microwave
JOURNAL

INTERNATIONAL EDITION □ VOL. 23, NO. 12 □ DECEMBER 1980

PASSIVE COMPONENTS

- Resonant Mode PIN Switch
- MIC Phase Shifter
- Lossy Microstrip Analysis

1980 INDEX

Microprocessor-Based Sweep Generator for Scalar Network Analyzer System

PASSIVE COMPONENT BUYERS GUIDE

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NEW SPECTRUM ANALYZERS

The performance you need... the economy you want.

100 kHz to 40 GHz

Here's what Polarad's new refined 3rd generation, 600 "B" Series Spectrum Analyzers offer you...

- 80 dB on-scale range for 10 dB/div. log scale.
- Improved accuracy for 2 dB/div. and linear scales.
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Model	Freq. Range	U.S.A. Prices (Sept. 80) Without Memory	Including Memory
632B-1	100 kHz to 2 GHz	N/A	$ 9,250
630B	3 MHz to 40 GHz	$11,325	$12,975
640B	3 MHz to 40 GHz with internal preselector	$15,325	$16,975

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Polarad Electronics, Inc. 5 Delaware Dr. Lake Sucess N.Y. 11042 Tel: 516-328-1100 TWX: 510-223-0414

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It is incredible...both filters have approximately the same low loss (true, there is a difference in bandwidth.) However, K&L's IB10 Series utilizes high Q circuits to achieve a surprisingly low insertion loss for the size. (A size that will fit perfectly on a circuit board.)

Frequencies from 30 MHz to 12 GHz...Contact us with your requirements.

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The most significant price breakthrough in DOUBLE-BALANCED MIXERS!

...from Mini-Circuits of course!

$3.95 100 Pieces
$4.50 (10-49)

For demanding industrial and commercial applications, where low-cost and high-performance are critical; model SBL-1 will fill your need.

Don't let the low price mislead you. As the world's number one manufacturer of double-balanced mixers, Mini Circuits' has accumulated extensive experience in high-volume production and testing, a key factor in achieving a successful low cost/high performance line of products.

The tough SBL-1 covers the broad frequency range of 1-500 MHz with 6 dB conversion loss and isolation greater than 40 dB. Only well-matched, hot-carrier diodes and ruggedly constructed transmission-line transformers are used. Internally, every component is bonded to the header for excellent protection against shock, vibration and acceleration.

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Of course, our one-year guarantee applies to these units.

Model SBL-1

metal case, non hermetic seal

Frequency Range, MHz

LO 1-500 RF 1-500 IF DC-500

Conversion Loss, dB		Typ.	Max.
One Octave from Band Edge		5.5	7.5
Total Range		6.5	8.5
Isolation, dB		**Typ**	**Min.**
Lower Band Edge to	LO-RF	50	35
One Decade Higher	LO-IF	45	30
Mid Range	LO-RF	45	30
	LO-IF	40	25
Upper Band Edge to	LO-RF	35	25
One Octave Lower	LO-IF	30	20

Signal, 1dB Compression Level +1dBm
Impedance, All Ports 50 ohms
Electronic Attenuation Min (20mA) 3dB

World's largest manufacturer of Double Balanced Mixers

Mini-Circuits

MINI-CIRCUITS LABORATORY
A Division of Scientific Components Corp

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21 Rev IBL

POWER DIVIDERS

Broadband, 0.5 — 4.2 GHz • Only 0.2 dB insertion loss
Isolation over 30 dB midband, 25 dB at bandedges • Octave bandwidths
Two way • up to 10 W (matched output)

- High performance microstrip construction
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- Meets MIL-202E standards
- Also useful as power combiners at signal levels up to +10 dBm

$39.95 (1-9)

Now you can specify and purchase state-of-the-art power dividers at 1/3 to 1/2 the price of competitive units, with immediate off-the-shelf delivery. . . from Mini-Circuits, of course.

This breakthrough in price/performance is a natural extension of our extensive experience in high-volume manufacturing, exacting quality control and thorough testing. This expertise assures you highly reliable power dividers with guaranteed repeatability of performance at lowest cost.

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Model	Frequency Range, GHz	Insertion Loss, dB Typ	Insertion Loss, dB Max	Isolation, dB Typ	Isolation, dB Min	Amplitude Unbalance, dB	VSWR (All Ports) Typ	Power Rating-W Divider	Power Rating-W Combiner	Price	Qty.
ZAPD-1	0.5-1.0	0.2	0.4	25	19	±0.1	1.20	10 W	10 mW	$39.95	1-9
ZAPD-2	1.0-2.0	0.2	0.4	25	19	±0.1	1.20	10 W	10 mW	$39.95	1-9
ZAPD-4	2.0-4.2	0.2	0.5	25	19	±0.2	1.20	10 W	10 mW	$39.95	1-9

Dimensions 2" × 2" × 0.75" **Connectors Available:** BNC, TNC, available at no additional charge; $5.00 additional for SMA and Type N

World's largest manufacturer of Double-Balanced Mixers

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contents

ON THE COVER: Wiltron Co.'s microprocessor-based sweep generator simplifies procedures for and enhances accuracy of automatic scalar network analyzer measurements.

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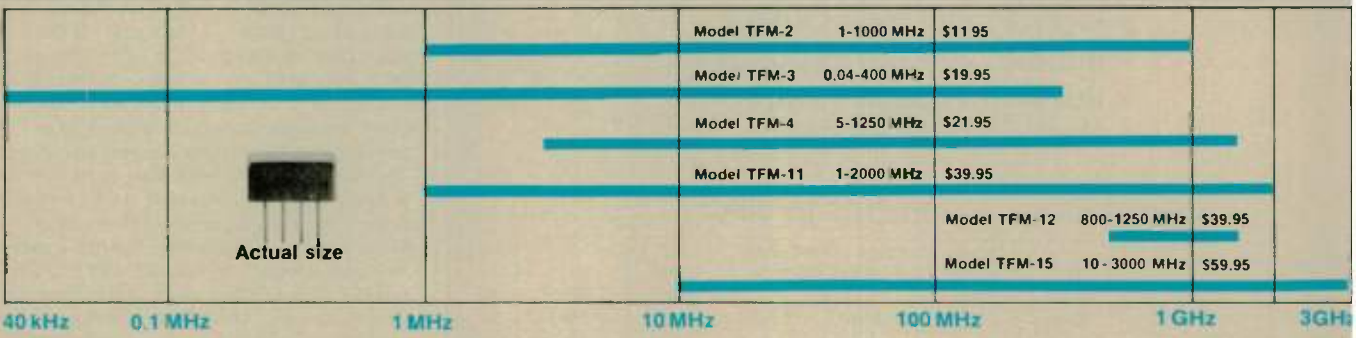
40 kHz - 3 GHz

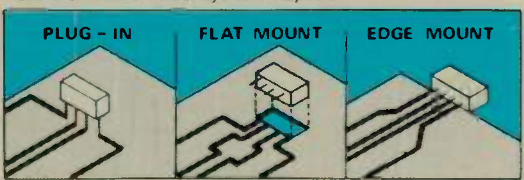
$11.95 MODEL TFM-2 $11.95 (6-49)

ACT NOW TO IMPROVE YOUR SYSTEM DESIGNS, increase your packaging density, and lower your costs. . . specify Mini-Circuits new microminiature TFM series. These tiny units, 0.5" x 0.21" x 0.25" the smallest off-the-shelf Double Balanced Mixers available today, cover the 40 kHz - 3 GHz range and offer isolation greater than 45 dB and conversion loss of 6 dB. Each unit carries with it a 1-year guarantee by MCL. Upgrade your new system designs with the TFM, rapidly becoming the new industry standard for high performance at low cost.



Simple mounting options offer optimum circuit layout.

Use the TFM series to solve your tight space problems. Take advantage of the mounting versatility—plug it upright on a PC board or mount it sideways as a flatpack.



Model	Frequency, MHz			Conv. loss, dB				Isolation dB												Cost	
				One Octave From Band Edge		Total Range		Lower Band Edge To one Decade Higher				Mid Range				Upper Band Edge To Octave Lower					
								LO-RF		LO-IF		LO-RF		LO-IF		LO-RF		LO-IF			
Model No.	LO	RF	IF	Typ	Max	Typ	Max	Typ	Min	Typ	Min	Typ	Min	Typ	Min	Typ	Min	Typ	Min	Quantity	Price
TFM-2	1-1000	1-1000	DC-1000	6.0	7.5	7.0	8.5	50	45	45	40	40	25	35	35	30	25	25	20	6-49	$11.95
TFM-3	.04-400	.04-400	DC-400	5.3	7.0	6.0	8.0	60	50	55	40	50	35	45	30	35	25	35	25	5-49	$19.95
TFM-4	5-1250	5-1250	DC-1250	6.0	7.5	7.5	8.5	50	45	45	40	40	30	35	25	30	25	25	20	5-49	$21.95
TFM-11	1-2000	1-2000	5-600	7.0	8.5	7.5	9.0	50	45	45	40	35	25	27	20	25	20	25	20	1-24	$39.95
TFM-12	800-1250	800-1250	50-90	—	—	6.0	7.5	35	25	30	20	35	25	30	20	35	25	30	20	1-24	$39.95
*TFM-15	10-3000	10-3000	10-800	6.3	7.5	8.5	9.0	30	20	30	20	30	20	30	20	30	20	30	20	1-9	$59.95

Signal 1 dB compression level +1 dBm. Impedance all ports 50 ohms. Total input power 50 mW. Total input current peak 40 mA. Operating and storage temperature -55°C to +100°C. Pin temperature 510°F (10 sec).
*LO power +10dBm, 1 dB compression +5dBm

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CIRCLE 6 ON READER SERVICE CARD

B32/REV. ERL

Coming Events

WARC '79 SYMPOSIUM JAN. 26-27, 1981 Sponsors: AIAA, IEEE. Place: IEEE Hq., United Engineering Bldg., 345 E. 47th St., New York, NY. Theme: "WARC '79 – Issues and Impacts." Contact: Dr. W.C.Y. Lee, ITT Defense Communications Div., 492 River Rd., Nutley, NJ 07110. Tel: (201) 284-3373.

1981 IEEE/MTT-S INT'l MICROWAVE SYMPOSIUM JUNE 15-17, 1981 Call for Papers. Sponsor: IEEE MTT-S (held jointly with IEEE AP-S on June 17-19, 1981). Place: Bonaventure Hotel, Los Angeles, CA. Theme: "Around the World with Microwaves," includes such topics as CAD and measurement techniques, microwave and mm-wave solid-state devices and ICs, etc. Submit 35-word abstract and 500- to 1000-word summary by Jan. 15, 1981 to: Dr. Don Parker, Technical Program Chrmn., MTT-S Symposium, Hughes Aircraft Co., Bldg. 268, M.S. A54, Canoga Park, CA 91304.

INT'L ELECTRICAL, ELECTRONICS CONF. & EXPO. OCT. 5-7, 1981 Call for Papers. Sponsor: IEEE – Canadian Region. Place: Automotive Bldg., Exhibition Place, Toronto, Canada. Topics: Microcomputer and Computer Technology, Power Technology and Systems, Electronic Circuits & Systems, Communications, Industrial and Energy Systems, Biomedical Engrg. and Electromagnetic Capability. Submit 3 copies of 1-page abstract by Feb. 27, 1981 to Conference Office, R.T. Copley, Tech. Program Comm. Chrmn., 1450 Don Mills Rd., Don Mills, Ontario M38 2X7. Tel: (416) 445-6641; TLX: 06-966612.

6TH INT'L CONF. ON INFRARED & MM WAVES DEC. 7-12, 1981 Call for Papers. Sponsors: IEEE MTT-S and IEEE Quantum Electronics and Applications Society. Place: Carillon Hotel, Miami Beach, FL. Session Topics: Millimeter Sources, Devices or Systems, Millimeter and Submillimeter Propagation, Atmospheric Physics and Propagation, Plasma Interactions and Diagnostics, Guided Propagation and Devices and Calibration Standards, etc. Submit 35- or 40-word abstract by June 30, 1981 to: Mr. K.J. Button, Program Chrmn., MIT, Francis Bitter Nat'l Magnet Lab, 170 Albany St., Cambridge, MA 02139. Tel: (617) 253-5561; TLX: 92-1473.

Wavetek introduces the first microwave signal generator with internal sweep.

In the 7 to 12.4 GHz frequency range, you're going to have a tough time finding a more versatile signal generator than the new Model 907A. Especially at just $7,295.

The 907A is an all-solid-state, and pulse modulation capabilities—plus its unique internal sweep feature.

The instrument's frequency range is continuously variable with front panel or external voltage control. Output is displayed on a 3½-digit LCD. Output level is continuously adjustable from 0 to -127 dBm and leveled to half a dB. Another 3½-digit LCD displays the level.

You can get FM and pulse modulation from the 907A's internal modulator, or these plus AM from an external source. Because of its full modulation capabilities, the 907A is ideal for such applications as testing radar receiver sensitivity.

programming of frequency and amplitude is optionally available.

We only know of one other microwave signal generator that approaches the Model 907A in versatility, accuracy, and purity. And that's our Model 907—the 7 to 11 GHz version which goes for $6,795.* Either one gives you exceptional performance for the dollar. And that's something we put into *everything* we make.

Wavetek San Diego, 9045 Balboa Ave., P.O. Box 651, San Diego, CA 92112. Tel: (714) 279-2200. TWX, 910-335-2007.

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*U.S. prices

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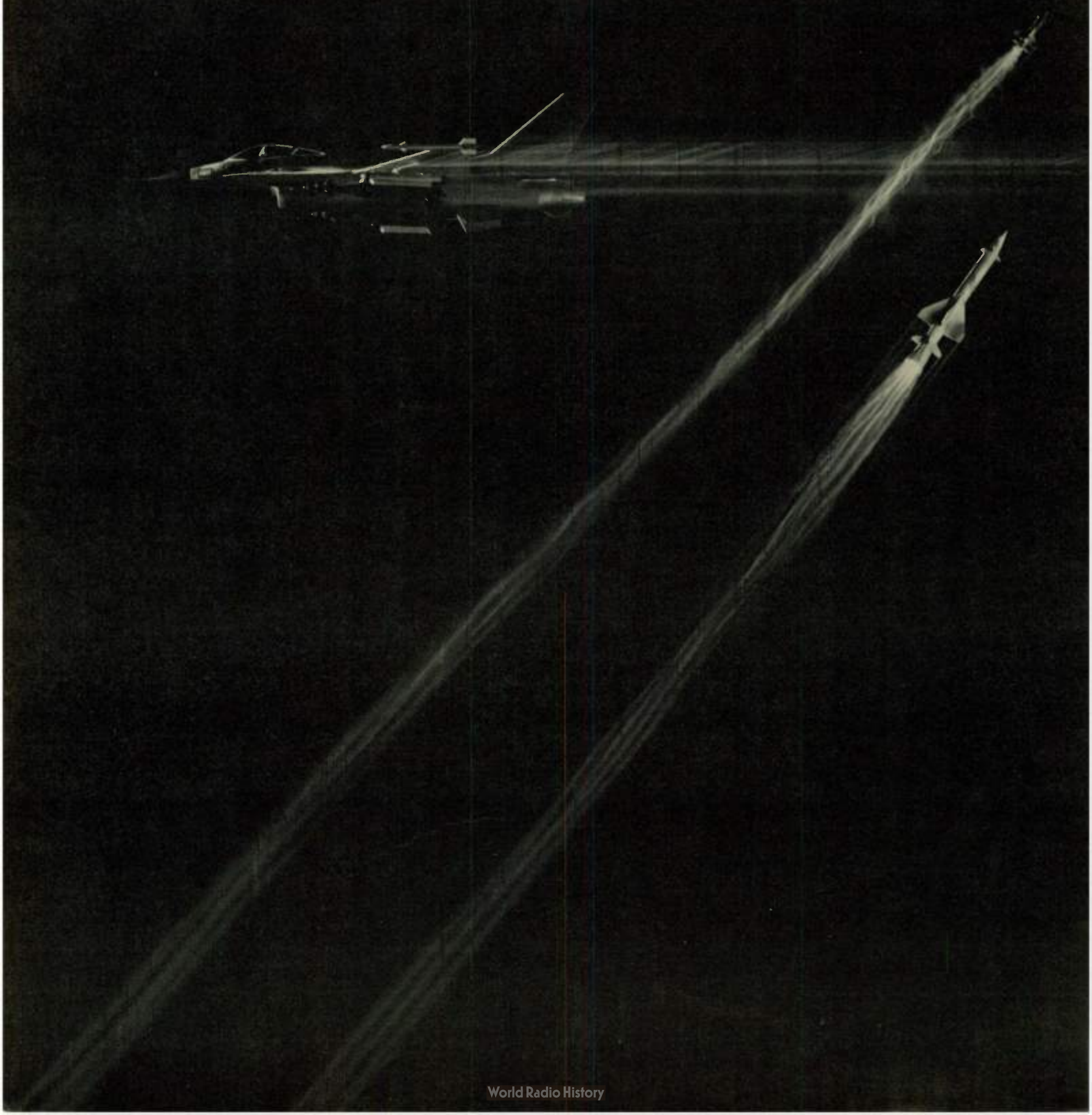
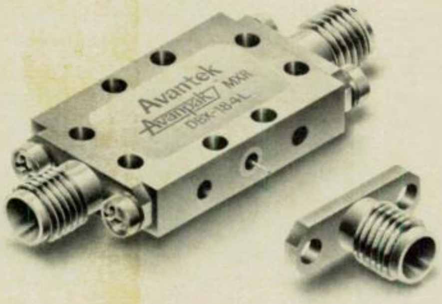


New Avantek 2-18 GHz mixers with high IF bandwidths boost wideband superhet performance.

Higher isolation, lower conversion loss, and low VSWR plus extremely wideband performance for fast, band folding receivers. Avantek now has production quantities of the DBX series of wideband double balanced microwave mixers in stock.

Isolation is typically greater than 30 dB, that is 5-10 dB better than anything previously available for increased system dynamic range. Conversion loss is typically 6.0 dB and only 7.5 dB at 18 GHz with a 6.0 GHz IF for increased receiver sensitivity. IF flatness is less than 1.0 dB across 2.0–6.0 GHz for accurate amplitude translation. R port and L port VSWR is <2.0:1 to ensure a good 50 ohm match with components such as switches and filters. Avantek has combined all of these features with a 2.0 to 7.0 GHz and 4.0 to 18.0 GHz RF frequency coverage and IF frequencies to 6.0 GHz.

The Avanpak package eases the transition from prototype to production. Take your choice of pin or field-replaceable coaxial connectors with the hermetically-sealed Avanpak package.



Test or screen components and breadboard your system with coaxial connections. Then just remove the connectors and bolt the package directly to the ground plane for microstrip assembly. The Avanpak package mixers measure only 0.22″ × 0.66″ × 0.96″–0.14 inches³.

Data and product available today.
If you're designing a wideband superhet EW receiver, jammer, warning receiver or spectrum analyzer, call or write Avantek today. Avantek, 3175 Bowers Avenue, Santa Clara, CA 95051. Telephone (408) 727-0700.

Avanpak Mixer Performance

Model	Typical Conversion Loss (dB)	Typical Isolation (dB)	Typical L&R Port VSWR	Operating Frequencies f_R & f_{LO} (GHz)	Operating Frequencies f_I (GHz)
DBX-184L/M*	6.0	30	2.0:1	6.0–16.0	DC-0.5
	6.5	30	2.0:1	6.0–16.0	DC-4.0
	7.5	30	2.0:1	4.0–18.0	DC-4.0
DBX-185L/M	6.0	30	2.0:1	5.0–18.0	DC-0.5
	6.5	30	2.0:1	5.0–16.0	DC-6.0
	7.5	30	2.0:1	5.0–18.0	DC-6.0
DBX-167L/M	6.0	30	2.0:1	7.0–16.0	DC-1.0
	6.5	30	2.0:1	7.0–16.0	DC-4.0
DBX-158L/M	5.5	30	2.0:1	8.0–15.0	DC-0.5
	6.0	30	2.0:1	8.0–15.0	DC-1.0
DBX-72L	5.5	35	1.7:0	2.0– 7.0	DC-0.3
	6.5	35	1.7:0	2.0– 7.0	DC-0.8

*The L suffix has an input intercept point of +15 dBm and requires only +7.0 dBm LO drive level.
The M suffix has an input intercept point of +20 dBm and requires +13 dBm LO drive level.

Avantek

A RESONANT MODE PIN SWITCH

In the search for ever faster switching speeds for PIN diode switches, the author demonstrates that bias networks which are not critically damped can provide RF pulse widths and rise and fall times that are shorter than those of the applied bias pulse. Experimental results for a 1 W X-band switch employing a commercially available diode module and a deliberately underdamped bias circuit are shown. A theoretical analysis of this mode of switching is also included.

Sum Up

GLASSED MOAT PIN PHASE SHIFTER DIODE

A PIN diode structure employing borosilicate glass passivation in an etched moat around the diode mesa offers greater diode capacitance reproducibility than conventional techniques at some sacrifice in breakdown voltage rating. Within this limitation, however, diodes capable of handling 300 W (500 V breakdown) and 500 W (840 V breakdown) have been produced. Characteristics of 3-bit phase shifters for both power levels centered at 9 GHz using diodes with junction capacitance of 0.1 and 0.15 pF are shown. The high power evaluation methods and results are discussed in detail and four different sets of reliability tests are described.

LOSSY MICROSTRIP ANALYSIS POCKET CALCULATOR PROGRAM

Based on Wheeler's single formula for the computation of characteristic impedance of narrow and wide line microstrip, analysis programs for the TI58 and HP67 calculators are presented. Given microstrip dimensions and properties of substrate material, the programs compute characteristic impedance, effective dielectric constant, frequency dependent values of Q, attenuation constant and dispersive dielectric constant. Provision is also made for differing strip and ground plate conductivities. Complete programs for the two calculators as well as step-by-step illustration of their use are included.

PASSIVE COMPONENT BUYERS GUIDE

Over 180 US and foreign suppliers of passive microwave components are listed in the final 1980 Microwave Journal Buyers Guide. The products covered include filters, couplers, attenuators, mechanical switches, rotary joints and similar components. Full addresses for listed suppliers who advertise in the Microwave Journal follow the product/supplier matrix. A Reader Service Inquiry number is provided for each product category.

Howard Ellowitz

Workshops & Courses

GWU CEE COURSES

Sponsor: George Washington University, School of Engrg. and Applied Science
Site: The Royal Quality Inn, 4875 N. Harbor Dr., San Diego, CA
Dates: & Fees: Course No. 302SD – Jan. 26-30, 1981; $645 Course No. 426SD – Feb. 2-6, 1981; $645
Content: Spread Spectrum Communications Systems (No. 302SD) – definition and techniques involved. ECM and ECCM for Digital Communications (No. 4262D) – fundamental concepts of ECM and ECCM techniques.
Contact: Director, Cont. Engrg. Ed., George Washington U., Washington, DC; Tel: (202) 676-6106 or (800) 424-9773.

FIBER OPTICAL COMMUNICATIONS INTENSIVE SHORT COURSE

Sponsor: University Conference Services, Arizona State U.
Site: Arizona State University, Tempe, AZ
Date: March 9-11, 1981
Fee: $395
Instructor: Dr. Joseph Palais, ASU
Subject: Focuses on transmission medium optical sources and detectors, and systems.
Contact: U. Conf. Services, Arizona State U., Tempe, AZ 85-81; Tel: (602) 965-5757.

GIT SHORT AND CE COURSES

Sponsor: Georgia Institute of Technology, Engineering Exp. Station and Dept. of Continuing Ed.
Site: GIT, Atlanta, GA
Dates: & Fees: Millimeter-Wave Systems and Technology – Feb. 2-4, 1981; $350, ECM Short Course, March 2-4, 1981; $300
Topics: MM-Wave Systems Technology – Covers mm-wave system fundamentals. ECM Short Course – Provides description of principles of ECM, ESM, & ECCM.
Contact: Dept. of Cont. Ed., GIT, Atlanta, Georgia; Tel: (404) 894-2400.

Another Design Headache?

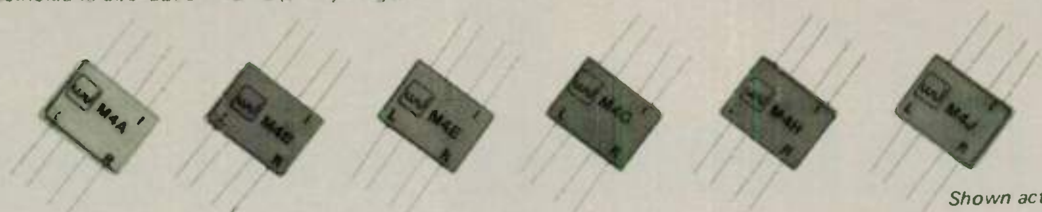
Are you having headaches trying to design your system around mixer packages? Watkins-Johnson's traditional quality and reliability built into these flatpack mixers provide superior performance over broad bandwidths, high 3rd order intercept points and exceptional isolation. This package style has an extensive space qualification history on programs such as FleetSatCom, Marisat, GPS, Leasat and Space Shuttle.

Get quick relief for your design headaches. Contact the Watkins-Johnson Field Sales Office in your area or phone Mixer Applications Engineering in Palo Alto, California at (415) 493-4141, ext. 2637.

Performance Characteristics

Model	L, R Frequency (MHz)	IF Frequency (MHz)	Typical Conversion Loss (dB)	Typical Isolation[1] (dB)	Typical 3rd Order Intercept Point (dB)
WJ-M4A	10–1500	DC-1000	<6.5	>35	+12
WJ-M4B	10–1500	DC-1000	<7.0	>35	+22
WJ-M4E	10–1000	DC-600	<8.0	>25	+30
WJ-M4G	800–3500[2]	DC-1500	<7.0	>25	+12
WJ-M4H	800–3500[2]	DC-1500	<7.0	>25	+18
WJ-M4J	10–1500	DC-600	<9.0	>25	+22

Note 1. Performance at low end of band is generally better.
Note 2. R Port restricted to 800–2200 MHz frequency range.



Shown actual size.

Designing can be painless with W-J's M4 Series of flatpack mixers.

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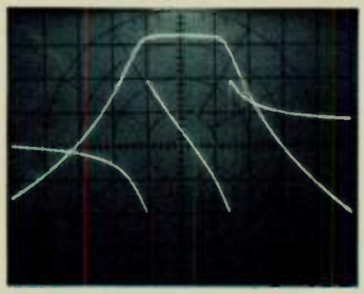
HP's new 8754A Network Analyzer brings speed, convenience and economy to RF measurements. It costs only $12,400 and consists of:

- Built-in 4-1300 MHz swept source with +10 dBm leveled output, calibrated sweeps and crystal markers.
- Three channel receiver to measure any two transmission or reflection parameters simultaneously with > 80 dB dynamic range.
- CRT display for fully calibrated rectilinear and polar plots with resolution to 0.25 dB and 2.5° per major division.

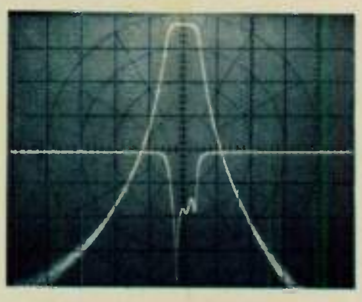
Just add the test set appropriate for your application and you're prepared to make thorough and accurate measurements quickly and easily. Here are just a few of the things you can do with the 8754A:

Transmission Magnitude and Phase



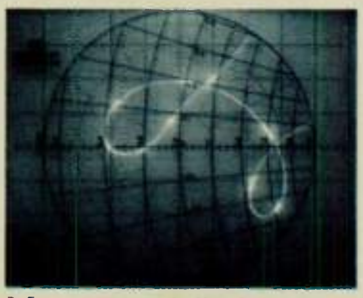
It's easy to measure loss, gain and phase shift using just the 11850 Power Splitter ($675). You can completely identify filter passbands and skirt characteristics without misleading harmonic or spurious response.

Simultaneous Transmission and Reflection

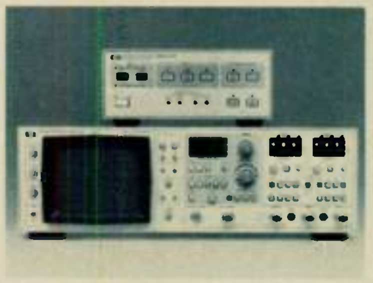


Using the 8502 Test Set ($2250) you can see the trade offs between transmission gain or loss and input match in a single test setup. For complete two-port characteristics of networks, including devices like transistors, an S-parameter test set is available.

Impedance



Measure and display impedance in polar form with convenient Smith Chart overlays. Test sets are available for both 50 and 75 ohm systems. The 8754A's crystal markers give precise frequency data. In addition, probes are available for in-circuit measurements.



Add a storage/ normalizer and increase the 8754A's capabilities even more!

The HP 8750A Storage/Normalizer can automatically remove system frequency response variations. And you can make comparison measurements easily because normalization directly displays the difference between two responses. The 8750A's digital storage permits flicker-free displays, even for measurements requiring slow sweep rates.

Best yet, all this capability is offered at an affordable price. A call to your nearby HP field sales office is all you have to do to get more information, or write 1507 Page Mill Road, Palo Alto, CA 94304.

Domestic US prices only.

HEWLETT PACKARD

CIRCLE 11 ON READER SERVICE CARD

Thomas W. **Parker** *is the General Manager of the Microwave Component Division of Omni Spectra, Inc., A M/A-Com company. He attended Stanford University, receiving his B.S. in Physics in 1967 and an M.S. in Applied Physics from Johns Hopkins University in 1973. He is currently completing an M.BA. program at Pepperdine University.*

Mr. Parker started his industry career with the Westinghouse Electric Corp. in 1968, where he was involved in the design and development of state-of-the-art passive and active microwave components for system applications. Prior to joining Omni Spectra in 1978, he was the engineering manager of the Component Division of Addington Laboratories.

The Passive Component Challenge in the 1980's

THOMAS W. PARKER
Omni Spectra, Inc.
Microwave Component Division
Burlington, MA

The 1980s present formidable challenges to passive microwave component manufacturers. Market demand for these products during the past three years has exceeded capacity in many cases with lead times for "off the shelf" catalog components stretching beyond twenty weeks. Due to the continued build-up of military spending and the emphasis on complex electronic systems, both in the US and abroad, the demand outlook remains strong, especially over the next three to five years.

Indeed, for a market that has been sometimes regarded as mature in growth and technology, there continues to be emerging market opportunities and a significant amount of technological innovation. Perhaps the greatest technical challenges result from the requirements being generated by airborne ECM and missile applications. System technology trends have been pressing passive component manufacturers to respond with more miniaturization, broader bandwidths and increased integration of functions in a single package. In the newest systems now under development such as ASPJ and AMRAM, packaging density will be the biggest overall hurdle.

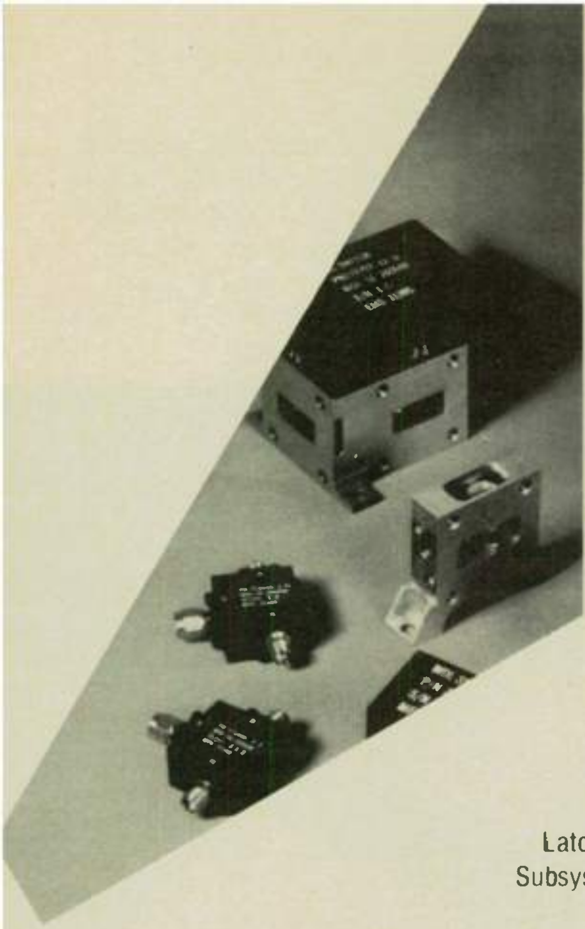
The use of microstrip on high dielectric constant substrate materials as a transmission medium and air dielectric slot line has found widespread acceptance among passive component manufacturers. This technology will continue to take hold with improved processing techniques promising decreased costs, particularly in large volume multifunction production applications, where size and performance constraints make the use of stripline prohibitive. Also under development, are microstrip chip components such as attenuators and LC networks which can be installed in integrated package supercomponents and offer electrical performance compatible with broadband requirements through K_a band and above. In these areas, passive component manufacturers will utilize thin film technology developed for active networks and integrated circuits.

Channelized receiver requirements have spurred growth in the filter multiplexer market. Segmenting the 2-18 GHz band into multiple channels has been done with several innovative design techniques, but these passive components are still cost driven by highly skilled labor. System requirements in the 1980s will place strong emphasis on lowering the cost of performing this type of function and on developing techniques to circumvent their use.

After several decades of false starts, it appears that the millimeter-wave market will become a reality in the 1980s, with high volume applications for many passive components. Applications will be radar, proximity fusing and secure communications. The large quantities associated with these requirements will increase the availability of standardized components that can be offered from the catalog. To participate in this market, the passive component manufacturer will have to invest a large amount of capital in development and equipment.

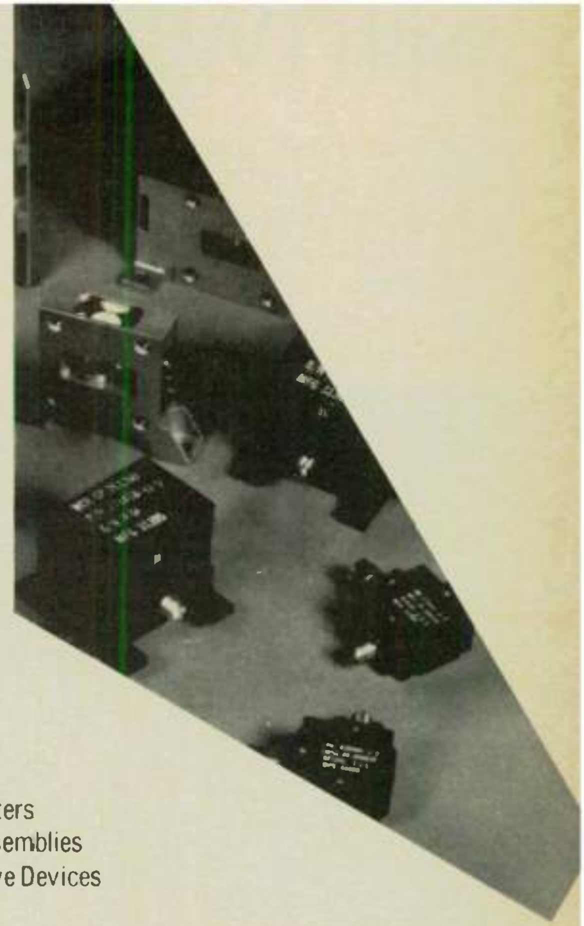
Better electrical performance and increased reliability will be required of all microwave interconnects, such as cable assemblies and coaxial connectors. The sub-miniature market will experience the most rapid growth, with the strongest trend in hermetic sealed versions used in MIC and hybrid packages. To meet volume constraints, system designers will continue to look for a flush mount integrated connector type that performs well

(continued on page 21)



For over a decade, Electromagnetic Sciences has developed, qualified, and supplied microwave components for at least 30 satellite projects, many involving contracts with more than one customer.

The experience on these space programs has given EMS considerable understanding of the importance of weight and reliability, as well as experience in making the necessary trade-offs between such items. Techniques for reducing weight while maintaining structural integrity have been part of most of the programs undertaken by EMS. Among the devices included in previous "High-Rel" programs are:



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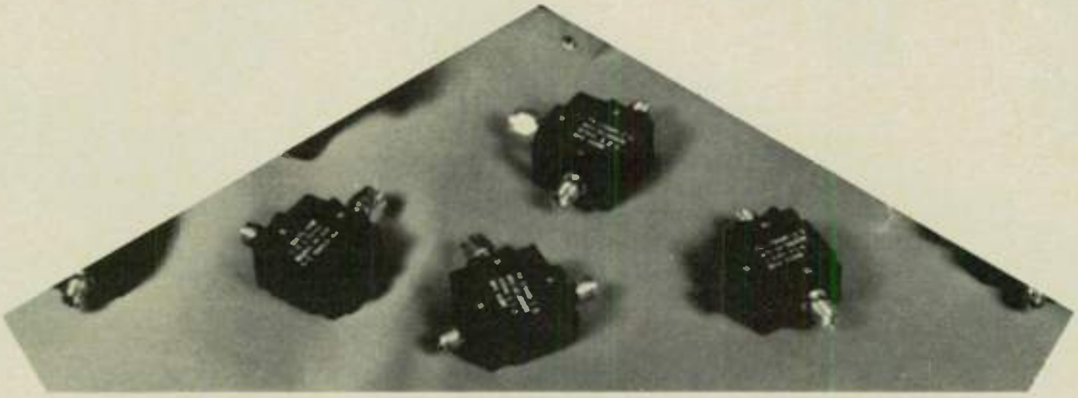

Electromagnetic Sciences, Inc.
125 Technology Park/Atlanta
Norcross, Ga. 30092
Tel: 404-448-5770 TWX: 810-766-1599

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NEC TWTs for 6, 8 and 11GHz Radio Links.

FREQUENCY BAND	6GHz	8GHz	11GHz
TYPE NUMBER	LD4353	LD4359	LD4362
FREQUENCY RANGE	5.6—7.1GHz	7.1—8.5GHz	10.7—12.7GHz
SATURATED POWER	23W	23W	24W
OVERALL EFFICIENCY	38%	38%	39%
SMALL SIGNAL GAIN	48dB	48dB	50dB

DIMENSIONS: 48 x 56 x 260mm. WEIGHT: 900 grams approx.

RF CONNECTIONS: SMA coaxial connectors.

NEC

Nippon Electric Co.,Ltd.
Tokyo, Japan

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broadband. This type of interconnect system is intended to eliminate cable assemblies and allow components to be "plugged" together directly. The approach would increase the designer's flexibility with respect to levels of component integration and enhance system maintainability. The eventual emergence of a standard interconnect system to meet these needs will necessitate a close cooperative development effort between the connector manufacturer and the system and component users.

In addition to meeting the technical challenges of the 1980s, microwave component manufacturers will be confronted with higher levels of reliability screening and software requirements. In the past, many passive microwave components have been sold almost as commodity items with relatively low levels of screening and testing. This began to change in the last decade, especially for those supplying to satellite applications. Now, however, stringent reliability requirements are being imposed on nearly all military systems and are passed down to the component supplier by the system manufacturer. This trend is likely to continue due to the increased complexity and sophistication of passive components.

The costs of screening, testing and reliability support are volume-related and favor the larger component houses who can afford to take on the added management burden. Many of these requirements such as high level end item screening, strict configuration control and trade ability mean that the manufacturer must be able to separate program-oriented business from standard products which are generally more direct labor and material cost driven. Certainly the risks will be higher for the passive component manufacturer who must deal with hardware that has software and testing costs that are a large percentage of the total end item cost. One trend that may help to hold down some of these costs is the push for QPL components. This allows the user to purchase a qualified part that has been manufactured as a standard with high volume savings.

Manufacturers of passive microwave components have good reason to be optimistic about the prospects for future growth. If the risks are higher, then so should be the rewards. To be successful, component houses will have to recognize and act on the technology and management requirements of future system programs. Emphasis will be on integration, and miniaturization and a broad component expertise will be needed to participate in the higher growth market segments. ■

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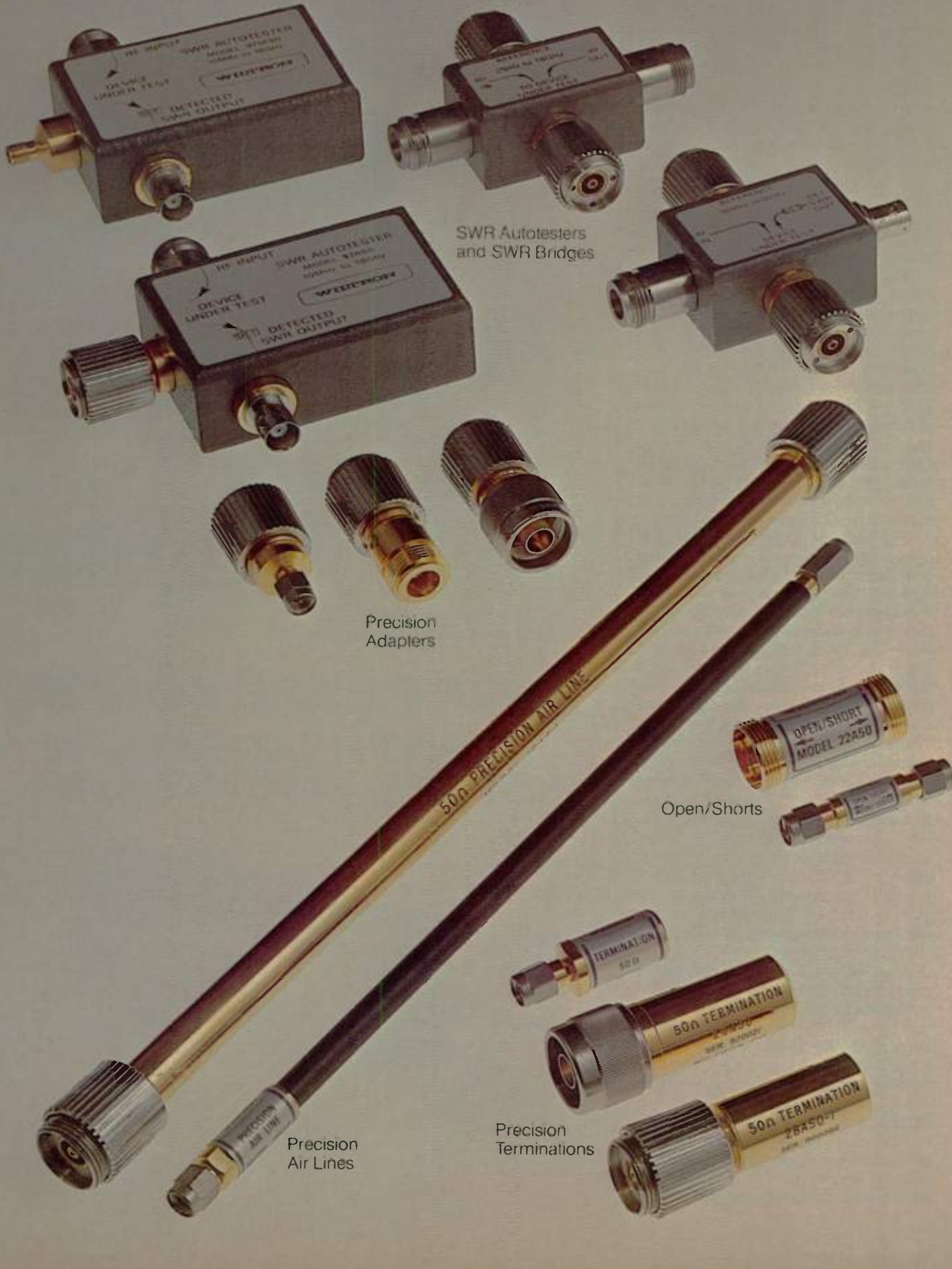

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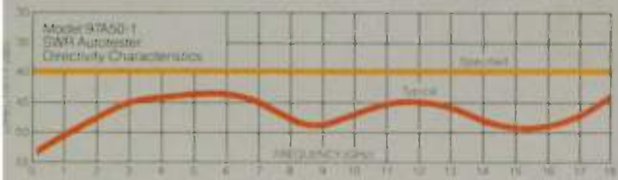
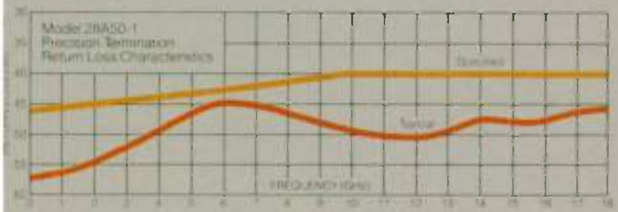
And you thought we only made quality microwave instrumentation. The U.S. National Bureau of Standards, the standards labs of Japan, West Germany, Great Britain and quite a few others know better.

Wiltron is also a precision components house. No one else is better prepared to show you how to make microwave measurements simply and accurately and then provide you with all the precision components and the measurement system you need. No one offers a comparable group of SWR Autotesters, precision air lines, terminations, adapters, SWR Bridges, open/shorts and RF detectors.



SWR Autotesters

Latest in Wiltron's family of SWR Autotesters is the Series 97. Here in one small package, we integrate a broadband microwave bridge, a precision termination, a detector and your choice of test port connectors. Performance is exceptional with directivity of 40 dB and a frequency range of 10 MHz to 18 GHz. Several other models with N or WSMA test ports offer comparable performance. The Wiltron family of SWR Bridges is equally accurate over most of its 10 MHz to 18 GHz range.

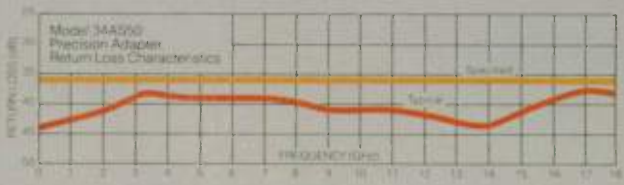


Terminations and Open/Shorts

Wiltron Terminations provide an accurate reference for SWR measurements as well as a termination for test instruments and devices under test from DC to 26.5 GHz. They are available in GPC-7, N and WSMA connectors and feature aged termination resistors for long-term stability. Maximum SWR varies from 1.002 at low frequencies to 1.135 at 26.5 GHz. Wiltron 22 Series Open/Shorts for the DC to 18 GHz range are offered with a choice of connectors.

Precision Air Lines

When you want better accuracy in measuring return losses from 0dB to 55dB, you'll need a Wiltron Air Line. These 50-ohm Air Lines provide both a standard impedance and a time delay for use in Wiltron Ripple Averaging and Magnified Reflection Measurement Techniques. Series 18 covers the 2 to 18 GHz range. The 18A50 offers a GPC-7 connector and features an SWR of 1.002. The 18N50 has an N male or female connector and an SWR of 1.006. Series 19 operates from 2 to 26.5 GHz with an SWR of 1.006 to 18 GHz and 1.01 to 26.5 GHz.



Precision Adapters for Accurate Measurements

Wiltron 50-ohm Series 34 Adapters virtually eliminate errors caused by mismatch. The adapters are available in GPC-7/N, GPC-7/WSMA, N/N and WSMA/WSMA. Range is DC to 26.5 GHz. Typical SWR ratios are 1.02 to 18 GHz and 1.1 to 26.5 GHz.

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For more information, call or write Walt Baxter, Wiltron, 825 East Middlefield Road, Mountain View, CA 94043. Phone (415) 969-6500.

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Microwave Devices and Circuits:
Contract Items at ERADCOM

V. G. GELNOVATCH
US Army Electronics Technology and Devices Laboratory
Fort Monmouth, NJ

As has been customary with past reviews of ERADCOM work, this status report will deal with the review and update of microwave and millimeter-wave device and circuit contractual work excluding thermionic devices which will be offered in a later, separate review. Additionally, surface acoustic wave (SAW) work will be reported for the first time. Recently initiated, currently active and recently completed work will be presented.

Texas Instruments, under contract DAAB07-78-C-2966, is developing a 3.5 watt GaAs FET with 5 dB of gain and 35% efficiency at K_u-band. This effort is the supporting work for a second objective which is a 10 watt transmitter with 25 dB gain and 25% efficiency over the 12-16 GHz band. The driver amplifiers which produce .5 watt output over the band have been completed. The output devices which are 4800 μm gate width via hole grounded chips are producing 2.1 watts and have lower than expected gain. The via hole concept is being temporarily given up since TI sees no improvement in performance over the air bridge approach. A new device structure, currently under Navy sponsorship which yields 600 mW at 6 dB of gain from a gate width of 1350 μm will be pursued for possible application to the Army program.

As a back up to the above transmitter program, a new program has just been initiated with Hughes DAAK20-80-C-0527 to develop a 3.5 watt K_u-band GaAs FET device and a 6 watt amplifier at 15 GHz with 10 dB gain and 30% efficiency. The approach in the proposal centers of using a total 3.6 mm gate width device to achieve the objective from a combined cell (using Nagi combiners) architecture.

An effort to develop analog monolithic GaAs microwave IC's is being conducted at Rockwell International Corporation under contract DAAB07-78-C-2999. There are two objectives in this effort; the first being to develop a monolithic dc-10 GHz amplifier with 20 dB gain and noise figure of 5 dB, the second being a 15 GHz receiver with 1 GHz bandwidth and a 8 dB noise figure. The monolithic amplifier was successful and reported in the previous (the first generation used distributed elements) report. A second generation amplifier using lumped element matching was designed to reduce GaAs substrate area. It has resulted in 1/8 x 1/8" chip (first generation was 1/8 x 1/4") layout. The K_u-band receiver has been designed and fabricated. The above amplifier is utilized as a wide band IF amplifier within the K_u-band receiver. The receiver is fabricated on a 1/4" x 1/4" GaAs chip and uses an RF GaAs FET amplifier and a dual gate mixer as well as the wideband IF amplifier. The LO source will be external to the chip for this feasibility demonstration. It is anticipated that the chip will be scribed into separate functions for testing. No test data is available yet.

As part of the Army monolithic technology thrust, a brand new contract (DAAK20-80-C-0279) has been awarded to TRW. We will develop a voltage tunable local oscillator operating over the 13-15 GHz frequency range in monolithic format to essentially round out limitations of the previous contract. The key performance parameters will be frequency control and stability. A mixer and wideband IF will be required. No data is available at this time.

Raytheon, under contract DAAK20-79-C-0269, is investigating monolithic on-chip matching techniques to provide an understanding of the means to optimize broadband performance and realize lowered costs in future microwave power GaAs FET device designs. The approach has been to investigate both all optimization and matching technology on GaAs substrates. Raytheon has worked with the 1600 μm state-of-the-art (SOA) cell which was optimized for power and gain prior to the Army program. Cell optimization has centered around thermal optimization while circuit work investigated both Wilkinson and Lange couples on 4 mil GaAs substrates. Current status of the program is that a physical layout of a 10-14 GHz power amplifier with a goal of 3 watt output on a 6.4 x 3.8 millimeter GaAs substrate has been completed. It consists of a four cell output amplifier together with a single cell, two cell and 50 Ω connected cell for test purposes. The various test configurations were chosen to yield maximum parameter information in the operation of the four cell output network. Additionally, a redesigned SAO cell with a .7 μm gate length has been completed.

A new program has been awarded to AVANTEK, DAAK20-80-C-0284, to develop a discrete GaAs Low Noise FET for 20 to 40 GHz wideband application. The specification at 22 GHz is 8 dB gain and 2 dB noise figure. Further useful performance is required to 40 GHz. Initial approaches as outlined in the proposal will be a gate whose mask dimensions will be 75 x .5 μm but after processing will have a length of $< .5$ μm. A "T" gate will be used to decrease gate resistance. The gate will be placed closer to the source.

TRW under contract DAAB07-77-2731 to develop a 65 watt 3.1 to 3.5 GHz bipolar power transistor has had a very significant breakthrough. After a

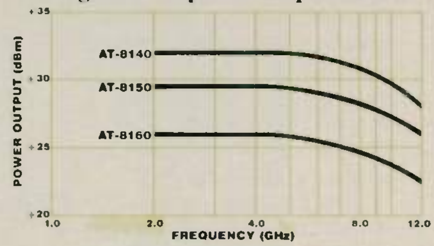
(continued on page 26)

new 250 mW to 1 W GaAs FETs with outstanding gain and efficiency.

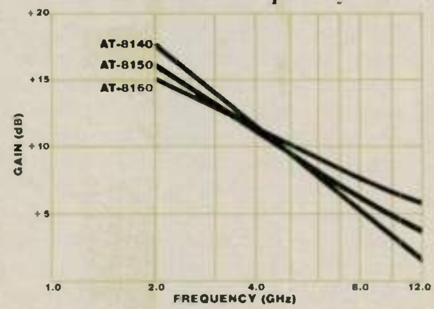
Get the smallest, easiest to use devices available today in the 250 mW to 1 watt range with Avantek's new family of power GaAs FETs. Choose from three power levels with up to 35% power added efficiency: the 250 mW AT-8160; the 500mW AT-8150; or the 1 watt AT-8140 All are available in flange packages for operation up to 8 GHz and in chips for up to 12 GHz.

In critical applications such as satellites, radar amplifiers, and ECM equipment, Avantek power GaAs FETs offer the industry's finest combination of gain and power added efficiency.

1 dB gain compression point.



Gain versus Frequency



Like all Avantek transistors, the AT-8100 series features all gold metallization to ensure maximum performance and reliability. Devices are 100% tested for RF and DC performance. Packaged devices are hermetically sealed and 100% leak tested. We also offer high reliability screening based on MIL-STD methods. For more information on Avantek's power transistors phone (408) 727-0700 or write Avantek, 3175 Bowers Avenue, Santa Clara, CA 95051.

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long and uphill struggle they have achieved 85 watts at 3.1 GHz and 76 watts at 3.5 GHz, although not from the same chip simultaneously. Incorporation of matching transformers will hopefully level the power output across the above band.

Hughes, under contract DAAB07-78-C-3002, is developing high cutoff frequency Schottky Barrier diodes and mixers at 60, 94, 140, 220 and 340 GHz for line of sight communications, radar, missile guidance and terminal homing projectiles. The approach has been to design and fabricate beam lead diodes using proton bombardment and mesa etching techniques for low capacitance using GaAs. Current emphasis is at 94 GHz using variable geometry honeycomb diodes which have achieved conversion loss as low as 4.6 dB. At 220 GHz, two parallel approaches are being made to develop the 220 GHz mixer, both of which are designed to be sub-harmonically pumped. The approach uses a four port waveguide junction with anti-parallel diode pairs mounted at the junction center. The second approach is exploring the feasibility of using a planar mixer module mounted on the feed horn of a parabolic reflector.

The Army has pursued the InP device technology heavily over the last half decade for application to low noise coherent local oscillators. A follow on effort to previous work DAAB07-78-C-2940 (which ended last year and was reported in the previous report) was initiated at Varian under contract DAAK20-79-C-0279. This program has three objectives; a) develop low noise single diode CW InP Gunn Oscillators, b) develop InP power combiners, c) develop high power pulsed InP Gunn oscillators. Progress to date is as follows: a new two zone cathode diode is undergoing processing, the single diode benchmark is 125 mW at 94 GHz and 95% combining efficiency has been demonstrated using two diodes. Future plans include development of super thin devices and larger area pulsed devices.

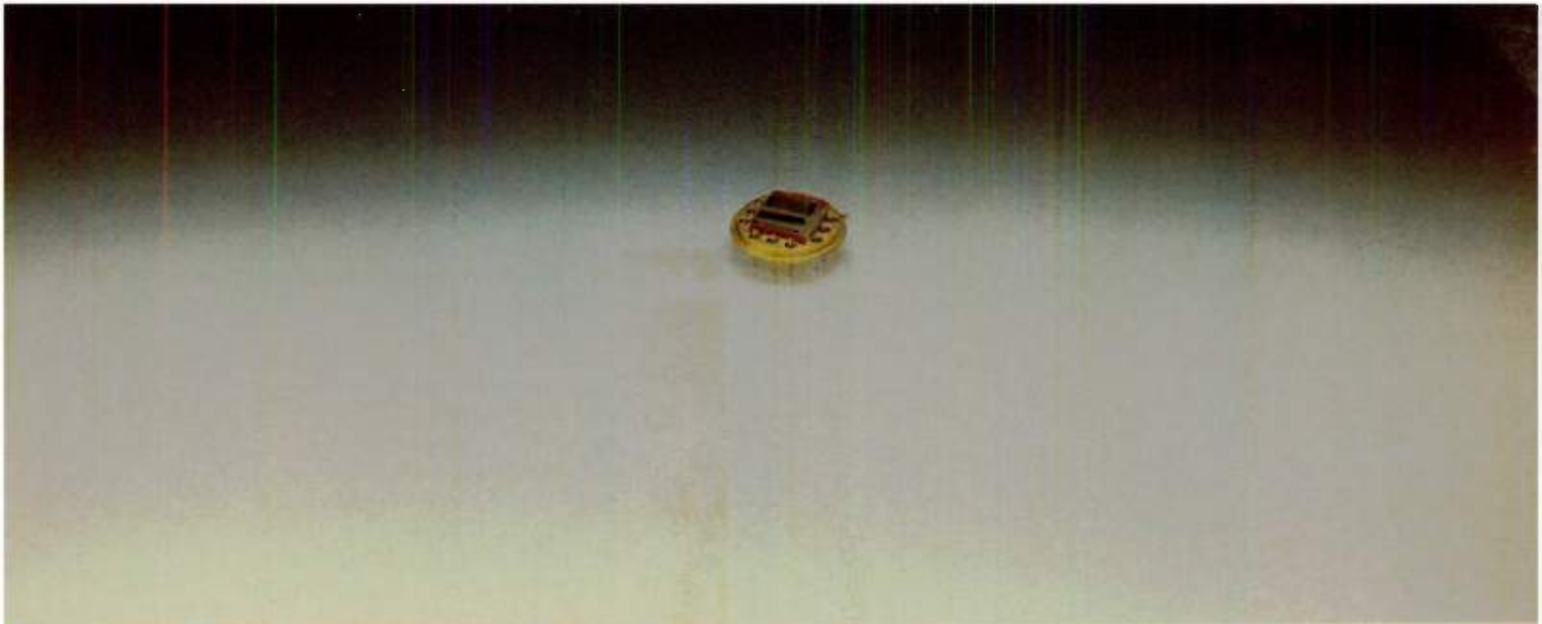
As part of the InP thrust, a 6.3A program was awarded to Varian to establish the reproducibility and reliability of the InP devices developed under the aforementioned 6.2 A work. The contract number is DAAK20-79-C-0280. Progress to date has shown results such as 195 mW at 57 GHz both repeatably and reproducibly from two zone cathode, five epi layer devices. This work includes the development of diamond in copper heat sinking packages and varactor tuning methods.

Hughes is currently developing a 10 watt combiner at 140 GHz for missile seeker application under contract DAAK20-79-C-0259. Current progress to date has demonstrated 9.2 watts (50 to 100 nsec pulse) at 141 GHz.

Texas Instruments is under contract to design a family of highly selective L-Band filters for pre-selector functions in TDMA communication systems such as GPS to replace the large and costly filters currently utilized (contract DAAK20-79-C-0257). The approach is to utilize surface acoustic wave technology (SAW) on both quartz and lithium niobate. The band to be covered is 1-1.5 GHz. The frequency of operation requires use of E-beam lithography to define the .5 μm transducer metal line widths. Progress to date has been the generation of a computer program for generating apodization and/or withdrawal weighted transducers and the design of two filters (1227 MHz and 1575 MHz) for quartz or lithium niobate. This approach should yield significantly lower insertion loss and steeper sloped/higher out of band rejections performance than available hithertofore. Size will be reduced dramatically.

A program to significantly increase the frequency stability of Army meteorological probes at L-band through the use of SAW delay line technology has resulted in an increase in stability from 1700 ppm to 300 ppm of the standard Army radiosonde probe. This new technology replaces the stripline cavity stabilized oscillator previously used. On a follow on contract TRW (DAAK20-80-C-0260) is designing and fabricating a 403 MHz version for use in parts of the world where regulations prohibit the use of the L-band frequency. Due to experience gained through the L-band effort a design architecture has already been chosen. No other results are yet available.

In an effort to marry the GaAs microwave monolithic technology with the SAW signal processing technology, a new and innovative effort with far reaching consequences has been initiated at United Technologies Research Center (DAAK20-79-C-0263). The objective of this effort is centered around the fact that GaAs is weakly piezoelectric and thus offers the possibility of fabricating SAW structures upon it. The impact is, of course, that the possibility is available to build complete monolithic GaAs receivers (including signal processing such as correlation, convolution, etc.) on a single chip. The demonstration vehicle will be a voltage tunable oscillator using a SAW resonator on GaAs. Work to date has dealt primarily with resonator parameters for surface wave propagation and temperature stability and looks very promising. ■



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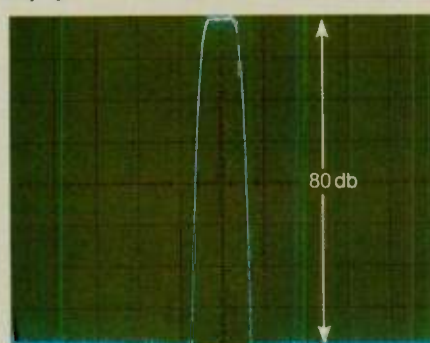

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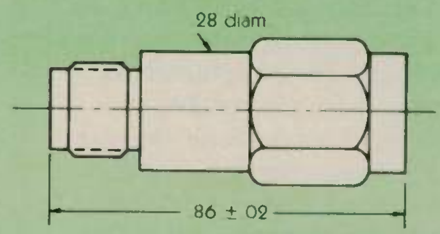
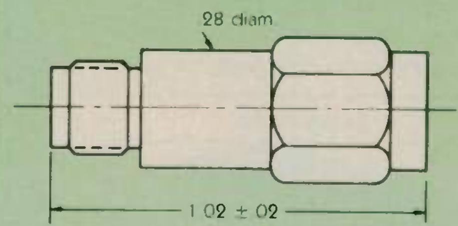


1 through 12dB Weight: 5 grams (0.175 oz.)



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DC to 18.0 GHz
HIGH PERFORMANCE

- Model 290, M290, F290
- Maximum VSWR: 1.07 +0.015fGHz
- Input Power: 2 watts average at +25°C derated linearly to 0.5 watts at +125°C
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

ATTENUATION VALUE	ACCURACY
1,2,3,4,5, and 6dB	±0.3dB
7,8,9,10 thru 20dB	±0.5dB
21 thru 30 dB	±1.0dB

DC to 12.4 GHz
HIGH PERFORMANCE

- Model 291, M291, F291
- Maximum VSWR: 1.07 +0.015fGHz
- Input Power: 2 watts average at +25°C derated linearly to 0.5 watts at +125°C
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

ATTENUATION VALUE	ACCURACY
1,2,3,4,5 and 6dB	±0.3dB
7,8,9,10 thru 20dB	±0.5dB
21 thru 30dB	±1.0dB

DC to 8.0 GHz
HIGH PERFORMANCE

- Model 292, M292, F292
- Maximum VSWR: 1.07 +0.015fGHz
- Input Power: 2 watts average at +25°C derated linearly to 0.5 watts at +125°C
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

ATTENUATION VALUE	ACCURACY
1,2,3,4,5,6,7,8,9,10dB	±0.3dB
11 thru 20dB	±0.5dB
21 thru 30dB	±1.0dB

DC to 2.0 GHz
HIGH PERFORMANCE

- Model 294, M294, F294
- Maximum VSWR: 1.15
- Input Power: 2 watts average at +25°C derated linearly to 0.5 watts at +125°C
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

ATTENUATION VALUE	ACCURACY
1 thru 20dB	±0.3dB
21 thru 30dB	±0.5dB

DC to 18.0 GHz
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- Model 444, M444, F444
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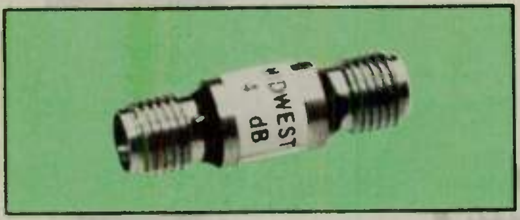
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

ATTENUATION	ACCURACY	
VALUE	DC to 12.4 GHz	12.4 to 18.0 GHz
1,2,3,4dB	±0.75dB	±0.75dB
5,6,7,8dB	±0.75dB	±1.00dB
9,10,11,12dB	±1.00dB	±1.25dB
13 thru 20dB	±1.50dB	±1.50dB
21 thru 30dB	±2.0dB	±2.0dB

Double Male Connectors
(M PREFIX TO MODEL NO.)

dB VALUE	OVERALL LENGTH
1-12dB	.98"
13-30dB	1.12"

Double Female Connectors
(F PREFIX TO MODEL NO.)



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Around the Circuit

PERSONNEL

At Sylvania Systems Group – West Div. **E. Arthur Meyers** assumed the position of Manager, EW Engineering Dept. within the EW Organization. . .**Susan B. MacDonald** joins COMPAC as Sales Manager. . .In its movement to centralize management, TRW Semiconductors appointed **Chuck Thompson** divisional marketing mgr. for long range planning and **Majid Basy** assumes Mr. Thompson's prior post as manager of power operations, TRW Semiconductors. . .Other changes in corporate ranks include the promotion of **Frank J. Thomas** to V.P. of Operations and appointment of **Richard C. Singleton** as Controller at Antekna Inc. . .**Garrett E. Pierce** becomes the Financial V.P. at Materials Research Corp., a newly created position. . .Laser Diode Labs, the Valtec Inc. subsidiary, appointed **Steven Klunk** as Sales Manager . . .**David Sobo** was named V.P. of Marketing at Leasametric, Inc. . .Microlab/FXR named **David Garippa** as Vice President and Treasurer. . .**S. Edward Brown** has been promoted from Eastern to Nat'l Sales Manager at Frequency Sources West Division. . .At TerraCom, the Loral Corp. Div., **John A. McGuire** was named Executive V.P. . .**Mason Carter, Jr.** joins Metex Corp. as General Manager of the newly established Electronic Products Div., **William E. Sweetman** is appointed General Mgr. of its recently formed Technical Products Div. and **Jack Bernstein** becomes Senior V.P. for Corporate Development, a new position. . .Narda Microwave Corp.'s shareholders elected **Paul N. Fulton** a Director and **Glenn B. DeBella** was elected Vice President by the Narda Board. . . .**Colonel Robert R. Rankine, Jr.** assumes the directorship of the Air Force Avionics Lab, at WPAFB.

CONTRACTS

GTE received a $7.4M contract from the US Army to develop the AN/MLQ-33 countermeasure system. . .Other US Army awards include $3M from ERADCOM (Electronics Research & Development Command) to produce a new ground radar detector and radio direction-finding system. **Bunker Ramo Corp.** is contractor for the AN/MSQ-103 TEAMPACK system and **GTE** Products will install the 50-ft. antenna masts on the AN/TSQ-114 Special Purpose Detection Sets (TRAILBLAZER). . .CORADCOM, the US Army Communications Research and Development Command, awarded a contract to **Harris Corp.** for satellite communications earth stations. Initial funding for production of super-HF, jam-resistant, secure terminals amounts to $12.7M. . . .An AF contract valued at $16.4M has been awarded by Aeronautical Systems Div. to **ITT Avionics Div.** for developing an ECM self-protection system for manned strategic aircraft. . .**Ford Aerospace & Communications Corp.'s Western Development Labs** received a $2.7M, 2-year contract from NASA – Lewis Research Center to develop a multibeam, scanning spot beam spacecraft antenna system. . .**California Microwave, Inc.** signed a $6.6M contract to supply radio modernization equipment to Mexico's Sec. of Communication & Transportation. . .Cal. Microwave also received a $1.3M turnkey contract award from Supreme Headquarters Allied Powers Europe to supply the electronic system for an experimental satellite earth terminal at SHAPE's Technical Centre. . .**Hughes Aircraft Co.'s Electron Dynamics Div.** received an order from **P. T. Radio Frequency Communications**, Bandung, Indonesia, for 40 of the Hughes 40 W communications power amplifiers.

NEW MARKET ENTRY

Reactel, Inc. has announced a full line of LC, tubular, cavity and waveguide filters for the 2 kHz-18 GHz range. Principals in the venture are D. E. Claycomb, Pres. and Manny Assurian, V.P. Company is located at 645-C Lofstrand Lane, Rockville, MD 20850. Tel: (301) 279-5535.

FINANCIAL NEWS

AEL Industries, Inc. reported second quarter results for the period ended August 29, 1980 of net income of $369K or 19¢ per share on sales of $14.6M. This compares with 1979 quarterly net income of $812K or 43¢ per share and sales of $13.6M. . .For the first quarter ended September 30, 1980, **California Microwave, Inc.** reported net income of $469K or 22¢ a share on sales of $12.1M. This compares with FY80 first quarter net income of $608K or 29¢ a share on sales of $9.9M. . .For the third quarter ended September 28, 1980, **EPSCO, Inc.** reported net income of $261K or 28¢ per share and net sales of $4.3M. This compares with 1979 third quarter net income of $228.3K or 25¢ per share and net sales of $3.24M. . .**M/A-COM, Inc.** and its subsidiaries reported results for the fiscal year ended September 27, 1980 of net sales of $322.5M and net income of $24.9M or 77¢ per share. In FY79, net sales were $227M, net income totalled $13.2M or 46¢ per share. . .For the second quarter ended September 30, 1980, **Alpha Industries, Inc.**reported net sales of $6.5M, net income totalling $559K or 23¢ per share. During the same quarter of 1979, net sales of $4.7M, net income of $393K or 20¢ per share were reported. . .**Scientific-Atlanta, Inc.** had first quarter results of sales of $55.6M, net earnings of $3.6M or 35¢ per share for the period ended September 30, 1980. During the comparable 1979 quarter, sales were $39.5M, net earnings were $2.2M or 24¢ per share. . .During the first quarter ended September 27, 1980, **Sage Labs, Inc.** reported sales of $623K, net earnings of $74K or 17¢ per share. For the comparable 1979 quarter, sales were $481K, net income of $48K or 11¢ per share. . .During its first quarter ended September 30, 1980, **Narda Microwave Corp.** had sales of $5.5M, net income of $311K, or 26¢ per share. In the first FY80 quarter, sales totalled $3.7M, net income was $177K or 15¢ per share. . .For the first quarter ended September 30, 1980, **Radiation Systems** announced earnings of $180K or 27¢ per share on sales of $1.8M. This compares with last year's first quarter earnings of $162K, or 21¢ per share on sales of $1.3M. . . During the third quarter ended September 30, 1980, **Eaton Corp.** reported sales of $732M, net income of $15.5M, or 58¢ per share. This compares with 1979 third quarter sales of $793, net income of $34M or $1.30 per share. **Tektronix, Inc.** reported its 1980 results for the year ended May 31, 1980 of net sales of $971M, earnings of $85M or $4.66 per share. This compares with 1979 fiscal year net sales of $786.9M, earnings of $77.1M or $4.28 per share.

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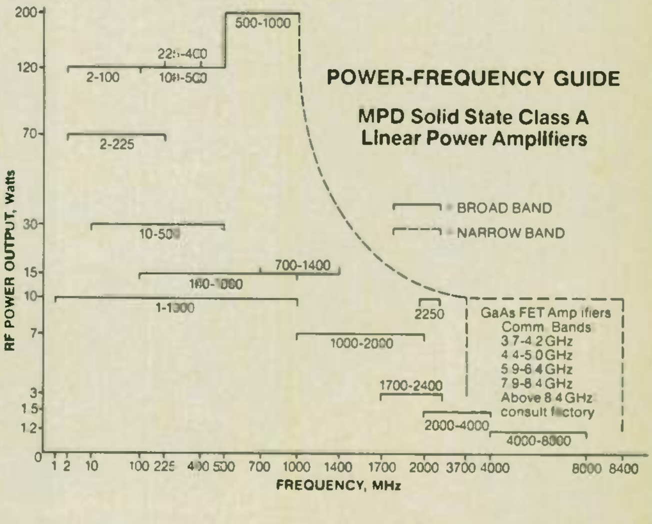

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The Resonant Mode PIN Switch

R. J. CHAFFIN
Sandia National Laboratories†
Albuquerque, NM

This paper describes a new mode of operation of the PIN diode shunt RF switch. This mode produces RF switching speeds that are considerably faster than the applied bias pulse rise-time and pulse widths that are considerably shorter than the applied bias pulse width. The basic principle utilizes the fast "snap-off" action of the PIN diode to shock excite an L-C bias network. The bias is easily adjusted so that RF can flow through the switch for only one half-cycle of this bias circuit ringing.*

This new mode of operation is important to the development of very fast rise time RF switches for communication and radar systems.

INTRODUCTION

The schematic of a conventional[1] shunt mode PIN diode switch is shown in Figure 1. When the diode is reverse biased, it essentially disappears from the circuit and allows RF to pass freely from the input to the output with little attenuation. When the diode is forward biased, it "shorts" the 50 Ω line and causes most of the RF input to be reflected rather than transmitted. Thus, by varying the bias, one can turn the RF on and off at the output. (Note C_A and C_B are just dc blocks and do not affect the RF, and L looks like an RF open to keep the RF from going out the bias port).

Attempts to raise the switching speeds of such circuits have led to circuits using smaller inductors and diodes with narrower I regions. In all cases up to now, the bias network has been critically damped to prevent ringing and overshoot. Present designs using this technique can produce pulse widths of ~ 10 ns with rise and fall times of 3-4 ns[2] at the several watt level. Half-nanosecond rise times have been demonstrated at the 20 mW level.[3]

Instead of fighting the problem of ringing and overshoot it is possible to harness these effects to produce improvements in switching speed by deliberately underdamping the circuit.

RESONANT MODE PIN SWITCH

In working with switches of the type shown in Figure 1 we made the observation that if C_A and C_B in Figure 1 were made very small, it would reduce the RF pulse width at the switch output. A further observation was made that if the reverse bias pulse width was widened the RF output would oscillate on and off as shown in Figure 2. The traces

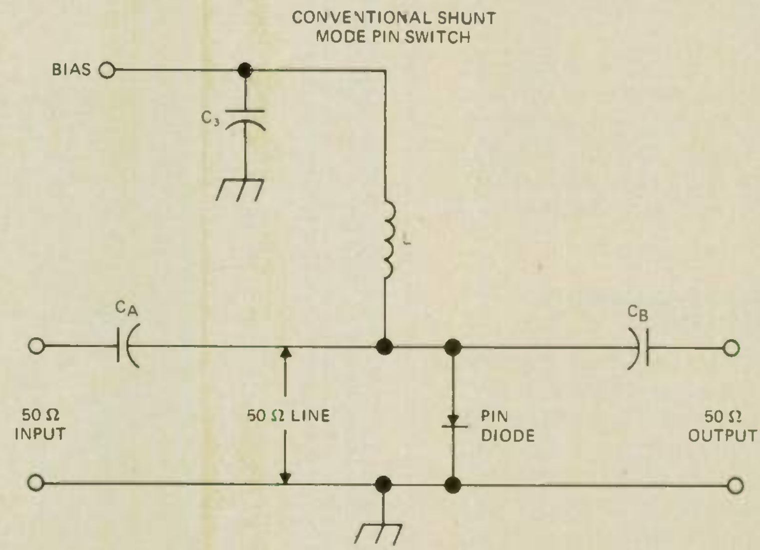

Fig. 1 Conventional shunt mode PIN RF switch.

* This work sponsored by the US Department of Energy (D.O.E.) under Contract DE-AC04-76-DP00789.

† A US Department of Energy facility.

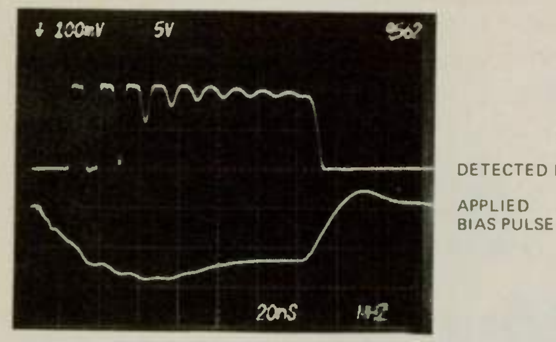

Fig. 2 Applied bias pulse and detected RF for small values of blocking capacitance in the coaxial PIN diode switch (L = 570 nH, 20 ns/div)

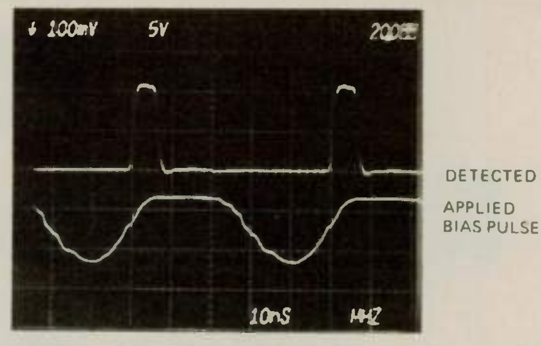

Fig. 3 Detected RF output from coaxial switch using narrow bias pulse (10 ns/div).

in Figure 2 were taken at X-band using a Hewlett-Packard coaxial PIN diode switch (HP-33144A), driven by an Amperex ATF-456A driver. This switch was modified by placing 1.1 pF chip capacitors in series with each of the two existing 200 pF blocking capacitors in the unit. If the applied bias pulse is narrowed a single pulse out the chain shown in Figure 2 could be obtained. This is shown in Figure 3. *The important observation from* Figure 3 *is that the output RF pulse width and rise and fall times are shorter than the applied bias pulse.* Figure 4 shows a sampling scope photo of the RF output pulse corresponding to the detected pulse shown in Figure 3. The peak output shown in Figure 4 is 1 W in X-band. The insertion loss in the "on" state is 1.8 dB and the isolation in the off state is > 80 dB.

The results shown in Figures 2-4 were clearly due to some type of ringing in the switch, but the package of the 33144A coaxial switch did not lend itself to internal probing to determine the cause.

EXPERIMENTAL CIRCUIT MEASUREMENTS

In an effort to understand this effect, the experimental microstripline circuit depicted in Figure 5 was constructed. This circuit was built on 1/16" thick, teflon-glass circuit board. The diode module was a Hewlett-Packard 33644A coaxial hermetic package, containing four narrow base PIN diodes. This module is the same one used inside the HP-33144A coaxial switch described earlier. A schematic diagram of the experimental microstripline switch is shown in Figure 6.

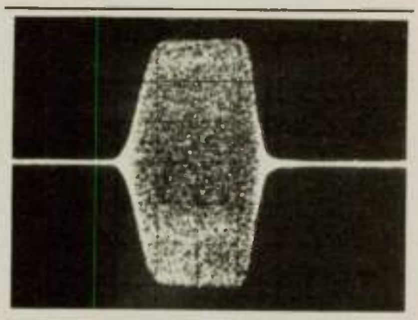

Fig. 4 Sampling Scope Signal corresponding to Figure 3 (X-band, 1 W, 2 ns/div, L = 570 nH).

The microstripline circuit's behavior was found to be similar to that of the modified coaxial switch tested earlier. It allows easy probing of the voltages and currents in the different circuit paths.

Figure 7 shows the measured voltage waveform across the PIN diodes when the bias is switched from forward to reverse and held there (corresponding to a wide "on" pulse). The inductance used was 143 nH. The voltage is found to ring at a frequency determined by the bias inductance and switch capacitance and it eventually reaches a steady state reverse voltage. This ringing is excited by the snap-off[4] action of the narrow base PIN diodes. Figure 7 explains the effect seen in Figure 2, i.e. the voltage across the PIN diodes is ringing from forward to reverse bias which turns the RF off and on, respectively. The voltage eventually settles to the applied reverse value which leaves the RF output on. (Note the difference in ringing frequencies between Figures 2 and 5 is due to the different bias inductances used in the coaxial and microstripline circuits).

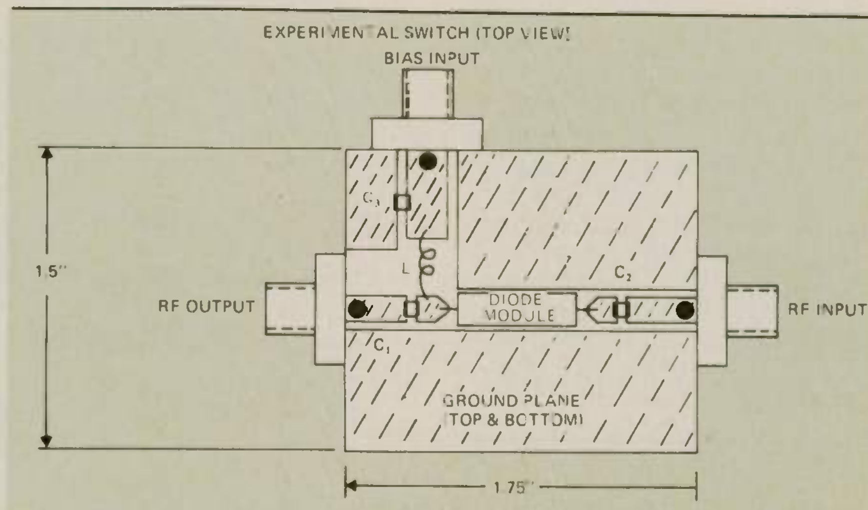

Fig. 5 Experimental resonant mode PIN switch in microstripline format.

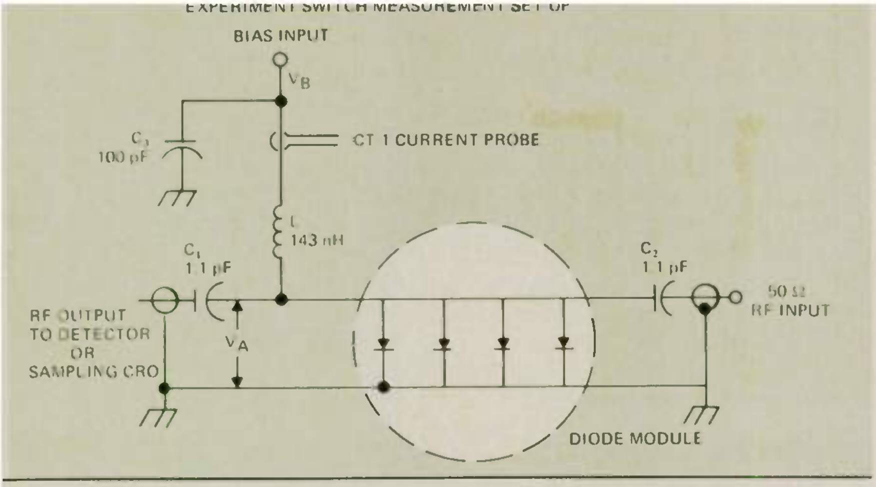

Fig. 6 Schematic diagram of experimental resonant mode PIN switch.

Figure 8 shows all of the pertinent waveforms corresponding to this mode of PIN switch operation. These waveforms were measured on the microstrip line switch. The top trace is the applied bias pulse measured at the bypassed end of the bias inductor. (Note – the fall time of the bias pulse is sped up by the ringing action of the circuit.) The second trace on Figure 8 shows the current in the inductor. When reverse bias is applied, the current through the bias inductor begins to ramp towards larger reverse values, extracting the stored charge from the PIN diodes. After all the charge has been removed the diode current ceases abruptly (because of the snap-off action of the narrow base PIN diode). This abrupt cessation of current causes a ringing to occur in the L-C circuit consisting of the bias inductance and switch capacitance. One half-cyle of this ringing can be seen on the third trace in Figure 8 which corresponds to the voltage across the PIN diodes. This voltage would have continued ringing (such as shown in Figure 7) except for the fact that the applied bias has gone back to the forward bias state, preventing another ringing cycle. The bottom trace in Figure 8 shows the detected RF output. It can be observed that the RF output occurs during the half cycle of ringing in the reverse bias direction.

THEORETICAL ANALYSIS

The basic theoretical explanation of the operation of this switching mode can be summarized by saying that the abrupt cessation (or "snap-off") of current flow in the narrow base PIN diode that occurs when it is switched from forward to reverse bias causes the bias circuit to ring if it is underdamped. If the applied bias pulse returns to forward bias before the ringing voltage is allowed to ring back to reverse bias again, a single pulse of

(Where $f_r = (2\pi\sqrt{LC})^{-1}$. Hence, the rise and fall times and pulse width are determined by the L-C network, not the bias pulse, i.e.:

$$\text{Pulse Width} \simeq \frac{1}{2f_r} = \pi\sqrt{LC}\,. \qquad (1)$$

A simplified equivalent circuit of the PIN switch is shown in Figure 9. The inductance, L, is just the bias inductor shown in Figures 5 and 6. The capacitance is the reverse bias capacitance of the diodes in parallel with the two 1.1 pF blocking capacitors shown in Figure 6. (It can be shown that for the ringing circuit the 50 Ω line impedances and bias inductor bypass capacitor can be considered as short circuits to first order).[5] The switch shown in the equivalent circuit represents the "snap-off" action of the diodes, i.e. the diodes are a "short circuit" until all of the charge is extracted and then they become an open circuit. This will occur when a reverse charge,

$$Q = \int_0^t I_R\, dt \cong I_F \cdot \tau \qquad (2)$$

where I_R = reverse current

I_F = forward bias current

τ = minority carrier lifetime in diodes

has been extracted from the diodes (since all four diodes are assumed identical we can treat them as one diode with four times the area). The minority carrier lifetime of the diodes was measured using the charge removal method[4] and is 50 ns. For the data shown in Figure 8, the forward bias current was 40 mA.

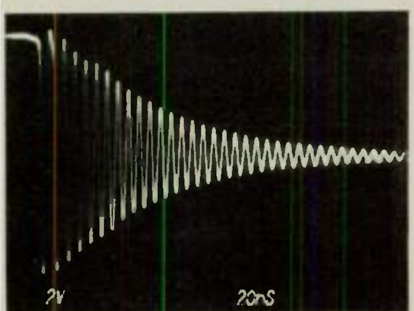

Fig. 7 Ringing voltage across diodes for a very wide bias pulse (L = 143 nH).

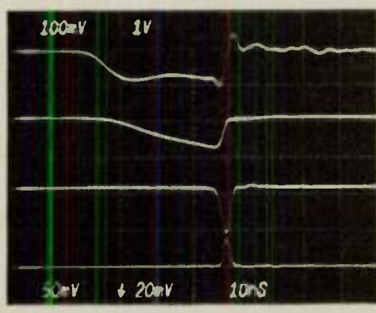

Fig. 8 Internal waveforms of experimental switch adjusted for single pulse output (L = 143 nH).

This means that $Q = I_F \cdot \tau = (.04A) \cdot (50 \times 10^{-9}\ sec) = 2.0 \times 10^{-9}$ coulombs. Hence, diode snap-off should occur when the area under the current trace on Figure 8 is equal to this charge. The area under the diode current trace in Figure 8 between the zero crossing and snap-off is about 1.1 square divisions. Since each square division corresponds to $(200\ mA) \cdot (10\ ns) = 2 \times 10^{-9}$ coulombs the charge removed is $(1.1\ div^2) \cdot (2 \times 10^{-9}) = 2.2 \times 10^{-9}$ coulombs. Hence, the snap-off time measured agrees very well with its theoretical value. The exact shape of the bias current waveform does not matter as long as all the charge is withdrawn in a time much shorter than the carrier lifetime, then diode snap-off will occur at a time defined by Eq. 2. The inductance used to obtain the waveform shown in Figure 8 was L = 143 nH.

The frequency of the ringing shown in Figure 7 is 175 MHz. The value of capacitance needed to cause this resonance with 143 nH is 5.78 pF. This agrees closely with the values used in the experimental circuit shown in Figures 5 and 6 (4 pF total diode capacitance in parallel with the two 1.1 pF blocking capacitors). One further test that can be made on the simple theoretical model is the amplitude of the ringing voltage. Figure 8 shows a current step of 160 mA in 3 ns or a $di/dt = 5.3 \times 10^7$ amps/second. The voltage across the diodes should be approximately $L \cdot di/dt$. This voltage is $(5.3 \times 10^7\ A/s) \cdot (143 \times 10^{-9}\ H) = 7.6$ volts. This compares favorably with the 6.5 volt spike seen in Figure 9. The conclusions to be drawn from the above results are that the effect is well understood and the model shown in Figure 9 is correct.

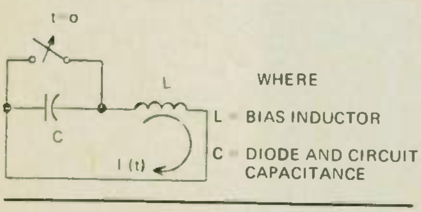

Fig. 9 Simplified equivalent circuit of resonant mode PIN switch.

The capacitance of the L-C network cannot be made appreciably smaller due to the limitation imposed by the diode capacitance. Hence, to shorten the pulse width it is necessary to reduce the value of the bias inductor (or use a lower capacitance shunt diode). However, one cannot make the inductance too small or the Ldi/dt "kick" will be insufficient to fully reverse bias the diodes and the insertion loss will increase. For full turn-on of a 1 W X-band output we found that the minimum value of L we could use was 64 nH in the switch shown in Figure 5. The resulting output is shown in Figure 10. The "junk" that occurs at the end of the RF pulse is transient ringing in a different part of the switch and not the LC bias ringing. This is more clearly shown in the lower trace on Figure 10 which was taken with the RF input source replaced by a termination.

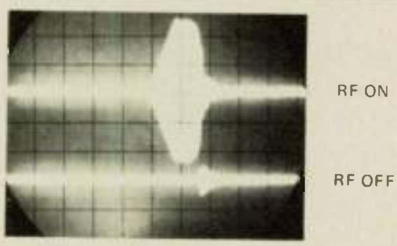

Fig. 10 Experimental switch, shortest full height pulse achievable (1W X-band 1 ns/div L = 64 nH).

This mode of operation also works well for applied bias pulse repetition frequencies (PRF's) up to very high values. We have been able to generate pulse widths of a few nanoseconds at PRF's up to 100 MHz under control of the external bias pulse generator. (The pulse width is controlled by the L-C bias circuit and the PRF is controlled by applied bias pulse generator).

CONCLUSIONS

This paper has analyzed a newly discovered mode of operation of the shunt mode PIN RF switch. This mode produces switch rise times that are faster and pulse widths that are narrower than the applied bias pulse. The basic principle utilizes the "snap off" action of a PIN diode to shock excite an underdamped series resonant L-C bias network. The circuit is easily adjusted to allow RF to pass through the switch for only one-half cycle of this ringing. Hence, the switch rise-time and pulse width are controlled by the L-C network instead of the applied bias pulse.

A model of the switch was generated and shown to be consistent with measured data.

ACKNOWLEDGMENT

The author would like to thank B. L. Burns for his assistance in fabricating the switches and taking of data as well as helpful comments supplied by J. G. Webb.

REFERENCES

1. Watson, H. A., (editor), *Microwave Semiconductor Devices and Their Circuit Applications*, Chapter 10, McGraw-Hill, 1969.
2. Garver, R. V., "PIN Diode Switches — Speed vs Power," *The Microwave Journal*, Feb 1978, p. 54.
3. Brown, N. J., "Fast ECL Switches Speed PIN Control," *Microwave Semiconductor News*, Aug 1979, p. 131.
4. Moll, J. L., S. Krakauer, and R. Shen, "P-N Junction Charge Storage Diodes," *Proc. IRE*, Vol. 50, p. 43, 1962.
5. Chaffin, R. J., "A Fast PIN RF Switch Utilizing a Resonant Bias Network," Sandia Report SAND78-1946, available upon request from author.

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Pocket Calculator Program for Analysis of Lossy Microstrip

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Department of Electrical Engineering
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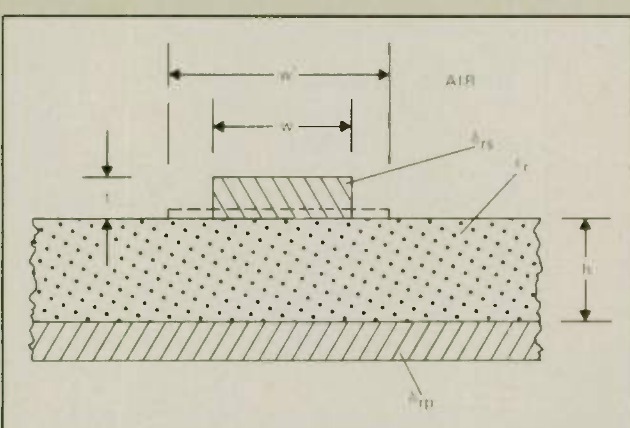
Anyone working with microstrip circuits knows the two formulas published by Wheeler in 1965,[1] one for the calculation of the characteristic impedance of narrow strips and the other for wide strips. Some busy workers may have missed Wheeler's more recent paper[2] in which he derived a single formula for computation of the characteristic impedance of narrow as well as wide strips. In combination with the incremental inductance rule,[3] the new formula can be used for the analysis of the Q factor and attenuation of microstrip transmission lines of an almost arbitrary shape.

In his 1977 paper, Wheeler emphasized that his procedure was very suitable for programmable pocket calculators. When dispersion effects are also taken into account, which can be easily done by applying the Getsinger model,[4] a procedure is obtained for complete analysis of microstrip transmission lines at microwave frequencies. Such analysis programs, which will be described here, have been written for the TI59 and HP67 calculators. Starting with specified microstrip dimensions and specified properties of the substrate material, the programs compute the characteristic impedance Z_o and the effective dielectric constant ϵ_{effo} for low frequencies. Furthermore, the programs compute the frequency dependent values of the Q factor, the attenuation constant α, and the dispersive dielectric constant ϵ_{eff}. In order to also permit analysis of laminates with aluminum backing, the programs are written so that the strip conductivity and the ground plate conductivity are each entered separately. This article will discuss the program written in algebraic logic of the TI59 calculator, with the differences pertaining to the reverse Polish notation of the HP67 calculator pointed out in square brackets [ ].

LOSSLESS MICROSTRIP

The computation of the characteristic impedance is accomplished by the steps shown in Figure 1. The physical width w of the strip conductor is first corrected by amount Δw in order to obtain the equivalent width w' (Formulas (1), (2), and (3)). This computation is performed in the subroutine SBR 001 which is located between positions 001 and 076. The output of this subroutine is the value of the corrected width w' which is stored in register 12.



$$(1)\qquad a = \frac{1 + 1/\epsilon_r}{2}$$

$$(2)\qquad \Delta w = \frac{t}{\pi}\left\{1 + \ln\left(\frac{4}{\sqrt{\left(\frac{t}{h}\right)^2 + \left[\frac{1}{\pi\left(\frac{w}{t} + 1.1\right)}\right]^2}}\right)\right\}$$

$$(3)\qquad w' = w + a\,\Delta w$$

$$(4)\qquad b = \left(\frac{14 + 8/\epsilon_r}{11}\right)\cdot\left(\frac{4h}{w'}\right)$$

$$(5)\qquad Z_o = \frac{42.4}{\sqrt{\epsilon_r + 1}}\ \ln\left\{1 + \left(\frac{4h}{w'}\right)\left[b + \sqrt{b^2 + a\pi^2}\right]\right\}$$

Fig. 1 Lossless microstrip.

TABLE I

Strokes TI59	Strokes HP67	Comments
2 STO 11	2 STO B	enter h
1 STO 12	1 STO C	enter w
.01 STO 13	.01 STO D	enter t
10 STO 14	10 STO E	enter ϵ_r
SBR 001	GSB a	compute w′
SBR 080		compute Z_o

The computation of the characteristic impedance according to Equation (5) is performed in the subroutine 080, located between positions 080 and 158. The result of computation is Z_o which appears in the display register. [In the HP67 program, computations of w′ and of Z_o are both performed in subroutine a.]

Subroutines 001 and 080 may be used independently of the rest of the program, if only the properties of a lossless microstrip are of interest. As an example, the characteristic impedance will be computed for the following microstrip transmission line: h=2 mm, w=1 mm, t=0.1 mm, ϵ_r=10. Listed in Table I are the instructions which are to be entered in the calculator.

After keying the instruction "SBR 001," the calculator will briefly flash the values of w and w′, and then display steadily the value of w′. In the present example, the brief displays will be "1." and then "1.013161134." The latter value then reappears in the permanent display. When the last instruction "SBR 080" is keyed in, the resulting value of Z_o appears in the display, first as a flash, then steadily. In the present example, the value is 65.7139774. The values beyond the third digit are meaningless, since Wheeler's procedure has an accuracy of 2% or better. These digits are presented here only as the verification of the proper execution of the program. [w and w′ flash and Z_o is displayed.]

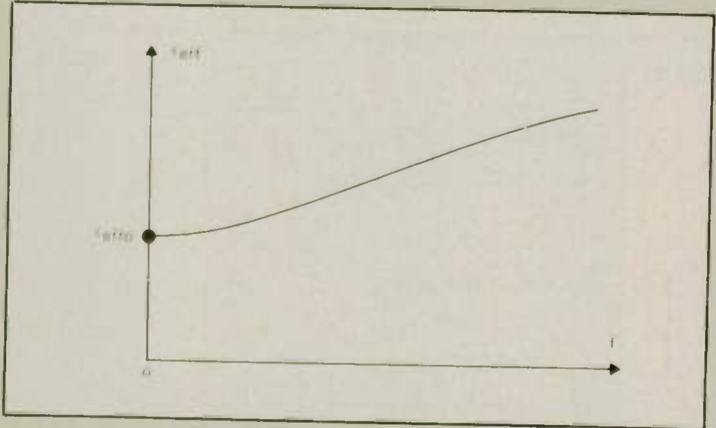
To find the effective dielectric constant of this microstrip, the characteristic impedance must be computed again for the same microstrip dimensions but with dielectric removed. The characteristic impedance of the air filled microstrip is denoted by Z_o'. The effective dielectric constant at low frequencies ϵ_{effo} can be now computed by Equation (6). If the calculator has stayed on after completing the previous example, ϵ_{effo} may be found as in Table II. The value of ϵ_{effo} seen in the display is 6.3239161.

TABLE II

Strokes TI59	Strokes HP67	Comments
1 STO 14	1 STO E	enter ϵ_r=1
1 STO 12		enter w, because register 12 presently contains value of w′ from the previous example
SBR 001	GSB a	compute w′ for the air dielectric
SBR 080		compute Z_o' for the air dielectric
: 65.714 = x^2	65.714:x^2	divide by previous Z_o and square the result

DISPERSION

Knowledge of the effective dielectric constant is important for calculations of the wavelength in the microstrip, which is $1/\sqrt{\epsilon_{eff}}$ times the free space wavelength. ϵ_{eff} is a slowly varying function of frequency, as indicated in Figure 2. This effect is known under the name dispersion. The low-frequency value of the effective di-



$$\text{(6)} \quad \epsilon_{effo} = \left(\frac{Z_o'}{Z_o}\right)^2$$

$$\text{(7)} \quad f_p\,(\text{GHz}) = \frac{Z_o}{0.8\,\pi\, h\,(\text{mm})}$$

$$\text{(8)} \quad G = 0.6 + 0.009\, Z_o$$

$$\text{(9)} \quad \epsilon_{eff} = \epsilon_r - \frac{\epsilon_r - \epsilon_{effo}}{1 + G\left(\frac{f}{f_p}\right)^2}$$

Z_o ..... computed with dielectric removed

Z_o ..... computed with dielectric present

Fig. 2 Dispersion.

ϵ_{effo}. Behavior at other frequencies may be approximately described by Equation (9) which has been derived by Getsinger.[4] In this formula f_p and G are two auxiliary constants defined by Equations (7) and (8). Note that the units selected for the program are millimeters for h, and gigahertz for f and f_p.

The dispersive value ϵ_{eff} is computed in subroutine 180, located between positions 180 and 230. [On HP67, ϵ_{eff} is computed in the main program, and may be verified only by observing the final result in register E.] After execution, the output is contained in the display register. To verify whether subroutine 180 is working properly, we may compute the following example which is taken from Getsinger's ϵ_{effo}=7.37, Z_o=29 Ω. In order to evaluate the effective dielectric constant at 10 GHz, we must enter the following instructions in the calculator (see Table III). The resulting ϵ_{eff} is in agreement with Getsinger's Figure 4.

TABLE III

Strokes	Comments
.05 x 25.4 = STO 01	enter h in mm
10.1 STO 04	enter ϵ_r
10 STO 08	enter f in GHz
29 STO 25	enter Z_o in Ω
7.37 STO 26	enter ϵ_{effo}
SBR 180	display: 8.763745531

SKIN EFFECT

The skin depth δ depends on the frequency of operation and on the conductivity of the material. The two typical materials for microstrip conductors are copper and aluminum. The conductivity of copper is σ=5.8 x 10^7 S/m (same as mhos/m), and the conductivity of aluminum is σ = 3.62 x 10^7 S/m. In order to avoid entering the conductivity into the calculator for each computation, the conductivity of copper is already incorporated in Formula (10). Only the relative conductivity, σ_r, has to be entered. For copper, σ_r = 1, and for aluminum σ_r = 3.62/5.8 = 0.62.

The skin depth is computed by subroutine 160 [subroutine b]. In order to check the operation of this subroutine, we will compute the skin depth of aluminum at 2 GHz. The instructions for the calculator are given in Table IV. Therefore, the skin depth is approximately .0019 mm, or 1.9 μm.

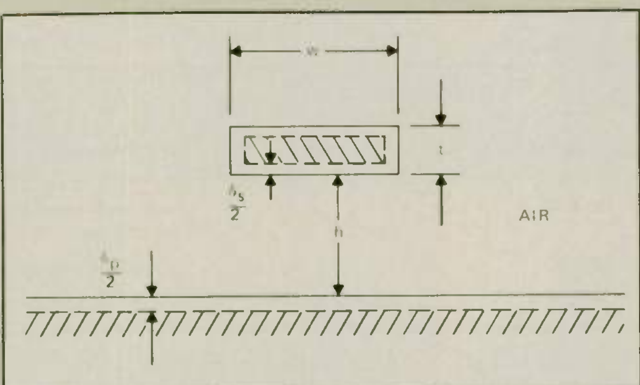
The lossy in microstrip consist of dielectric losses and conductor losses. They may be expressed in terms of Q factors: Q_d for dielectric losses, Q_c for conductor losses. Instead of Q factor, Wheeler prefers to use the power factor p, which is identical to 1/Q.

TABLE IV

Strokes TI59	Strokes HP67	Comments
2 STO 08	2 STO 8	enter f
.62 STO 17	.62 Enter	enter σ_r
SBR 160	GSB b	display: .00187670

The dielectric losses in the microstrip transmission line are computed from the dielectric dissipation factor tan δ, usually given by the manufacturer of the dielectric substrate. For most substrates, tan δ has a value between 0.001 and 0.0001. Since only a portion of the total electric field in microstrip transmission line is contained within the dielectric material, the value of tan δ is to be multiplied by the Wheeler's "filling fraction," as seen in Equation (11).

Computation of the conductor losses is based on the skin effect consideration which is illustrated in Figure 3. Note that in this



Dimensions (when ϵ_r = 1)			Result
h	w	t	Z_o'
$h + \delta_p / 2$	w	t	Z_o''
$h + \delta_s / 2$	$w - \delta_s$	$t - \delta_s$	Z_o'''

(10) $$\delta\ (mm) = \frac{1}{20\pi\sqrt{f\,(GHz) \cdot 58 \cdot \delta_r}}$$

(11) $$\frac{1}{Q_d} = \frac{1 - 1/\epsilon_{eff}}{1 - 1/\epsilon_r} \tan\delta$$

(12) $$\frac{1}{Q_c} = \frac{Z_o'' - Z_o' + Z_o''' - Z_o'}{Z_o'}$$

(13) $$Q = \frac{1}{1/Q_c + 1/Q_d}$$

(14) $$\alpha\ (dB/m) = 90.96\sqrt{\epsilon_{eff}}\ \frac{f\,(GHz)}{Q}$$

Fig. 3 Losses.

computation the dielectric has been removed, and the whole space between conductors is filled with air. The characteristic impedance for the air-filled transmission line must be computed three times, the corresponding results being denoted Z_0', Z_0'', and Z_0'''.

The first of these characteristic impedances, Z_0', is computed for the air-filled microstrip made out of perfectly conducting materials (skin depth is zero); thus, the dimensions are h, w, and t. The second characteristic impedance, Z_0'', is computed for a microstrip in which the ground plane conductor has been receded by one-half of the corresponding skin depth. Finally, characteristic impedance Z_0''' is computed for a microstrip in which all the sides of the strip conductor have been receded by one-half of the skin depth for the strip conductor. Using the values of Z_0', Z_0'', and Z_0''', the inverse of Q_c can be computed by (12). Afterwards, the overall Q and the attenuation constant are obtained from (13) and (14).

The entire computation is controlled by the main program which is stored between position 240 and postion 447 [000 and 118]. The examples which have been computed above are only the intermediate stages of the entire analysis, and they have been necessary only for a better familiarization with the program. The entire analysis proceeds through all the intermediate states automatically. The user must only enter the input data into registers 01 through 08, [1 through 8], call the main program by the command "SBR 240" [GSB a], and then read the results from the registers 25 through 29 [A through E].

The computational procedure will be explained on the following example. Suppose the microstrip dimensions are h=1 mm, w=2.75 mm, and t=0.1 mm. The dielectric constant of the substrate is ϵ_r=2.5 and its dissipation factor is tan δ=0.001. The strip is made of copper and the ground plate is made of aluminum. The instructions for the calculator shown in Table V.

TABLE V

Strokes TI59	Strokes HP67	Comments
1 STO 01	1 STO 1	h in mm
2.75 STO 02	2.75 STO 2	w in mm
.1 STO 03	.1 STO 3	t in mm
2.5 STO 04	2.5 STO 4	ϵ_r of the substrate
1 STO 05	1 STO 5	σ_r for the strip conductor
.62 STO 06	.62 STO 6	σ_r for the ground plate
.001 STO 07	.001 STO 7	tan δ of the substrate
2 STO 08	2 STO 8	f in GHz
SBR 240	GSB a	execute the main program

The calculator will now compute a sequence of four different characteristic impedances Z_0, Z_0', Z_0'', Z_0''' through the use of subroutines 001, 080, and 160 [a and b] which are familiar from the earlier discussion. In each computation, the values of w, w' and the corresponding characteristic impedance will be flashed on the display. In this way, the user can monitor the progress of the computation. After the fourth characteristic impedance has flashed in the display, the Q factor appears in permanent display signifying that the computation has been computed [on HP67, display contains α]. The entire computation takes about 50 seconds [35 s]. For the example at hand, the first six digits of the display are 382.047 [.681647]. Because of the slight differences in computational techniques, the results computed by the two calculators disagree in the last one (or several) digits. In the results presented here, only those digits are shown which are identical on both calculators. All the pertinent results may now be read from the appropriate registers in Table VI. It can be seen that the dispersion is not yet pronounced, ϵ_{eff} differs only slightly from ϵ_{effo}. In the effective dielectric constant at 10 GHz is now to be computed, the procedure is as follows in Table VII. The effective dielectric constant has increased from 2.04 to 2.14.

TABLE VI

Strokes TI59	Strokes HP67	Display	Comments
RCL 25	RCL A	49.458131	Z_0 in Ω
RCL 26	RCL B	2.04437532	ϵ_{effo}
RCL 27	RCL C	382.047	Q
RCL 28	RCL D	.681647	α in dB/m
RCL 29	RCL E	2.04924136	ϵ_{eff}

TABLE VII

Strokes TI59	Strokes HP67	Display	Comments
10 STO 08	10 STO 8		enter new operation frequency
SBR 240	GSB a		repeat the analysis
RCL 29	RCL E	2.14120670	ϵ_{eff} at 10 GHz

LIMITATIONS

The display of the pocket calculator has ten digits, but only the first two digits of the displayed results may be considered reliable, and even those must be viewed with some reservations. First of all, very seldom can the microstrip dimensions be fabriated with two digits of accu-racy. Also, the cross section of the strip conductor only roughly approximates a rectangular shape (the edges are not smooth, etc.).

As far as the theoretical value of the characteristic impedance is concerned, Wheeler has found that his formula is accurate within 2%, with a typical error smaller than 1%.

The thickness t used in computations should be limited by:

$$t < w.$$

Thus, the cross section of the strip may be either a flat rectangle, such as shown in **Figures 1** and **3**, or up to a square. Wheeler says that for a square shape more accurate results are obtained if the strip is narrow (i.e. when $w < h$), but he shows an example in which the correct result is obtained for a square shape on a wide strip which has $w = 2h$.

The range of widths for which Wheeler has presented his results is:

$$0.1\,h \leqslant x \leqslant 10\,h.$$

Another limitation of the described procedure stems from the fact that the loss computation is based on the assumption of conductor dimensions being much larger than the skin depth. At low frequencies, this assumption may be violated, because the skin depth δ may become larger than the conductor thickness t. In such a case, the corrected thickness $t - \delta_s$ for computation of Z_o''' comes out to be a negative number. The computation of Z_o''' proceeds formally in the same way as before, based on w' which is smaller than w. The main program has a built-in warning against this situation. If $\delta_s > t$, the final display is not anymore set equal to Q, but the display is set to "-1." When this signal is encountered at the end of execution, it serves only as a warning. The computation is completed as usual, and the results are stored in registers 25 to 29 as before. However, the values of Q and α are not reliable in this case. The attenuation of strips which are thin in comparison with the skin depth has been studied by Horton, Easter, and Gopinath,[5] and also by Rizzoli.[6] Both studies show that when $t \leqslant 2\delta$, the attenuation becomes much larger than the value computed by the method described here.

[For the HP program execution stops with the value of $t - \delta_s$, a negative number, displayed in the register. The correct value of Z_o is still available in register A.]

REFERENCES

1. Wheeler, H. A., "Transmission Properties of Parallel Strips Separated by a Dielectric Sheet," *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-13, March 1965, pp. 172-185.
2. Wheeler, H. A., "Transmission-Line Properties of a Strip on a Dielectric Sheet on a Plane," *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-25, Aug. 1977, pp. 631-647.
3. Wheeler, H. A., "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, Sep. 1942, pp. 412-424.
4. Getsinger, W. J., "Microstrip Dispersion Model," *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-21, Jan. 1973, pp. 34-39.
5. Horton, R., B. Easter, A. Gopinath, "Variation of Microstrip Losses with Thickness of Strip," *Electron Lett.*, Vol. 7, 1971, p. 490.
6. Rizzoli, V., "Losses in Microstrip Arrays," *Alta Frequenza*, Vol. 14, No. 2, 1975, pp. 32E to 40E.

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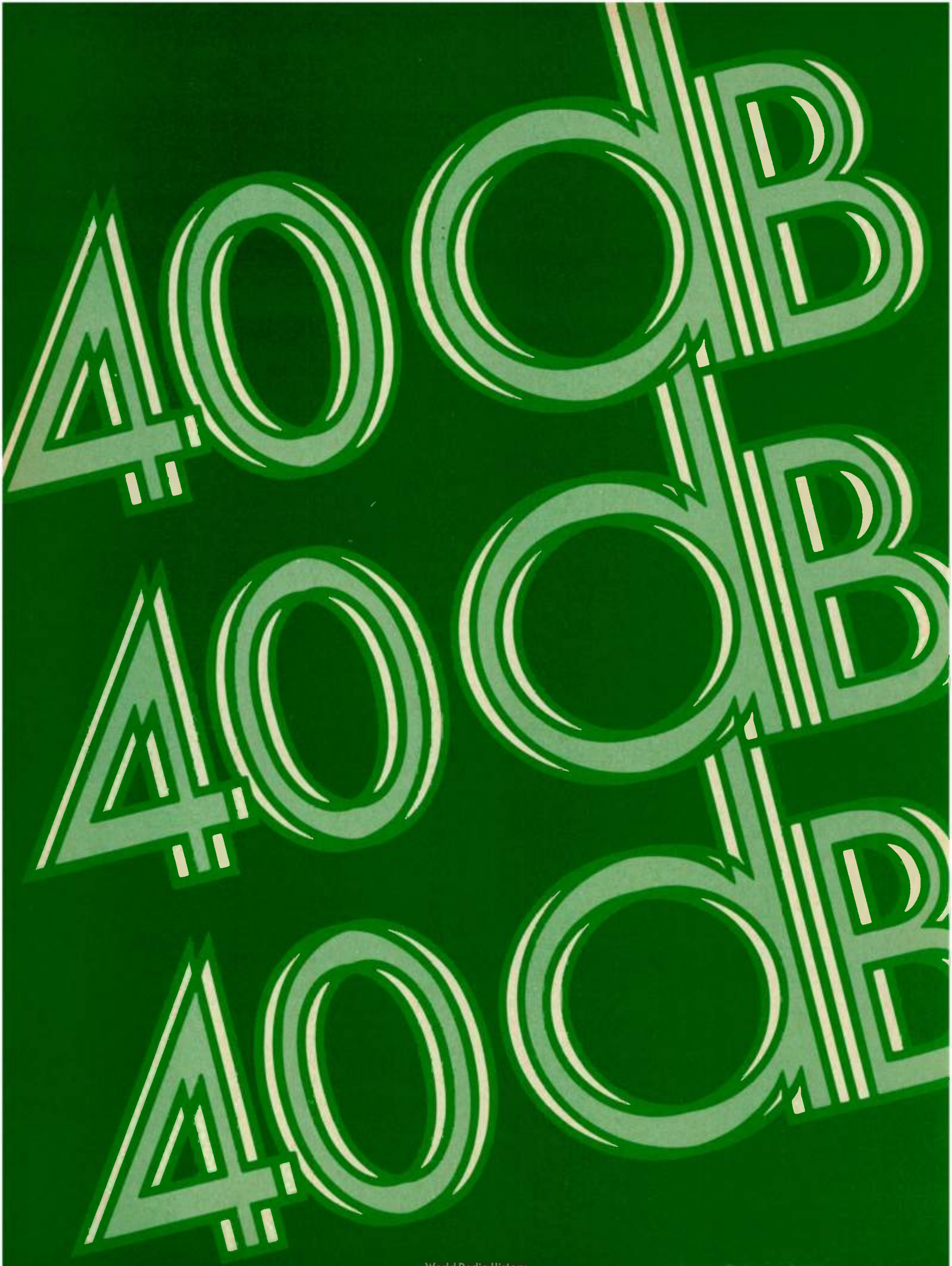
Mark Tew is an assistant professor of Electrical Engineering at the University of Mississippi. He received the Ph.D. from the University of Illinois in 1979. Prior to that, he was an antenna engineer with TRW Systems Group, and research engineer with Kaman Sciences Corporation. He received the B.S.E.E. (with highest honors) in 1971 and M.S. in 1973, both from the University of Mississippi.

"HP-67 PROGRAM"

STEP	COMMAND	CODE	STEP	COMMAND	CODE	STEP	COMMAND	CODE
001	Label A	31 25 11	011	RCL 3	34 03	021	RCL 1	34 01
002	2	02	012	STO D	33 14	022	+	61
003	00	0	013	GSB a	32 22 11	023	STO B	33 12
004	STO (i)	35 33	014	1	01	024	GSB a	32 22 11
005	RCL 4	34 04	015	STO E	33 15	025	RCL 5	34 05
006	STO E	33 15	016	GSB a	32 22 11	026	GSB b	32 22 12
007	RCL 1	34 01	017	RCL 6	34 06	027	STO 9	33 09
008	STO B	33 12	018	GSB b	32 22 12	028	2	02
009	RCL 2	34 02	019	2	02	029	÷	81
010	STO C	33 13	020	÷	81	030	RCL 1	34 01

(Program Continued)

(continued on page 46)


40dB
40dB
40dB

STEP	COMMAND	CODE	STEP	COMMAND	CODE	STEP	COMMAND	CODE
031	+	61	093	RCL 4	34 04	155	RCL C	34 13
032	STO B	33 12	094	1/x	35 62	156	PAUSE	35 72
033	RCL 2	34 02	095	1	01	157	+	61
034	RCL 9	34 09	096	−	51	158	PAUSE	35 72
035	−	51	097	÷	81	159	1/x	35 62
036	STO C	33 13	098	RCL 7	34 07	160	4	04
037	RCL 3	34 03	099	x	71	161	x	71
038	RCL 9	34 09	100	RCL C	34 13	162	RCL B	34 12
039	−	51	101	+	61	163	x	71
040	STO D	33 14	102	ENTER	41	164	STO O	33 00
041	$x < 0$	31 71	103	1/x	35 62	165	8	08
042	R/S	84	104	STO C	33 13	166	RCL E	34 15
043	GSB a	32 22 11	105	R↓	35 53	167	÷	81
044	isz	31 34	106	RCL 8	34 08	168	1	01
045	isz	31 34	107	x	71	169	4	04
046	RCL (i)	34 24	108	RCL E	34 15	170	+	61
047	+	61	109	$\sqrt{x}$	31 54	171	1	01
048	isz	31 34	110	x	71	172	1	01
049	RCL (i)	34 24	111	9	09	173	÷	81
050	÷	81	112	0	00	174	x	71
051	2	02	113	·	83	175	ENTER	41
052	−	51	114	9	09	176	x^2	32 54
053	STO C	33 13	115	6	06	177	π	35 73
054	RCL (i)	34 24	116	x	71	178	x^2	32 54
055	RCL A	34 11	117	STO D	33 14	179	RCL 9	34 09
056	÷	81	118	R/S	84	180	x	71
057	x^2	32 54	119	LABEL a	32 25 11	181	+	61
058	STO B	33 12	120	RCL C	34 13	182	$\sqrt{x}$	31 54
059	RCL 4	34 04	121	RCL D	34 14	183	+	61
060	x⇄y	35 52	122	÷	81	184	RCL O	34 00
061	−	51	123	1	01	185	x	71
062	RCL 8	34 08	124	·	83	186	1	01
063	RCL 1	34 01	125	1	01	187	+	61
064	x	71	126	+	61	188	1n	31 52
065	π	35 73	127	π	35 73	189	4	04
066	x	71	128	x	71	190	2	02
067	·	83	129	1/x	35 62	191	·	83
068	8	08	130	x^2	32 54	192	4	04
069	x	71	131	RCL D	34 14	193	x	71
070	RCL A	34 11	132	RCL B	34 12	194	RCL E	34 15
071	÷	81	133	÷	81	195	1	01
072	x^2	32 54	134	x^2	32 54	196	+	61
073	RCL A	34 11	135	+	61	197	$\sqrt{x}$	31 54
074	·	83	136	$\sqrt{x}$	31 54	198	÷	81
075	0	00	137	4	04	199	PAUSE	35 72
076	0	00	138	÷	81	200	STO (i)	33 24
077	9	09	139	1/x	35 62	201	ds z	31 33
078	x	71	140	ln	31 52	202	RETURN	35 22
079	·	83	141	1	01	203	LABEL b	32 25 12
080	6	06	142	+	61	204	RCL 8	34 08
081	+	61	143	π	35 73	205	x	71
082	x	71	144	÷	81	206	5	05
083	1	01	145	RCL D	34 14	207	8	08
084	+	61	146	x	71	208	x	71
085	÷	81	147	RCL E	34 15	209	$\sqrt{x}$	31 54
086	RCL 4	34 04	148	1/x	35 62	210	π	35 73
087	x⇄y	35 52	149	1	01	211	x	71
088	−	51	150	+	61	212	2	02
089	STO E	33 15	151	2	02	213	0	00
090	1/x	35 62	152	÷	81	214	x	71
091	1	01	153	STO 9	33 09	215	1/x	35 62
092	−	51	154	x	71	216	RETURN	35 22

(continued on page 48)

Military Users
Get M-OV on your side

1. M-OV Magnetrons attract special attention!

M-OV have been supplying magnetrons for over 40 years and vacuum tubes for over 60 years.

Many types are now available, for example, small rugged metal ceramic magnetrons built to withstand the rigours of GW applications with an operational readiness time of 3 seconds from switch on of simultaneous heater and h.t. The kind of customers who have M-OV on their side speak for themselves... Seaslug, Rapier, Bloodhound, Sea Dart, Sea Wolf, Skyflash to name but a few.

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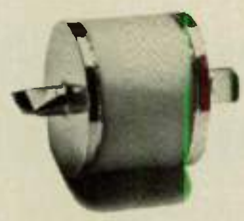
1.

Type	Peak output Power (kW)	Peak anode Voltage (kV)	Peak anode Current (A)	Pulse Duration (μs)	Duty Cycle
MAG15	8·00	5·80	5·0	0·12	0·0015
MAG17	0·30	0·85	1·5	0·35	0·0014
MAG19	35·0	11·0	11·0	0·5	0·001
MAG23	1·50	2·25	3·0	0·25	0·001

2.



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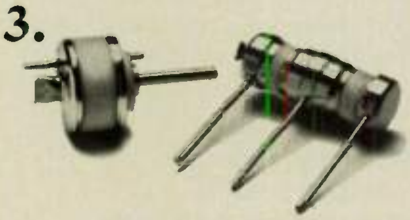

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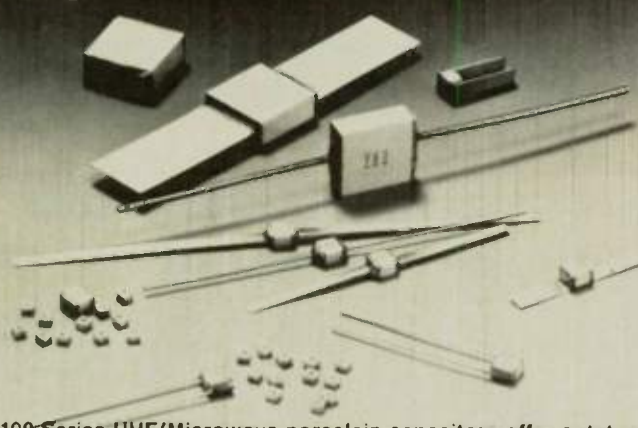

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CIRCLE 28 ON READER SERVICE CARD

(from page 46) CALCULATOR

TI-59 PROGRAM

THICKNESS CORRECTION:

```
001 ( RCL 13 : RCL 11 ) x² STO 15
011 ( ( RCL 12 2nd Pause                    w
016 : RCL 13 + 1.1 ) X 2nd π ) x²
028 1/x SUM 15 ( ( ( RCL 15 √x 1/x
038 X 4 ) lnx + 1 ) : 2nd π )
048 STO 15 RCL 13 2nd Prd 15 ( (
056 RCL 14 1/x + 1 ) : 2 ) STO 16
067 2nd Prd 15 RCL 15 SUM 12
073 RCL 12 2nd Pause                        w'
076 INV SBR
```

CHARACTERISTIC IMPEDANCE:

```
080 ( RCL 11 X 4 : RCL 12 ) STO 17
091 ( ( 14 + 8 : RCL 14 ) : 11 )
105 STO 15 RCL 17 2nd Prd 15 (
112 2nd π x² X RCL 16 ) STO 18
120 (RCL 15 x² ) SUM 18 RCL 18 √x
130 SUM 15 ( ( RCL 15 X RCL 17 + 1
141 ) lnx X 42.4 : ( RCL 14 + 1 )
155 √x ) 2nd Pause                          Zo
158 INV SBR
```

SKIN DEPTH:

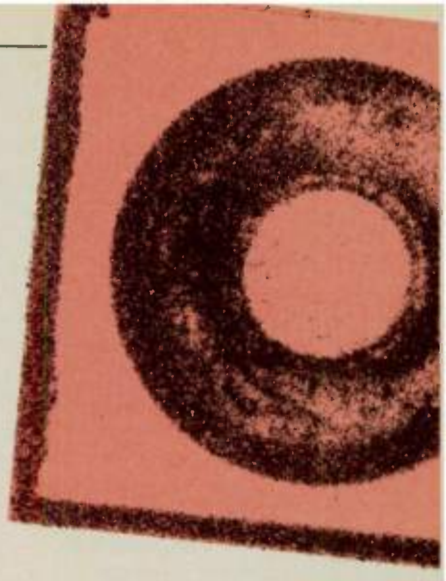
```
160 ( ( RCL 08 X RCL 17 X 58 ) √x
172 X 20 X 2nd π ) 1/x
179 INV SBR                                 δ
```

DISPERSION:

```
180 ( ·8 X 2nd π X RCL 01 X
189 RCL 08 : RCL 25 ) x² STO 15 (
199 RCL 25 X .009 + .6 ) 2nd Prd 15
212 1 SUM 15 ( RCL 04 - ( RCL 04 -
223 RCL 26 ) : RCL 15 )                     εeff
230 INV SBR
```

MAIN PROGRAM:

```
240 RCL 01 STO 11 RCL 02 STO 12
248 RCL 03 STO 13 RCL 04 STO 14
256 SBR 001 SBR 080 STO 25                  Zo
264 1 STO 14 RCL 02 STO 12 SBR 001
274 SBR 080 STO 10                          Z'o
279 RCL 02 STO 12 RCL 06 STO 17
287 ( SBR 160 : 2 ) STO 21                  δp/2
296 SUM 11 RCL 02 STO 12 SBR 001
305 SBR 080 STO 22                          Z''o
310 RCL 05 STO 17 RCL 02 STO 12
318 SBR 160 STO 23                          δs
323 INV SUM 12 RCL 01 STO 11
330 ( RCL 23 : 2 ) SUM 11 RCL 23
340 INV SUM 13 SBR 001 SBR 080              Z'''o
349 SUM 22 RCL 10 INV SUM 22
356 INV SUM 22 ( RCL 22 : RCL 10 )
366 STO 19                                  1/Qc
368 ( RCL 10 : RCL 25 ) x² STO 26           εeffo
378 SBR 180 STO 29                          εeff
383 ( ( 1 - RCL 29 1/x ) : ( 1 -
395 RCL 04 1/x ) X RCL 07 ) STO 20          1/Qd
405 SUM 19 RCL 19 1/x STO 27                Q
412 ( RCL 29 √x X RCL 08 X 90.96 :
426 RCL 27 ) STO 28                         α
431 0. x⇌t RCL 13 INV 2nd x≥t A
439 RCL 27 2nd Pause INV SBR
444 2nd Lbl A 1. +/-
448 R/S
```



Novel PIN Diode for MIC Phase Shifter

A novel PIN diode structure utilizing borosilicate glass in an etched moat around the diode mesa offers a low cost diode passivation technique. Diode chips made in this form have been utilized to make an X-band MIC phase shifter measuring only 20 x 41 x 10 mm yet operating to 300 - 500 W peak RF power (depending upon the diode breakdown voltage employed with short circuit loads.

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Electronics Equipment Division
Toshiba Corporation
Kawasaki, Japan

INTRODUCTION

High power PIN diode phase shifters have been reported+ for use at L- and S bands.[1,2] These are operable to peak RF powers of 1 kW, as required in surveillance type radars operating at these frequencies.

At X-band frequencies and above, however, it becomes increasingly difficult to design a phase shifter having a cross section which does not exceed a half-wavelength in any dimension, because the physical size of the phase shifter is not insignificant compared with the half wavelength dimension at these high frequencies. Equally important, the phase shifter must be made very light weight, since X-band radars are typically used for airborne applications.

In this paper describes the development of a small size and light weight X-band 3 bit MIC phase shifter having peak RF power handling of 300 W (with 500 volt breakdown diodes) or 500 W (with 840 volt breakdown).

Emphasized in the paper are 1) the diode structure and characteristics, 2) the circuit configuration and design criteria, and 3) measured RF performance of the phase shifter, both under high and low power.

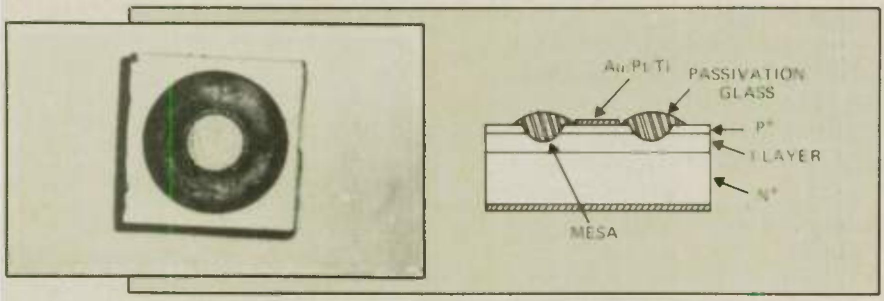

Fig. 1 Grooved mesa PIN diode. (a) photograph of a chip and (b) cross sectional view.

GLASSED MOAT PIN DIODES

The maximum RF power sustainable by a PIN diode for short pulsed conditions in the reversed bias state is limited by the magnitude of the RF voltage swing compared to the diode breakdown voltage. Accordingly, higher diode breakdown voltage results in higher peak power performance for the phase shifter.

Three types of diodes were developed for the present X-band phase shifter. Design parameters of these are summarized in Table 1. The type A_1 diode has a junction capacitance, C_j, of 0.10 pF and breakdown voltage, V_B, of 500 volt. The type A_2 diode is the same as the type A_1 except the $C_j = 0.15$ pF. the type B diode, with $C_j = 0.10$ pF, has higher V_B than the type A_1 and A_2.

Diode wafers were fabricated by p-type diffusion into the I layer, which had been grown epitaxially on an N+ substrate. The diode structure is shown in Figure 1. The mesa is formed by a groove which does not reach the N+ substrate, and is covered with lead-boro-silicate glass for passivation. This grooved mesa structure offers greater diode capaci-

TABLE 1

DESIGN PARAMETERS OF PIN DIODES

Type	Junction Capacitance C_j at 100 V	Forward Resistance R_s at 100 mA	Breakdown Voltage V_B	I Region Width	Chip Size
A_1, A_2	A_1 : 0.10 pF A_2 : 0.15 pF	0.74 Ω	500 V	40 μm	500 μm □
B	0.10 pF	0.88 Ω	840 V	50 μm	700 μm □

+ J. F. White, *Semiconductor Control*, Artech House, Dedham, MA, 1977, p. 464.

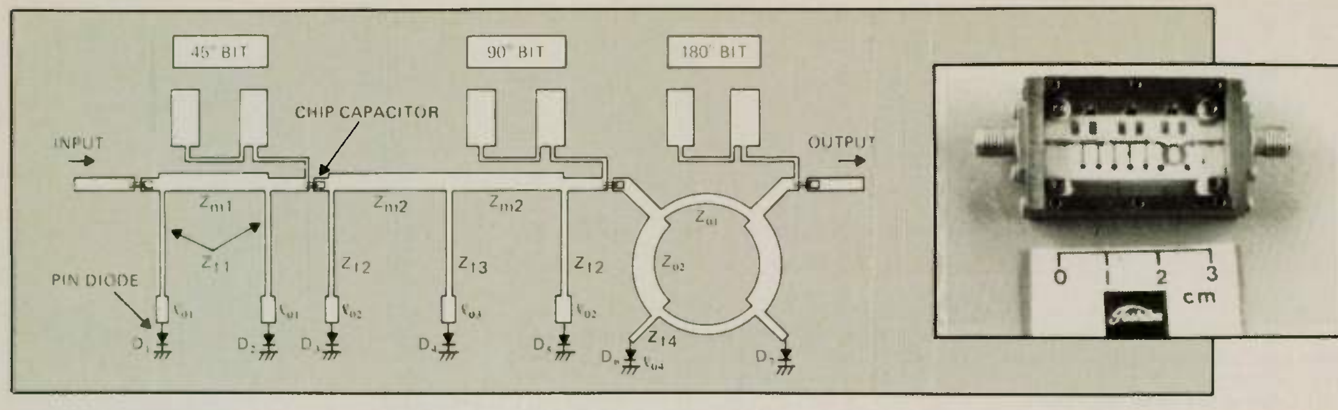

Fig. 2 (a) 3-bit circuit configuration and (b) photograph of a phase shifter.

tance reproducibility than does the conventional technique in which the mesa structure is etched through (to the N+ substrate). It does so, however, at the sacrifice of breakdown voltage. The capacitance tends to be more reproducibly obtained because, when the etching proceeds only part way into the I layer, it does not encroach as much on the cylindrical center area which defines the diode's capacitance. On the other hand, because the complete I layer boundary of the diode is not totally covered by the glass some leakage path ultimately is encountered as the applied high voltage causes wide spreading of the depletion zone; and therefore a lesser breakdown is experienced. Sufficient breakdown, however, is realized to permit the desired peak power handling for the phase shifter, as will be seen. In this case, after some experimental tradeoffs were conducted between junction capacitance variation and realizable breakdown voltage, a groove depth of 40 to 50 microns was chosen. The resultant structure, shown diagrammatically in Figure 1, was used to produce diodes having 500 volts of breakdown (with 40 μm groove depth) to 840 volts (with 50 μm groove). A subset consisting of 0.10 and 0.15 pF junction capacitance for the 500 volt breakdown diodes was used to accommodate the extra capacitance appropriate for smaller phase shift bits. These can be used in both 300 W and 500 W circuits, since voltage stress is low in these positions. The resultant design parameters of these three diode types are shown in Table 1.

PHASE SHIFTER CIRCUIT DESIGN

As shown in Figure 2a, the 3-bit phase shift circuit is composed of a 45° two-stub loaded line bit, a 90° three-stub loaded line bit and a 180° branchline hybrid bit. The 180° section affords moderately wideband performance around 9 GHz by tolerating ± 10° phase shift error. (See footnote p. 49.) Single plate chip capacitors are used for dc isolation between individual bits, and the whole circuit is integrated on a 13 mm x 0.63 mm alumina substrate.

In the 300 W phase shifter, the type A_1 diode (Table 1) is used for diodes D_4, D_6 and D_7 and type A_2 for the rest of the diodes. In the 500 W phase shifter, diodes D_4, D_6 and D_7 are replaced with the 840 volt, type B diodes.

The diode chip is mounted on a gold plated molybdenum pedestal, which in turn is soldered to the metal ground plane within a hole drilled in the alumina circuit adjacent to the required diode circuit connection. Since it is in this vicinity that the circuit is most likely to have a voltage arc over, possibly between the diode connection wire or strap and the base of the diode or its metal pedestal mount, a silicon rubber compound was applied to the chip after installation. this coating has a thickness of a few tens of microns. Sharp discontinuities of the microstrip circuit could also induce an arc over near the diode holes, consequently, the circuit patterns were modified to have rounded corners in these areas.

MEASURED LOW POWER PERFORMANCE

Electrical performance of the 300 W phase shifter over a 6% fractional bandwidth centered at 9 GHz is summarized in Table 2.

TABLE 2

ELECTRICAL PERFORMANCE OF THE 300 W PHASE SHIFTER

Phase shift bits	3	Max. rated input power	300 W (peak)
Phase shift range	0 ~ 315°	Max. rated input power	5 W (CW)
Max. phase shift error (*)	± 15°	Forward bias supply	+ 2 V, 300 ma/3 bit
Rms phase shift error (*)	8°	Reverse bias supply	–40 V
Insertion phase variation (*) (*)	± 10°	Operating temperature range	–30° to +60 C
Max. insertion loss	2.3 dB	Weight	17 g
Max. VSWR	1.6	RF connectors	SMA type female

(*) Over all bias states and frequencies

(*) (*) Unit to unit

er of 300 W is defined under the condition of 1 microsecond pulse width and 0.001 duty cycle. Measured small signal characteristics of phase shift, insertion loss and SWR are shown in Figure 3.

Performance for the 500 W phase shifter is the same except that more forward bias (+100 milliamperes instead of +50 milliamperes per diode) is used in order to regain the 2.3 dB insertion loss while using the higher voltage (and hence, higher forward resistance) diodes.

HIGH-POWER EVALUATION

Three kinds of high power RF experiments were performed in order to establish the power handling capability of the two phase shifter designs.

First, the dependence of insertion loss on RF input power was measured for the 300 W and 500 W phase shifters using reverse bias voltage (V_R) as a parameter. Figure 4, from which it can be seen that for peak input power levels below 500 W and 900 W respectively, the insertion loss of the all reversed biased circuits (V_R = -40V) is below the corresponding loss of the circuit when all diodes are forward biased. This indicates that, below these RF power levels, little RF heating and/or diode breakdown is induced by the incident RF voltage waveforms.

In the second set of tests, the output port of the phase shifter was terminated with a sliding short circuit which was moved through a half wavelength of travel for each high RF power level (incident at the other port). This test was repeated using increased RF power levels until diode burnout, signified by a dc short-circuited diode, was observed. It was found that the burnout power so obtained depended upon the way in which the RF input power was increased. For example, when the input power was taneously sliding the short circuit termination through all phases as well as simultaneously electronically switching the diode back and forth between forward and reverse bias between RF pulses) the 180° bit diode burned out at P_{in} = 580 W for the 300 W phase shifter design. On the other hand, if the input power was abruptly applied, diode failures in the 180° bit occurred at only P_{in} = 380 W peak. This difference in power handling capability could be due to the relatively long time constant associated with surface charge build up of the PIN diode itself. Alternatively, it could be associated with some transient heating phenomena in the diode, possibly even in the overshoot of RF voltage in the test circuit or in the diode phase shifter circuit. In any case, however, the practical phase shifter must be able to sustain rapid application of rated power and accordingly a rating below 380 W peak is necessary when only the 500 bolt breakdown (type A) diodes are used.

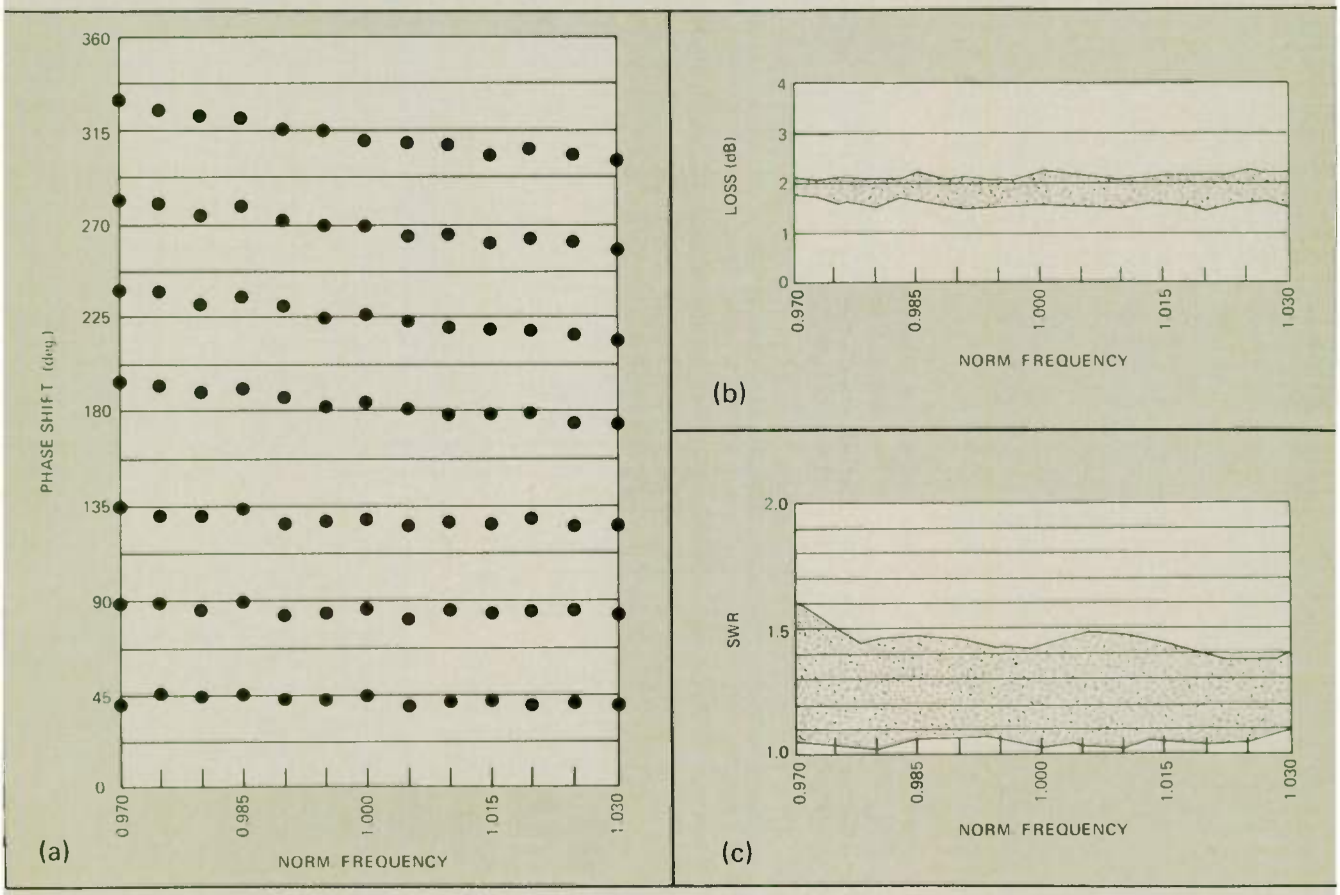

Fig. 3 Small signal performance of the 300 W phase shifter (a) Phase shift, (b) Insertion loss, (c) SWR.

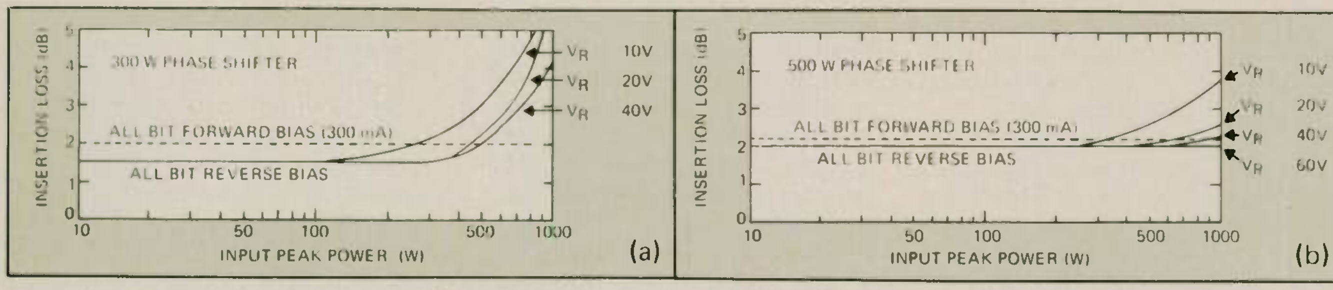

Fig. 4 Dependence of insertion loss on RF input power (a) 300 W phase shifter and (b) 500 W phase shifter.

A third method for evaluating the phase shifter under high power consisted of observing the dc leakage current induced in the diodes when the RF power is applied. This was done in a single diode test fixture consisting of a 50 ohm microstrip line which the diode terminates. The equivalent circuit, including the biasing and oscilloscope measuring hookup, is shown in Figure 5a. In this test it was found that no leakage current was measured for the reverse bias condition (–40 volts) until the input power reached a peak of 130 W. Further increase of P_{in} produced the rectified waveform shown in Figure 5b. With continuing power increase this waveform develops a slight bump near the trailing edge, as shown in Figure 5c. Once the onset of this bump is observed, its magnitude is found to increase rapidly as a function of increasing P_{in}, with burnout typically encountered at P_{in} = 530 W (under the condition that RF was applied quickly from the off to on condition. In a separate analysis it was estimated that 530 W in this experimental fixture corresponded to the 380 W which likewise produced burnout in the 180° bits of the complete phase shifter circuit. This estimate was performed taking into account the additional circuit losses found in the complete phase shifter compared with the lower loss of the single diode test fixture.

Based on the results of these three tests, it is felt that the 300 W rating represents both a conservative and realistic rating for reliable operation of the phase shifters in a complete phased array antenna. Further reliability testing, described in next section, supports this view. Using the same criteria in the 500 W rated design (with positions D_4, D_6 and D_7 occupied by 840 volt breakdown (type B) diodes, burnout occurred at a minimum critical power of 580 W, and the rating of 500 W accordingly was applied in this case.

RELIABILITY TESTING

Four types of reliability tests were conducted to verify the diode and circuit design.

First, ten complete phase shifters were operated at room temperature with an incident peak power of 300 W (at 1 μsec pulses, 0.001 duty cycle and matched loads) for 8000 hours.

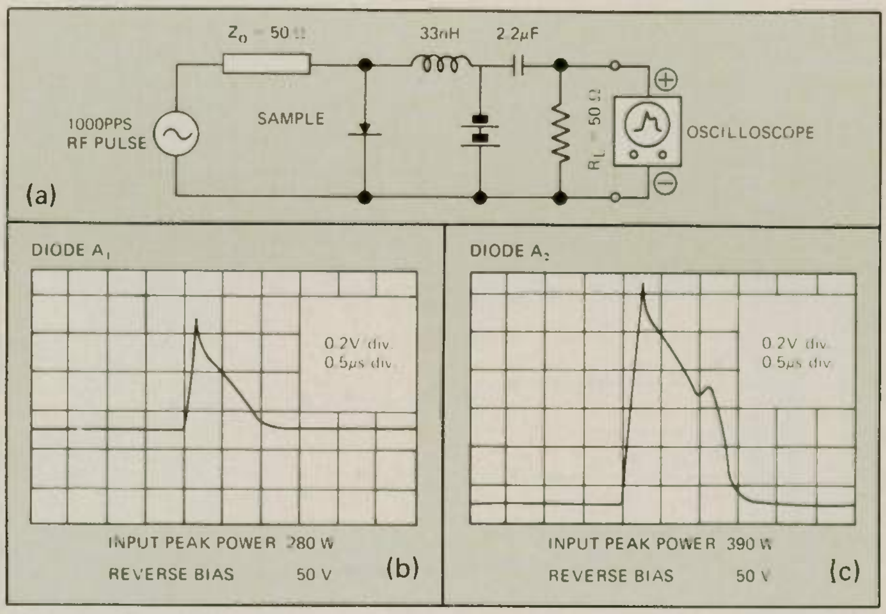

Fig. 5 Rectified current waveforms (a) measurement circuit, (b) waveform at P_{in} = 280 W and (c) at P_{in} = 390 W.

Second, a single phase shifter was switched under an ambient temperature of 100°C from forward (+100 mA) to reverse bias (–40 V) at a 100 Hz rate for 1000 hours.

Third, 50 diodes were biased at 200 volts at an ambient temperature of 60°C and at a relative humidity of 90/ for 2000 hours, then tested to determine whether their reverse dc leakage current at room temperature was below 10 μA at the rated breakdown voltage. No failures were observed for any of these tests, thereby confirming the integrity of both the diode and circuit designs.

Fourth, HTRB (High Temperature Reverse Bias) tests were performed at three levels of temperatures (175, 200, and 245°C) for 10 Type-B diodes each. The diodes were reverse-biased at 400 V peak with a 100 Hz half-wave rectified voltage source. An MTF (Median-Time-to-Failure), or time at which 50% cumulative failure occurs, was found to be 3500, 400, and 10 hours for the 175, 200, and 245°C tests, respectively, with a diode failure criterion of 30% decrease in breakdown voltage. From Arrhenius plots, the MTF of diodes,

(continued on page 82)

This table lists various types of passive microwave components and [illegible] which manufacture them. Companies marked by an asterisk are advertisers in the Microwave Journal and will provide literature for their products in response to Reader Service inquiries. Addresses and telephone numbers for those same companies may be found at the end of the listings.

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Cablewave Systems Inc.							●	●	●			(203) 239-3311
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Credowan Ltd.	●	●			●		●				●	(0243) 670711 (Eng)
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Flann Microwave Instruments Ltd.	●	●	●	●	●						●	Bodmin (0208) 3161 (Eng)
Flexco Microwave								●	●			(201) 627-8442
Frequency Engineering Laboratories	●	●	●	●	●		●				●	(201) 938-9000
Frequency Sources - Contours & West Div.*	●	●			●						●	(408) 249-2850
Frequency Sources - Sources & GHz Div. *			●									(617) 256-8101
Frequency Sources - Wavecom Div. *	●	●									●	(213) 882-3010
Gamma-F Corp.	●	●	●				●				●	(213) 539-6704
General Microwave Corp. *			●		●							(516) 694-3600
GenRad, Inc.			●		●			●			●	(617) 369-4400
W. L. Gore & Associates, Inc. *									●			(302) 738-4880
GTE Sylvania Systems Group - West Div.							●					(415) 966-9111
Harris Corp./PRD Div.			●			●						(516) 364-0400
Hatfield Instruments Ltd.		●	●	●	●						●	(0752) 772773 (Eng)
Herley Industries		●	●	●		●						(516) 364-0100
Hewlett-Packard Co.	●	●	●	●	●					●	●	(415) 856-1501
Huber & Suhner AG Ltd. *	●	●	●		●		●	●	●		●	(071 53 15 15) (Switz)
Hughes Aircraft Co. *		●		●			●				●	(213) 534-2121
Hylectronics Corp.		●	●	●	●						●	(617) 486-8911

Reader Service No.	Filters 174	Couplers 175	Attenuators 176	Switches 178	Phase Shifters 179	Rotary Joints 180	Antennas 181	Connectors 182	Cables 183	Capacitors 184	Power Dividers 185	Telephone No.
Innowave	●											(408) 737-9622
ITT Components Group							●			●		(0803) 550762 (Eng)
JFD Electronic Components Corp.										●		(516) 536-7200
Johanson Dielectrics										●		(213) 848-4465
Johanson Manufacturing Corp.										●		(201) 334-2676
Kay Elemetrics			●									(201) 227-2000
KDI Pyrofilm Corp. *			●							●		(201) 887-8100
Kevlin Manufacturing *						●		●	●			(617) 935-4800
Kings Electronics		●						●				(914) 793-5000
K & L Microwave *	●											(301) 749-2424
Kollmorgen Corp.	●						●					(413) 586-2330
Krytar *		●										(408) 734-5999
LaBarge, Inc., Electronics Div.							●	●	●			(918) 836-7611
Lark Engineering	●											(714) 642-9200
LNR Communications, Inc.	●											(516) 273-7111
Locus Inc. *	●	●									●	(814) 466-6275
Lorch Electronics Corp.	●	●	●		●						●	(201) 569-8282
3M Electronic Products Div.							●	●	●			(612) 733-7408
Marconi Electronic Devices Ltd. *	●	●	●	●	●		●			●	●	(0522) 29992 (Eng)
Marconi Electronics, Inc.						●						(201) 767-7250
Marconi Instr. - Microwave Prod. Div. *		●	●		●		●	●				(0438) 2311 (Eng)
MAST Microwave *		●				●						(617) 273-4640
Maury Microwave Corp. *	●	●	●	●		●		●			●	(714) 987-4715
Mecca Electronics, Inc.		●	●	●							●	(201) 625-0661
Merrimac Industries, Inc. *		●	●	●	●						●	(201) 575-1300
Metex Corp.	●											(201) 287-0800
Microlab/FXR *	●	●	●	●	●						●	(201) 992-7700
Micromega (Bunker Ramo Corp.)	●	●	●								●	(213) 889-2211
Micro Metalsmiths Microwave Ltd.	●	●	●			●					●	(0751) 31671/31620
Micronetics *		●	●	●							●	(201) 767-1320
Microphase	●	●										(203) 661-6200
Microwave Applications Group *	●	●	●		●						●	(213) 882-7333
Microwave Associates, Inc. *	●	●	●	●	●	●	●				●	(617) 272-3000
Microwave Control Co.	●											(201) 458-3000
Microwave Development Labs, Inc. *	●	●	●	●	●	●					●	(617) 655-0060
Microwave Filters *	●	●										(315) 437-3953
Microwave Power Devices *	●	●	●								●	(516) 433-1400
Microwave Products	●	●					●				●	(213) 882-3434
Microwave Research Corp.	●	●	●				●				●	(617) 685-2776
Microwave Semiconductor Corp-Diode Op*										●		(617) 667-7700
Midwest Microwave *		●	●		●						●	(313) 971-1992
Mini Circuits *		●			●						●	(212) 769-0200

Reader Service No.	Filters 174	Couplers 175	Attenuators 176	Switches 178	Phase Shifters 179	Rotary Joints 180	Antennas 181	Connectors 182	Cables 183	Capacitors 184	Power Dividers 185	Telephone No.
Mu-Del Electronics, Inc.	●		●								●	(301) 587-6087
Narda Microwave Corp. *		●	●					●			●	(516) 349-9600
Nore Microwave		●									●	(03708) 4255 (Eng)
Norlin Communications		●									●	(301) 948-5210
Norsal Industries, Inc.		●	●	●	●						●	(516) 234-1200
Nurad, Inc.							●					(301) 462-1700
OK Machine & Tool Co.								●	●			(212) 994-6600
Olektron Corp.	●	●			●		●				●	(617) 943-7440
Omni Spectra, Inc. *	●	●	●	●	●			●	●		●	(617) 272-4046
Omniyig, Inc. *	●											(408) 241-1226
P & H Laboratories	●				●							(213) 882-5616
Philips Ind. - Elcoma Div. *		●	●		●			●		●		(040) 79 11 11 (Neth)
Plessey Avionics & Communications Ltd.						●						01 478 43046 (Eng)
Plessey Connectors Ltd.				●			●					N Hampton 712000
Plessey Hydratec UK	●											2 7489 / 2 7480 (Eng)
Plessey Resistors Ltd.			●									Swindon 36251 (Eng)
Plessey Optoelectronics & Microwave							●					(714) 540-9934
Polarad Electronics, Inc. *							●					(516) 328-1100
Premier Microwave Corp. *	●	●	●	●	●	●	●				●	(914) 939-8900
Prodelin Inc.							●	●	●			(609) 448-2800
Radiall		●	●	●		●		●				(854) 80 40 (Fr)
Radio Research Inst. Co.							●					(303) 792-6666
Raytheon Co.			●	●	●							(617) 899-8400
Resdel Engineering Corp.		●									●	(213) 684-2600
RF Products, Inc.	●	●										(609) 365-5500
RGA Research & Development Co.			●		●							(315) 469-8593
RLC Electronics	●	●	●	●	●						●	(914) 241-1334
Rockland Systems Corp.	●											(201) 767-7900
Rockwell International		●									●	(214) 996-6432
Rohde & Schwarz			●									(201) 575-0750
Rohde & Schwarz GmbH & Co.							●					(4989) 4129-1 (Ger)
Rowe Industries									●	●		(419) 729-9761
RTC La Radiotechnique-Compelec										●		(1) 355 44 99 (Fr)
RYT Industries, Inc.	●											(408) 727-5750
Sage Laboratories, Inc. *	●	●	●	●	●	●					●	(617) 653-0844
Sanders Associates, Inc.	●	●	●	●	●		●	●			●	(603) 669-4615
Scientific-Atlanta, Inc.							●					(404) 449-2270
Sealectro Corp. *	●		●					●				(914) 698-5600
Siemens AG *								●	●	●		(089) 4144-1/722-1 (Ger)
HRB Singer							●					(814) 238-4311
Sivers Labs	●		●	●		●						08-18-03-50 (Sweden)
Socapex								●				(213) 887-0750

Reader Service No.	Filters 174	Couplers 175	Attenuators 176	Switches 178	Phase Shifters 179	Rotary Joints 180	Antennas 181	Connectors 182	Cables 183	Capacitors 184	Power Dividers 185	Telephone No.
Socapex								●				(1) 7229 / 13 (Fr)
Solitron/Microwave *							●	●	●			(305) 287-5000
Struthers Electronics Corp.	●	●	●	●	●	●	●				●	(516) 420-9000
Summit Engineering *		●		●							●	(406) 587-4511
Systron-Donner Corp. - Adv. Comp. Div. *	●											(408) 735-9660
Tasker Systems Div. (Whittaker Corp.)							●					(213) 341-3010)
Tayburn Electronics Inc.							●					(714) 438-5444
Technicraft - Tech Systems Group *	●	●	●		●						●	(203) 283-5801
Tecom Industries *							●					(213) 341-4010
Tekelec-Airtronic *										●		(1) 534-75-35 (Fr)
Teledyne MEC	●											(415) 493-1770
Teledyne Microwave *	●			●								(415) 963-2211
Telonic Berkeley	●	●										(714) 494-9401
Texscan Corp. *	●		●									(317) 357-8781
Thomson-CSF - Microwave Comp. Div. *	●	●	●	●	●						●	(1) 743-96-40 (Fr)
Thomson-CSF Comp. and Materials Ltd.*								●				(256) 29 155 (Eng)
Thomson-CSF GmbH *								●				(89) 76 751
Times Wire & Cable								●	●			(203) 265-2361
Transco Products Inc. *	●	●	●	●			●					(213) 822-0800
Triangle Microwave Inc. *	●	●									●	(201) 884-1423
TRW Capacitors										●		(213) 679-4561
Unaworld Ltd.	●	●	●	●	●	●		●	●	●	●	(0494) 444061 (Eng)
Uniform Tubes	●							●	●			(215) 539-0700
United Microwave *								●	●			(213) 320-1244
UTE Microwave, Inc.	●											(201) 922-1009
UZ, Inc. *				●								(213) 839-7503
Varian Associates *	●		●									(415) 592-1221
Vari-L *											●	(303) 371-1560
Vega Precision Laboratories							●					(703) 938-6300
Voltronics Corp.										●		(201) 887-1517
Watkins-Johnson Co. *	●						●					(415) 493-4141
Wavetek-Indiana	●		●									(317) 783-3221
Weinschel Enginnering *			●					●			●	(301) 948-3434
Western Microwave	●	●									●	(408) 734-1631
W & G Instruments			●									(201) 994-0854
Yig-Tek	●											(415) 244-3240

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Sunnyvale, CA 94086
John Moore
(408) 732 0880

Alan Industries, Inc
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Columbus, IN 47201
William D. Kennedy
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Woburn, MA 01888
Dennis M. Loger
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Kate L. Dwyer
(516) 271 9600

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Bloomfield, CT 06002
Ernest P. Hoder
(203) 242 0761

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W. W. Berridge
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Baytron Company
344 Salem Street
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T. Kozel
(617) 391 1550

– C –

Compac
279-1 Skidmore Rd
Deer Park, NY 11729
Ken Borden
(516) 667 3933

– D –

Delta Microwave
755 Lakefield Road
Unit K
Westlake Village, CA 91361
Richard Reed
(213) 889 6582

Diamond Antenna and Microwave
35 River Street
Winchester, MA 01890
E. N. Andersen
(617) 729 5500

Dielectric Laboratories, Inc
P.O. Box 326
Cazenovia, NY 13015
Alfred Sommer
(315) 655 8710

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James Campbell
(408) 245 6810

Electromagnetic Sciences, Inc
125 Technology Park Atlanta
Norcross, GA 30092
William K. Alverson
(404) 448 5770

Emerson & Cuming
Dewey & Almy Chemical Div
Canton, MA 02021
Jeanne B. O'Brien
(617) 828 3300

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Sunnyvale, CA 94086
Robert Kyle
(408) 733 0611

Engelmann Microwave
Skyline Drive
Montville, NJ 07045
Carl Schrading
(201) 334 5700

English Electric Valve Co. Ltd
Waterhouse Lane
Chelmsford, Essex CM1 2QU
United Kingdom
David Pye
0245 61777

– F –

Ferranti Ltd
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Dundee DD23PN, Scotland
J. M. Lowe
0382 89311

Frequency Sources
Contours & West Div
3140 Alfred Street
Santa Clara, CA 95050
Tom Pinkston
(408) 249 2850

Frequency Sources
Sources & GHz Division
16 Maple Road
Chelmsford, MA 01824
R. C. Antinucci
(617) 256 8101

Frequency Sources
Waveram Division
9036 Winnetka Avenue
Northridge, CA 91324
Harvey J. Elmes
(213) 882 3010

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General Microwave Corporation
155 Marine Street
Farmingdale, NY 11735
Moe Wind
(516) 694 3600

W. L. Gore & Associates, Inc
555 Paper Mill Rd
P.O. Box 8734
Newark, DE 19711
Samuel L. Chambers
(302) 738 4880

– H –

Huber & Suhner AG Ltd
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Switzerland
O. Schmid
071 53 15 15

Hughes Aircraft Company
Electron Dynamics Div
3100 W. Lomita Blvd
Torrance, CA 90509
Marilyn M. Talley
(213) 534 2121

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Al Arfin
(201) 887 8100

Kevlin Manufacturing
26 Cornell Street
Woburn, MA 01801
Ernest W. Lattenzi
(617) 935 4800

K & L Microwave
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Salisbury, MD 21801
Charles Schaub
(301) 749 2424

Krytar
574 Weddell Drive
Unit 5
Sunnyvale, CA 94086
Thomas J. Russell
(408) 734 5999

– L –

Lorch, Inc
Box 740, Science St
State College, PA 16801
Walt Coyle
(814) 466 6275

– M –

Marconi Electronic Devices Ltd
(MEDL)
(formally AEI Semiconductors Ltd.)
Carholm Rd, Lincoln LN1 1SG
David Westgarth
(0522) 29992

Marconi Instruments
Microwave Products Div
P.O. Box 10
Gunnels Wood Rd., Stevenage
Herts, England SG1 2AU
Will Foster
(0438) 2311

Mast Microwave
8 Ray Avenue
Burlington, MA 01803
Chris Theophile
(617) 273 4640

Maury Microwave Corp
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Cucamonga, CA 91730
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(714) 987 4715

Merrimac Industries, Inc
41 Fairfield Place
W. Caldwell, NJ 07006
Dan S. Brodow
(201) 575 1300

Microlab FXR
10 Microlab Road
Livingston, NJ 07039
Harry Aupenbrick
(201) 992 7700

Micrometrics
36 Oak Street
Norwood, NJ 07648
Gary Simonyan
(201) 767 1320

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Chatsworth, CA 91311
Walter R. Reed
(213) 882 7333

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R. Conway
(617) 272 3000

Microwave Development Labs, Inc
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Natick, MA 01760
E. Bannister
(617) 655 0060

Microwave Filters
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Emily Bostick
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Microwave Power Devices
Adams Court
Plainview, NY 11803
Richard J. Sheloff
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Diode Operation
11 Executive Park Dr
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John A. Caruso
(617) 667 7700

Midwest Microwave
3800 Packard Rd
Ann Arbor, MI 48104
Herb Gaudet
(313) 971 1992

Mini Circuits
2425 E. 14th St
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– N –

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Plainview, NY 11803
R. E. Sowden
(516) 349 9600

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(617) 272 4046

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(408) 988 0843

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Materials Div
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Edward Feldman
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Jules Simmonds
(914) 939 8900

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Tony Cerri
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S. Lescarboura
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(089) 4144 1

Siemens AG
Bereich Kommunikationstechnik
Hofmannstrasse 51
D 8000 Munich 70, W. Germany
(089) 722 1

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Catie Bossard
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Ron Bowers
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– T –

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Larry W. Stilley
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Ken Mills
(415) 968 2211

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Raleigh B. Stelle III
(317) 357 8781

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(1) 743 96 40

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Hants RG240QG, UK
(256) 29155

Thomson CSF GmbH
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D 8000 Munich
W. Germany
(89) 76 751

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4241 Glencoe Avenue
Venice, CA 90291
Ray E. Williams
(213) 822 0800

Triangle Microwave, Inc
11 Great Meadow Lane
E. Hanover, NJ 07936
James Beard
(201) 884 1423

– U –

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1815 W. 205 St
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Ed Jacobs
(213) 320 1244

UZ, Inc
9522 W. Jefferson Blvd
Culver City, CA 90230
(213) 839 7503

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Varian Associates
Electron Device Group
301 Industrial Way
San Carlos, CA 94070
(415) 592 1221

Vari L
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Denver, CO 80239
Carol Kiser
(303) 371 1560

– W –

Watkins Johnson Co
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Finally a way to make noise figure measurements—10 MHz to 18 GHz—that are accurate and repeatable.

HP's new 346B Noise Source can cut your uncertainty in half.

In conventional noise figure measurements, you now get better accuracy because ENR (excess noise ratio) has an RSS uncertainty of ±0.1 dB from 10 MHz to 8 GHz, ±0.19 dB at 18 GHz, and is plotted on the nameplate at 20 frequencies. Low SWR of <1.15 from 30 MHz to 5 GHz and <1.25 to 18 GHz further reduces uncertainty.

When used with conventional meters, the 346's built-in current regulator makes the noise output insensitive to 28 ± 1V drive variations. HP 340B/342A meters use the 11711A adapter. Prices: 346B, $1200*; 11711A, $125.*

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DESIGNED FOR HP-IB SYSTEMS

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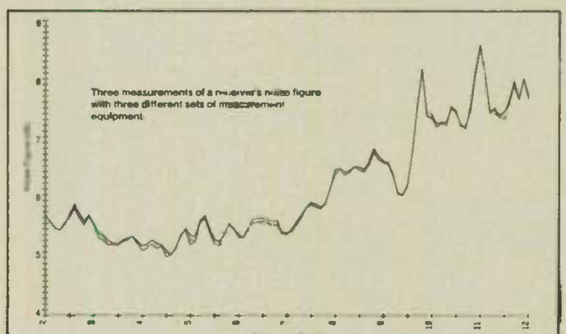
Using an off-the-shelf power meter, local oscillator, and a few instruments and accessories, you can automatically measure both gain and noise figure, while correcting for second stage noise, ENR variations, and ambient temperature effects; as fast as 100 frequencies per minute.



The X-Y chart shows excellent repeatability with 3 separate plots of receiver noise figure using 3 different power meters, sensors, and noise sources. Peak excursions are <± 0.1 dB from 2 to 12 GHz.

*Domestic U.S. prices only.

04002

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Microwave Products

Instrumentation

GAS NOISE GENERATOR POWER SUPPLY

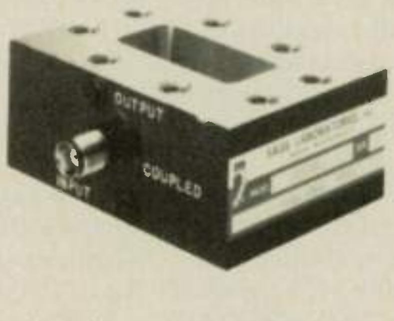
AILTECH model 7175 is a triggerable gas noise generator power supply for both manual and automatic noise figure or noise temperature measurements with AILTECH 70 Series Noise Generators. Remote mode input is +25 to +30 V (pulsed or CW) when on, 0 V when off, trigger rate is 50 Hz to 2 kHz. Power input is 115/220 Vac ± 10%, 50/60 Hz, 120 W. Size: 17" W x 16" L x 5¼" H. Weight: 20 lbs. (9.1 kg) net and 25 lbs. (11.4 kg) shipped. Del: 6 wks. **Eaton Corp., Electronic Instrumentation Div., City of Industry, CA. (213) 965-4911.** **Circle 152.**

MICROPROCESSOR-BASED SWEEP OSCILLATOR

Model 8350A is a microprocessor based sweep oscillator mainframe available with 6 RF plug-ins, (83500 series) covering the 10 MHz to 26.5 GHz frequency range. The unit also accepts plug-ins from existing HP solid state sweepers (19 types spanning 10 MHz to 22 GHz bands) with special (11869A) adapter. All functions can be set by knob, step keys, and keyboard via HP-IB. Calibrated power output levels and a calibrated power sweep may be set in the same manner for the 83500 plug-ins and up to 9 complete operating states may be stored for recall. The 83592A plug-in covers 10 MHz to 20 GHz in one sweep; its CW frequency accuracy is ± 20 MHz. Other plug-ins cover narrower ranges. Price & Del.: Sweep Oscillator Mainframe ($4250) 8 wks. ARO; RF Plug-Ins ($7,450 - $23,500); Adapter - $200), 8 wks. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.** **Circle 146.**

Components

HIGH POWER, 82 dB DIRECTIONAL COUPLER



Model FC2606 is a high power 82 dB directional coupler with 20 dB minimum directivity over a 10% bandwidth. Mainline mates with aluminum WR 187 waveguide. The coupled output is a TNC connector. Size: 1.5" long. **Sage Laboratories, Inc., Natick, MA. Ken Paradiso, (617) 653-0844.** **Circle 163.**

MINIATURE 8-18 GHz ISOLATOR

An isolator which covers the 8-18 GHz frequency range, Model 60A2051, has a volume of .125 cu. in. Guaranteed performance is 16 dB minimum isolation, 0.7 dB maximum insertion loss and 1.5 maximum SWR over the temperature range of -45 to +85°C. Connectors are SMA female. Price: $138, small qty. Del: 2 wks. **TRAK Microwave Corp., Tampa, FL. Thomas L. Roberts, (813) 884-1411.** **Circle 170.**

STANDARD 3-FILTER FAMILY FOR 2 GHz RADIOS

The TX65 family of filters for the 2 GHz band, are production built filters with measured insertion losses as low as 0.50 dB. Models TX65-8280 and TX65-8278, are 30 MHz bandwidth filters with center frequencies in the 2120 and 2170 MHz range. They have stringent group delay, insertion loss and amplitude flatness specifications plus normal in-band SWR and out-of-band rejection specifications. Model TX70-7.5-5SS1, is a 70 MHz IF filter with a 7.5 MHz, 3 dB bandwidth. **Telonic Berkeley, Laguna Beach, CA. (714) 494-9401.** **Circle 166.**

4-WAY DIVIDER/COMBINER SPANS 8-12, 4 GHz

Model D412M is a resistor isolated power divider which operates over the 8-12 GHz frequency range with 18 dB minimum isolation. When used as a power divider, input SWR is 1.70 max.; when used as a 4-way power combiner, input SWR to each port is 1.50 max. Insertion phase from input to any output is within ± 5° port to port, and amplitude balance is within ± 0.2 dB. Maximum passive insertion loss is 1.0 dB. Power rating of internal resistors is .25 W CW, 1 kW peak. Price: $175 per unit. Del: 60 days ARO. **Engelmann Microwave Co., Montville, NJ. Carl Schraufnagl, (201) 334-5700.** **Circle 142.**

DOUBLE-BALANCED BIASABLE MIXER

Model FN-1008 is a broadband, 6.0-18.0 GHz biasable double balanced mixer. LO frequency range is 6.2-17.8 GHz; IF bandwidth is 260 to 470 MHz and IF band flatness is ± 0.5 dB (peak to peak). Conversion loss is 9 dB maximum. LO input power is 0 dBm to + 10 dBm. Port-to-port rejection in 20 dB minimum, SWR (all ports) is 2.0 max. Bias voltage is +15 Vdc at 10 mA. Connector is SMA (Female). **Triangle Microwave, Inc., E. Hanover, NJ. James Beard, (201) 884-1423.** **Circle 171.**

BIASABLE DOUBLE-BALANCED MIXER FOR 8-18 GHz BAND

Model MB-8018 is a double-balanced biasable mixer which covers the 8-18 GHz range. IF bandwidth is 4 GHz. At 0 dBm LO, + 5 Vdc @ 7 mA., conversion loss is 7.6 dB max. to 1 GHz IF, 9.5 dB max to 3 GHz IF; port-to-port isolation is 20 dB min. Construction is thin-film beam lead. Size: 1.18" L x 1.00" H x .50" D. **Western Microwave, Inc., Sunnyvale, CA. (408) 734-1631.** **Circle 172.**

NOISE SOURCE LINE

Series NSP7 are precision, solid state noise sources available with 7 mm connectors. Sources with noise outputs of 15.5 dB ENR are available for 10 MHz - 18 GHz applications. Input power is 28 V and 20 mA maximum. Size: 2.78" L. Del: Stock to 4 wks, ARO. **Micronetics, Inc., Norwood, NJ. Gary Simonyan, (201) 767-1320.** **Circle 155.**

(continued on page 62)

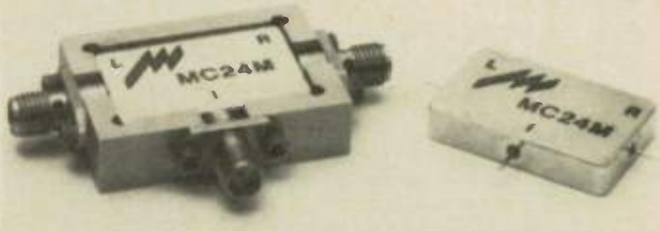
HIGH POWER, FLEXIBLE CABLE ASSEMBLIES

A series of flexible, low loss .290" O.D. microwave cable assemblies with high power capabilities to 18 GHz are offered. For 10 ft. cables with straight SMA connectors, typical insertion loss ranges from 0.5 dB at 1 GHz to 3.3 dB at 18 GHz. Impedance is 50 ± 1 ohm and time delay is 1.2 nsec/ft. Capacitance of 26 pf/ft, maximum and maximum SWR is 1.25 through 18 GHz. Dielectric withstanding voltage is 1,500 V, RMS; minimum bend radius is 1.5". Temperature range is −55° to 200°C for cable; −55°C to 150°C for assemblies. Weight: 36.0 gms/ft of cable, plus 38.0 gms per SMA connector pair. **W. L. Gore & Associates, Inc., Electronic Assembly Div., Newark, DE. (302) 368-3700.** **Circle 144.**

MICROMINIATURE TE MODE BANDPASS FILTERS

The FV series of microminiature, evanescent TE Mode bandpass filters covers the 0.5-18 GHz frequency range. Bandwidths from 4-70% may be specified and filters can be manufactured with 2-17 resonant sections. As a coaxial device, normal RF terminals are SMA jack connectors. RF pins can be provided for mounting in microstrip circuitry. Vol: from 0.14 cu. in. Price: Unit qty., from $250. Avail: 6 wks. **K & L Microwave, Inc., Salisbury, MD. Charles J. Schaub, (301) 749-2424.** **Circle 148.**

MICROWAVE MIXERS SPAN 3.7-4.2 GHz BAND



A line of Magnum-pac™ microwave mixers designed for both stripline and coaxial applications, Models MC24M and MC24P, operate in the 3.7-4.2 GHz band. Units have typical 5 dB conversion loss and 30 dB isolation. MC24M is stripline mountable; MC24P includes push-on SMA connectors for coaxial applications. Del: 2-4 wks. **Magnum Microwave Corp., Sunnyvale, CA. David Fealkoff, (408) 738-0600.** **Circle 154.**

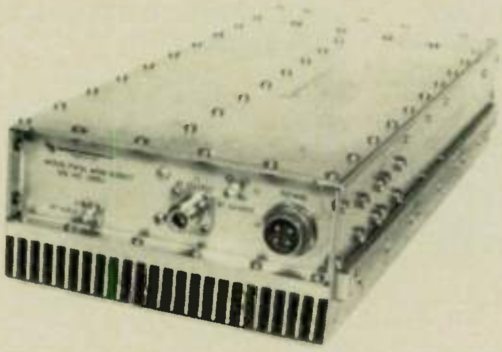
HYPERABRUPT, VARACTOR TUNED OSCILLATORS

The 2.6-5.2 GHz HTO-2600 and 4-8 GHz HTO-4000 are hyperabrupt varactor-tuned oscillators/buffer amplifiers which offer highly linear voltage vs frequency curves and a maximum +14 Vdc tuning voltage. Power output for each is +10 dBm, min. Both combine a bipolar transistor oscillator with a built-in buffer amplifier that isolates the oscillator from variations in load. Pulling for all phases of a 12 dB return loss is 18 and 12 MHz, respectively. Packaging is in hermetic TO-8 packages which may be qualified to MIL-E-5400 and MIL-E-16400. Price: HTO-2600: $1,470; HTO-4000: $1,600, small qtys. Del: 90-120 days, ARO. **Avantek, Inc., Santa Clara, CA. David Gray, (408) 727-0700.** **Circle 137.**

YIG-TUNED BAND REJECT FILTER

Model M103R is a multioctave YIG tuned band reject filter that can be tuned electronically from 4 GHz to 12.4 GHz. Insertion loss in the 4-12.4 GHz is less than 1 dB and the 20 dB rejection bandwidth is 6 MHz. Temperature drift is 200 kHz/°C. Analog or TTL drivers are available as integrated filter components. **Omniyig, Inc., Santa Clara, CA. William Capogeannis, (408) 988-0843.** **Circle 159.**

SOLID STATE AMPLIFIER FOR 400-500 MHz BAND



Model 4050-12/5552 is a compact, solid-state amplifier providing 50 dB saturated gain and 100 W CW saturated output power over the 400-500 MHz frequency band. The amplifier operates from a single +28 Vdc power source at 17A. It meets the vibration requirements of MIL-T-5422F and includes protection against high load SWR, thermal overload and reverse voltage application. Connectors are SMA Female (Input) and N Female (Output). Size: 3.375" H x 7.5" W x 18" D. **Microwave Power Devices, Inc., Hauppauge, NY. Richard Sheloff,** (516) 231-1400. **Circle 156.**

SMA RIGHT-ANGLE BENT ASSEMBLIES

Series of SMA right angle bent assemblies are designed to lessen the distance between mating surface of the connector and center line of the cable. Employing a new semi-rigid miniature coaxial cable, the cable is bent 90° at the plug entrance and the assembly achieves the basic dimensions of a right angle plug without introducing any right angle plug discontinuity. Available for either .141 or .086 cable. **Cablewave Systems, Inc., North Haven, CT.** (203) 239-3311. **Circle 138.**

HIGH POWER, FIXED COAXIAL ATTENUATORS

A line of high power, fixed coaxial attenuators, A-201 Series, can handle powers up to 35 W from dc to 4 GHz. Attenuation values above 6 dB are undirectional with input normally on the male connector. Distributed attenuator elements are used and attenuator accuracy is typically ± .5 dB. Size: less than 3¼" L. May be ordered up to 33 dB in 1 dB increments. Price: From $125, unit qty. Del: 4-6 wks., small qty. **RLC Electronics, Inc., Mt. Kisco, NY.** (914) 241-1334. **Circle 162.**

MINIATURE FREQUENCY STANDARD

Model YH-1100 is a miniature frequency standard which provides an output frequency in the 1-60 MHz range with a stability of ± 5 x 10^{-8} /day. Output will drive up to 10TTL loads and it operates from a single +5 Vdc input. Size: 4.5 cu. in. Price: $175, in qtys of 100. **Greenray Industries, Inc., Mechanicsburg, PA. Glenn R. Kursenknabe,** (717) 766-0223. **Circle 145.**

Systems

POWER AMPLIFIERS SPAN 220 - 400 MHz BAND

Models 50HA and 200HA are power amplifiers which offer, respectively, 50 W and 200 W CW output into 50 ohms. Both units are flat within ±1.0 dB from 220 MHz to 400 MHz, and both offer completely untuned operation for sweep or frequency-hopping applications. Amplifiers are unconditionally stable, and will continue to operate at rated output, without damage or shutdown, even into an open or shorted load. They offer typical harmonic distortion levels of 25 dB below fundamental at frequencies above 260 MHz; both amplifiers require 1 mW of input power for full rated output. **Amplifier Research, Souderton, PA.** (215) 723-8181. **Circle 136.**

(continued on page 64)

MILLIMETER ANTENNA RANGE

Model 5752 is a compact millimeter antenna range for the 4.0-60 GHz frequency range. This range is designed for the development and testing of antennas in laboratory and indoor areas. It reduces, and in some cases eliminates, the need for outdoor facilities requiring a large amount of real estate. Price: $255,000. Del.: 6 months.

Scientific-Atlanta, Inc., Atlanta, GA. Gerald Hickman, (404) 449-2000. Circle 165.

Service

SERVICE FOR CALIBRATING MM-WAVE POWER STANDARDS

A calibration service for millimeter-wave power standards (bolometer mounts) in the 94-95 GHz frequency range is available at the Boulder Colorado Laboratories of NBS. Effective efficiency and reflection coefficient calibrations are offered. **National Bureau of Standards, Boulder, CO. Manly Weidman or Paul Hudson, (303) 497-3210/3939. Circle 151.**

Software

PROGRAM FOR CAD MICROWAVE CIRCUITS

A software package for computer-aided design of microwave circuits, SUPERCOMPACT™, incorporates the circuit analysis and optimization features of pre-existing programs and extends the versatility and applications of the package. Interactive graphics, databanks for transistor and dielectric device data, topology generator, a new optimization technique and text-editing have been added. Pricing: $40,000 licensing fee (partial credit allowance for current users until December 31, 1980) for licensing on in-house computer and available via commercial timesharing beginning November 30, 1980. **Compact Engineering, Palo Algo, CA. Jim Lindauer, (415) 858-1200. Circle 140.**

Tubes

600 W FROM HELIX TWT

TH 3591B is a 600 W helix traveling-wave tube which covers the 14.0-14.5 GHz band. Tube has a gain of approximately 50 dB at full power and operates with a beam voltage of approximately 10.5 kV. Constructed of all-brazed helix assembly, model offers superior heat transfer and low RF losses. Unit uses power-saving samarium-cobalt PPM beam confinement. Life exceeds 30,000 hours and cathode loading had been held below 1 A/cm^2. **Thomson-CSF Electron Tubes Div., Clifton, NJ. (201) 779-1004. Circle 169.**

Materials

RESISTANCE CARD ATTENUATORS

The A3BT01 is a 200 ohms per sq. thick film attenuator deposited on .032 in. thick alumina substrate designed for waveguide applications. It is capable of withstanding temperatures in excess of 350 C. A variety of configurations are available. **KDI Pyrofilm, Applications Engineering Dept., Whippany, NJ. (201) 887-8100. Circle 147.**

HIGH DIELECTRIC CONSTANT SUBSTRATE

Improved Epsilam 10 is a high dielectric constant substrate material with water absorption value of approximately .05%. In addition, its dielectric constant is more tightly controlled than that of the original Epsilam-10 and its peel strength has been increased to 10 pounds/inch of width. Constructed of ceramic filled Teflon compound material is intended for microstrip and stripline designs. Size: 9" x 9" sheet, standard; in .010, .025, .050, .075 or .100 mil thicknesses. **3M, Electronic Products Div., St. Paul, MN. (612) 733-9214. Circle 168.**

A CHOICE SELECTION:

High Performance at a low price with HP's new 8559A

Look at the performance you get for only $10,875: Frequency coverage from 10 MHz to 21 GHz; flat frequency response, ± 3 dB to 21 GHz; −111 to +30 dBm measurement range; distortion products are >70 dB down; 1 kHz to 3 MHz resolution bandwidths; digital frequency readout with typically better than 0.3% accuracy.

All this in a rugged, lightweight plug-in for the HP 182T display. Easy to use, too. You simply tune to the signal, set frequency span (resolution and sweep time are automatically optimized), and then set the amplitude reference level. It's HP's new budget-minded spectrum analyzer. Reader Service No. 57

Modularity means value with the HP 8555A.

Buy only what you need for your current microwave requirements; you can add different RF tuning plug-ins or companion instruments as your needs expand. The HP 8555A RF Tuning Unit covers 10 MHz to 18 GHz (extendable to 40 GHz), has a ± 2 dB frequency response, and narrow resolution of 100 Hz. These features combine to provide you with an accurate and sensitive microwave signal analyzer. The 8555A with the 8552B RF Section and installed in the 141T Variable Persistence Display Section costs $15,975.

When your applications require input overload protection, elimination of multiple responses, or 100 dB harmonic distortion measurement range, add the HP 8445B Automatic Preselector. For wide dynamic range swept response measurements to 1.5 GHz, just add the 8444A Tracking Generator. For versatile coverage at audio, VHF, UHF and microwave frequencies, this modular family offers value for present and future needs. Reader Service No. 58

45005B

World Radio History

CRYSTAL VIDEO PRODUCTS

An extensive line of crystal video products is described in a new brochure now available from Aertech Industries. The 12-page brochure contains electrical specifications, performance curves, and outline drawings covering linear and logarithmic detector video amplifiers, threshold detectors, and, the newest member of this product line, mini-detector log video amplifiers. Also included is a section on applications and a Video Products Selection Guide. **Aertech Industries, 825 Stewart Drive, Sunnyvale, CA 94086. (408) 732-0880.** **Circle 101.**

SOLID STATE AMPLIFIERS

A brochure containing information on a complete line of low noise and power amplifiers from 755 MHz to 18 GHz. Aydin Microwave's product line of solid state bipolar and GaAs FET amplifiers provide the latest state-of-the-art in computer aided thin film design. These amplifiers are used in microwave radio links, troposcatter terminals, satellite earth stations, electronic warfare and military special test equipment. The brochure contains performance specifications for all standard models. **Aydin Microwave Division, 75 East Trimble Road, San Jose, CA 95131. Hal Sawert. (408) 946-5600.**
Circle 103.

DOUBLE-BALANCED MIXER DATA SHEET SERIES

DBX-184 and DBX-185 series of double-balanced microwave mixers offer performance over multi-octave RF, IF and LO bandwidths – and are packaged in the Avanpak™ miniature hermetic case for microstripline or coaxial-interfaced systems. Their design permits overlapping RF/LO and IF frequency ranges with greater than 25 dB RF-IF isolation and up to 6 GHz IF bandwidths. Designed for high performance, wideband microwave receiving systems. **Avantek, Inc., Advanced Solid-State Products, Bowers Avenue, Santa Clara, CA 95051. (408) 727-0700.** **Circle 102.**

STANDARD RF AMPLIFIERS

Aydin Vector Short Form describes over 35 RF amplifiers and cascaded combinations. Their standard modular, plug-in, hybrid, RF amplifiers are available in five (5) basic series; MHD, MHT, GHT, GA and MHA. The MHD series have multiple stages of amplification on a single alumina substrate and are packaged in a 4 PIN DIP, MHT and GHT units have a single stage of amplification and are packaged in a TO-8 configuration. GA Series units also have one stage and are packaged in a modified TO-12. MHA voltage variable attenuators are available in a TO-8 or DIP configuration. **Aydin Vector, P.O. Box 328, Newtown, PA 18940. (215) 968-4271.** **Circle 104.**

CRYSTAL OSCILLATOR BROCHURE

Comstron, the technology leader in oscillators for military, commercial and deep-space applications can assist with crystal oscillator requirements. Through proprietary computer-generated design, testing and production techniques, Comstron delivers state-of-the-art low noise performance on VCXOs, TCXOs, oven controlled crystal oscillators and phase locked sources to 1 GHz. Design for Optimum Performance (DOP) programs provide optimization of performance and sensitivity analysis. **Comstron Corp., 200 East Sunrise Highway, Freeport, NY 11520. Len Borow, (516) 546-9700.**
Circle 105.

(continued on page 71)

(from page 68)

GaAs FET COMPONENT DATA SHEETS

DEXCEL announces the release of new data sheets for its quality microwave GaAs FET components. The new four page data sheets are available on Dexcel's broadband microwave amplifiers, oscillator assemblies. TVRO low noise amplifiers, and gallium arsenide field effect transistors. All existing data sheets have been replaced with new data sheets containing additional information required by the RF designer. **DEXCEL, Inc., 2285C Martin Ave., Santa Clara, CA 95050. (408) 727-9833.** Circle 106.

CATALOG OF INSTRUMENTS AND COMPONENTS

General Microwave's 72-page catalog contains information on both their components and instruments. Included are specifications on power measuring equipment, PIN diode control devices from single pole through multi-pole, from .1 to 18 GHz; RAHAM Radiation Hazard Meters — low cost instruments to measure electromagnetic radiation levels for compliance with OSHA Safety and Health standards and solid state microwave signal sources from .4 to 18 GHz. **General Microwave, 155 Marine St., Farmingdale, NY 11735. Moe Wind, (516) 694-3600.** Circle 108.

MICROWAVE POWER TRANSISTORS

IMD's new catalog contains specifications on over 75 units including oscillator devices from 2 to 6 GHz; Class A, Class C discrete devices from 2.3 to 4.0 GHz and Class A/Class C matched devices from 1.4 to 2.7 GHz. IMD delivers highest quality devices, provides knowledgeable technical assistance and satisfies both your prototype and production requirements quickly. **International Microwave Devices, 51 Chubb Way, Somerville, NJ 08876. John Locke, (201) 231-1990.** Circle 110.

NEXT GENERATION FREQUENCY COUNTERS TO 40 GHz

A six-page gatefold brochure describes Models 545/548 microwave counters. The two-color pamphlet gives key measurement capabilities to the 40 GHz band plus key specifications, time base, general operational features, plus such options as remote sensor, D to A converter, power meter, extended frequency, remote programming, GPIB, rear input and chassis slides. Also highlights major performance features, frequency offsets, limits, and extension, Dac output and power measurement and serviceability. **EIP, 2731 North First St., San Jose, CA 95134. (408) 946-5700.** Circle 107.

SIGNAL PROCESSING CATALOG

This comprehensive 320 page catalog describes our complete line of signal processing components and integrated networks employing lumped element designs in the frequency range of dc to 4 GHz. Specifications, illustrations and dimensional outline drawings are included for every device. Catalog M-80 has a high reliability section that describes quality assurance procedures and an engineering aid section that contains application information and various curves and graphs. **Merrimac Industries, 41 Fairfield Place, West Caldwell, NJ 07006. Dan Brodow, (201) 575-1300.** Circle 111.

MULTI-BAND SWEEP GENERATOR

Two new models are added to the MSG-2100 series of microwave sweep generators: MSG-2100A: 18-26.5 GHz sweeper with +10 dBm leveled output. MSG-2100B: 26.5-40 GHz sweeper with +5 dBm leveled output. Both units are completely solid state, and optional 488 Bus control is available. Power output variation, without leveling, is less than + or − 1.5 dB. A complete line of sweep generators from .01-40 GHz also offered. **Division sion of INTEGRA, Inc., 1400 Coleman Ave., Santa Clara, CA 95050. (408) 727-9601/TWX: 910-338-0585.** Circle 109.

ANALOG ROTARY-FIELD PHASE SHIFTERS

A new four-page brochure including supplemental technical information, applications data and specifications for the complete series of rotary-field ferrite phase shifters. Analog ferrite phase shifters have been developed for applications requiring an accurate relationship between phase shifter and control current. These units provide unlimited phase shift with uniformly low hysteresis and dispersionless phase shift versus frequency characteristic. **Microwave Applications Group, 10019-21 Canoga Ave., Chatsworth, CA 91311. (213) 882-7333.** Circle 112.

SPECTRUM ANALYZERS

New 16-page brochure describes their 600B Series spectrum analyzers with new enhanced performance capabilities and versatile accessories. Design refinements and new accessories provide significantly upgraded performance capabilities. "B" Models replace the popular "A" Models with the same, compact size, easy to use controls, and internal digital memory and data processing interface. The third generation includes many circuit improvements, RF module integration and a new IF design to provide enhanced performance. **Polarad Electronics, 5 Delaware Drive, Lake Success, NY 11042. Joe Schindler, (516) 328-1100.** Circle 115.

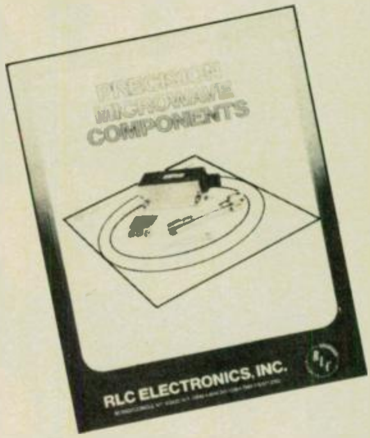
AUTOMATED 10 MHz - 40 GHz SCALAR NETWORK ANALYZER SYSTEMS

A new family of Automated Scalar Network Analyzer Systems covering the 10 MHz to 40 GHz range is described in this 16-page brochure. Included are specifications and application notes for measuring return loss, transmission loss/gain and power in coax or waveguide. Block diagrams show how the system consisting of a new programmable sweep generator, network analyzer, desktop controller and precision components with 40 dB directivity are connected for the fastest, most accurate measurements. **WILTRON Co., 825 E. Middlefield Rd., Mountain View, CA 94043. (415) 969-6500.** Circle 119.

COMPONENTS

New catalog describes the broad line of high performance microwave diodes available from Metelics Corporation. Types offered include step recovery diodes (T_t as low as 20 picoseconds), PIN diodes (fast switching, limiter, high power up to 1600 volt V_{BR}), Schottky and zero bias Schottky, and high Q tuning varactors. Chips, beam leads, various packages. Established high reliability capability. **Metelics Corp., 1031C East Duane Ave., Sunnyvale, CA 94086. (408) 737-8181.** **Circle 113.**

New product data sheets now offered which describe mixers, mixer/preamplifiers, wide band, low noise amplifiers, C, X and K_u-Band communication converters and frequency translators for satellite communications Applications. **MITEQ Inc., 100 Ricefield Lane, Hauppauge, NY 11787. (516) 543-8873.** **Circle 114.**



RLC Electronics' new 76-page catalog describes their complete lines of switches, filters and attenuators from dc to 18 GHz. The catalog contains both electrical and mechanical specifications plus environmental information and typical operating curves. In addition to their standard lines, RLC has engineered thousands of custom designs and produced substantial quantities of special units within short time spans. **RLC Electronics, 83 Radio Circle, Mt. Kisco, NY 10549. Alan Borck (914) 241-1334.** **Circle 116**

(continued on page 76)

Will your country's telephone system be able to keep up with your country?

It's clear that a booming population will need more and more telephone service.

Which is why telephone authorities all over the world are considering new phone exchanges at this very moment.

As cities grow, ITT's new System 12 will grow with them.

But with voice and computer traffic making urgent new demands on phone systems, it's important that any new exchange really be new.

And not just an updating of some older design.

This is all by way of introducing ITT's new System 12, a unique exchange system based on the latest technology. In fact, future technology.

But let us explain.

Before ITT created this system, we carefully mapped the direction telecommunications will take over the next decades.

Which irresistibly pointed toward an integrated worldwide information delivery network—what we at ITT have called Network 2000.™

And everything we foresee in this ultimate network, we've anticipated in the revolutionary architecture of System 12.

It's a fully digital system, able to handle voice and high-speed computer data with equal ease.

And a system whose fully distributed processing permits telephone planners to expand and modify an existing network—virtually without limit.

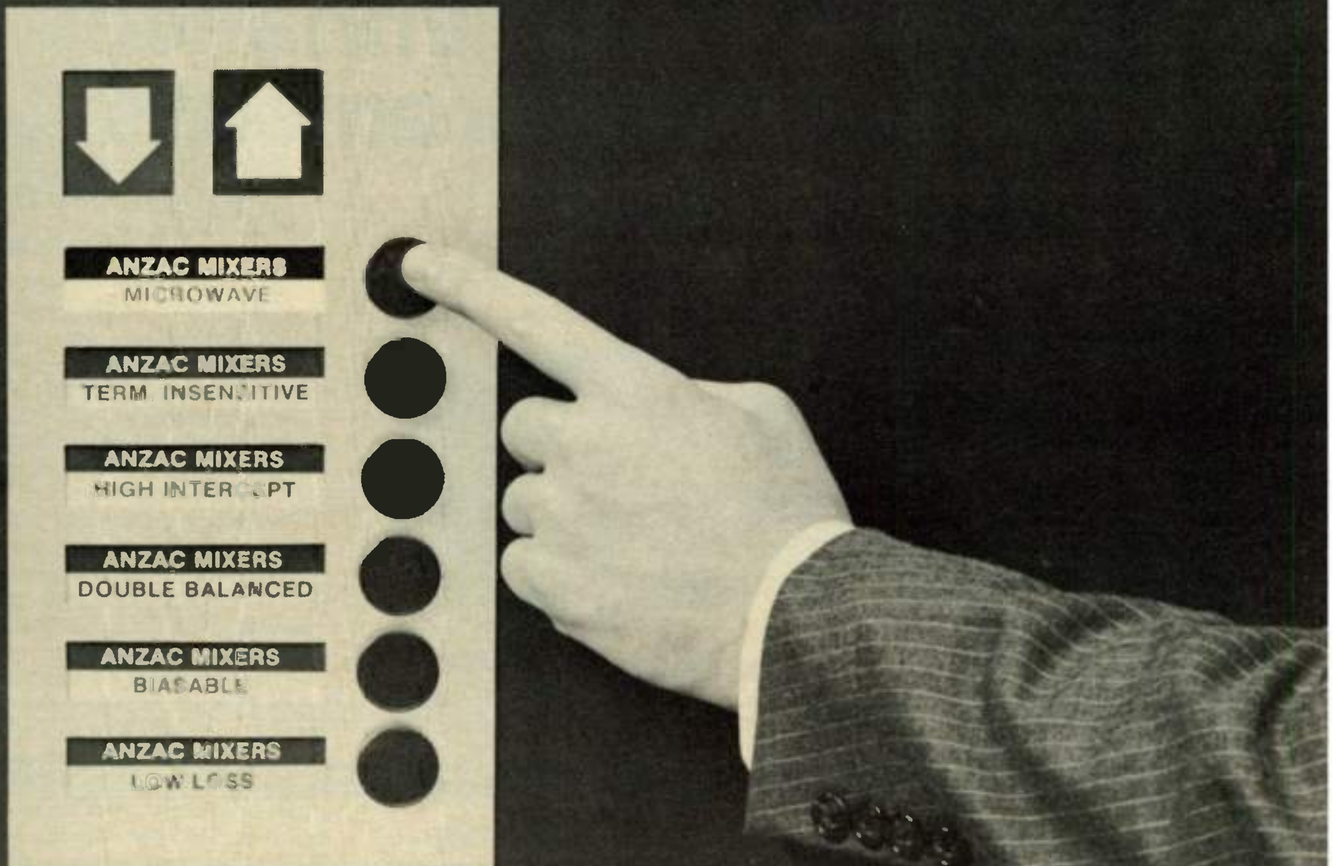
It stands to reason that any country that's growing (and what country isn't?) must have telephone exchanges that can keep up with the growth.

Which narrows the choice quite a bit.

ITT

ITT NETWORK 2000

Going up . . .



. . . to 18 GHz!

Now - Microwave Mixers from Anzac. Eleven new hermetically sealed models cover the 0.5 to 18 GHz range in octave, multi-octave, and special-interest bands. Termination-Insensitive versions as well as regular double-balanced units. Each available in either drop-in flatpack or connectorized versions. All are built for military environments. And like all Anzac standard products, these Microwave Mixers are available from stock. Send for the special 20-page catalog supplement which describes these new mixers. Specifications and performance curves included.

Anzac Microwave Mixers. Going up to 18 GHz!

Adams Russell
ANZAC DIVISION

80 Cambridge Street, Burlington, MA 01803 (617) 273-3333 TWX 710-332-0258

CIRCLE 41 ON READER SERVICE CARD

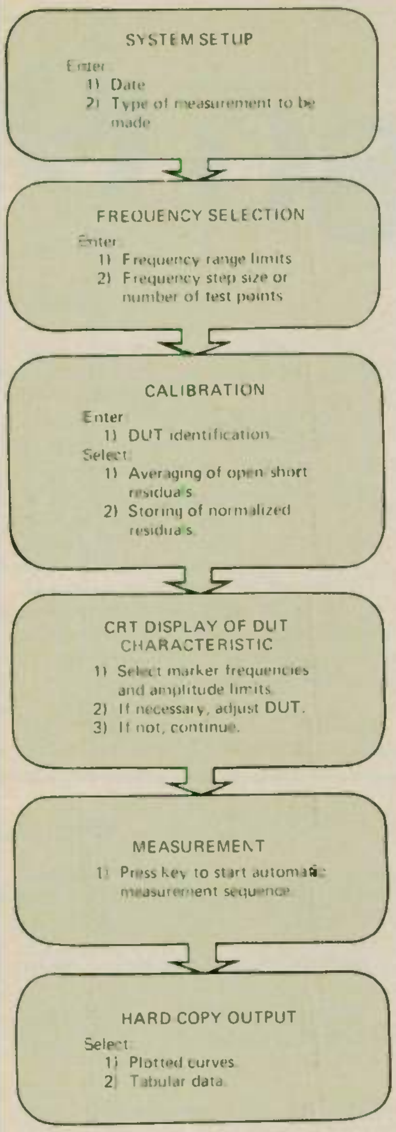


Fig. 2 Series 5600 operational procedure.

displays and interfaces directly with the main processor.

In addition to the microprocessor control sweeper, each Series 5600 system includes a GPIB-programmable scalar network analyzer, desktop controller with interactive software and all required measurement components.

To use the system, the operator simply inserts a preprogrammed cartridge into the controller, enters the few inputs in accordance with the interactive instructions and quickly obtains computer-corrected data in tabular or graphical format. **Figure 3** allows the kind of hard copy available from the printing controller.

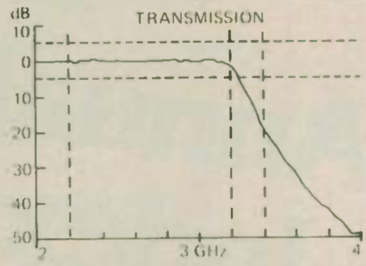


Fig. 3 Hard copy output from printing controller.

As indicated in **Table I**, six separate models in the series offer a variety of frequency ranges and specific applications can be served at minimum cost. When required, the RF module may be replaced when other applications require different frequency coverage.

The Series 5600 system offers 40 dB directivity from 10 MHz to 18 GHz (see **Figure 4**) dynamic range is 66 dB and sensitivity is -50 dBm. Programmable attenuation of 82 dB is available in 0.1 dB steps and ROM-corrected frequencies are accurate to ± 10 MHz from 10 MHz to 18 GHz.

The network analyzer system employs an unmodulated signal which simplifies testing of active devices and avoids errors caused by modulation asymmetry or modulation-sensitive test devices. The internal memory for calibration data is not effected by scale changes and front panel controls can be set for optimum. CRT displays without the need to recalibrate or revise stored data.

Bus interfaces are internal in both the sweeper and analyzer eliminating the need for any external interface box.

Circle 121 on Reader Service Card

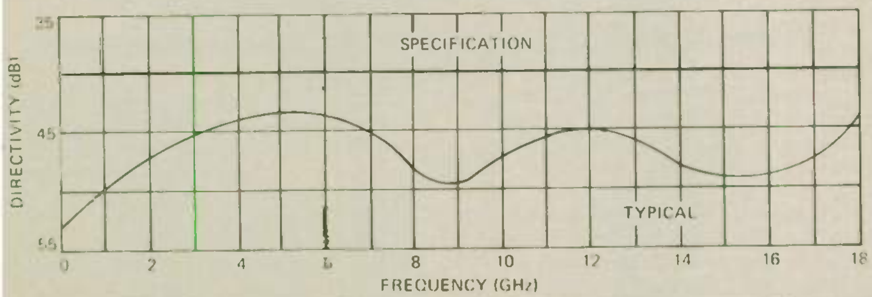


Fig. 4 Model 97A50-1 SWR Autotester directivity.

(from page 81) INDEX

SPECIAL REPORTS

ERRATUM

In the October, 1980 issue of *Microwave Journal*, the article, "Millimeter Wave Coupled Line Filters," by D. Rubin and A. R. Hislop was published without the computer program in the appendix detailing the even and odd mode impedances for doubly terminated Tchebycheff filters. It is reproduced here as follows:

APPENDIX

```
100 PRINT "PROG. CALCULATES ZOE,
    ZOO FOR TCHEBYCHEFF FILTER"
110 INIT
120 PRINT "Z0= ?";
130 INPUT Z0
140 PRINT "F1=, F2= ";
150 INPUT F1, F2
160 REM CALCULATE G VALUES (PG 99 MATTHAEI)
170 PRINT "N= ? "; "RIPPLE = ? ";
180 INPUT N, D
190 PRINT
200 X=D/17.37
210 E1=EXP( X)
220 E2=EXP(X)
230 E=LOG( (E2+E1)/(E2 E1) )
240 X=E/(2*N)
250 G1=0.5*(EXP(X) EXP( X) )
260 DIM A(N)
270 DIM B(N)
280 DIM G(N+1)
290 FOR K=1 TO N
300 A(K)=SIN( (2*K 1)*PI/(2*N) )
310 B(K)=G1↑2+SIN(K*PI/N)↑2
320 NEXT K
330 G(1)=2*A(1)/G1
340 IF N=1 THEN 440
350 FOR K=2 TO N
360 G(K)=4*A(K 1)*A(K)/(B(K 1)*G(K 1) )
370 NEXT K
380 IF  1↑N  0 THEN 440
390 X=E/4
400 E2=EXP(X)
410 E1=EXP( X)
420 G(N+1)=( (E2+E1)/(E2 E1))↑2
430 GO TO 450
440 G(N+1)=1
450 REM CALCULATE  ZOE, ZOO (PG 473 MATTHAEI)
460 W=2*(F2 F1)/(F2+F1)
470 G0=1
480 DIM J(N)
490 J0=SQR(PI*W/(2*G0*G(1) ) )
500 J(N)=SQR(PI*W/(2*G(N)*G(N+1) ) )
510 IF N=1 THEN 550
520 FOR K=1 TO N 1
530 J(K)=PI*W/(2*SQR(G(K)*G(K+1) ) )
540 NEXT K
550 PRINT " N    ZOE    Z00    "
560 Z2=Z0*(1+J0+J0↑2)
570 Z1=Z0*(1 J0+J0↑2)
580 PRINT USING 590;1,Z2,Z1
590 IMAGE 2D.1D, 6D.1D, 6D.1D
600 FOR K=1 TO N
610 Z2=ZC*(1+J(K)+J(K)↑2)
620 Z1=Z0*(1 J(K)+J(K)↑2)
630 PRINT USING 640:K+1,Z2,Z1
640 IMAGE 2D.1D, 6D.1D, 6D.1D
650 NEXT K
660 END
```

EXAMPLE

```
RUN
PROG. CALCULATES ZOE, ZOO FOR TCHEBYCHEFF FILTER
Z0= ?85
 F1=, F2= 26, 34
N= ? RIPPLE = ? 5, .5

 N      ZOE      Z00
1.0    148.0    63.8
2.0    116.7    67.5
3.0    109.9    69.6
4.0    109.9    69.6
5.0    116.7    67.5
6.0    148.0    63.8
```

(from page 52) NOVEL PIN

operated at a junction temperature of 100°C, was estimated to be 2×10^7 hours.

CONCLUSION

Using a new glass filled moat structure PIN diode chip, permits a compact high power X-band phase shifter in an MIC format measuring 20 x 41 x 10 mm and weighing below 0.7 ounces. Peak RF power ratings of 300 W (using 500 volt diodes) and 500 W (using 840 volt diodes) were demonstrated to be realistic thru a series of reliability tests, including an 8000 hour lifetest under RF power. This phase shifter design and its diode are well suited to airborne array antennas at X-band and above.

ACKNOWLEDGEMENT

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REFERENCES

1. White, J. F., *Semiconductor Control*, Artech House Pub., Dedham, Mass., 1977. Also, J. F. White, et al, "PIN Diode and Circuit Performance for 15,000 High Power L-Band Phase Shifters," 1975 5th EMC Conference Proceedings, pp. 723-727.
2. Schwarzmann, A., "High Power Performance of 5 kW MIC Diode Phase Shifter," *Microwave J.*, 21, Dec. 1978, pp. 66-67.
3. Hirai, K., et al, "Practical Design of C-Band, MIC, PIN, Phase Shifters," IEEE 1979 MTT Symp. Digest, pp. 229-231.

Susumu Kamihashi was born in Shizuoka, Japan, on June 6, 1948. He received the B.S. and M.S. degrees in electrical engineering from Keio University, Yokohama, Japan, in 1971 and 1973, respectively. Since 1973 he has been with the Toshiba Corporation, Kawasaki, Japan, where he has been engaged in the research and development of microwave circuit components, especially microwave digital phase shifters.

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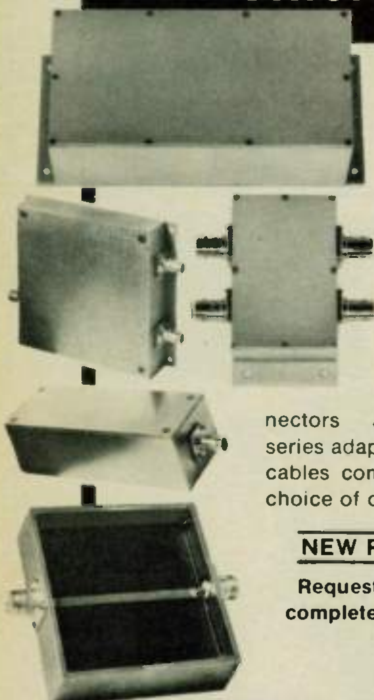

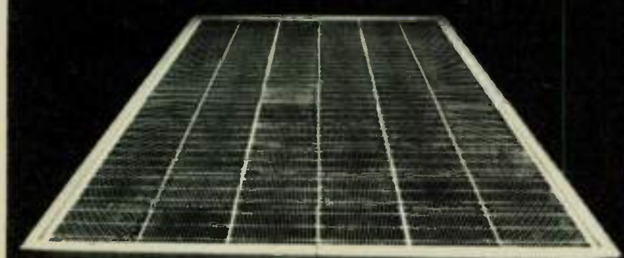

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Reader Service Number	Advertiser	Page Number
45, 46	Aertech Industries	83
27	American Technical Ceramics	48
19	Andersen Laboratories, Inc.	27
41	Anzac Division Adams Russell	78
9, 16	Avantek, Inc.	10, 11, 25
22	Baytron Company, Inc.	32
32, 33	California Eastern Laboratories	62, 63
47	Compac	84
12	Electromagnetic Sciences, Inc.	17
37	EM Systems, Inc.	72
51	Evershed Power Optics Ltd.	20A*
52	Ferranti Ltd.	20B*
26	GEC MO Valve	47
11, 29, 57, 58, 59, 60	Hewlett Packard Co.	14, 15, 59, 66, 67
	Houghton Mifflin	68B*
3	Hughes Aircraft Co.	COVER 4
53	Italtel/SIT	68A*
	ITT Avionics	84
39, 55	ITT Telecommunications	74, 75
	Jet Propulsion Laboratory	79
	J & G Industries, Inc.	79
4	K & L Microwave, Inc.	3
25	Locus, Inc.	44, 45
50	Microlab/FXR	85
35	Microwave Applications Group	65
21	Microwave Power Devices, Inc.	31
2, 7	Microwave Semiconductor Corp.	COVER 3, 8
20	Midwest Microwave, Inc.	28, 29
6, 61	Mini Circuits Laboratory	4, 5, 7
13	Nippon Electric Co., Inc.	18
28, 38	Omni Spectra, Inc.	48, 73
1	Polarad Electronics, Inc.	COVER 2
17, 18	Rogers Corp.	26
14	Sage Laboratories, Inc.	21
	Solarex	84
44	Solitron/Microwave	81
31	Tech Systems Corporation Technicraft Division	61
23	Tecom Industries, Inc.	37
24	Teledyne Microwave	38
30	Texscan Corp.	60
34	Transco Products, Inc.	64
40	UZ, Inc. A Dynatech Co.	76
10	Watkins Johnson Co.	13
8, 56	Wavetek San Diego, Inc.	9
15	Wiltron Co.	22, 23

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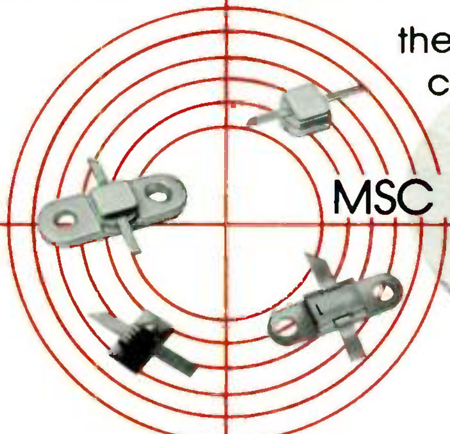

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MSC 88000	6000	0.060	0.050	8	8	90	45	FLIP-CHIP HERMETIC
MSC 88001	6000	0.200	0.175	40	8	150	35	FLIP-CHIP HERMETIC
MSC 88002	6000	0.400	0.350	90	9	300	25	FLIP-CHIP HERMETIC
MSC 88004	6000	1.000	0.800	200	9	700	20	FLIP-CHIP HERMETIC
MSC 88012	6000	3.700	3.500	800	10	2000	7	FLIP-CHIP HERMETIC
X-BAND SERIES								
MSC 88100	12000	0.060	0.050	16	8	90	45	FLIP-CHIP CARRIER
MSC 88101	12000	0.200	0.175	56	8	150	35	FLIP-CHIP CARRIER
MSC 88102	12000	0.400	0.350	125	9	300	25	FLIP-CHIP CARRIER
MSC 88104	12000	1.000	0.800	280	9	700	20	FLIP-CHIP CARRIER
Ku-BAND SERIES								
MSC 88199	15000	0.030	0.025	6	8	70	40	FLIP-CHIP CARRIER
MSC 88200	15000	0.110	0.100	25	8	120	35	FLIP-CHIP CARRIER
MSC 88201	15000	0.250	0.200	70	8	160	29	FLIP-CHIP CARRIER
MSC 88202	15000	0.450	0.400	140	9	325	23	FLIP-CHIP CARRIER
MSC 88204	15000	0.900	0.800	316	9	675	15	FLIP-CHIP CARRIER

NOTE (1) Power Output at the 1 dB Gain Compression point is defined as the point where further increases in input power cause the output power to decrease 1 dB from the linear portion of the curve.

NOTE (2) Thermal Resistance determined by Infra-Red Scanning of Hot Spot Channel Temperature at rated RF operating conditions. Reference MSC Application Note TE 212.

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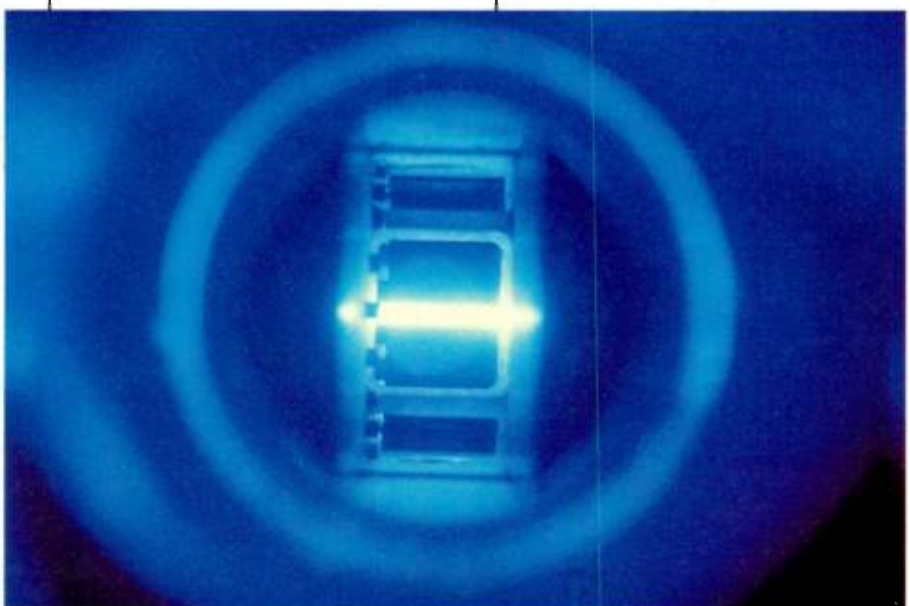

Photo of plasma in a linear confinement device taken through optical window.

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