisfactory performance. For a single-balanced mixer, even harmonics of the LO combining with odd harmonics of the RF appear at the IF port, whereas odd harmonics of the LO combining with even harmonics of the RF appear at the RF and IF ports. This assumes that a balanced transformer is placed at the LO port, which is a logical choice due to the fact that the highest level signal appears at the LO port. Since the desired odd-order IF products appear at both the RF and IF ports, a need arises for a diplexing network to isolate the RF and IF signals.

The subharmonic modulator design provides a unique way to isolate the RF and IF signals. A single-balanced harmonic mixer offers good LO-to-RF and LO-to-IF isolation but poor RF-to-IF isolation. Fortunately, harmonically-related signals are spaced well apart in the frequency spectrum, simplifying filtering of harmonically-related signals.

Harmonic mixing also works well with low LO power levels, with somewhat lower 1-dB compression on the RF port than with fundamental-frequency mixing. The ability to operate with LO frequencies that are a fraction of the carrier frequency (1/2, 1/4, 1/6, etc.) significantly reduces the cost of an LO source, especially at higher frequencies. Also, using lower-frequency LO sources helps avoid the signal-leakage problems inherent with higher-frequency LO sources. Minimizing signal leakage, especially at higher frequencies, becomes expensive and bulky.

Subharmonic mixing offers several advantages:

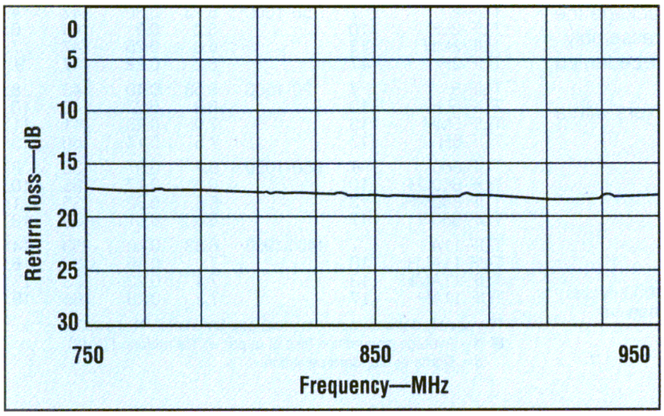
(1) The technique offers the ability to operate at LO frequencies that are 1/2, 1/4, or 1/6 of the carrier frequency. For example, for an IF of 100 MHz at an RF of 2 GHz, the LO can be $(2000 \pm 100)/2 = 950$ or 1050 MHz.

(2) The LO's even harmonics are strongly attenuated.

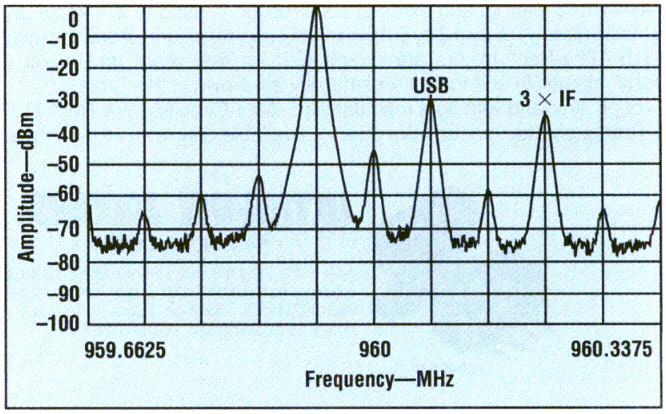
(3) The filtering requirements for fundamental-frequency and odd-harmonic signals of the LO are not critical.

(4) The cost of generating the LO is reduced due to the fact that the LO frequency need only be a fraction of the carrier frequency.

The novel design approach (Fig. 3) has opened the way for a new line of products specifically designed for applications in the cellular bands. Frequency coverage extends from 500 to 3000 MHz with applications in a wide range of systems, including the Advanced Mobile Phone Service (AMPS), the Digital European Cordless Telephone (DECT) system, the European Global System for Mobile



7. The novel harmonic SSB modulator's return loss was measured at the RF port.



8. This plot of carrier and sideband rejection was measured for the novel harmonic SSB modulator operating at cellular frequencies.

Communications (GSM), the Nordic Mobile Telephone (NMT) system, the North American Digital Cellular (IS-54 and IS-95 standards) system, the Japanese Personal Handy Phone (PHP), and the Total Access Communications System (TACS).

As an example of the performance improvements possible with the subharmonic mixers, units were evaluated at both cellular (935-to-960-MHz) and PCN/PCS (1.8-to-1.9-GHz) bands. For a conventional SSB modulator at 1.9 GHz fed with +10-dBm modulation signals, carrier rejection is barely 10 dB (Fig. 4). Sideband rejection can be improved by tuning, but the carrier rejection is controlled by the LO-to-RF isolation of the double-balanced mixers.

Fundamental-frequency double-balanced mixers with high isolation at cellular and PCN bands are very expensive and large when special techniques are used to improve LO-to-RF isolation. In contrast, the subharmonic nature of the new approach allows the use of lower-frequency, less-expensive components in the modulators' construction.

The subharmonic modulators offer an improvement of more than 15 dB in carrier suppression compared to the conventional approach (Fig. 5). The measured VSWR (return loss) at the LO and RF ports is better than 1.50:1 (Figs. 6 and 7). Measurements made on a cellular-band SSB modulator reveal carrier rejection on the order of 40 dB (Fig. 8). Typical insertion loss is 7 dB while sideband rejection is 30 dB.

By the virtue of harmonic mixing, even-order mixing products are attenuated by about 30 dB with respect to the desired modulated output signal. The fundamental-frequency feedthrough into the output port is approximately 5 dB lower than the desired modulated signal, whereas the fourth-harmonic mixing with the modulating signal is approximately 10 dB lower. Typical loss for fourth-harmonic mixing is 17 to 19 dB while maintaining 30 dB of carrier rejection.

Since harmonically-related products are well-spaced in frequency, filtering undesired signals is relatively inexpensive using standard octave-band bandpass filters. Low-cost commercial bandpass filters typically offer better than 40-to-50-dB attenuation of unwanted harmonic signals. Constant-impedance bandpass filters offering good impedance match at desired stopbands can also be used in cases where harmonically-related products require impedance termination within a system.

The subharmonic modulator design is easily retrofitted to custom frequencies. Conversion of an SSB modulator with output frequency corresponding to twice the LO frequency to one with output corresponding to four times the LO frequency requires only one component change, in the form of a signal-combining network at the modulator's output. Although the conversion loss of the fourth-harmonic LO component mixing with the modulating signal is in the vicinity of 18 dB, the cost of generating the LO signal is drastically reduced with the subharmonic modulator. In spite of higher signal loss, the carrier rejection is still at least 30 dB at the fourth harmonic, and harmonically-related products can be eliminated with an inexpensive filter.

The new harmonic SSB modulators are available in a variety of packages, including leaded and non-leaded (EMI-shielded) metal surface-mount types, leaded and unleaded plastic surface-mount types, and standard industrial plug-in relay headers. Other package styles are available upon request. P&A: stock. **Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (201) 881-8800, FAX: (201) 881-8361.**

CIRCLE NO. 51

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COMPACT SPECTRUM ANALYZER GRABS 2.2-GHz SIGNALS

This lightweight instrument is ideal for field testing and general-purpose troubleshooting from 9 kHz to 2.2 GHz.

PORTABLE spectrum analyzers are often less than portable for the average person, weighing typically 40 lbs. (18.12 kg) or more. But the U4941 portable spectrum analyzer from Tektronix, Inc. (Beaverton, OR) lives up to its appellation. The 14-lb. (6.3-kg) instrument measures just 5.75 × 11.37 × 13.25 in. (14.61 × 28.88 × 33.66 cm), but packs an accurate analyzer spanning 9 kHz to 2.2 GHz. The U4941 operates with AC power, DC supplies from +10 to +16 VDC, and an optional rechargeable nickel-cadmium battery pack.

The U4941 spectrum analyzer (see figure) is small and light enough to be carried to a mountaintop for on-site testing of cellular base stations and radio repeaters. The analyzer features markers which can be set anywhere along a swept trace, with frequency-counter resolution of 1 Hz to 10 kHz. Display traces are shown on a 6-in. color liquid-crystal-display (LCD) screen.

Resolution-bandwidth filters are defined by their 3-dB bandwidths and cover a range from 1 kHz to 3 MHz. Likewise, video-bandwidth filters range from 10 Hz to 3 MHz. The instrument includes an AM/FM detector and built-in speaker and headphone jacks for monitoring demodulated signals.

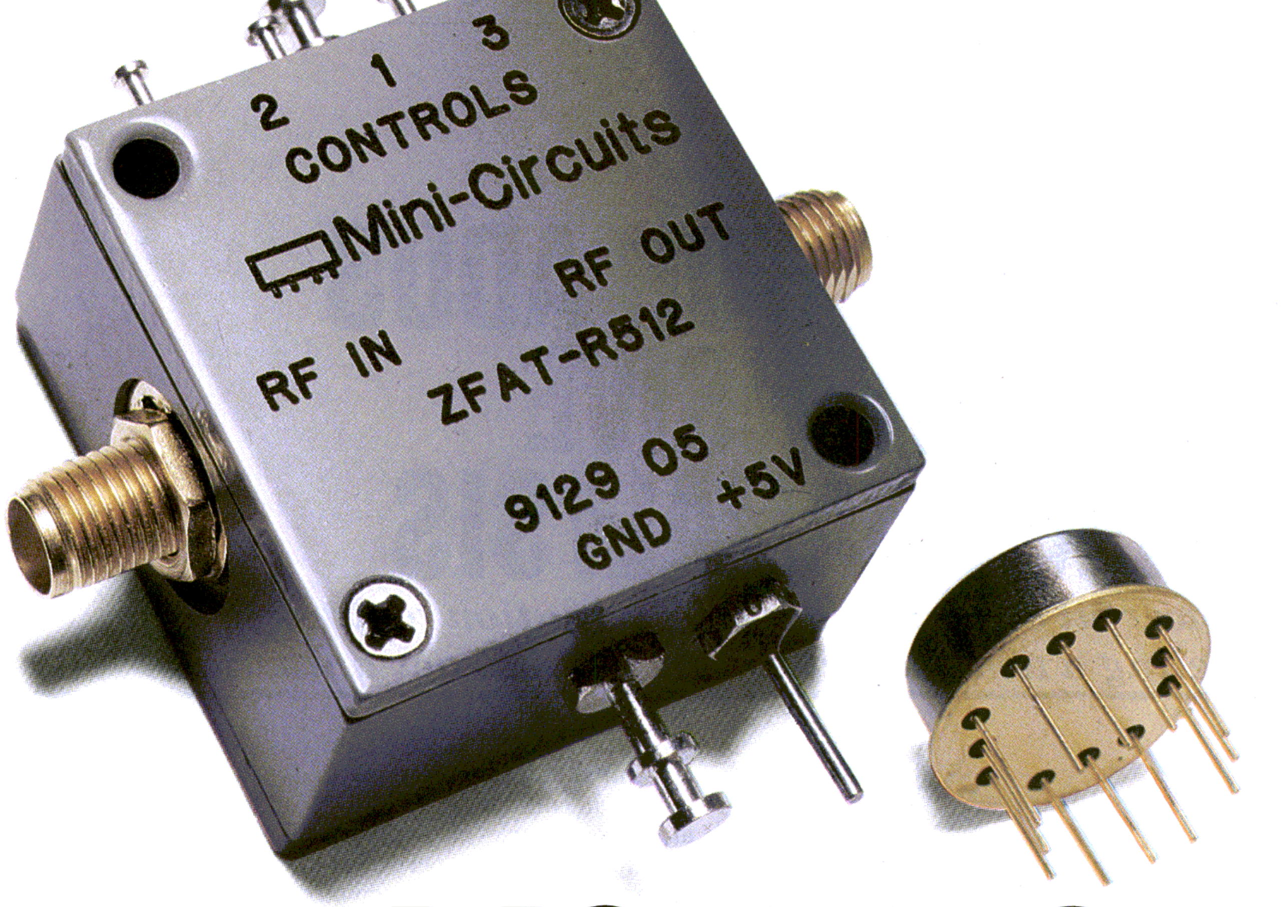
The spectrum analyzer has a display dynamic range of 90 dB, making measurements with or without the aid of an internal preamplifier. The instrument handles levels from –84 to +10 dBm with the preamplifier and –64 to +40 dBm without it. With or without the preamplifier, amplitude accuracy is better than ±1 dB from 100 kHz to 2 GHz and better than ±2 dB from 9 kHz to 2.2 GHz. For measuring high-level signals, the instrument includes an input attenuator with a 0-to-50-dB range, adjustable in 10-dB steps.

The instrument relies on a built-in crystal-oscillator frequency reference with $\pm 2 \times 10^{-6}$/year long-term frequency stability and frequency accuracy of $\pm 1 \times 10^{-5}$ across temperatures from 0 to +50°C. In addition, an input port allows a 10-MHz external frequency reference source to be connected for enhanced frequency stability and accuracy. Noise sidebands are equal to or less than 100 dBc/Hz measured at an offset of 20 kHz from the carrier.

The U4941 spectrum analyzer features full-sized measurement power from 9 kHz to 2.2 GHz in a package weighing only 14 lbs.

The U4941 spectrum analyzer is equipped with a 50-Ω test port; it is also available with a 75-Ω test port as model U4941N. Versatile marker functions improve measurement speed and repeatability. In addition, a window function allows a portion of a displayed sweep to be delimited for faster update rates. Two PCMCIA memory-card slots are available for data storage, while GPIB and RS-232C ports are provided for instrument control and printer/plotter connections. P&A: $14,500; 10 wks. **Tektronix, Inc., Test & Measurement Products, P.O. Box 1520, Pittsfield, MA 01202; (800) 426-2200.**

CIRCLE NO. 52



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0.5	**0.12**	**1.0**	**0.2**	**3.0**	**0.3**	**4.0**	**0.3**	**5.0**	**0.3**
1.0	**0.2**	**2.0**	**0.2**	**6.0**	**0.3**	**8.0**	**0.3**	**10.0**	**0.3**
1.5	0.32	3.0	0.4	9.0	0.6	12.0	0.6	15.0	0.6
2.0	**0.2**	**4.0**	**0.3**	**10.0**	**0.3**	**16.0**	**0.5**	**20.0**	**0.4**
2.5	0.32	5.0	0.5	13.0	0.6	20.0	0.8	25.0	0.7
3.0	0.4	6.0	0.5	16.0	0.6	24.0	0.8	30.0	0.7
3.5	0.52	7.0	0.7	19.0	0.9	28.0	1.1	35.0	1.0

Price $ (1-9 qty) TOAT $59.95/ZFAT $89.95
bold faced values are individual elements in the units

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F 140 REV

EM SIMULATOR ADDS COMPREHENSIVE ANTENNA ANALYSIS

This powerful electromagnetic simulation tool takes aim at modeling a wide variety of high-frequency antennas.

ANTENNA designers have long felt abandoned in terms of the paucity of commercially-available software programs targeted at their particular area. Fortunately, the latest version of the electromagnetic (EM) simulator Microwave Explorer from Compact Software (Paterson, NJ) features advanced antenna-modeling capabilities to help these designers look at accurate predictions of antenna performance before they leap into a prototype design.

Microwave Explorer is one of a select number of commercially-available computer simulation tools based on the solution of Maxwell's equations to predict current flow and coupling effects through discontinuous circuit structures. The software's speed and accuracy have contributed to its favor among designers of single- and multilayer hybrid and monolithic microwave integrated circuits (MMICs); the complex geometries and viaholes in these circuits would otherwise impose unreasonable computation times and complexities for standard circuit simulators. Running on workstations and technical computers, Microwave Explorer provides the accuracy and computational power to solve for current flow, impedance, and other parameters within these complex geometries, thus many designers use it as an adjunct to a circuit simulator such as Microwave Harmonica.

Microwave Explorer can model circuits in either a packaged or open environment. The user can switch between single- or double-precision accuracy to reduce memory requirements—the software will automatically alert the user if accuracy will suffer significantly. Additionally, the software employs several techniques to overcome the operating speed limitations common to EM simulators. For example, two-dimensional Fast Fourier transforms (FFT) are used in the solution of the electric-field integral equations (Maxwell's equations). A novel formulation that incorporates various FFT tables is used to speed simulation by reducing the number of unknowns in the equations. Novel techniques for modeling vertical currents make analysis time almost independent of the number of viaholes and vertical striplines.

Finally, a gridding algorithm in Microwave Explorer automatically matches the software's computational power to a particular application. For example, when modeling currents near a discontinuity, more basis functions are employed than for modeling currents at further distances from the discontinuity (where the solution is less complex and simpler to predict).

With the addition of antenna-modeling capabilities, Version 3.0 of Microwave Explorer adds extensive design power for engineers working with (in a package) and without (in free space) boundaries. The antenna-analysis capabilities allow users to model a wide variety of antennas with arbitrary shapes. The software takes the effects of antenna radiation losses and surface-wave losses into account. Microwave Explorer supports different forms of antenna-feed excitations, including coaxial pin, slot feeding, and microwave line feeding.

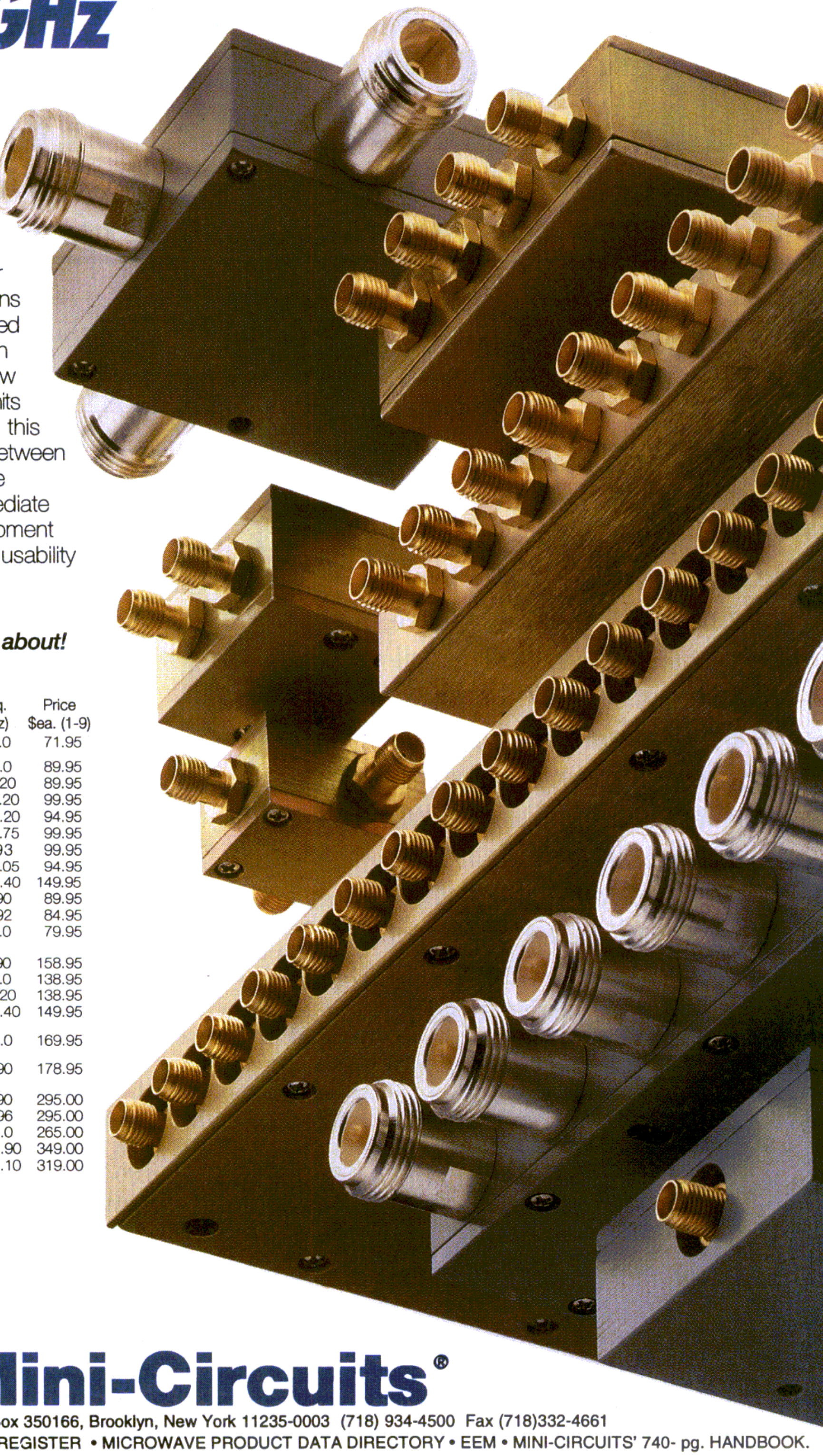
Results of antenna simulations can be shown as current distributions, scattering parameters (for use in linear and nonlinear circuit simulators), and input impedance. Future versions of the software will include the ability to visualize far-field antenna patterns, antenna gain, and directivity.

Microwave Explorer runs on Sun SPARCstations and HP 700/800 Series engineering workstations. For engineers needing absolute accuracy in predictions of coupling and current flow in high-frequency components and antennas, the software is a valuable addition to any software suite. **Compact Software, Inc., 201 McLean Blvd., Paterson, NJ 07504; (201) 881-1200, FAX: (201) 881-8361.**

CIRCLE NO. 53

POWER DIVIDERS

500MHz - 8.4GHz



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■ ZN2PD-920	.80-.92	59.95
■ ZN2PD-92OW	.70-1.05	54.95
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■●▼ ZAPD-21	.50-2.0	59.95
■ ZN3PD-900	.80-.90	74.95
■ 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
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■ ZC6PD-960W	.70-1.0	119.95
■ ZC6PD-1900	1.70-1.90	134.95
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■● ZB6PD1-960	.89-.96	139.95
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■● ZAPDQ-4 (90°)	2.0-4.20	79.95

MODEL	Freq. (GHz)	Price $ea. (1-9)
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■● ZA4PD-4	2.0-4.20	89.95
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■ ZN4PD-920	.80-.92	84.95
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■ ZC8PD-900	.80-.90	158.95
■● ZB8PD-2	1.0-2.0	138.95
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■ 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
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F 177 Rev A

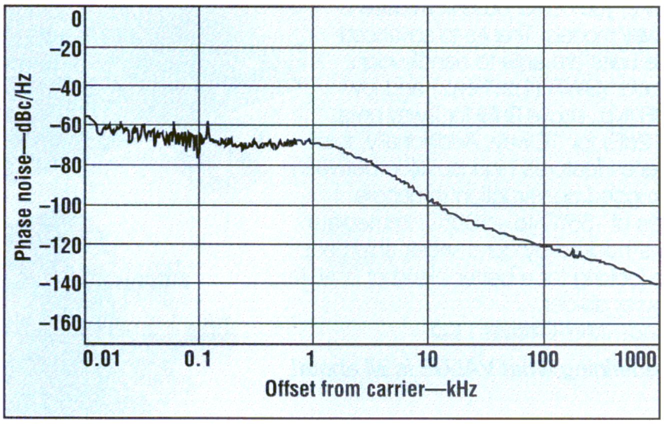
SURFACE-MOUNT PLL SYNTHESIZERS ENHANCE WIRELESS RADIO DESIGN

A line of compact PLL frequency synthesizers offers low-phase-noise in a low-cost, surface-mount package.

PHASE-LOCKED-LOOP (PLL) frequency synthesizers are key components in most portable radios and system repeaters. High cost is generally associated with such sources and performance degradation usually complicates the equation when PLL synthesizers are miniaturized. Fortunately, the MLS line of surface-mount PLL synthesizers from RDL, Inc. (Conshohocken, PA) overcomes the tradeoffs and high costs associated with miniaturized PLL sources through the use of advanced fractional-N synthesis techniques and high-volume manufacturing processes.

1. The low-phase-noise MLS synthesizers are available with any 10-percent bandwidth from 50 to 2500 MHz.

DARRYL R. SCHICK, Vice President of Engineering, RDL, Inc., 7th Ave. and Freedley St., Conshohocken, PA 19428; (610) 825-3750, FAX: (610) 825-3530.



2. Typical phase noise for an MLS-803 synthesizer operating from 869.010 to 896.980 MHz in 30-kHz steps is typically –95 dBc/Hz offset 10 kHz from the carrier.

Each packaged MLS component (Fig. 1) contains a PLL synthesizer with a voltage-controlled oscillator (VCO), loop filter, and digital dividers. The sources incorporate fractional-N synthesis techniques to improve phase noise within the loop bandwidth.

The PLL synthesizers can be programmed with frequencies over any 10-percent bandwidth from 50 to 2500 MHz, with standard models covering common radio bands. These include models MLS-802 for coverage from 810 to 830 MHz in 25-kHz steps, MLS-803 with coverage from 824 to 895 MHz in 30-kHz steps, and MLS-910 with coverage from 900 to 965 MHz in 25-kHz steps.

The surface-mount synthesizers can be programmed using serial or parallel formats. If programming lines are not available, the MLS synthesizers can use an optional internal programming device that loads a preset frequency when turning on the power to the synthesizer.

Typical phase noise for an MLS-803 synthesizer is –95 dBc/Hz offset 10 kHz from the carrier (Fig. 2). The phase noise inside a loop bandwidth of 1 kHz is typically –65 to –70 dBc/Hz, compared to about –55 dBc/Hz for synthesizers not employing fractional-N techniques.

The MLS synthesizers are built on an RF printed-circuit board (PCB) with a tin-plated steel lid that shields the circuitry from outside interference and prevents the synthesizer from radiating RF energy to external equipment. The synthesizers measure just 0.20 × 1.25 × 1.25 in. (0.51 × 3.18 × 3.19 cm). RF, DC, and programming connections are made by means of plated terminals along the PCB edge. P&A: $28 and up (5000 qty.); 6 wks. **RDL, Inc., 7th Ave. and Freedley St., Conshohocken, PA 19428; (610) 825-3750, FAX: (610) 825-3530.**

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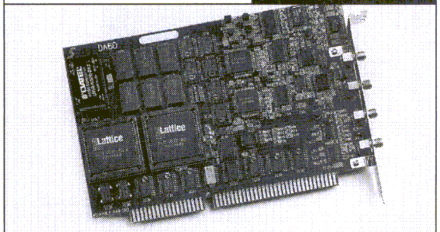

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SIGNATEC CIRCLE 559

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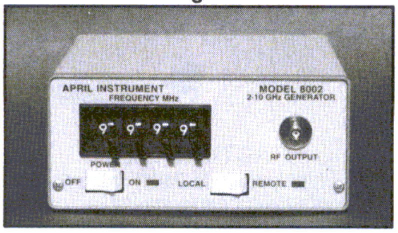

The model 8002 handheld, programmable microwave signal generator operates over the frequency range from 2 to 10 GHz in 1 MHz increments with a guaranteed output power of +10 dBm. Phase noise at a 20 KHz offset from the carrier is -80 dBc with -90 dBc typical. Full band switching speed mav be set to 350 or 25ms.
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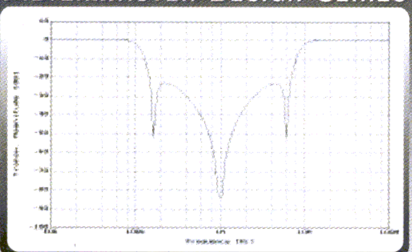

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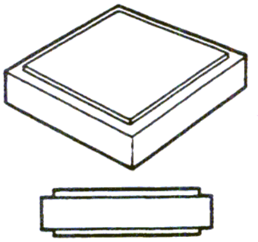

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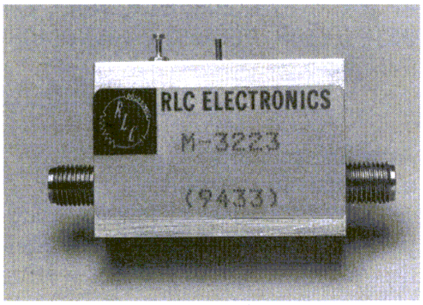
The model M-3223 bias tee spans the frequency range of 3.5 to 13.5 GHz. Insertion loss is less than 0.25 dB while VSWR is 1.25:1. The unit



can handle 500-mA input current. The bias tee is designed for use in biasing amplifiers and DC-blocking components. **RLC Electronics, Inc., 83 Radio Circle, Mount Kisco, NY 10549; (914) 241-1334, FAX: (914) 241-1753.**

CIRCLE NO. 111

RF amplifier has 1-GHz bandwidth

Model TK16201 is a monolithic RF amplifier featuring a 1-GHz bandwidth and 10-dB insertion gain. Operating from a 10-V power supply, the amplifier's input and output impedances are matched to 50 Ω. Output power at the 1-dB compression point is +5 dBm; the third-order intercept point is +15 dBm. The component is available in a surface-mount SOT-89-5 package and operates from –40 to +85°C. **Toko America, Inc., 1250 Feehanville Dr., Mount Prospect, IL 60056; (800) PIK-TOKO, FAX: (708) 699-7864.**

CIRCLE NO. 112

Oscillator features 5-to-12-MHz range

Designed for commercial communications, instrumentation, and global-positioning-system (GPS) applications, the model 2930201 ovenized oscillator covers the frequency range of 5 to 12 MHz. Typical phase noise at 10 MHz is –110 dBc/Hz offset 10 Hz from the carrier, –140 dBc/Hz offset 100 Hz from the carrier, –160 dBc/Hz offset 1 kHz from the carrier, and –165 dBc/Hz offset 10 kHz from the carrier. The aging rate at time of shipment is 5×10^{-10}/day. Frequency stability is $\pm 1 \times 10^{-8}$ over a temperature range of –20 to +60°C. The oscillator measures 2.00 × 2.00 × 0.74 in. (5.08 × 5.08 × 1.91 cm). P&A: $220 to $260 (500 qty.). **Piezo Crystal Co., 100 "K" St., Carlisle, PA 17013; (717) 249-2151, FAX: (717) 249-7861.**

CIRCLE NO. 113

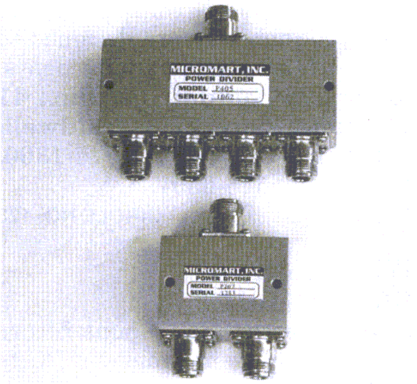
Multiplier operates from 2.9 to 3.2 GHz

Model MAXZ0026 is a ×20 multiplier operating from 2.9 to 3.2 GHz. Minimum output power is 0 dBm and minimum input power is +10 dBm. Maximum power variation across the –40 to +70°C temperature range is ±2 dB. Typical rejection is 65 dB. The multiplier measures 4.5 × 1.5 × 0.5 in. (11.43 × 6.35 ×1.27 cm). **MITEQ, 100 Davids Dr., Hauppauge, NY 11788; (516) 436-7400, FAX: (516) 436-7430.**

CIRCLE NO. 114

Dividers/combiners power telecommunications bands

A line of power dividers/combiners has been designed to handle the standard telecommunications bands. A typical unit, model P405, covers the frequency range of 3.60 to 4.25



GHz. Return loss is 20 dB, insertion loss is 0.6 dB, and isolation is 20 dB. Amplitude balance is rated at ±0.2 dB. **Micro Mart, Inc., 1822 Samos Circle, Lafayette, CO 80026; (303) 665-4971, FAX: (303) 665-6154.**

CIRCLE NO. 115

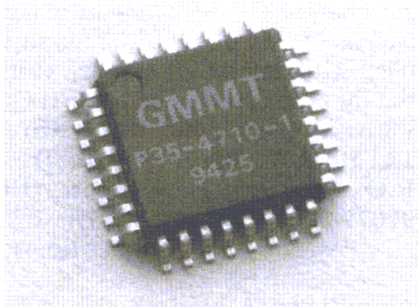
Opamp dissipates 13-mA current

Model OPA648 is a high-speed, current-feedback operational amplifier that delivers a 1-GHz gain bandwidth. The opamp dissipates 13-mA quiescent current and provides a 1200-V/µs slew rate. Settling time is 20 ns to 0.01 percent of a final value. Differential gain and phase errors are 0.02 percent and 0.02 deg., respectively. The opamp operates from ±5-V power supplies and is available in eight-pin DIP, SOIC, and hermetic ceramic housings. P&A: $5.95 (100 qty.); stock. **Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734; (800) 548-6132.**

CIRCLE NO. 116

Transceiver suits WLAN applications

Designed for wireless local-area-network (WLAN) applications at 2.4 GHz, the model P35-4710 GaAs MMIC transceiver incorporates a voltage-controlled oscillator (VCO), upconverter, preamplifier, post-amplifier, transmit/receive switch, downconverter, low-noise amplifier,



and buffer amplifiers. DC current consumption is 38 mA in the receive mode and 180 mA in the transmit mode; standby current is less than 0.5 mA. The transceiver is housed in a 7-mm² surface-mount package. **DAICO Industries, Inc., 2453 E. Del Amo Blvd., Rancho Dominguez, CA 90220; (310) 631-1143, FAX: (310) 631-8078.**

CIRCLE NO. 117

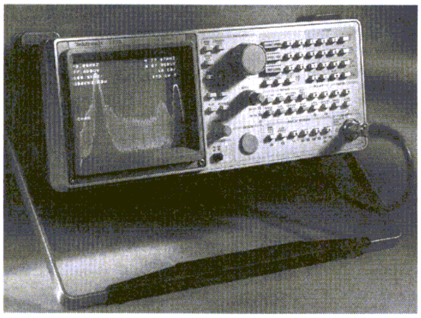
OCXOs are stable from 0.01 to 50 MHz

A line of oven-controlled crystal oscillators (OCXOs) spans the frequency range of 1 kHz to 50 MHz. Stability is rated at 5×10^{-9} from –20 to +70°C while the aging rate is 3×10^{-10}. Output power is less than 1.6 W at +25°C. **Bliley Electric Co., 2545 W. Grandview Blvd., P.O. Box 3428, Erie, PA 16508; (814) 838-3571, FAX: (814) 833-2712.**

CIRCLE NO. 118

Spectrum analyzer aids CATV testers

Designed as a cost-effective solution for in-service RF testing of cable-television (CATV) systems, the model 2715 Cable TV Spectrum Analyzer operates from 1 kHz to 1.8 GHz with a wide range of automatic functions required by CATV service technicians. The 75-Ω test instrument checks channel spacing,



depth of modulation, FM deviation, and hum, in addition to a wide range of amplitude-versus-frequency measurements. The instrument, which weighs just 23 lbs. (10.4 kg), is supplied with dedicated software written for the personal computer (PC). P&A: $15,900. **Tektronix, Inc., 14150 S.W. Karl Braun Dr., P.O. Box 500, Beaverton, OR 97077-0001; (503) 627-5757.**

CIRCLE NO. 119

Amplifier provides 200-W CW power

Model APB 960-200 is a Class AB power amplifier with 200-W CW output power. Designed for American Mobile Phone System (AMPS) and Global System for Mobile Communications (GSM) transmitters, the amplifier features 50-dB gain and 35-V reverse-polarity protection. **Chesapeake Microwave Technologies, Inc., 11 Industrial Rd., Glen Rock, PA 17327; (717) 235-1655, FAX: (717) 235-2501.**

CIRCLE NO. 120

Bias tees range from 1 to 18 GHz

The SBT series of bias tees supplies 10-A bias current and 30-V bias voltage from 1 to 18 GHz. Insertion loss is rated at 0.5 dB, maximum VSWR is 1.22:1, and maximum RF power is 50 W. The bias tees measure 50 × 52 × 20 mm or 90 × 70 × 20 mm. **Tecdia, 2672 Bayshore Pkwy., Suite 702, Mountain View, CA 94043; (415) 967-2828, FAX: (415) 967-8428.**

CIRCLE NO. 121

DAC delivers 16-b resolution

Digital-to-analog converter (DAC) model AD768 features 16-b resolution and 30-MSamples/s performance. The spurious-free dynamic range is 83 dB at 1 MHz while the settling time is 25 ns to within 0.025 percent. The DAC incorporates a precision 2.5-V reference and draws 500 mW. It operates from a ±5-V power supply. The component is packaged in a 28-pin SOIC housing specified for a temperature range of –40 to +85°C. P&A: $19.95 (1000 qty.); stock. **Analog Devices, Inc., 181 Ballardvale St., Wilmington, MA 01887; (617) 937-1428, FAX: (617) 821-4273.**

CIRCLE NO. 122

Dividers/combiners cover 2 to 1000 MHz

The PDNL-80 series of in-line, four-way power dividers/combiners covers the frequency range of 2 to 1000 MHz. Typical isolation is 25 dB and typical insertion loss is 0.8 dB. Featuring type N connectors, the dividers/combiners are designed to meet MIL-P-23971 requirements. **Merrimac Industries, Inc., 41 Fairfield Place, West Caldwell, NJ 07006-6287; (201) 575-1300, FAX: (201) 575-0531.**

CIRCLE NO. 123

Filters span DC to 2.5 GHz

A line of surface-mount filters spans the frequency range of DC to 2.5 GHz. Typical insertion loss is less than 2 dB while rejection is better than 60 dB. VSWR is rated at 1.50:1. The filters are available in custom sizes. **KW Microwave Corp., 1985 Palomar Oaks Way, Carlsbad, CA 92009; (619) 929-9800, FAX: (619) 929-9899.**

CIRCLE NO. 124

Amp delivers 4 W from 1.5 to 2.5 GHz

GaAs MMIC amplifier model SMM-280-2 delivers up to 4-W power from 1.5 to 2.5 GHz. Gain is 25 dB while output power is +33 dBm from 1.7 to 2.3 GHz and +32 dBm at the band edges. The output third-order intercept point is +42 dBm and typical VSWR is 1.50:1. P&A: $195 (1000 qty.); stock. **Stanford Microdevices, 2880 Zanker Rd., Suite 203, San Jose, CA 95134; (408) 730-2614, FAX: (408) 746-3630.**

CIRCLE NO. 125

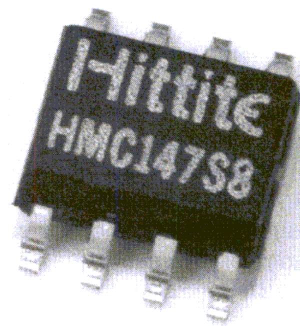
Amplifiers handle satellite downlinks

The AWG series of low-noise amplifiers is suited for Ku-band satellite-downlink applications. Covering the frequency range of 10.95 to 12.75 GHz, the amplifiers have 1-dB maximum noise figure. Input and output return losses are 20 and 14 dB, respectively. The available gain ranges from 32 to 50 dB. The amplifiers are housed in a weatherproof waveguide-to-coaxial-adapter configuration. **MITEQ, 100 Davids Dr., Hauppauge, NY 11788; (516) 436-7400, FAX: (516) 436-7430.**

CIRCLE NO. 126

Mixer translates 1.6 to 3.2 GHz

Model HMC147S8 is a double-balanced GaAs MMIC mixer with an RF and local-oscillator (LO) range from 1.6 to 3.2 GHz and intermediate-frequency (IF) range from DC to 1 GHz. The noise figure is 8.5 dB and the input third-order intercept point is +18 dBm. The mixer's pas-



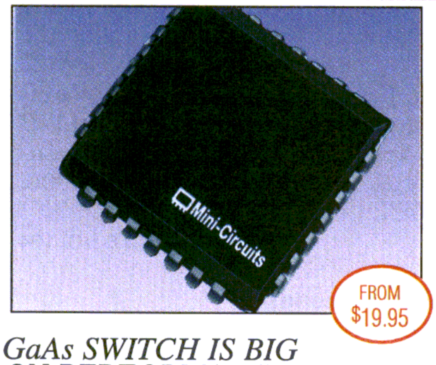
sive reciprocal design requires no DC bias; the mixer may be used as both an upconverter and downconverter. As a downconverter, conversion loss is 8.5 dB at 2.4 GHz with +13-dBm LO drive. **Hittite Microwave Corp., 21 Cabot Rd., Woburn, MA 01801; (617) 933-7267, FAX: (617) 932-8903.**

CIRCLE NO. 127

NEW PRODUCTS

NO.8

RF/IF MICROWAVE COMPONENTS



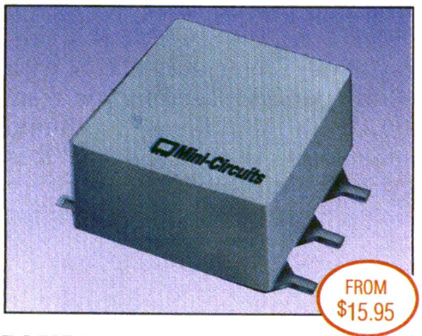
GaAs SWITCH IS BIG ON PERFORMANCE

Mini-Circuits new GaAs SP4T switch offers wide bandwidth, excellent repeatability and surface mount compatibility.

Bandwidth is DC - 3000MHz with specification limits 4.5σ typical from mean. It's housed in a low-cost 28-pin PLCC package and has strain relief J-leads. The GSWA-4-30DR is fast switching (25ns typ) with high isolation (30-40dB typ) and low video break through to 50Ω RF ports (30mV p-p typ).

The new switch is ideal for telecommunications, 2-way radio, receiver antenna switching and filter and local oscillator selection in bandswitched equipment.

CIRCLE NO. 276



COUPLER GIVES BIG SPACE SAVINGS

A new broad band (5-500MHz) surface mount miniature leaded coupler from Mini-Circuits provides outstanding performance in a package only 0.31"x0.31"x0.2".

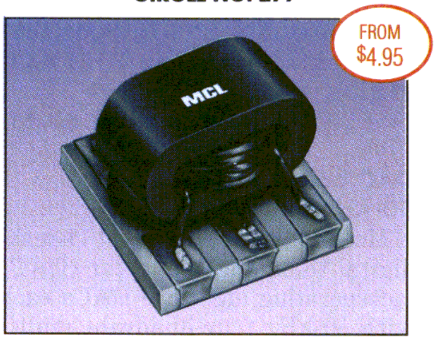
The LRDC-10-1 offers low insertion loss (1.0dB typ); high directivity (30dB typ) and very good VSWR (1.2 typ). Insertion loss has 4.5σ repeatability. Standard operating temperature range is -55°C to +100°C.

CIRCLE NO. 279

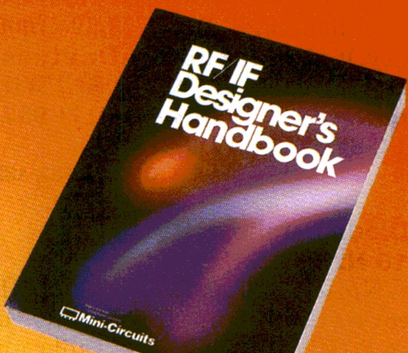
SURFACE MOUNTABLE RF TRANSFORMER

Compact size and wide bandwidth are key features of the new TC4-1W RF transformer from Mini-Circuits. Only 0.16"x0.16"x0.16", it is surface mountable, suitable for pick-and-place machinery and is also available in tape and reel. Bandwidth is 3 to 800MHz with DC isolation from primary to secondary. Rugged construction makes it ideal for impedance matching and land mobile radio applications.

CIRCLE NO. 277



REFERENCE GUIDE



740 Pages

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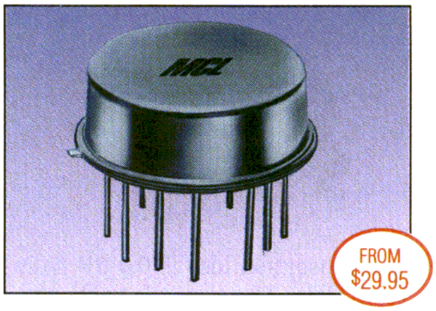
CIRCLE NO. 280



NEW 3-WAY, 50Ω SPLITTER

Mini-Circuits new TO8SC-3-1W, 3-way, 50Ω splitter provides a unique combination of cost effectiveness and high performance.

Wide band coverage is 80-800MHz with high isolation (25dB typ) and low insertion loss of 0.5dB typical in mid band.

Advantages also include excellent amplitude balance of 0.15dB typ and phase balance of 1.0 typ. Maximum input power is 1W and internal power dissipation is 0.375W maximum.

Housed in a hermetically sealed TO-8 (0.6" diameter) package, operating temperature range is -55°C to +100°C.

CIRCLE NO. 278

HIGH PERFORMANCE 2-WAY 90° SPLITTER

Housed in a low-cost plastic surface mount package, the new SCPQ-150 2-way 90° splitter from Mini-Circuits has good phase and amplitude balance (0.5° and 0.7dB).

Frequency range is 95-150MHz with typical isolation 22dB and typical insertion loss 0.3dB. Operating temperature range is -55°C to +100°C.

Typical applications include I&Q and QPSK modulators/demodulators, image rejection mixers and signal processing.

CIRCLE NO. 281

Mini-Circuits®

P.O Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500 Fax (718)332-4661

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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F 188 Rev Orig

Power dividers link 0.5 to 26.5 GHz

The PDM-45R series of four-way power dividers covers the frequency range of 0.5 to 26.5 GHz. Minimum isolation is 15 dB while maximum insertion loss is 0.9 dB from 5 to 18 GHz. The series is packaged in a machined housing with SMA connectors. **Merrimac Industries, Inc., 41 Fairfield Place, West Caldwell, NJ 07006-6287; (201) 575-1300, FAX: (201) 575-0531.**

CIRCLE NO. 128

VCO tunes 75 to 200 MHz

Model ESC 401-70 is a voltage-controlled oscillator (VCO) covering the 75-to-200-MHz frequency range with a tuning voltage of 0.2 to 20 VDC. Phase noise is –104 dBc/Hz offset 10 kHz from the carrier and –110 dBc/Hz offset 25 kHz from the carrier. The VCO operates from a +12-VDC power supply and draws 45-mA current. Output power is +2 dBm while the second harmonic is –10 dBm. **Electronic Surveillance Components, Inc., 33328 Howe Lane, Creswell, OR 97426; (503) 895-5071, FAX: (503) 895-5072.**

CIRCLE NO. 129

Diodes tag RFID systems

A series of zero-bias Schottky-barrier diodes is designed for RF-identification (RFID) and RF tagging systems operating at 915 MHz, 2.45 GHz, and 5.8 GHz. Forward voltage is typically 100 W at 0.1 mA while maximum capacitance is 0.3 pF at 1 GHz. At 2.45 GHz, tangential signal sensitivity is –57 dBm and voltage sensitivity is 30 mV/μW. The diodes are housed in SOT-23 and SOT-143 surface-mount packages and are supplied in tape-and-reel format. **Hewlett-Packard Co., Inquiries, 5301 Stevens Creek Blvd., P.O. Box 58059, Santa Clara, CA 95052-8059; (800) 537-7715 ext. 8495.**

CIRCLE NO. 130

Coupler spans 830 to 960 MHz

Stripline 90-deg. hybrid coupler model 1D1304-3 operates across a frequency range of 830 to 960 MHz. Maximum insertion loss is 0.4 dB and minimum isolation is 20 dB. Amplitude balance is ±0.3 dB while phase balance is 3 deg. The surface-mount coupler features an average power-handling capability of 100 W CW. It measures 0.56 × 0.35 in. (1.42 × 0.89 cm) and weighs 0.03 oz. (0.85 g). **Anaren Microwave, Inc., 6635 Kirkville Rd., East Syracuse, NY 13057; (800) 544-2414 ext. 204, FAX: (315) 432-9121.**

CIRCLE NO. 131

DAC controls 50-kHz bandwidths

Model AD8842 is an eight-channel digital-to-analog converter (DAC) incorporating eight 8-b DACs each with 50-kHz four-quadrant multiplying bandwidths. The converter offers 20-kΩ input impedance and consumes only 95 mW from ±5-VDC power supplies. Maximum voltage swing is ±3 V. The DAC is packaged in 24-pin plastic SOL and DIP housings. P&A: $5.69 (1000 qty.); stock. **Analog Devices, Inc., 181 Ballardvale St., Wilmington, MA 01887; (617) 937-1428, FAX: (617) 821-4273.**

CIRCLE NO. 132

Diode handles 10 Hz to 3 GHz

Noise diode model NC302LBL covers the frequency range of 10 Hz to 3 GHz, making it suitable for wireless applications. Excess noise ratio (ENR) ranges from 30 to 35 dB. The diode operates from a +12-VDC power supply biased at 8 mA and is available in a surface-mount, hermetically-sealed ceramic package specified for a temperature range of –55 to +125°C. P&A: $5.95 (10,000 qty.); stock. **NOISE/COM, Inc., E. 49 Midland Ave., Paramus, NJ 07652; (201) 261-8797, FAX: (201) 261-8339.**

CIRCLE NO. 133

LNA provides 0.5-dB noise figure

The model VMA 1.6C-126 low-noise amplifier (LNA) provides a 0.5-dB noise figure from 1.5 to 1.6 GHz. Gain is 24 dB and gain ripple is ±0.1 dB. The third-order intercept point is +16 dBm. Operating from a +15-VDC power supply, the LNA measures 1.00 × 1.00 × 0.22 in. (2.54 ×2.54 × 0.56 cm). **Veritech Microwave, Inc., 111-B Corporate Blvd., South Plainfield, NJ 07080; (908) 769-0300, FAX: (908) 769-0330.**

CIRCLE NO. 134

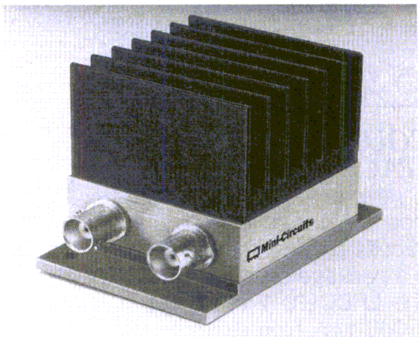
Filter passes 1022.5 to 1062.5 MHz

Model SB-1042.5/X40 is a band-pass filter offering a center frequency of 1042.5 MHz with a 1-dB bandwidth of 1022.5 to 1062.5 MHz. Insertion loss at the center frequency is 4.5 dB while VSWR is typically 1.50:1. The 40-dB bandwidth is 175 MHz maximum. The surface-mount filter measures 1.00 × 0.50 × 0.27 in. (2.54 × 1.27 × 0.69 cm). **KeL-Com, 408 Coles Circle, Salisbury, MD 21801; (410) 749-6774, FAX: (410) 749-6887.**

CIRCLE NO. 135

Combiner/splitter runs 200 to 500 MHz

Model ZA2CS-500-15W is a two-way, 0-deg. combiner/splitter with 0.3-dB typical insertion loss from 200 to 500 MHz. The maximum power rating is 15 W and VSWR is 1.15:1. Typical amplitude imbalance is 0.1 dB while typical phase imbalance is 0.3 deg. Isolation is typically 30 dB. The component is supplied with BNC connectors. P&A: $74.95. **Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235-0003; (718) 934-4500, FAX: (718) 332-4661.**



CIRCLE NO. 136

Module tracks antenna systems

The model MC1680 monopulse converter module provides a 1680-MHz center frequency for application in antenna tracking systems. Insertion loss at the pointing-error channels is 3.5 dB and 2.5 dB at the sum channel. VSWR at all ports is 1.50:1 maximum. Elevation-to-azimuth phase is 90 ±3 deg. while bi-phase switching phase is 0/180 ±3 deg. The module has a maximum switching time of 0.5 μs and operates from a +5- or –12-VDC power supply. **Vectronics Microwave Corp., 113 Lincoln Blvd., Middlesex, NJ 08846-1045; (908) 356-2377, FAX: (908) 356-6782.**

CIRCLE NO. 137

Resonator rejects 244 and 262 MHz

Dielectric resonator model 4DN-380-244/262 offers –45-dBc rejection of the 244- and 262-MHz bands. Insertion loss is 1.75 dB from 220 to 400 MHz while power is 25 W CW. The unit measures 5.75 × 3.25 × 1.57 in. (14.61 × 8.26 × 3.99 cm). **K&L Microwave, Inc., 408 Coles Circle, Salisbury, MD 21801-3299; (301) 749-2424.**

CIRCLE NO. 138

ADC samples 1-MHz signals

Analog-to-digital converter (ADC) model ADS-917 features 14-b resolution at a 1-MHz sampling rate. Suitable for time-domain and frequency-domain applications, the signal-to-noise ratio (SNR) is 79 dB and the total harmonic distortion (THD) is –80 dB. Requiring ±5- and ±15-VDC supplies, the ADC typically dissipates 1.7 W. The component operates from –55 to +125°C. **DATEL, Inc., 11 Cabot Blvd., Mansfield, MA 02048; (508) 339-3000, FAX: (508) 339-6356.**

CIRCLE NO. 139

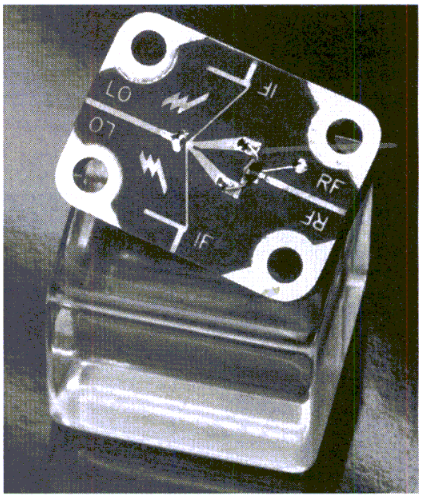
Mismatches aid calibration applications

A series of precision coaxial mismatches incorporates type N and 7-mm connectors to introduce a specified VSWR into a 50-Ω transmission-line system. The mismatches cover the frequency range of DC to 18 GHz and feature 1-percent maximum calibration accuracy. VSWR values of 1.05:1, 1.10:1, 1.20:1, 1.30:1, 1.50:1, 1.75:1, and 2.00:1 can be selected. Power-handling capability is 1 W average and 1 kW peak. **Maury Microwave Corp., 2900 Inland Empire Blvd., Ontario, CA 91764; (909) 987-4715, FAX: (909) 987-1112.**

CIRCLE NO. 140

Mixers target VSAT systems

A line of microstrip carrier-based upconverter mixers covers C- and Ku-band very-small-aperture-terminal (VSAT) frequencies. Four models operate from 4.7 to 5.4 GHz with 47-dB typical LO-to-RF isola-



tion. Four additional models cover 13.8 to 14.7 GHz with LO-to-RF isolation of typically 45 dB. The mixers measure 0.80 × 0.59 × 0.15 in. (2.03 × 1.50 × 0.38 cm). **Magnum Microwave Corp., 4575 Cushing Pkwy., Fremont, CA 94538; (510) 657-9898, FAX: (510) 490-3351.**

CIRCLE NO. 141

Amplifier covers 290 to 320 MHz

Operating from 290 to 320 MHz, an amplifier offers an output-power level of 120 W CW. Typical bias enable and disable time is 15 μs. The unit delivers a minimum of 35-dB gain and operates from +24- or +28-VDC supplies. The amplifier measures 4.84 × 2.00 × 1.00 in. (12.29 × 5.05 × 2.54 cm). **LCF Enterprises, 651 Via Alondra, Unit 712, Camarillo, CA 93012; (805) 388-8454, FAX: (805) 389-5393.**

CIRCLE NO. 142

Resistors handle 20-W power

A series of power resistors provides 20-W power from a TO-220-style package incorporating copper heat sinks. The resistance range is 0.05 Ω to 1.0 MΩ while temperature compensation is ±100 PPM/°C. Induction is less than 0.1 μH and dielectric strength is 1000-V RMS. The power resistors are rated for tolerances of 1, 2, 5, and 10 percent. P&A: $3.11 (1000 qty.). **Vishay Resistors, 63 Lincoln Hwy., Malvern, PA 19355; (610) 296-0657.**

CIRCLE NO. 143

LNA covers 825 to 845 MHz

Model ANR 17835 is a low-noise amplifier (LNA) covering the frequency range of 825 to 845 MHz. Intended for use in AMPS and IS-54 cellular systems, the LNA has a gain of 15 ±1 dB and gain flatness of ±0.25 dB. Noise figure is specified as 2.2 dB maximum. The output power at 1-dB gain compression is 0 dBm while input/output VSWR is 2.00:1. The LNA operates from +15- to +30-VDC power supplies and requires 100-mA current. It measures 0.50 × 0.90 × 0.38 in. (12.70 × 22.86 × 9.65 mm). **TRM, Inc., 280 South River Rd., Bedford, NH 03110; (800) TRM-ASIM, (603) 627-6000, FAX: (603) 627-6025.**

CIRCLE NO. 144

Lowpass filter spans DC to 1.6 GHz

Model 713L-2075/R1000-XP/XP is a lowpass filter featuring less than 1-dB insertion loss from DC to 1.6 GHz. VSWR is 1.50:1 and attenuation is 80 dB. The filter measures 1.50 × 0.38 × 0.38 in. (3.81 × 0.97 × 0.97 cm). **K&L Microwave, Inc., 408 Coles Circle, Salisbury, MD 21801-3299; (301) 749-2424.**

CIRCLE NO. 145

Bandpass filters serve 1 to 38 GHz

A series of waveguide bandpass filters is available with up to 12 sections and 3-dB bandwidths from 0.1 to 10 percent of the center frequency (center frequencies from 1 to 38 GHz can be specified). A typical unit, model WG-21500-140-5-R-S1, operates at a center frequency of 21.5 GHz and a 3-dB bandwidth of 140 MHz. Insertion loss is less than 2 dB while response is 40 dBc at 21.33 and 21.69 GHz. VSWR is less than 1.50:1 over 80 percent of the 3-dB bandwidth. **RLC Electronics, Inc., 83 Radio Circle, Mount Kisco, NY 10549; (914) 241-1334, FAX: (914) 241-1753.**

CIRCLE NO. 146

Amplifier supports GPS systems

A global-positioning-system (GPS) low-noise amplifier features a typical gain of 15 dB and a noise figure of 0.8 dB. Output power at the 1-dB gain compression point is better than +5 dBm. Measuring 1.5 × 1.1 × 0.5 in. (3.81 × 2.79 × 1.27 cm), the amplifier consumes +12 VDC at 50 mA. **KW Microwave Corp., 1985 Palomar Oaks Way, Carlsbad, CA 92009; (619) 929-9800, FAX: (619) 929-9899.**

CIRCLE NO. 147

Phase shifters suppress 20-dB noise

Operating across 0.5 to 10 GHz, a series of 4-b phase shifters offers 20-dB carrier and sideband suppression. Non-harmonic spurious suppression is 40 dB and return loss is 14 dB. Translation loss ranges from 3 to 5 dB depending on the center frequency. The phase shifters operate from +5- and −15-VDC power supplies, with RF input-power levels up to 1 W. **Vectronics Microwave Corp., 113 Lincoln Blvd., Middlesex, NJ 08846-1045; (908) 356-2377, FAX: (908) 356-6782.**

CIRCLE NO. 148

Crystals resonate at 155.52 MHz

A line of fundamental-frequency oscillator crystals operates at 155.52 MHz. Designed for synchronous-optical-network (SONET) telecommunications applications, the crystals are supplied in HC-45 cold-weld packages. Crystals with fundamental frequencies to 90 MHz are also available. **Reeves-Hoffman, Inc., 400 W. North St., Carlisle, PA 17013; (717) 243-5929, FAX: (717) 243-0079.**

CIRCLE NO. 149

RF transformers span 500 to 2500 MHz

The E-series of RF transformers handles 250-mW maximum power from 500 to 2500 MHz. The transformers have an impedance ratio of 4:1. The maximum insertion loss is 3 dB and maximum DC current is 30 mA. The transformers are designed for operating temperatures from –20 to +85°C. **M/A-COM Eurotec Operations, Youngline Centre, Pouladuff Rd., Cork, Ireland; 353-21-311266, FAX: 353-21-311890.**

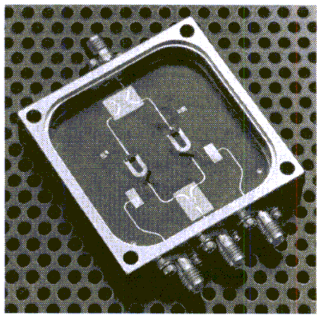
CIRCLE NO. 150

Software analyzes source performance

The Crystal Oscillator Design and Analysis (CODA) software program has been upgraded to Version 3.0. The program offers seven basic oscillator designs plus variations for using any resonator, including surface-acoustic-wave (SAW) and AT-cut crystal types. Design components can be changed to tune performance. An expanded operating manual is included. **Albert Benjaminson, Inc., 420 Amaranth Rd., Kiawah Island, SC 29455; (803) 768-7420, FAX: (803) 768-7420.**

CIRCLE NO. 151

I/Q demodulator covers 6 to 12 GHz



The model IQM-4D-9G in-phase/quadrature (I/Q) demodulator operates with an instantaneous RF bandwidth of 6 to 12 GHz. The standard video bandwidth is from DC to 2 GHz. The demodulator is suitable for use as a single-sideband (SSB) unit. It measures 2.0 × 2.0 × 0.5 in. (5.08 × 5.08 × 1.27 cm). **Merrimac Industries, Inc., 41 Fairfield Place, West Caldwell, NJ 07006-6287; (201) 575-1300, FAX: (201) 575-0531.**

CIRCLE NO. 152

Switches channel DC to 8.4 GHz

The FS9028 series of single-pole, eight-throw (SP8T) coaxial switches spans DC to 8400 MHz. Minimum isolation is 70 dB while insertion loss is typically 0.25 dB. Maximum VSWR is 1.30:1 and maximum switching speed is 50 ns. The RF power rating is 200 W CW at 1.0 GHz. The pulse-latching operation mode features break-before-make contacts. **Sage Labs, Inc., 11 Huron Dr., Natick, MA 01760; (508) 653-0844, FAX: (508) 653-5671.**

CIRCLE NO. 153

Amplifiers detect 10 to 160 MHz

The RTL-4 series of successive-detection log video amplifiers (SDLVAs) operates at center frequencies from 10 to 160 MHz. The SDLVAs feature a dynamic range of 80 dB (–80 to 0 dBm) and linearity of ±1 dB. The amplifiers operate over bandwidths from 3 to 40 MHz with rise times ranging from 0.03 to 0.50 μs. **Radar Technology, Inc., 15 Hale St., Haverhill, MA 01830; (508) 372-8504, FAX: (508) 372-3241.**

CIRCLE NO. 154

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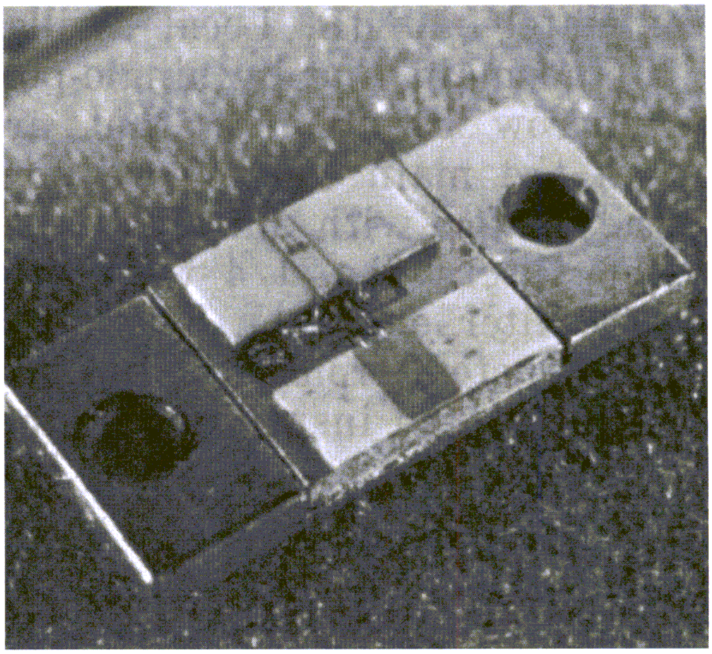

Twenty-two years ago, new levels of solid-state power were made available by Microwave Semiconductor Corp. (Somerset, NJ). The company's MSC 4005 NON silicon transistor delivered 5-W CW output power at 4 GHz with 4-dB power gain and 30-percent power-added efficiency. The device was supplied in a low-loss metal flange package.

DECEMBER PREVIEW

WIRELESS SHOW ISSUE

- **First look at the 1995 WIRELESS Show**
  Preview technical presentations and key products.
- **In the news: The state of the wireless industry**
  Learn about current events in wireless applications.
- **The Return of Software Solutions**
  Review some of the latest CAE packages.

WITH MUCH MORE

- **High-Speed Outlook's optical showcase**
  Several articles examine fiber-optic receivers.
- **The Top Products of 1994**
  What products were winners during a banner year?
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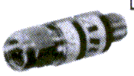
FIXED ATTENUATORS DC-18 GHz $40.

- Models to 55 dB
- SMA or Type N conn.
- 50 W average models

4425 Types

Freq. Range (GHz)	Average Power (W)	Model No. N Conn.	Model No. SMA Conn.
DC-18.0	1	N9412 *	9412-*
DC- 5.0	1	N4402 *	4401-*
DC- 4.0	5	N4405 *	4405-*
DC- 4.0	10	N4410 *	4410-*
DC- 4.0	25	N4425 *	4425-*
DC- 4.0	50	N4450 *	4450-*

*Value of attenuation



9412 & 4401 Types (1.14")

N9412 Types (2.42")

Write for new literature or call (516) 231-8400

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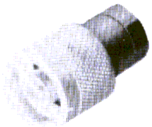

- DC-18 GHz model
- 50 W model
- SMA or Type N conn.

Freq. Range (GHz)	Average Power (W)	Model No. N Conn.	Model No. SMA Conn.
DC-18.0	1		9512
DC-12.4	2	N9512	
DC-12.4	5	N9505	9505
DC-12.4	10	N9510	9510
DC- 8.0	25	N9525	9525
DC- 8.0	50	N9550	

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WAVEGUIDE LOADS

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Freq. Range (GHz)	Medium Power Average (W)	Medium Power Model No.	High Power Average (W)	High Power Model No.
2.60- 3.95	1200	284-925	4500	284-920
3.30- 4.90	1000	229-925	3000	229-920
3.95- 5.85	750	187-925	2000	187-920
4.90- 7.05	625	159-925	1500	159-920
5.85- 8.20	500	137-925	1000	137-920
7.05-10.0	425	112-925	600	112-920
7.00-11.0	325	102-925	500	102-920
8.20-12.4	225	90-925	500	90-920
12.4 -18.0	200	62-925	250	62-920

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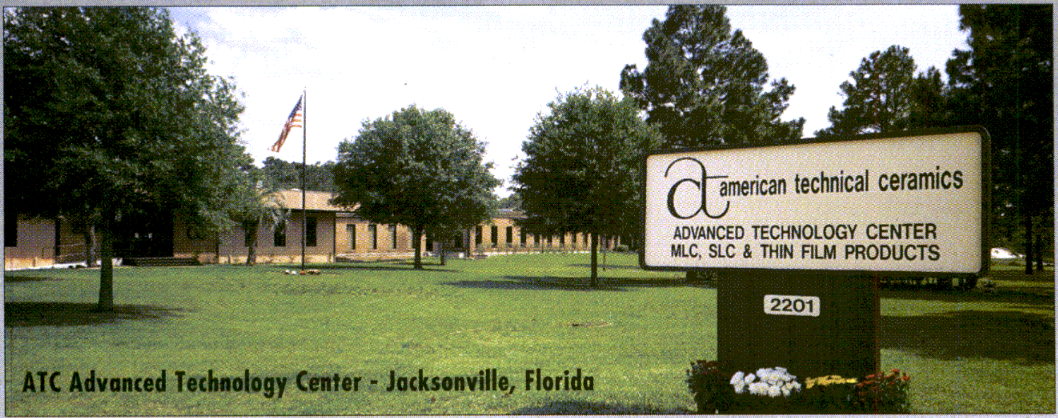
CIRCLE NO. 246

ATC THIN FILM PRODUCTS AND SERVICES



ATC Advanced Technology Center - Jacksonville, Florida

ATC brings a new standard of responsiveness and quality to thin film technology products and services. Custom metalization and patterned substrates are offered to address a broad spectrum of deposition and hybrid circuit fabrication requirements. Custom metalization consists of sputtered and electroplated coatings made to specifications. Products may include via holes and odd shaped substrates in a wide choice of ceramics and dielectric materials. Three-target, batch sputtering systems with load-locks are utilized for producing the most consistent film quality. Etched or pattern-plated substrates are also made to specifications. Designs may include metalized or solid via holes, cross overs and air bridges.

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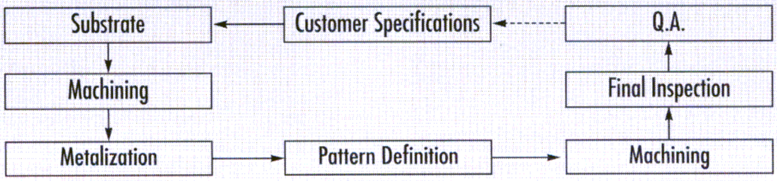
THIN FILM PROCESSES AND SERVICES



SPUTTERED AND ELECTROPLATED COATINGS

MATERIALS COATED: Alumina • Beryllia • Dielectrics • Ferrites • Quartz • Sapphire • Other

BARRIER LAYERS: Titanium/Tungsten (TiW) • Palladium (Pd)

ADHESION LAYERS: Chromium (Cr) • Titanium (Ti) • Titanium/Tungsten (TiW) • Nickel/Chromium (NiCr)

CONDUCTIVE LAYERS: Copper (Cu) • Gold (Au)

RESISTIVE LAYERS: Tantalum Nitride (TaN) • Nickel/Chromium (NiCr)

CUSTOM SERVICES

PATTERNED SUBSTRATES: Pattern Plating • Wet Chemical Etch-Back • Dry Etch (Ion beam milling)

SUBSTRATE MACHINING: Laser • Precision Diamond Saw • Ultrasonic

ATC RESPONSIVENESS

FACTORY ENGINEERING SUPPORT: Direct consultation from experienced thin film technology experts is available as required. This is the same high level of support that ATC customers traditionally receive.

SALES SUPPORT: Typical quotes are usually provided by the factory within 24 hours. Contact your authorized ATC Thin Film Products representative or call direct for additional information and quotations:

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