microwave JOURNAL

INTERNATIONAL EDITION □ VOL. 23, NO. 5 □ MAY 1980

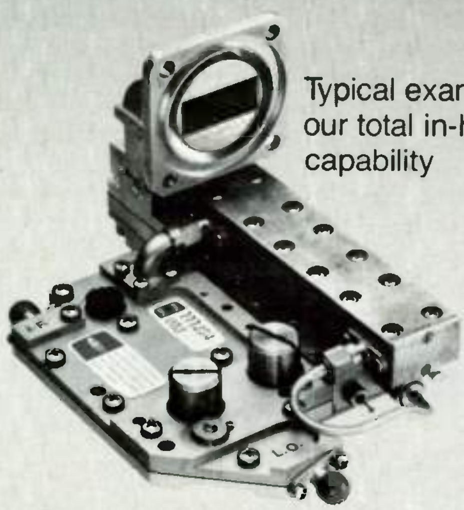
1980 MTT-S Symposium
Washington, DC

Symposium Program
& Exhibition Guide
plus
mm Mixer Technology
Monolithic Microwave IC's
Microstrip-Slotline IC's
ogrammable Spectrum Analyzer

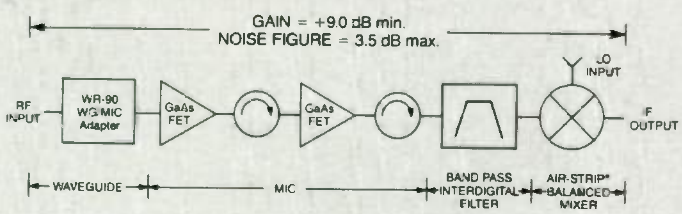
An old friend... MRI with new microwave capability

S-D's half rack size 5000A Sweeper lets you pick and choose the coverage you want from 1 MHz to 26 GHz.

The industry's most versatile and only half rack size sweeper is now even more versatile. We've added two new RF plug-ins to an already broad range. Model 5018 covers 18—26 GHz; Model 5031 covers 18—18 GHz. With the addition of these plug-ins, you have a total of 14 standard interchangeable plug-ins for the most reliable sweeper ever built. Call us and let us know exactly what your requirements are—even if they're special straddle- band applications.



Typical example of our total in-house capability



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Systron-Donner can meet your specialized microwave subsystem needs from antenna arrays through complete receivers, transmitter duplexers and everything in between. Our integrated subsystems use proven state of the art MIC circuits and other techniques such as AIR-STRIP* transmission lines, solid state oscillators and waveguide components. S-D subsystems are available in wide bandwidths and small, lightweight packages. Let us hear from you!

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Circle 1 on Reader Service Card

MITEQ UPDATE ON MIXERS and MIXER/PREAMPLIFIERS

ANNOUNCING

EXTENDED FREQUENCY COVERAGE IN NEW DESIGNS • DECREASED CONVERSION LOSS • INCREASED ISOLATION • IMPROVED PERFORMANCE IN EXISTING DESIGNS

MIXERS

Model	RF and LO Band GHz	IF Band GHz	Conversion Loss dB Typical	Minimum Isolation LO/RF	Minimum Isolation LO/IF	Price
MLO-1A	1-2	0-0.5	5.0	25	15	$125.-
MSO-1A	2-4	0-1.0	5.0	25	15	$150.-
MCO-1A	4-8	0-2.0	6.0	25	20	$225.-
MXO-1A	8-12	0-3.5	6.5	25	20	$250.-
MKO-1A	12-18	0-3.5	6.5	20	15	$275.-
MSO-WB	1.5-6	0-1.0	6.5	20	15	$250.-
MCO-WB	3-10	0-2.0	6.0	20	20	$275.-
MXO-WB	4-15	0-2.5	6.5	20	20	$295.-
MKO-WB	6-18	0-3.5	7.0	20	20	$325.-
M2C	2-18	0-0.5	7.0	20	15	$395.- NEW
	2-12	0-0.5	6.5	25	25	

MIXER/PREAMPLIFIERS

Model	LO/RF GHz	RF/IF Gain Minimum dB	Noise Figure Typical dB	Output Dynamic Range dBm	Price
1-160 MHz IF AMPLIFIER					
MLO-2A-0160	1-3	22	6.5	0	$475.-
MSO-2A-0160	1.5-6	22	7.0	0	$495.-
MCO-2A-0160	3-10	22	7.5	0	$575.-
MXO-2A-0160	4-15	22	7.5	0	$625.-
MKO-2A-0160	6-18	22	8.0	0	$650.-
M2C-2A-0160	2-18	22	8.0	0	$725.- NEW
1-500 MHz IF AMPLIFIER					
MLO-2A-0550	1-3	22	7.0	+8	$475.-
MSO-2A-0550	1.5-6	22	7.5	+8	$495.-
MCO-2A-0550	3-10	22	7.5	+8	$575.-
MXO-2A-0550	4-15	22	8.0	+8	$625.-
MKO-2A-0550	6-18	22	8.5	+8	$650.-
M2C-2A-0550	2-18	22	8.5	+8	$725.- NEW

*Note: For Octave band Mixer/Preamplifiers, deduct $50 from prices.

For additional models with higher RF/IF gains (up to 40 dB) and wider IF bandwidths (5-2000 MHz) call. . . .

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FROM **$7.95** (500 pieces) $ 9.95 (6-49)

For complete specifications and performance curves, refer to 1979-80 MicroWaves Product Data Directory pages 161-369, or 1979 EEM pages 2770-2970.

SELECT THE MODEL YOU NEED

Model	Freq. range (MHz)	Min. isol.-dB (Mid-band	Max. insert. loss-dB (Mid-band)	See notes below	Price (Qty.)
2-WAY 0°					
PSC-2-1	0.1-400	20	0.75		$9.95 (6-49)
PSC-2-1W	1-650	20	0.9		$14.95 (6-49)
PSC-2-2	0.002-60	20	0.6		$19.95 (6-49)
PSC-2-1-75	0.25-300	20	0.75	1	$11.95 (6-49)
PSC-2375	55-85	25	0.5	1	$19.95 (6-24)
PSC-2-4	10-1000	20	1.2		$19.95 (6-49)
MSC-2-1	0.1-450	20	0.75		$16.95 (5-24)
MSC-2-1W	2-650	25	0.8		$17.95 (5-24)
ZSC-2-1	0.1-400	20	0.75	3	$27.95 (4-24)
ZSC-2-1-75	0.25-300	20	0.75	1,3	$29.95 (4-24)
ZSC-2-1W	1-650	20	0.8	3	$32.95 (4-24)
ZSC-2-2	0.002-60	20	0.6	3	$37.95 (4-24)
ZSC-2375	55-85	25	0.5	3	$37.95 (4-24)
ZMSC-2-1	0.1-400	20	0.75	4	$37.95 (4-24)
ZMSC-2-1W	1-650	20	0.8	4	$42.95 (4-24)
ZMSC-2-2	0.002-60	20	0.6	4	$47.95 (4-24)
ZFSC-2-1	5-500	20	0.6	5	$31.95 (4-24)
ZFSC-2-1W	1-750	20	0.8	5	$35.95 (4-24)
ZFSC-2-2	10-1000	20	1.0	5	$39.95 (4-24)
ZFSC-2-4	0.2-1000	20	1.0	5	$44.95 (4-24)
ZFSC-2-5	10-1500	20	1.0	5	$49.95 (4-24)
ZFSC-2-6	0.002-60	20	0.6	5	$36.95 (4-24)
ZFSC-2-6-75	0.004-60	20	0.8	5	$38.95 (4-24)
ZAPD-1	500-1000	19	0.6	6	$39.95 (1-9)
ZAPD-2	1000-2000	19	0.6	6	$39.95 (1-9)
ZAPD-4	2000-4000	19	0.8	6	$39.95 (1-9)
2-WAY 90°					
PSCQ-2-13	12-14	25	0.7†	2	$12.95 (5-49)
PSCQ-2-14	12-16	25	0.6†	2	$16.95 (5-49)
PSCQ-2-40	23-40	18	0.7†	2	$16.95 (5-49)
PSCQ-2-50	25-50	20	0.7†	2	$19.95 (5-49)
PSCQ-2-90	55-90	20	0.7†	2	$19.95 (5-49)
PSCQ-2-180	120-180	15	0.7†	2	$19.95 (5-49)
ZSCQ-2-50	25-50	20	0.7†	2,3	$39.95 (4-24)
ZSCQ-2-90	55-90	20	0.7†	2,3	$39.95 (4-24)
ZSCQ-2-180	120-180	15	0.7†	2,3	$39.95 (4-24)
ZMSCQ-2-50	25-50	20	0.7†	2,4	$49.95 (4-24)
ZMSCQ-2-90	55-90	20	0.7†	2,4	$49.95 (4-24)
ZMSCQ-2-180	120-180	15	0.7†	2,4	$49.95 (4-24)
2-WAY 180°					
PSCJ-2-1	1-200	25	0.8		$19.95 (5-49)
PSCJ-2-2	0.01-20	25	0.5		$29.95 (5-49)
ZSCJ-2-1	1-200	25	0.8	3	$37.95 (4-24)
ZSCJ-2-2	0.01-20	25	0.5	3	$47.95 (4-24)
ZMSCJ-2-1	1-200	25	0.8	4	$47.95 (4-24)
ZMSCJ-2-2	0.01-20	25	0.5	4	$57.95 (4-24)
ZFSCJ-2-1	1-500	25	1.5	5	$49.95 (4-24)
ZFSCJ-2-3	5-300	25	1.5	5	$39.95 (4-24)

1. 75 ohms impedance
†2. Average of coupled outputs less 3 dB
3. BNC connectors standard, TNC available
4. SMA connectors only
5. BNC connectors standard, TNC available, SMA & Type N available at $5 additional cost
6. BNC, TNC, SMA & Type N at $5 additional cost. Please specify connectors
7. TNC, SMA & Type N at $5 additional cost. Please specify connectors
8. SMA connectors standard, BNC on request.
9. BNC connectors standard, TNC available, SMA available at $15 additional cost

Model	Freq. range (MHz)	Min. isol.-dB (Mid-band	Max. insert. loss-dB (Mid-band)	See notes below	Price (Qty.)
3-WAY 0°					
PSC-3-1	1-200	25	0.7		$19.95 (5-49)
PSC-3-1W	5-500	15	1.4		$29.95 (5-49)
PSC-3-1-75	1-200	25	0.7	1	$20.95 (5-49)
PSC-3-2	0.01-30	25	0.45		$29.95 (5-49)
PSC-3-13	1-200	35	0.6		$24.95 (5-49)
ZSC-3-1	1-200	25	0.7	3	$37.95 (4-24)
ZSC-3-1-75	1-200	25	0.7	1,3	$38.95 (4-24)
ZSC-3-2	0.01-30	25	0.45	3	$47.95 (4-24)
ZSC-3-2-75	0.02-20	25	0.6	1,3	$48.95 (4-24)
ZMSC-3-1	1-200	25	0.7	4	$47.95 (4-24)
ZMSC-3-2	0.01-30	25	0.45	4	$57.95 (4-24)
ZFSC-3-1	1-500	20	0.9	5	$39.95 (4-24)
ZFSC-3-1W	2-750	20	1.0	5	$41.95 (4-24)
ZFSC-3-13	1-200	35	0.6	5	$39.95 (4-24)
4-WAY 0°					
PSC-4-1	0.1-200	20	0.75		$28.95 (6-49)
PSC-4-1-75	1-200	20	0.9	1	$24.95 (6-49)
PSC-4-3	0.25-250	20	0.75		$23.95 (6-49)
PSC-4A-4	10-1000	15	1.1		$49.95 (6-49)
PSC-4-6	0.01-40	25	0.5		$29.95 (6-49)
ZSC-4-1	0.1-200	20	0.75	3	$46.95 (4-24)
ZSC-4-1-75	1-200	20	0.8	1,3	$46.95 (4-24)
ZSC-4-2	0.002-20	25	0.5	3	$69.95 (4-24)
ZSC-4-3	0.25-250	20	0.75	3	$43.95 (4-24)
ZMSC-4-1	0.1-200	20	0.75	4	$56.95 (4-24)
ZMSC-4-2	0.002-20	25	0.5	4	$79.95 (4-24)
ZMSC-4-3	0.25-250	20	0.75	4	$53.95 (4-24)
ZFSC-4-1	1-1000	18	1.5	8	$89.95 (1-4)
ZFSC-4-1W	10-500	20	1.5	8	$74.95 (1-4)
ZFSC-4375	50-90	30	1.2	1,8	$89.95 (1-4)
6-WAY 0°					
PSC-6-1	1-175	18	1.0		$68.95 (1-5)
ZFSC-6-1	1-175	20	1.2	9	$89.95 (1-4)
8-WAY 0°					
PSC-8-1	0.5-175	20	1.1		$68.95 (1-5)
PSC-8-1-75	0.5-175	20	0.8	1	$69.95 (1-5)
PSC-8A-4	5-500	18	1.8		$89,95 (1-5)
PSC-8-6	0.01-10	23	1.1		$79.95 (1-5)
ZFSC-8-1	0.5-175	20	1.1	10	$89.95 (1-4)
ZFSC-8-1-75	0.5-175	20	1.0	1,10	$90.95 (1-4)
ZFSC-8375	50-90	25	1.3	1,10	$119.95 (1-4)
ZFSC-8-4	0.5-700	20	1.5	10	$129.95 (1-4)
ZFSC-8-6	0.01-10	23	1.1	10	$109.95 (1-4)
16-WAY 0°					
ZFSC-16-1	0.5-125	18	1.6	11	$174.95 (1-4)
24-WAY 0°					
ZFSC-24-1	0.2-100	20	2.0	12	$264.95 (1-4)

10. BNC connectors standard, TNC available at $10 additional cost, SMA at $25 additional cost.
11. BNC connectors standard, TNC available at $20 additional cost, SMA available at $45 additional cost.
12. BNC connectors standard, TNC available at $35 additional cost, SMA available at $65 additional cost.

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Mini-Circuits

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ON THE COVER: The new Tektronix 492P programmable spectrum analyzer simplified measurements in the 50 kHz - 220 GHz range. See Technical Feature beginning on page 89.

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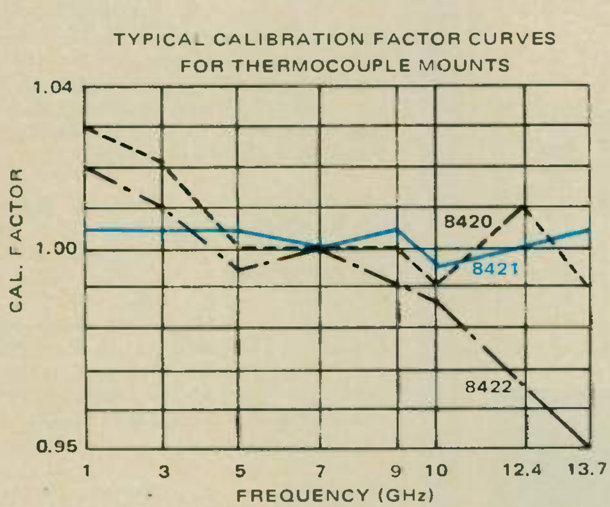
NEW 30 dB Mini-Power Meter



Makes accurate measurements from .01 to 13.7 GHz Inexpensively

This new 30 dB dynamic range power meter is an inexpensive, hand size, battery operated device which makes it easy to measure accurately RF power in the 10 MHz to 13.7 GHz range. It is particularly convenient for use in radar and TV antenna applications . . . at satellite communication facilities . . . broadcast stations and CATV, as well as for aircraft applications. Two mounts provide a dynamic range of 1 μW to 100 mW (−30 dBm to +20 dBm). In addition to the 50 ohm mounts, a 75 ohm mount is also available for CATV applications. For complete specifications and information, write The Narda Microwave Corporation, Plainview, N.Y. 11803.

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Coming Events

1980 INT'L SYMPOSIUM JUNE 2-6, 1980
Sponsors: IEEE Antennas and Propagation Society (AP-S) and the North American Radio Science Meeting of the International Union of Radio Science (URSI). Site: Université Laval, Québec. Contact: Prof. Jules A. Cummins, Chrm., Steering Comm., Département de génie électrique, Université Laval, Cité universitaire, Québec, Canada G1K 7P4. Tel: (418) 656-2143.

15th SYMPOSIUM ON ELECTROMAGNETIC WINDOWS JUNE 18-20, 1980
Sponsor: Georgia Institute of Technology. Place: GIT, Atlanta, GA. Topics: radomes and radome techniques. Contact: D. J. Kozakoff, Engineering Experiment Station/EML/RSD, GIT, Atlanta, GA 30332. Tel: (714) 632-2584.

38th DEVICE RESEARCH CONFERENCE JUNE 23-25, 1980
Sponsor: Rockwell International. Place: Cornell University, Ithaca, NY. Contact: Fred A. Blum, Conference Chrmn., Rockwell Int'l, P.O. Box 4761, Anaheim, CA 92803. Tel: (714) 632-2584.

AFCEA 34th ANNUAL CONVENTION JUNE 24-26
Sponsor: Armed Forces Communications and Electronics Association (AFCEA). Place: Sheraton Washington Hotel, Washington, DC. Topics: electronics, computers, a-v, C^3, intelligence systems, plus exhibition. Contact: Judith H. Shreve, Ed., Signal Magazine, One Skyline Place, 5205 Leesburg Pike, Suite 300, Falls Church, VA 22041.

10th EUROPEAN MICROWAVE CONFERENCE SEPT. 8-12, 1980
Sponsors: Association of Polish Electrical Engineers, EUREL, IMPI, URSI and IEEE Region 8 — in association with Microwave Exhibitions and Publishers Ltd. Place: Warsaw, Poland. Contact: Prof. Andrzej Sowiński, EuMC Conf. Chrmn., Industrial Inst. of Electronics, ul Długa 44/50, 00-241, Warszawa, Poland.

MILITARY MICROWAVES '80 CONFERENCE AND EXHIBITION OCT. 22-24, 1980
Sponsor: Microwave Exhibitions and Publishers Ltd. Place: Cunard Int'l Hotel, London. Topics: Military applications of microwave engineering. Contact: R. C. Marriott, Mng. Dir. MEPL, Kent TN13 1JG. Tel: (0732) 59533/4. Telex: 95604 YNLTD G.

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Thin-Film Performance ...Thick-Film Price

These new thick-film, TO-8 packaged microwave amplifiers give you a high-performance, low-cost alternative to thin-film devices

Now Alpha's Optimax Division offers a line of microwave amplifiers that combine miniature size, outstanding performance and reliability, and at very attractive prices.

Employing discrete, lumped-parameter elements on a thick-film substrate, these hybrid modules offer the microwave equipment manufacturer a practical and economical alternative to thin-film devices.

The new series is the result of a specially-developed manufacturing process oriented to high-volume production. All models are constructed to MIL-M-38510A specifications, and can meet the rigorous screening of MIL-STD-883 Class B.

MICROWAVE MODULAR AMPLIFIERS (TO-8 Hermetic Package)

Optimax Model #	Freq. Range MHz	Small Signal Gain (db)		Gain Flatness ± db	Noise Figure db		Power Out @ 1db Comp dbm		IP 3rd Order Min – 54/85°C	VSWR In/Out	DC Supply Voltage
		Typ 25°C	Min – 54/85°C	Max – 54/85°C	Typ 25°C	Max – 54/85°C	Typ 25°C	Min – 54/85°C		Max – 54/85°C	V/ma Typ
AH 11-1	5-1000	14.7	13.5	1.0	3.1	4.0	–2.0	–4.0	6.0	2.0	15/9
AH 11	5-1000	14.7	13.5	1.0	3.6	4.5	–2.0	–4.0	6.0	2.0	15/9
AH 63	5-1000	16.0	14.5	1.0	3.0	4.5	4.0	2.0	12.0	2.0	15/14
AH 15	5-1000	14.5	13.0	1.0	5.4	7.0	8.7	6.5	16.5	2.0	15/24
AH 17	10-1000	12.0	10.0	1.0	6.1	8.0	15.3	13.5	23.5	2.0	15/44
AH 23	5-1500	11.0	9.5	1.0	4.8	6.0	4.0	2.0	12.0	2.0	15/14
AH 25	5-1500	10.0	8.0	1.0	6.0	8.0	9.0	6.5	16.5	2.0	15/25
AH 28	5-1500	11.0	9.5	1.0	6.0	7.5	15.0	13.5	23.5	2.0	15/45
AH 33	10-2000	9.5	8.0	1.0	4.5	6.0	3.0	2.0	12.0	2.0	15/14
AH-35	10-2000	10.2	8.5	1.0	5.0	7.0	9.0	6.5	16.5	2.0	15/24
AH 37	10-2000	9.3	7.0	1.0	6.5	8.5	15.5	13.5	23.5	2.0	15/45

Call or write for price and performance data. Send for the Optimax RF Amplifier & Hybrid Circuit catalogs.

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See you at the **M.T.T.** Conference
Booth # 7

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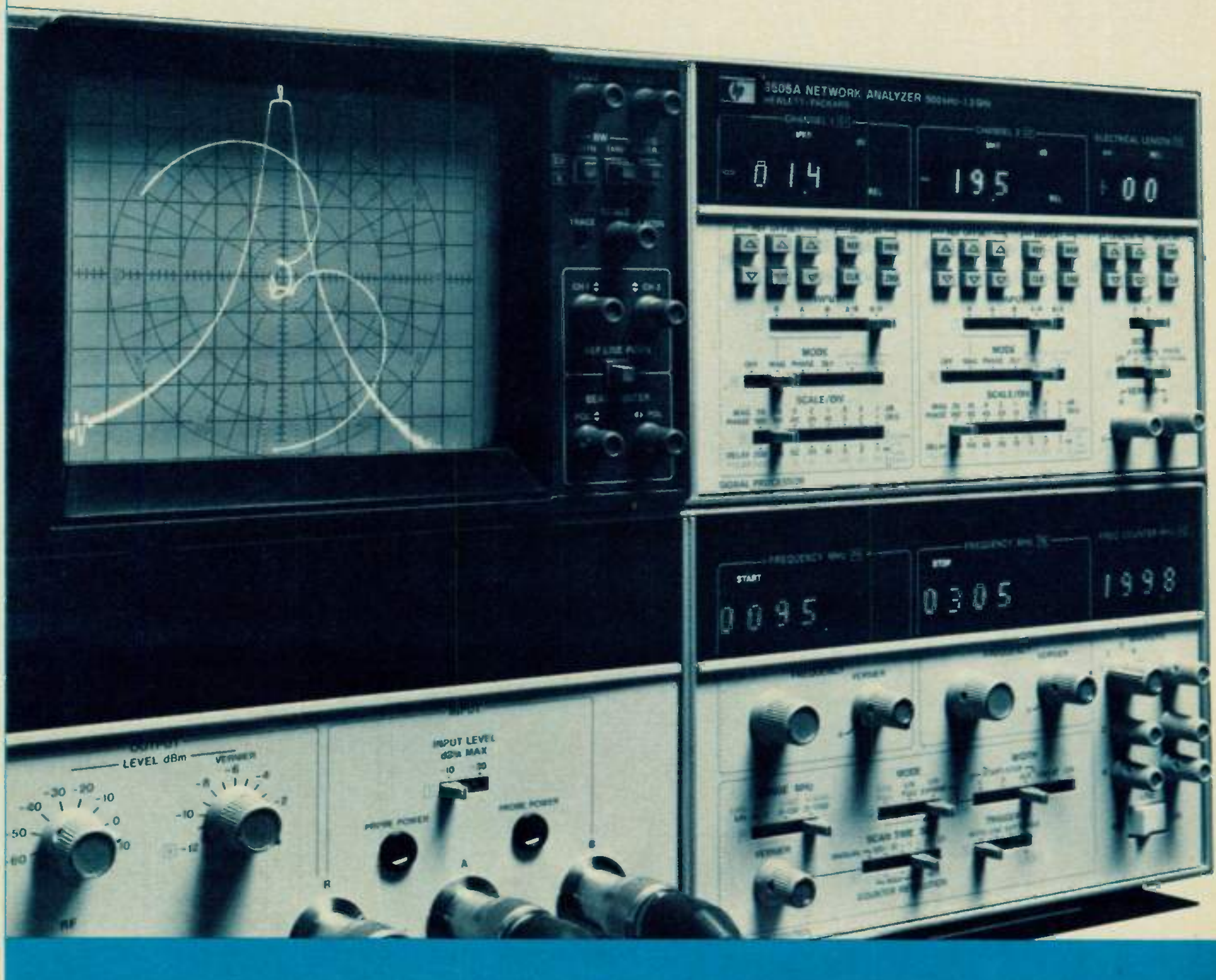
The 1300 MHz Network Analyzer–

Until now performance like this was beyond reach:



• Over 3 Decades of Swept Frequency Coverage
• 100 dB Dynamic Range
• Direct Measurement of Group Delay

HP's 8505A Network Analyzer brings the precision, resolution and range you need for the measurement of phase and magnitude of transmission and reflection, group delay and deviation from linear phase. And any two parameters can be measured and displayed simultaneously.

• Test signals come from the 8505A's built-in high performance sweeper with exceptional spectral characteristics and a wide variety of sweep modes (including two independent start/stop sweeps) to accommodate virtually any test requirement.

• The 8505A's 500 kHz to 1.3 GHz frequency range gives you the broad coverage you need to characterize such networks as filters, transistors, antennas, cables, SAW devices and crystals.

• Your measurements are fast and accurate thanks to a swept display with a marker system that provides a high resolution digital readout of the parameter's value at the frequency of any of five variable markers. And group delay measurements are made directly: no calculations required. Or you can observe phase distortions directly in the form of *deviation* from linear phase using the 8505A's revolutionary electronic line stretcher.

• With optional phase-lock capability, the 8505A can be locked to such precision signal sources as the HP 8640 and 8660 Signal Generators. This provides the stability and resolution needed to characterize ultra narrowband devices such as crystal filters.

Get the speed, precision and efficiency of automatic measurements.

Because the analyzer is programmable, via the Hewlett-Packard Interface Bus (IEEE-488), you can combine the 8505A with a computing controller such as HP Model 9825A Desktop Computer to configure a powerful automatic measurement system. With remarkably simple programming you can make many measurements quickly and with enhanced accuracy, and easily format the data to the form you want. The result is high throughput for cost-effective operation in both production test and design lab applications.

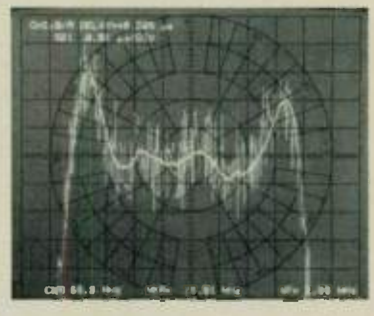
Find Out More.

We've only touched on the highlights of the 8505A's performance and capabilities here. For complete data, contact your nearby HP field sales office, or write 1507 Page Mill Road, Palo Alto, CA 94304.

Add capability with HP's Storage-Normalizer.

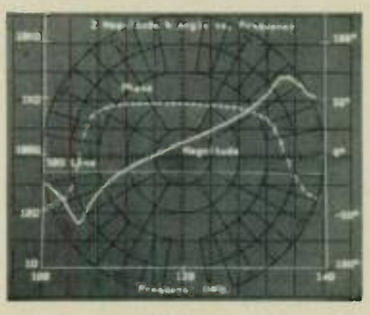
The companion HP 8501A Storage-Normalizer brings these additional features to the 8505A Analyzer:

- *Digital storage* for flicker-free displays.
- *Normalization* to remove errors and make direct comparisons.
- *Magnifier* for up to a tenfold increase in resolution.
- *CRT Labeling* that presents major 8505A settings and marker data.
- *Signal Averaging* that raises signal-to-noise ratio, thereby improving narrowband group delay and low signal level measurements.



Group Delay of 70 MHz bandpass filter with and without averaging (Vert scale 5nsec/div)

When the HP-IB programmable 8501A is combined with the automatic 8505A/computing controller combination, the system offers versatile display capabilities for text and graphics plus high-speed digitizing for fast, yet precise and comprehensive measurements.



Reflection Coefficient data reformatted to impedance magnitude and angle

45906A

HEWLETT PACKARD

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MTT-S '80

Consulting Editor Joe White provides an invaluable guide to all facets of the 1980 MTT-S Symposium/Exhibition. Replies from a number of the session chairmen to his questionnaire provide the kind of insight into session material which will be helpful when the parallel session format makes it necessary to select one session to attend from a number which are of interest. The spouses program is covered in detail and a complete guide to the Exhibition is provided.

MILLIMETER WAVE MIXER TECHNOLOGY

The article addresses mixers for the 60 to 340 GHz range. Three different Schottky barrier mixer diodes are considered, each of which is most suitable for a particular transmission medium. Performance and design trade-offs for the three diode types are discussed. Mixers in waveguide, suspended stripline, dielectric waveguide and quasi-optical systems are covered. Models of each type with performance data are shown.

Sum Up

MONOLITHIC MICROWAVE INTEGRATED CIRCUITS

The advent of GaAs semi-insulating substrates with resistivities as high as 10^9 ohm-cm and ion implantation doping technology, which affords highly precise control of active region doping, open the way to practical monolithic microwave integrated circuits. Based on work funded partially by ERADCOM, the article itemizes the benefits available from monolithic technology. It reviews appropriate material and process technology, discusses the transmission media available for circuit application and the circuit elements which are achievable. Examples of broad and narrowband amplifiers built with the techniques are discussed. An 8 GHz mixer circuit is also shown.

AUTOMATED SPECTRUM ANALYSIS

The virtues of a programmable spectrum analyzer which incorporates an ability to operate under remote program control and has internal processing capability are related to some practical measurement situations. A pattern recognition routine simplifies the identification of particular characteristics of a signal. Full GPIB compatibility benefits are illustrated with examples of analytical measurement routines. The ability to convert raw data into common units and routines to eliminate set up errors are also discussed.

MICROSTRIP-SLOTLINE COMPONENTS FOR MIC's

The usefulness of coupled lines in microstrip is limited by the difficulty of achieving tight coupling between such lines. A combination microstrip-slotline medium relieves those difficulties and broadens the range of components which can be realized. The paper illustrates the design of a three-section maximally flat 3 dB coupler for 4 GHz and a 3 GHz bandpass filter with a maximally flat characteristic in a 15% passband and an attenuation level higher than 30 dB outside of the passband. Both designs appear quite impractical in normal microstrip.

LUMPED ELEMENT IN-PHASE POWER DIVIDERS

Lumped element in-phase equal amplitude power dividers are viable alternatives to iron/aircore transformers at UHF and at frequencies above 1 GHz. The same approach may be applied to impedance transformers. The design procedure and design equations are given. An example of a 50 Ω divide for 400 to 450 MHz is shown with calculated and measured characteristic data.

Howard Ellowitz

Workshops & Courses

1980 ENGINEERING SUMMER CONFERENCES

Sponsor:	U. of Michigan, College of Engrg., Cont. Engrg. Ed.
Topics:	No. 16 – Microwave Sensing Technology (emphasis on synthetic aperture radar systems) No. 27 – Microwave Semiconductor Devices and Circuit Applications
Dates and Fees:	No. 16 – June 23-27, 1980, $475 No. 27 – July 28-August 1, 1980, $495
Chairmen:	No. 16 – Adam Kozma; No. 27 – George I. Haddad
Contact:	Engineering Summer Conferences, 800 Chrysler Cnt., N. Campus, The U of Michigan, Ann Arbor, MI 48109 Tel: (313) 764-8490

RADAR ECCM COURSE

Sponsor:	George Washington U.
Date:	July 21-25, 1980
Topics:	Overview of ECM techniques, including ECCM.
Fee:	$620
Contact:	Dir., Cont. Engineering Ed., George Washington U. Washington, DC 20052 Tel: (202) 676-6106

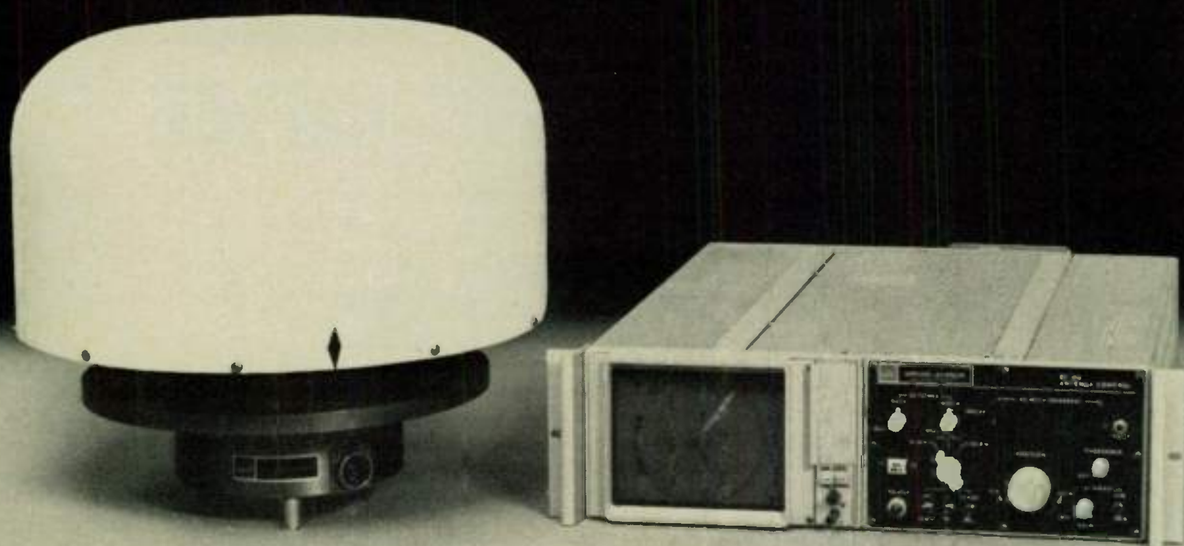
RADAR TECHNOLOGY SEMINAR

Sponsor:	Benelux Section of IEEE, Eindhoven U of Tech.
Date:	August 26-27, 1980
Subjects:	Radar, signal processing, solid-state, tubes, tracking, and detection.
Lecturer:	Eli Brookner, Consulting Scientist, Raytheon Co.
Contact:	Dr. Eduard J. Maanders, Dept. of Electrical Engrg., Eindhoven U. of Tech. Eindhoven, Netherlands. Tel: 040 - 473427, 473447, or 473417.

GIDEP ANNUAL WORKSHOP

Sponsor:	Government-Industry Data Exchange Program
Date:	October 21-23, 1980
Site:	Sheraton Brock Hotel, Niagara Falls, Canada
Topics:	Engrg., failure experience, reliability/maintainability, and metrology
Contact:	Connie Kirkpatrick, Publicity Chrmn., Rockwell Int'l, Space Systems Group, 12214 Lakewood Blvd., D/092 AE99, Downey, CA 90241.

DF Systems from Watkins-Johnson



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Watkins-Johnson Company, an established leader in state-of-the-art passive ECM receiving equipment, presents its smallest, most versatile spinning DF antenna system.

This compact system consists of the L-6-24 spinning DF Antenna and an EP-30 Pedestal which are controlled by an EC-60 Control/Display Unit.

Suitable for any type of installation — airborne, shipboard, or land-based — the control system is able to utilize a wide variety of other W-J antennas and pedestals. Their small, modular packaging makes the system ideal for space-critical installations.

Key features include:

EC-60 Control Unit
- More Compact
- True/Relative Capability
- Video Threshold Alarm
- SECTOR SCAN, SCAN, SLEW modes of operation

L-6-24 DF Antenna
- Smaller
- Receives circular, horizontal, and vertical polarization
- Dimensions: 8" x 15"
- Frequency Range: 1–18 GHz

EP-30 Pedestal
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- Fewer moving parts

Our units are still the same quality hardware you've come to expect from W-J. They're just smaller!

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Now you can automatically make the most important microwave measurements ...return loss (SWR), transmission loss or gain and absolute power...quickly and accurately over the 10 MHz to 18 GHz range with hard copy output. Straightforward program-guided inputs are easy to follow.

Wiltron's new 5610 desktop computerized system gives you a new level of accuracy, convenience and cost savings. You simply plug in the preprogrammed cartridge that comes with each system, enter a few simple inputs through the controller, then get hard copy test data over a 66 dB (+16 dBm to −50 dBm) dynamic range from 10 MHz to 18 GHz. No other scalar system is remotely comparable.

Turnkey system includes programming.

Wiltron's 5610 system is delivered complete and ready to work. The system includes a 560 Scalar Network Analyzer, 610D Sweep Generator, 560-97A50 (GPC-7) SWR Autotester, 560-7A50 Detector, HP 9825A Desktop Computer and HP 7225A Plotter. We also include the preprogrammed measurement software cartridge, as well as all cables and accessories. Option 3 provides a WSMA test port connector. Option 4 is Type N. Special versions are available for operation up to 40 GHz.

A new era in microwave measurement.

0.01 dB resolution. • SWR measurements with better than 40 dB directivity. • 66 dB dynamic range. • One sweep generator covers the 10 MHz to 18.5 GHz range. • A new WSMA (SMA compatible) connector with improved return loss measurement accuracy and life expectancy. • Digital memory techniques which substantially improve measurement accuracy. • Calibration techniques which correct for variations caused by frequency response variations and test port mismatch errors. • Refreshed display of memory-corrected measurement results.

Wide Application.

The 5610 is well suited to both laboratory and production line applications. Almost every kind of RF component or system can be tested. For instance:

Test amplifiers to measure gain, power, isolation and return loss over 66 dB dynamic range.

Test filters to plot insertion loss and return loss individually or together on a single page with 0.01 dB resolution.

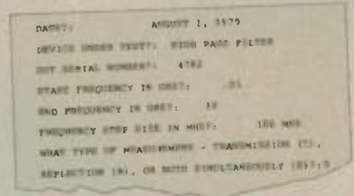
Test antennas to make precise return loss measurements with 40 dB directivity accuracy and memory-corrected test data.

In the lab, on the line, payback is fast.

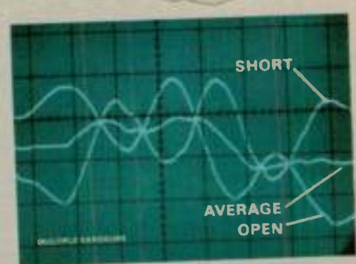
Even if you're only testing a single device, substantial savings are yours with the new Wiltron 5610 system. And, on the production line, you'll get your initial investment back even faster.

For an early demo or full data, phone Walt Baxter, (415) 969-6500, or address Wiltron, 825 East Middlefield Road, Mountain View, CA 94043.

Easy 4-step operation

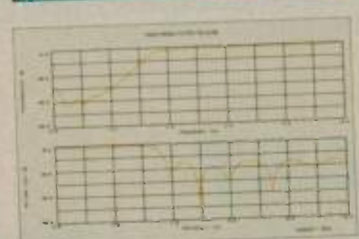


Enter test parameters on controller



Store system residuals in memory for later correction of test data

Use CRT display to confirm proper operation of system and to adjust device under test



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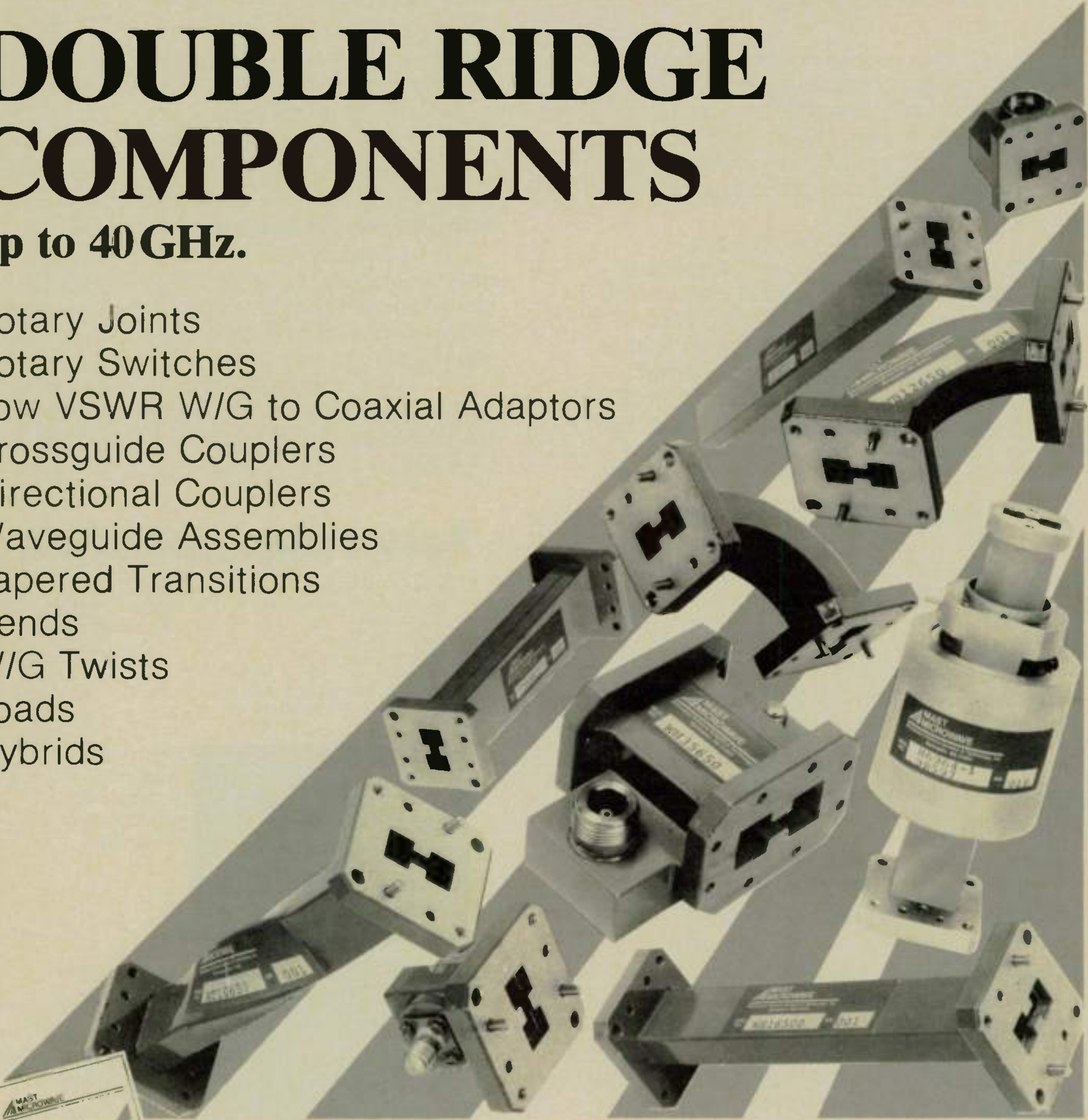

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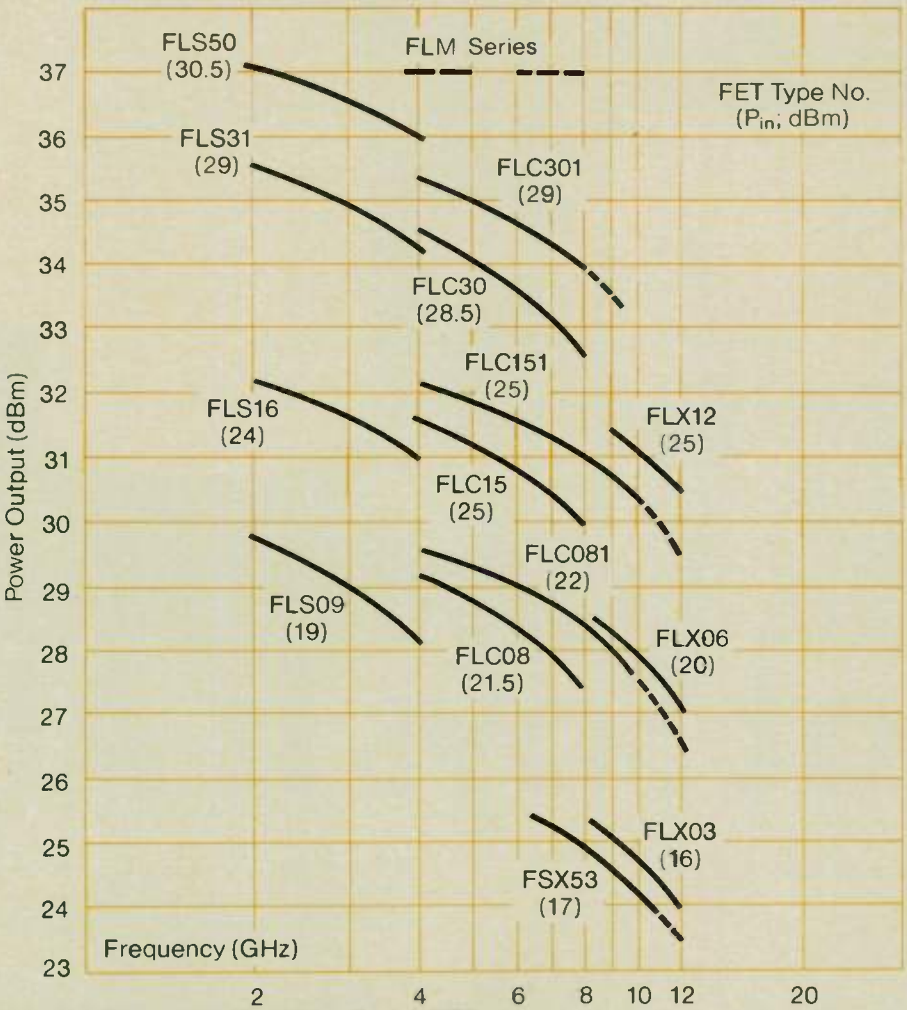
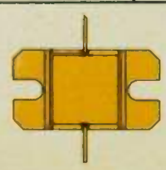
Get High Power With Internally Matched GaAs Power FETs

Fujitsu GaAs FET family



FLM Series (Internally Matched FET)

Device Type		FLM4450-5	FLM5964-5	FLM6472-5	FLM7177-5
Power Output (dBm) V_{DS} = 10V, $I_{DS} \approx 1/2\ I_{DSS}$	Min.	36	36	36	36
	Typ.	37	37	37	37
$Z_S = Z_L = 50\Omega$	P_{in} (dBm)	29	31	32	33
	Freq. Range (GHz)	4.4–5.0	5.9–6.4	6.4–7.2	7.1–7.7



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Fact is, no one makes more stripline substrates than Oak: A major U.S. corporation dedicated to producing all the substrates you need and the copper to clad them. For any application, all the way up to 300 GHz.

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E&C MICROWAVE BULLETIN

MICROWAVE ABSORBERS—ANECHOIC CHAMBERS--EMI/RFI SHIELDING—MICROWAVE DIELECTRICS

EMERSON & CUMING   DEWEY AND ALMY CHEMICAL DIVISION   W.R. GRACE & CO.

E&C Holds Down Silver Costs and Helps Find Alternatives

Like every other manufacturer in electronics, E&C is concerned about increasing and fluctuating prices of silver.

Many E&C products contain silver in varying amounts. They include ECCOBOND® conductive adhesives; ECCOSHIELD® conductive plastic gaskets and EMI/RFI shielding materials, anti-static, reflective and absorbtive coatings; and other conductive adhesives, coatings and casting resins.

Until this situation eases, we are adopting a simple policy which we believe will help our customers contain their costs and continue to gain the benefits of using E&C conductive plastics:

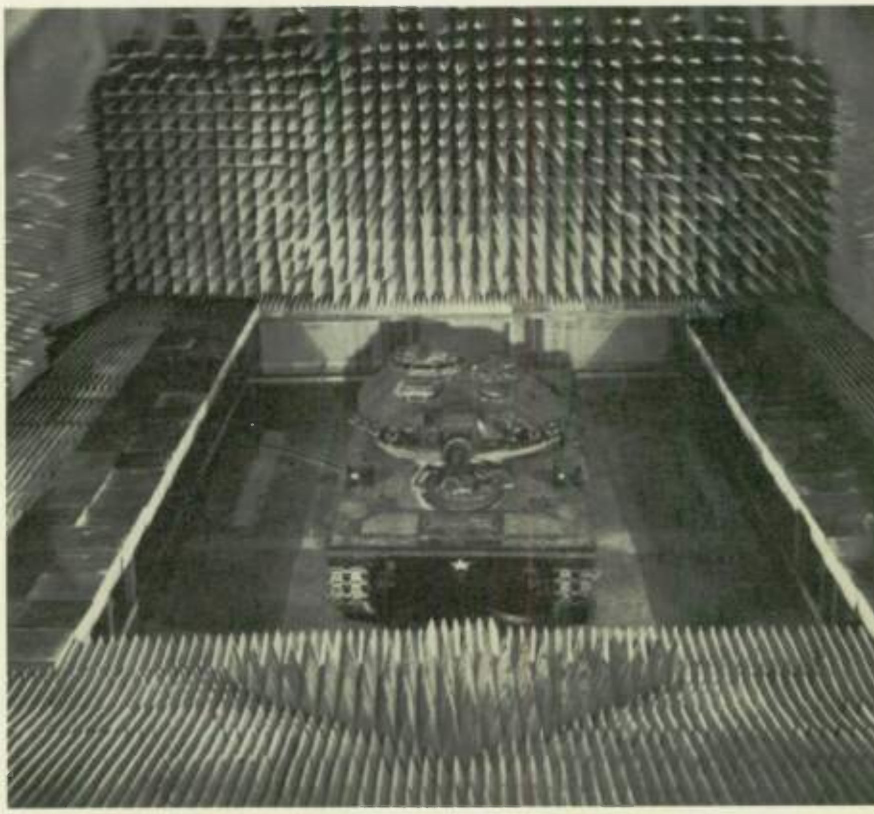
1. We will maintain adequate supplies of silver to meet customers' requirements for silver-loaded products.
2. We will maintain prices of silver-based products at pre-inflationary levels, adjusted only for the added cost of purchased silver — no mark-up, no added profit.
3. We will continue to work in our laboratories and with customers to supply satisfactory, alternative, non-silver materials where they can be cost-effectively applied.

A variety of conductive adhesives, coatings and resins — both with and without silver — are described in the E&C "Eccoamp" folder which we'll be pleased to send to you on request. It may answer some of your problems.

Eccobond Solder 56-C

Circle No. 51 on Reader Service Card

Anechoic Chamber for Testing Defense Systems Sets New Standards of Efficiency and Safety



ECCOSORB Anechoic Chamber No. 1063 is provided under contract by New Mexico State University Physical Sciences Laboratory for the U.S. Army, Office of Missile Electronic Warfare (OMEW) (EW Laboratory, ERADCOM) at White Sands Missile Range, New Mexico. It is one of the newest and most advanced facilities in the world for conducting electromagnetic research.

Emerson & Cuming was selected to provide anechoic design, engineering, fabrication, and testing of the chamber to meet NMSU specifications. Efficiency and personnel safety were primary goals.

The finished chamber comprises a 62-foot long "funnel" opening into a 50-foot (15 meters) long by 40-foot (12 meters) wide by 28-foot (8.5 meters) high rectangular volume. Guaranteed maximum reflectivity is −50 dB at 10 to 40 GHz and −20 dB at 0.2 to 0.5 GHz in a 15-foot (4.6 meters) diameter by 25-foot (7.6 meters) long cylindrical quiet zone. Reflectivity of −55 dB is achieved in a 13-foot (4.0 meters) spherical quiet zone at 40 GHz.

The chamber employs modern, high-performance materials in a configuration created by the most modern design technology. ECCOSORB VHP and HPY line the walls of the rectangular portion. ECCOSORB WG is used on the less critical funnel surfaces. All materials are NRL-type fire-retardant. Smoke detection and fire extinguishing systems also are installed. A special positioning system has been provided for moving equipment in and out of the chamber. The removable chamber floor supports heavy, self-propelled vehicles.

The OMEW Chamber is a prime example of E&C's capability to provide superior design, fabrication, and engineering management to achieve state-of-the-art performance in microwave anechoic chambers. Use the Reader Service Card to request more information.

Circle No. 52 on Reader Service Card

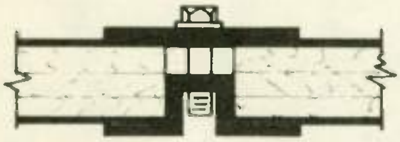
Folder Explains RF-Shielded Chamber Construction

ECCOSHIELD® RF-Shielded Chambers, Building Materials and Kits are described in a four-page illustrated folder available on request. Three basic constructions are shown. Highest performance is offered by ECCOSHIELD PG and KPG Kits. Kits include wall, ceiling and floor panels, joint strips, ECCOSHIELD MAS Magnetic Area Seal RF-Shielded Door, line filters, electrical system, lights, blower, ventilation system, and complete, easy-to-follow assembly instructions. Standard sizes of kits are 8′ x 8′ x 8′ (2.4 m x 2.4 m x 2.4 m) to 8′ x 16′ x 24′ (2.4 m x 4.9 m x 7.3 m); larger sizes available on special order.

ECCOSHIELD PG and KPG Panels are ¾-inch (1.9 cm) plywood with zinc-coated steel on both faces. They are mechanically joined and sealed by "hat-and-flat" joint hardware.

Typical insertion loss for a well-constructed PG and KPG Chamber is: magnetic fields 60 dB at 15 kHz, increasing to 100 dB at 250 kHz to 1 MHz; electric fields 100 dB from 15 kHz to 100 MHz; plane waves 100 dB from 100 MHz to 10 GHz.

E&C also offers a complete line of rf sealing, caulking, adhesive and lubricating products, as well as conductive plastic gaskets for EMI/RFI shielding applications.



Eccoshield PG & KPG "Hat-F-Pair" Joint Strip

Eccoshield PG & KPG "Hat-C-Pair" Joint Strip

Rigid High Temperature Plastic Foam Sheet Stock

ECCOFOAM® SH is a rigid polyurethane foam which remains rigid and withstands temperatures as high as 275F (135C). It is primarily useful as a high-temperature structural member or thermal barrier in electrical/electronic applications, such as radome sandwich cores, insulators and antenna dielectrics.

ECCOFOAM SH is available in bulk densities having a range from 2 to 14 lb/cu ft (0.3 to 0.22 g/cc). Unlike other polyurethanes, dissipation factor is kept extremely low and the stock is easily machinable. For continuous use, the temperature range is from −94F to 275F (−70C to 135C).

Sheet size is 12″ x 24″ (30.5 cm x 61 cm) and thicknesses range from 1″ to 4″ (2.5 cm to 10 cm). Other sizes and shapes are available on special order.

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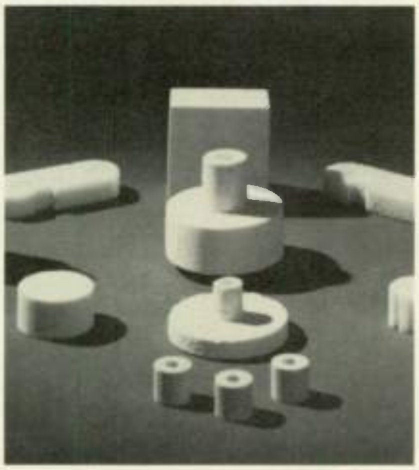

Machined Parts of ECCOFOAM® SH

Measuring "Termination VSWR"

When an anechoic chamber is used for antenna-impedance measurements or for coupling and EMC-compatibility measurements among various antennas, the performance criteria of the chamber should include the ratio between primary power transmitted by one antenna and reflected power received by the same antenna or by adjacent antennas.

This ratio can be measured and expressed as the equivalent VSWR of the chamber acting as a free-space termination for the transmitting antenna. Values of "termination VSWR" are typically very low (1.02 to 1.002 or lower) and usually can't be measured by the moving-probe slotted-line technique.

A simple procedure for making such measurements is given in a short "technical note" available from E&C.

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ECCOSORB® HPY

Improved Ultrahigh Performance Absorber for Anechoic Chambers

ECCOSORB HPY is a series of lightweight pyramidal foam microwave absorber combining state-of-the-art anechoic performance with low cost. The series, which is used in many advanced chambers throughout the world, has been improved significantly in recent years to keep pace with changing customer requirements.

New design features offer increased fire safety, a wider range of design options and improved installation techniques for designers, builders and users of microwave anechoic chambers.

An HPY version with vent holes (photo) permits escape of heat and entry of water used for fire extinguishment. Holes do not affect electrical performance.

These improvements, and others, are fully detailed in an updated Technical Bulletin recently issued by E&C. The bulletin also contains results of new and extensive electrical tests.

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Stephen F. Adam is a native of Hungary, born and raised in Budapest. He holds an equivalent to Masters Degrees in Mechanical and Electrical Engineering and a Doctorate in E.E. (1952, 1955, 1965); he also holds a teacher's degree and a California Teaching Life Credential. He was a member of the technical staff of the Telecommunications Research Institute in Budapest from 1951-1956 doing research and development in the field of microwave measurement. From 1957 he has been a member of the technical staff of Hewlett-Packard Company, involved with research and development of numerous microwave instruments. He is now in charge of a laboratory section of Stanford Park Division developing Microwave Test Instruments. He has taught microwave theory and measurements at Foothill College for 9 years and has written a textbook: "Microwave Theory and Applications" (Prentice-Hall, 1969) and several articles. He holds several patents and patents pending in the microwave field and is a Senior Member of IEEE, member of MTT-S, G-IM. Mr. Adam is a member of MTT-S ADCOM since 1972 and 1980 President of MTT Society, past chairman of the 1975 MTT-S Symposium Technical Program Committee, and past chairman of MTT-S Standards Coordinating Committee.

Technology Growth for the '80s

Technology Growth for the '80s is the theme of the IEEE MTT-S International Microwave Symposium this year to be held in Washington, DC May 28-30. Over 1,000 microwave specialists and people interested in microwaves are expected to attend from around the world at this, the biggest microwave gathering of the year. Since 1972 the annual Microwave Symposium, provides excellent technical sessions where advances in many related fields are presented as well as a very high level exhibition. Due to its thoroughly professional management; it became, for the microwave industry, the most desired place to show new developments.

Microwave product development strategies are driven mainly by two forces: market and technology. This year's symposium theme was very appriately chosen to deal with the growth of technology. With the rapid increase in computational speed of digital techniques, more and more people are applying microwave technologies. Many domestic and numerous proposed international projects most certainly press for great technological advances.

Our society's most active Technical Committees are sponsoring five workshops just before the Symposium. They are: "Gigabit Logic for Microwave Systems" by MTT-9; "Millimeter Wave Devices Using Gyrotropic Media" by MTT-4 and MTT-13; ARFTG, Automatic Radio Frequency Techniques" by MTT-11 and ARFTG; "Monolithic Microwave Analog I.C.'s" by MTT-6, MTT-7 and ED-S; "Symposium on Electromagnetic Dosimetric Imagery" by MTT-10 and DoD. We will also have two evening panel sessions: "The Solar Power Satellite System" by MTT-16; "Millimeter-Wave I.C.'s – Challenge of the '80s" by MTT-6.

Special commendation is due to Dr. Lawrence R. Whicker. Symposium General Chairman and his entire Steering Committee for organizing a most memorable Symposium in our Nation's Capital. Besides having a very comprehensive technical program, special events are planned, Washington style.

The Technical Sessions will contain 161 total papers. As for the past few years, we will have four parallel sessions. Special care was exercised in the timing of the sessions so as not to overlap sessions with similar areas of interest. We will again have a special invited Japanese Session on "Satellite Broadcasting in Japan" organized by the Tokyo MTT-S Chapter comprised of 9 papers, and a special invited Europian session on "Satellite Communication Systems in Europe." Another topic, "Microwave Engineering for Export" session promises to be a very interesting, timely one.

Dr. Arden L. Bement, Deputy Under Secretary of Defense (Research and Technology) is going to give DoD's view of Technology Growth for the '80s in his keynote address at the plenary, opening session.

This symposium is, again, truly an international one. Half of the papers are from the US, the rest are from Japan, 12 European countries, Canada, Australia and Egypt. Subjects will range from field theory, measurement techniques, systems and components through circuit applications to discussions of satellite communications, satellite broadcasting and biological applications and effects.

A question was raised not long ago. Is the microwave industry a mature industry destined to very slow growth, or even to shrink? Reviewing the activity above and looking forward to the '80s, anticipating the technological growth that is just before us. I can't help but feel great pride. The industry possesses a generic technology to be exploited for many years to come. Such shortsightedness has never bred curiosity. We are curious people extremely interested in new ventures. Markets and technology are the driving forces of industry; we have both of them at our disposal and we are going to turn it into products—systems for the betterment of mankind.

Again, on behalf of the Administrative Committee of our Society, I'd like to congratulate the entire Steering Committee for their hard work organizing a Symposium that promises to be a very memorable one.

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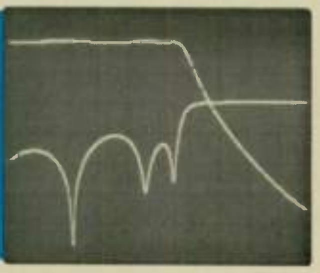

With the new IEEE Bus option (GPIB), you can read the Refresh Memory content or channel outputs; write standard response data to the vertical plug-in memories; write data to the Refresh Memory; or display calculated data for visual or photographic analysis.

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ATTENDING THE CONFERENCE

JOSEPH F. WHITE, Consulting Editor
Microwave Associates Inc.
Burlington, MA

Delegates to this year's MTT International Symposium should find that the scope of the technical program, the Washington, DC setting, and the planned non-technical activities and opportunities are simply too much to fit into one week's time. Being left, therefore, with the agreeable task of selecting *les perles parmi les perles* you will do well as a Symposium delegate to appraise yourself early of the lay of the technical and geographic surroundings. The Conference, itself, is held at the Shoreham Hotel and the map below shows the location of the Shoreham in the Washington, DC area. The extent of this map is about 3x6 miles; and therefore all points within it could be approached on foot if you're diligent. Within the hotel, as many as four technical sessions will be held simultaneously, so it will be worthwhile to become familiar right away with the location of the meeting rooms. See page 46 for the floor plan of the Shoreham. Also, a complete list of papers given in each of the technical sessions is presented beginning on page 26. Once again, you'll do well to review this in advance, identifying particularly those papers that you especially want to hear, because with the busy program it will be easy to forget and miss them.

In the March issue of the *Microwave Journal* we published a special report prepared from information supplied by the Session Chairman of many of this year's technical sessions at the Symposium. We asked the following questions:

A. What was the accepted to submitted paper ratio?
B. Why should somebody come across the Country to hear your session?
C. What advances are noteworthy?
D. What papers are exciting?
E. What comments apply to this session?

Session Chairman, being very individualistic, responded in a variety of ways to these questions, and we are reprinting the responses here because there is no closer source of information about these sessions than that of their technical chairmen.

1980 MTT/SESSIONS & WORKSHOPS

1. *Microwave Filters & Multiplexers:* Ralph Levy, 8 accepted/23 contributed
   Come because it's in Washington; besides this is a very good set of papers — with new synthesis technology, new MIC filters and varactor tuning; and famous authors, including J. D. Rhodes, Seymour Cohn and Walter Ku.

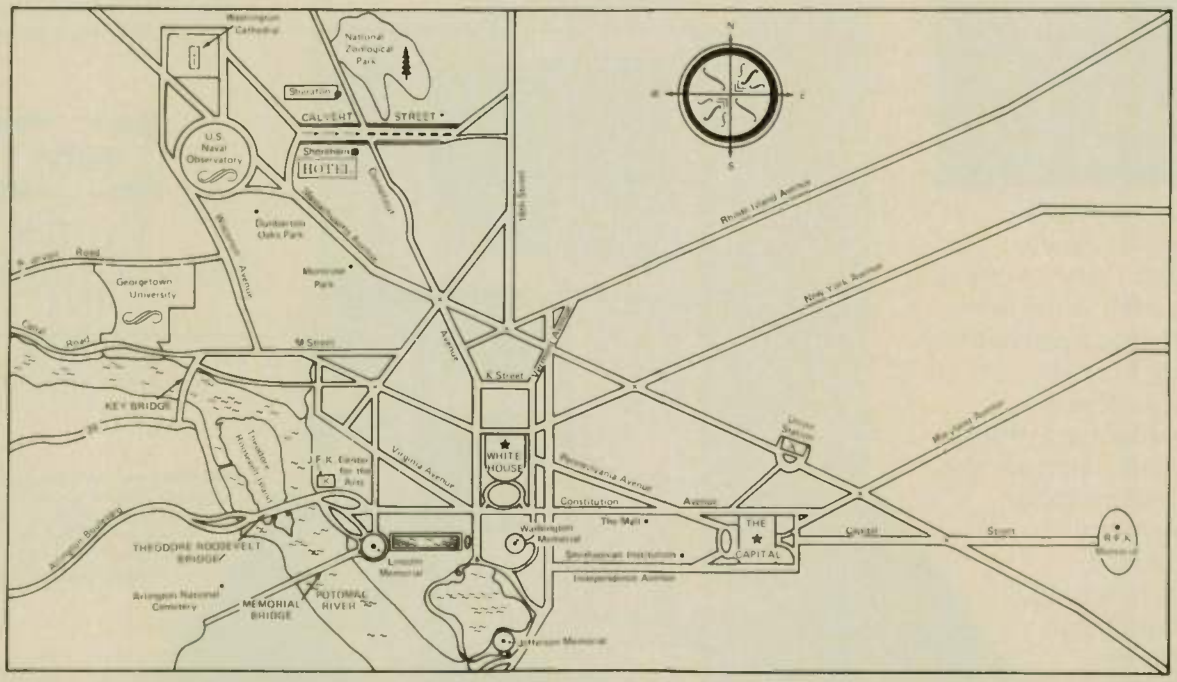
2. *(Workshop on) Gigabit Logic for Microwave Systems:* Paul Greiling
   The status of high-speed GaAs FET logic circuits at all major research labs working in this area will be presented. Invited experts are from the US, Europe and Japan. Attendees will be encouraged to participate in the discussion.

3. *Microwave Acoustics and Magnetostatic Waves:* Reynold S. Kagiwada, 4 accepted/6 contributed
   Dr. Eppers will give an invited talk, "Implementation of SAW Devices in Avionics," and Dr. Cafarella will give an invited paper on "Systems Aspects of Convolvers." An especially exciting paper will be "Adjustable Magnetostatic Surface Wave Directional Coupler" by J. Castera and P. Hartemann and a noteworthy advance in the art is described in "Efficient Thin Film InSb/LiNbO Convolver," by J. Yamanouchi, et al. This session is designed around system considerations.

4. *Computer Aided Techniques*, Walter H. Ku, 7 accepted/7 contributed
   In addition to contributed papers, the session will have an invited paper "Computer Modeling of Monolithic GaAs IC's" by Rory Van Quyl.

5. *MM Wave Power Generation*, John Kuno, 7 accepted/22 contributed
   This session covers predominantly IMPATT and Gunn devices. There are noteworthy advances in System Applications, Radar for Guidance and Weaponry.

6. *Microwave Power Transistors*, F. Haseyawa and Bert Berson, 4 accepted/7 contributed
   Bert suggested that even for the dedicated, a week in Washington, DC beats a week in the plant; and besides, the new state of the art in power GaAs FETs and silicon bipolar transistors will be presented. Noteworthy advances include:
   1) 100 Watts CW @ 1 GHz bipolar; and
   2) 25 Watts @ 6 GHz and 7 Watts @ 8 GHz with an internally matched chip.



MTT-S VIEW OF WASHINGTON

(continued on page 32)

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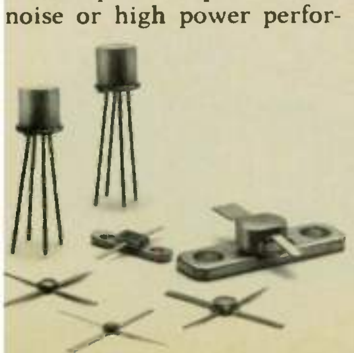
BIPOLAR SMALL SIGNAL LOW NOISE TRANSISTORS UP TO 500MHz			
VHF			
AT-0017A	1.2dB	25dB	60MHz
AT-0017	1.5dB	25dB	60MHz
UHF			
AT-0045	1.5dB	13dB	500MHz
AT-0025A	2.0dB	12dB	500MHz
AT-0025	2.5dB	11dB	500MHz
BIPOLAR SMALL SIGNAL LOW NOISE TRANSISTORS UP TO 4 GHz (70 mil pkg)			
AT-4680	2.8dB	8.8dB	4.0GHz
AT-4690	3.0dB	9.5dB	4.0GHz
AT-4641	3.5dB	7.5dB	4.0GHz
AT-4642	4.0dB	7dB	4.0GHz
AT-2645A	3.0dB	11dB	2.0GHz
AT-2645	3.5dB	11dB	2.0GHz
BIPOLAR SMALL SIGNAL LOW NOISE TRANSISTORS UP TO 4 GHz (100 mil pkg)			
AT-4880	2.8dB	8.8dB	4.0GHz
AT-4890	3.0dB	9.5dB	4.0GHz
AT-4841	3.5dB	7.5dB	4.0GHz
AT-4842	4.0dB	7dB	4.0GHz
AT-1845A	2.2dB	14dB	1.0GHz
AT-1845	2.5dB	14dB	1.0GHz
AT-1825	3.0dB	13dB	1.0GHz
GaAs FETS UP TO 12GHz			
AT-8110 Chip AT-8111	1.3dB	12dB	4GHz
AT-8060 Chip AT-8061	2.8dB 2.5dB	8dB 9dB	12GHz 12GHz

POWER-BIPOLAR UP TO 4 GHz

PART NO.	TYP. P_o (−1dB)	TYP. G @ P (−1dB)	TYP. P_o (SAT)	TEST FREQ.
AT-7510	27.5dB	9.5dB	29dBm	4GHz
PART NO.	**P_o (−1dB)**	**TYP $\|S_{21}\|^2$**	**G max**	**TEST FREQ.**
AT-3850	+20dBm	4.0	9dB	3GHz



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SYMPOSIUM PROGRAM

Dr. Arden L. Bement, Jr., recently selected Deputy Under Secretary of Defense for Research and Engineering will present a keynote address on the DoD (R & T) view toward the need for increased research and development efforts for the coming decade.

A. WELCOME AND KEYNOTE ADDRESS
Chairman: L. R. Whicker

A-1 **Welcome from General Chairman**
L. R. Whicker, NRL, Washington, DC 20375

A-2 **Comments from Technical Program Chairman**
R. C. Van Wagoner, NRL, Washington, DC 20375

A-3 **Welcome from MTT-ADCOM President**
S. F. Adam, Hewlett-Packard Co. Palo Alto, CA 94304

A-4 **Remarks from IEEE President**
L. Young, NRL, Washington, DC

A-5 **Keynote Address—Technology Growth for the '80s as Viewed by DoD (R&T)**
Dr. Arden L. Bement, Deputy Under Secretary of Defense (Research & Technology)

B. MICROWAVE POWER TRANSISTORS
Chairman: Fumio Hasegana

B-1 **Improved Elementary Cell GaAs Power FET Structure**
Pierre Baudet, LEP, France

B-2 **10 GHz-10W Internally Matched Flip-Chip Power GaAs FET**
Y. Mitsui, M. Kobiki, M. Wataze, K. Segawa, M. Otsubo, M. Nakatani and T. Ishii, Mitsubishi, Japan

B-3 **A 6 GHz-5W GaAs MESFET with an Experimentally Optimized Pattern**
A. Higashisaka, K. Honjo, Y. Takayama and F. Hasegawa, Nippon, Japan

B-4 **100W CW Microwave Bipolar Transistor**
David C. Anderson, Power Hybrids

C. MILLIMETER RECEIVERS AND COMPONENTS
Chairman: John Smith

C-1 **140 GHz All Solid State Receiver Noise Figure Less Than 6 dB DSB**
J. Putnam, A. Cardiasmenos, P. Boyd, M. Blustine, TRG Div. of Alpha Ind.

C-2 **A 200-300 GHz Heterodyne Receiver**
N. R. Erickson, Univ. of Mass.

C-3 **Cryogenic 90 GHz Receiver for Airborne Radiometry**
B. Vowinkel, J. K. Peltonen, W. Reinert, B.I.U., Bonn, W. Germany

C-4 **Noise Measurements of W-Band (75-100 GHz) CW GaAs Gunn and Silicon IMPATT Oscillators**
John Ondria, TRG Div. of Alpha Ind.

D. MICROWAVE ACOUSTICS AND MAGNETOSTATIC WAVES
Chairman: Dennis Webb

D-1 **The Implementation of Surface Acoustic Wave Devices in Avionics Systems**
W. J. Edwards and W. C. Eppers, WPAFB (Invited Paper)

D-2 **System Aspects of Surface Acoustic Wave Convolvers**
J. Cafarella, MIT Lincoln Labs, (Invited Paper)

D-3 **Efficient Thin Film $InSb/LiNbO_3$ Convolver**
K. Yamanouchi, S. Mitsui, K. Shibayama, Cornell U.

D-4 **Low Loss Multipole SAW Resonator Filters**
E. J. Staples, J. Schoenwald, J. Wise, T. Lim, Rockwell Int'l

D-5 **Adjustable Magnostatic Surface Wave Directional Coupler**
J. P. Castera, P. Hartemann, Thomson-CSF, France

D-6 **Simple Magnetostatic Delay Lines in Microwave Pulse Compression Loops**
K. W. Reed, J. Owens, C. Smith, R. Carter, U. Texas, Arlington

E. MICROWAVE ENGINEERING FOR EXPORT
Chairman: Edward A. Wolff

E-1 **U.S. Export Procedures**
R. Garnitz, Dept. of Commerce

E-2 **Import and Export Commodity Codes and Data**
W. Fletcher, U.S. Int'l Trade Comm.

E-3 **Policies and Techniques for Enhancing Exports**
S. Abrahamson, Control Data

E-4 **Critique of Microwave Export Performance**
T. Saad, Sage Laboratories

E-5 **Exporting Microwave Components and Instruments**
B. Weinschel, Weinschel Eng.

E-6 **Exporting Microwave Systems**
J. Bunker, Microwave Assoc.

F. MILLIMETER WAVE POWER GENERATION
Chairman: Apostle G. Cardiasmenos

F-1 **MM Wave Gunn Oscillator with Distributed Fin-Line Resonator**
H. Hoffman, AEG-Telefunken, West Germany

F-2 **Multidiode K_a-Band OSC, Using Hybrid Planar Circuit Design**
F. Sicking, H. Meinel, AEG-Telefunken, West Germany

F-3 **Gunn Diode Combining at U-Band**
Y. Ma, C. Sun, Hughes Aircraft

F-4 **MM-Wave Microstrip Amplifier Using InPh Gunn Diodes**
D. Rubin, NOSC

F-5 **The Behavior of a Pulsed MM-Wave (70 GHz) Impatt Diode Oscillator During Laser Illumination**
H. Gerlach, R. Wellman, HDL

F-6 **V-Band High Power IMPATT Amplifier**
Y. Ma, C. Sun, E. M. Nakaji, Hughes

F-7 **Performance of 94 GHz Coherent Pulsed IMPATT Transmitters**
M. D. Simonutti, D. C. English, F. J. Bernues, Hughes Aircraft Co.

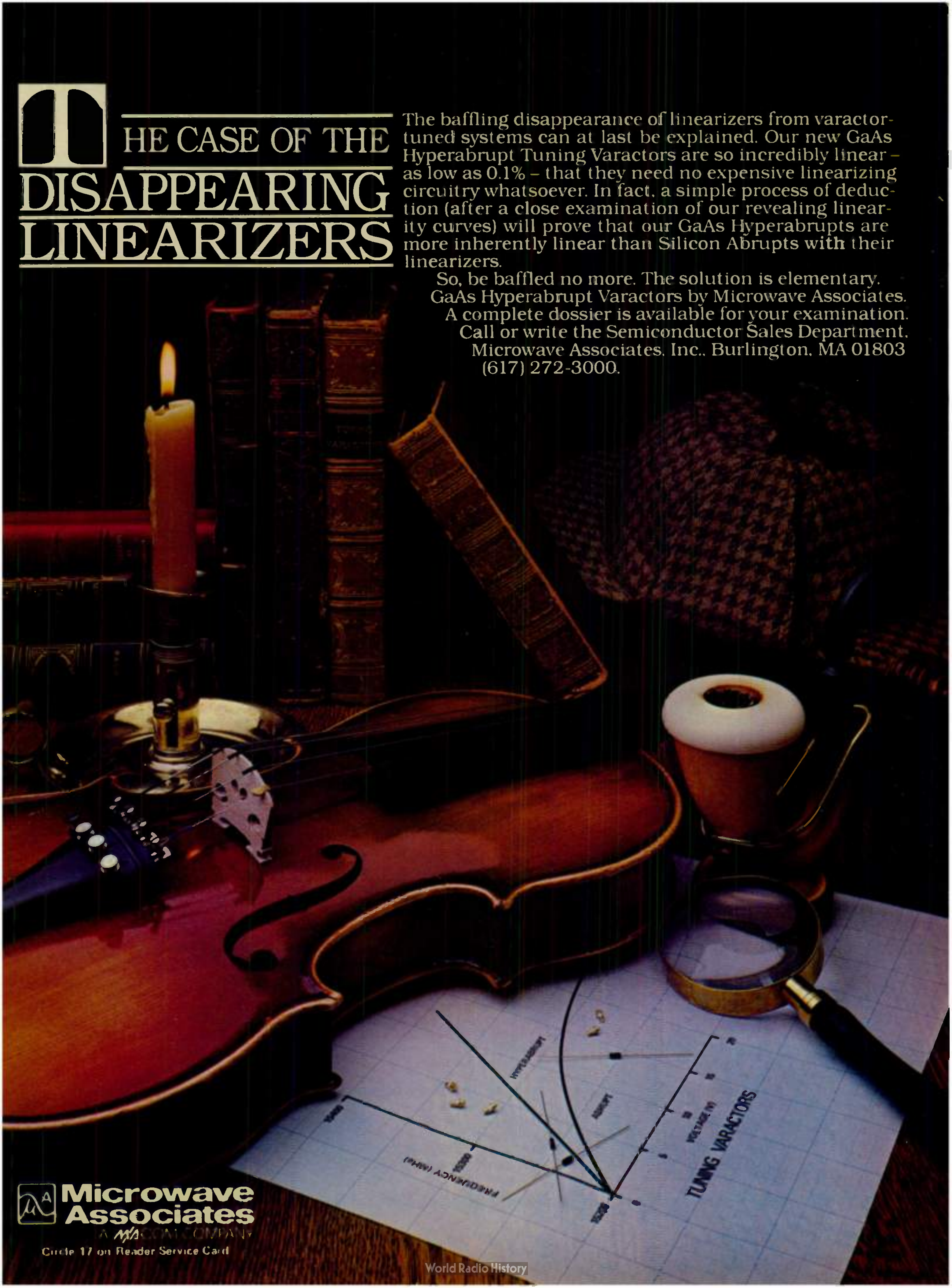
G. HIGH POWER DEVICES & TECHNIQUES
Chairman: H. Goldie

G-1 **High Power X-Band MIC Diode Phase Shifter**
M. Kuroda, K. Hirai, S. Kamihashi, Toshiba, Japan

G-2 **RF Energy Compressor**
Z. D. Farkas, SLAC, Stanford U.

G-3 **The Stability of Magnetrons Under Short Pulse Conditions**
B. Vyse, H. Levinson, M-O Valve Co., England

(continued on page 28)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SYMPOSIUM PROGRAM

G-4 **A Novel Approach to the Design of a High Power Automatic Impedance Measuring Scheme**
C. J. Hu, U. Colo., Boulder

G-5 **Mode Coupling and Power Transfer in a Coaxial Sector Waveguide with a Sector Angle Taper**
A. W. Flitlet, L. R. Barnett, J. M. Baird, BKD and V. L. Granatstein, NRL

G-6 **Circular-Electric Mode Waveguide Couplers and Junctions for use in Gyrotor Traveling-Wave Amplifiers**
L. R. Barnett, J. M. Baird, A. W. Flitlet, BKD and V. L. Granatstein, NRL

G-7 **Recent Advances in Gyrotrons**
H. Jory, R. Symons, P. Ferguson, J. Shively, J. Moran, Varian Assoc.

G-8 **Gain of the Gyrotron Amplifier with High Circular Waveguide Mode and Cyclotron Harmonic Number**
S. Ahn, J. Choe, NRL

H. MICROWAVE SYSTEMS - 1
Cochairmen: P. Greiling & F. Ivanek

H-1 **A Monolithic GaAs Decision Circuit for Gbits/PCM Transmission Systems**
M. Peltier, G. Nuzillat, M. Gloanee, Thomson-CSF, France

H-2 **Digital Generation of Wideband Linear FM Waveforms**
F. W. Hapwood, R. C. Tracy, Westinghouse Corp.

H-3 **16-Level QAM MIC Modulator with Phase Linearity Improved**
T. Takano, M. Niori, Y. Tokumitsu, K. Ozawa, Kawasaki, Japan

H-4 **High-Power Upconversion for SSB-AM Signals**
E. Loiser, K. Schuenemann, Inst. Hft. Tech. Univ., Braunschweig, Germany

H-5 **Instantaneous Bearing Discriminators with Omni-directional Coverage and High Accuracy**
S. Rehnmark, Anaren Microwave

H-6 **The Tiros-N Microwave Sounder Unit**
P. N. Swanson, W. M. Harris, E. J. Johnston, F. S. Soltis, JPL

H-7 **Two Microwave Complex Weighting Circuits**
M. J. Fithian, E-Systems

H-8 **Impedance Variations in Electronically Beam-Steered Active Lens Antennas for Space Based Radar**
D. W. Griffin, U. Adelaide, S. Australia

J. MICROWAVE FILTERS AND MULTIPLEXERS
Chairman: Ralph Levy

J-1 **Synthesis of Commensurate Comb-Line Band-Pass Filters with Half-Length Capacitor Lines**
S. B. Cohn, S. B. Cohn Assoc.

J-2 **Asymmetric Realization for Dual-Mode Bandpass Filters**
R. Cameron, ESA and J. Rhodes, U. Leeds, England

J-3 **Bandpass Filters Using Parallel-Coupled Strip-Line Stepped Impedance Resonators**
M. Makimoto, S. Yamashita, Matsushita, Japan

J-4 **General Extracted Pole Synthesis Technique with Application to Low Loss TE_{011} Mode Filters**
J. D. Rhodes, U. Leeds, England and R. J. Cameron, ESTEG

J-5 **Design of MIC Broadband Contiguous Multiplexers**
J. Dean, Filtronic, England and J. Rhodes, U. Leeds, England

J-6 **A Low Cost Multiplexer for Channelized Receiver Front Ends at Millimeter Waves**
K. Breuer and N. Warontzoff, AIL Eaton Corp.

J-7 **Microstrip Variable Band-Pass Filters Using Varactor Diodes**
S. Toyoda, Osaka Inst. Tech., Japan

J-8 **Advances in the Analytical and Computer-Aided Design of Optimum Equalizers for High Frequency RF and Microwave Solid State Amplifiers**
W. Ku, Cornell U.

K. HIGH-POWER SOLID-STATE CIRCUITS
Chairman: Don Parker

K-1 **A High-Power X-Band Diode Amplifier**
R. J. Pankow and R. G. Mastroianni, Norden

K-2 **X-Band Pulsed Solid-State Transmitters**
S. E. Hamilton, R. S. Robertson, F. A. Wilhelmi, M. E. Dick, Hughes

K-3 **Efficient, Higher Order-Mode Resonance Combiner**
M. Dydyk, Motorola

K-4 **A Corporate Structure for Combining Power from 3^N Oscillators**
S. Mizushina and M. Ashiki, Shizuoka Univ., Japan and J. Kondoh, Cornell University

K-5 **An Improved TRAPATT Oscillator Circuit**
R. Davies, P. L. Booth, B. H. Newton, Phillips, England

K-6 **Influence of Non-Ideal Circulator Effects on Negative Resistance Amplifier Design**
B. D. Bates, P. J. Kahn, U. Queensland, Australia

K-7 **Pulsed Power Performance of GaAs FET's at X-Band**
S. Temple, Z. Galani, J. Dormail, R. Healy, S. Hewitt, Raytheon

K-8 **A K-Band, 1 Watt GaAs FET Amplifier**
J. Sore and Y. Takayama, Nippon, Japan

K-9 **Thirty-Two Diode Waveguide Power Combiner**
S. Hamilton, Hughes Aircraft

L. SATELLITE COMMUNICATION SYSTEMS IN EUROPE (Invited Session)
Chairman: P. DeSantis

L-1 **Communications Satellite Payloads: A Review of Past, Present and Future ESA Developments**
M. Lopriore, ESTC, Netherlands

L-2 **GaAs FET's in Present and Future Communication Satellite Programs**
J. Turner, Plessey Co., England

L-3 **Microwave Technology Developments in Italian Space Program**
M. Massani, Selenia, Italy

L-4 **West German Microwave Activity State Of The Art in Satellite Communications**
H. Brand, U. Erlangen, Fed. Rep. Germany

L-5 **Some Advances in French Solid State Components and Technologies for Space Applications**
J. Magarshack, LEP, France

L-6 **Microwave Activity for Satellite Communication in Sweden**
L. Afzelius, Ericsson, Sweden

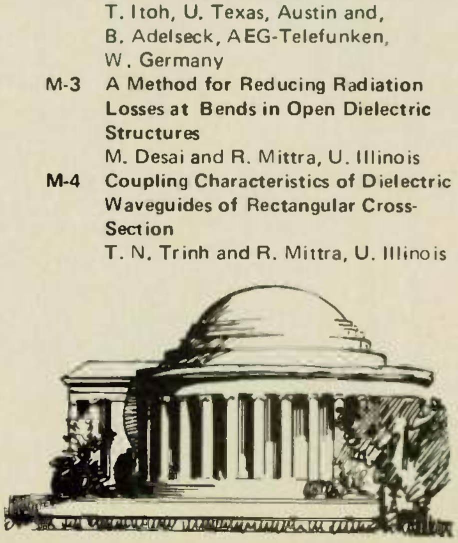
M. GUIDES AND COMPONENTS
Chairman: T. Itoh

M-1 **A Metal-to-Dielectric Waveguide Transition with Application to Millimeter-Wave Integrated Circuits**
T. N. Trinh, J. Malherbe, R. Mittra, U. Illinois

M-2 **Trapped Image Guide for Millimeter-Wave Circuits**
T. Itoh, U. Texas, Austin and, B. Adelseck, AEG-Telefunken, W. Germany

M-3 **A Method for Reducing Radiation Losses at Bends in Open Dielectric Structures**
M. Desai and R. Mittra, U. Illinois

M-4 **Coupling Characteristics of Dielectric Waveguides of Rectangular Cross-Section**
T. N. Trinh and R. Mittra, U. Illinois



M-5 **Resonant Frequency of Dielectric Resonators in Homogeneous Media**
R. Bonetti and A. Atia, COMSAT

M-6 **Analysis and Application of the Scattering Mechanism in an Abruptly Ended Rod Dielectric Waveguide**
P. H. Gelin, M. Petenzi, J. Citerne, P. Kennis, U. Sci. Tech. Lille, France

M-7 **The Complex Pointing Vector, and the Fractional Current on the Upper Surface of a Microstrip Line**
M. Lewin and T. Rnehle, U. Colo.

M-8 **A 40 GHz Microstrip Array Antenna**
W . Menzel, AEG-Telefunken, W. Germany

N. FERRITE APPLICATIONS
Chairman: A. Yarranton

N-1 **Parallel Component μ_z of Partially Magnetized Microwave Ferrites**
M. Igarashi, Tokai Univ. and Y. Naito, Tokyo

N-2 **Planar Meanderline Ferrite Phase Shifters with Multi-Layer Ferrite/Dielectric Imbedding**
E. R. Bertil Hansson, Chalmers Univ. Tech., Sweden

N-3 **New Nonreciprocal Devices in a Coplanar Waveguide**
Y. Naito and Y. Yamanaka, Tokyo Inst. Tech., Japan

N-4 **Magnetostatic Surface Wave Signal-to-Noise Enhancer**
S. N. Stitzer, H. Goldie, J. D. Adam, P. R. Emtage, Westinghouse Corp.

N-5 **A New Accurate Equivalent Network for Stripline Y-junction Circulators**
E. R. Bertil Hannson, K. Gunnar Filipsson, Chalmers Univ. Tech., Sweden

N-6 **Experimental Characterization of Junction Circulators Using Wye Resonators**
W. T. Nesbit, Lochend, Scotland and J. Helszajn, Heriot-Watt Univ., Scotland

N-7 **A New Type Circulator for Millimeter Integrated Circuits**
Y. Naito, M. Nuraguchi, A. Tsuji, Tokyo Inst., Tech., Japan

O. MILLIMETER WAVE IC's
Chairman: Nick Jansen

O-1 **Characteristics of Unilateral Fin-Line Structures with Arbitrarily Located Slots**
L. P. Schmidt, T. Itoh, Univ. Texas and H. Hofmann, AEG-Telefunken, W. Germany

O-2 **A Solution of the Earthed Fin Line with Finite Metalization Thickness**
A. Beyer, I. Wolff, Univ. Duisburg, W. Germany

O-3 **Cutoff Frequencies in Fin Lines Calculated with a Two-Dimensional TLM-Program**
Y. Shih, W.J.R. Hoefer, Univ. Ottawa, Canada

O-4 **Advances in Printed Millimeter-Wave Oscillator Circuits**
L. D. Cohen, AIL Div. Eaton Corp.

O-5 **E-Plane Components for a 94 GHz Printed-Circuit Balanced Mixer**
P. J. Meier, AIL Div. Eaton Corp.

O-6 **Phasing Type Image Recovery Mixers**
R. H. Oxley, P. L. Lowbridge, N.D.R. Sheperd, AEI Semi., England, M. J. Ming, J. E. Curren, GEC, England

O-7 **Low Cost MM-Wave Dielectric Loaded Mixer**
J. A. Paul and P. Yen, Hughes Aircraft

O-8 **Millimeter-Wave IC Components Using Fine Grained Alumina Substrate**
H. Yatsuka, M. Ishizaki, H. Komizo, Fujitsu, Japan

P. SATELLITE BROADCASTING IN JAPAN
(Invited Session)
Chairman: K. Suetake

P-1 **Main Transmit and Receive Station in Japanese BSE Program**
N. Imai, Y. Otsu and T. Tanaka, R.R.L. Min. Posts and Telecomm. Japan

P-2 **Performance Characteristics of Transportable Type — A Earth Station for Japan's Experimental Broadcasting Satellite System (BSE)**
S. Nishimura, S. Betsudan, M. Nakanishi, Mitsubishi, Japan, Y. Konishi, NHK, Japan, S. Hoshino, M. Takahashi, Nippon, Japan

P-3 **14/12 GHz Band Mobile-Type Earth Station for Japanese Broadcasting Satellite Communication**
H. Hayashida, S. Hikosaka, Y. Yamashita, I. Sato, H. Shimayama, Nippon, Japan

P-4 **Receive-Only Stations for Broadcasting Satellites Experimental**
S. Kikukawa, M. Kaijima, T. Chiba, Y. Sasaki, Toshiba, Japan, S. Hoshina, Y. Imahori, Nippon, Japan

Q. GUIDED WAVE OPTICS AND INTERACTIONS
Chairman: Thomas Giallorenzi

Q-1 **Guided-to-Radiation Mode Conversion in Heterostructure Planar Waveguides and Its Application to a Light Modulator**
H. Onodera, I. Awai, M. Nakajima, J. Ikenoue, Kyoto Univ., Japan

Q-2 **An Optically Coupled Microwave Switch**
R. Kiehl and D. Drury, Sandia Labs

Q-3 **A Field Strength Measurement System Using an Integrated Optical Linear Modulator**
H. I. Bassen, BRH, C. H. Bulmer and W. K. Burns, NRL

Q-4 **Nonreciprocal Effects in an Open Dielectric Waveguide with Grating Structures**
K. Araki, B. S. Song, T. Itoh, Univ. Texas

Q-5 **An Approximate Analysis of Rib Waveguides**
H. Shigesawa, M. Tsuji, K. Takijama, Doshisha Univ., Japan

Q-6 **Analysis of Chirped Grating Lenses**
S. Forouhar, W.S.C. Chang, Univ. Cal. La Jolla

Q-7 **Microwave Models of Blazed Dielectric Gratings for Integrated-Optics Applications**
T. Tamir, Polytech. Inst., N.Y.

Q-8 **Finite Element Analysis of Optical Waveguides**
N. Mabaya, P.E. Lagasse, Univ. Gent, Belgium

R. BIOLOGICAL APPLICATIONS AND EFFECTS
Chairman: Elliot Bostow

R-1 **Rationale for New ANSI C95 Recommended Safety Level with Respect to Human Exposure to RF Electromagnetic Fields**
A. W. Guy

R-2 **Electromagnetic Energy Deposition in an Inhomogenous Block Model for Near-Field Irradiation Conditions**
I. Cattorjee, M. J. Hagmann, O. P. Gandhi, Univ. Utah

R-3 **Microwave Effects on the Ocular Lens**
J. Stewart-Dehann, J. R. Trevithick, M. Creighton, L. Larsen, J. Jacobi, Univ. West. Ontario and WRAIR

R-4 **A Microstrip Microwave Biological Exposure System**
A. W. Friend, NMRI and H. Howe, Jr., Microwave Assoc. Inc.

R-5 **Dual Mode Microwave System to Enhance Early Detection of Cancer**
K. L. Carr, Microwave Assoc., A. L. El-Mahdi, J. Shaeffer, Eastern Va. Med. Sch.

SYMPOSIUM PROGRAM

R-6 Microwave Applicators for Localized Hyperthermia Treatment of Malignant Tumors
R. W. Paglione, F. Sterzer, RCA, J. Mendecki, E. Frendenthal, C. Botstein, Montefiore Hosp.

R-7 A 2450 MHz Slab-Loaded Direct Contact Applicator with Choke
G. Kantor, D. M. Witters, BRH

R-8 A Microstrip Antenna for Medical Applications
I. Bahl, S. S. Stuchly, Univ. Ottawa, Canada and M. A. Stuchly, RPB, Canada

S. GaAs FET CIRCUITS
Chairman: Eliot D. Cohen

S-1 A Monolithic GaAs I.F. Amplifier for Integrated Receiver Applications
D. R. Decker, A. K. Gupta, W. Petersen, D. R. Chen, Rockwell Int'l

S-2 Super Low Noise Packaged GaAs FET's for K_V Band
T. Suzuki, Y. Kadowaki, M. Ito, M. Nakatani, T. Ishii, Mitsubishi, Japan

S-3 A 12 GHz 140°K Low Noise GaAs FET Amplifier
Y. Fujiki, S. Fukuda, J. Haga, K. Okata, Nippon, Japan

S-4 Optimum Large Signal Design of Fixed-Frequency and Varactor-Tuned GaAs FET Oscillators
C. Rauscher, NRL

S-5 A Highly Stabilized 9-14 GHz GaAs FET Oscillator Using a Dielectric Resonator Feedback Circuit
T. Mori, O. Ishihara, M. Nakatani, T. Ishii, Mitsubishi, Japan

S-6 Ultra Low Chirp GaAs Dual-Gate FET Microwave Oscillators
R. S. Pengelly, J. Joshi, Plessey Co., England

S-7 An Osciplier at K-Band Using A Dual Gate GaAs MESFET
S. Chu, T. Chen, Hewlett-Packard Co.

S-8 GaAs IC Direct Coupled Amplifiers
D. Hornbuckle, Hewlett-Packard Co

S-9 Synthesis of Distributed Networks with Applications to the Design of Ultra-Wideband GaAs MESFET Power Ampliifiers
W. Ku, Cornell Univ. and H. Willing, NRL

T. COMPUTER AIDED TECHNIQUES
Chairman: Walter H. Ku

T-1 Computer Modeling of Monolithic IC's
R. Van Tuyl

T-2 Performance Optimization of Millimeter Wave Mixer Circuits
L. Casner, J. Paul, Hughes Aircraft

T-3 Frequency Scaling for Computer-Aided Fourier Mixer Diode Operation
H. C. Lin, Univ. Maryland, N. A. Papanicolaou, J. McClintock, Martin Marietta Corp.

T-4 MLS Simulation Facility
J. Beneke, C. W. Wightman, Calspan

T-5 Analysis and Sensitivity Evaluation of 2P-Port Cascaded Networks
J. W. Bandler, M.R.M. Rizk, McMaster, Canada

T-6 Accurate Models for Microstrip Computer-Aided Design
E. Hammerstand, O. Jensen, Univ. Trondheim, Norway

T-7 Computer Aided Optimization of Microwave Filter Networks for Space Application
C. M. Kudsia, Com. Dev., Canada, M.N.S. Swamy, Concordia Univ., Canada

T-8 A New Computer Aid for Microwave Filter Design
G. Szentirmai, L. Besser, Compact Engineering

U. MICROWAVE MEASUREMENTS
Chairman: H. George Oltman

U-1 Density-Independent Moisture Metering in Fibrous Materials Using a Double Cut-Off Gunn-Oscillator
W. Hoppe, W. Schilz, W. Meyer, Phillips, W. Germany

U-2 A General Approach to the Resonance Measurement of Asymmetric Microstrip Discontinuities
V. Rizzoli, Univ. Bologna, Italy

U-3 Accurate and Automatic Noise Figure Measurements
N. Kuhn, Hewlett-Packard Co.

U-4 Precision Automated Reflectometer Using Air-Line References Spans UHF Through Millimeter Ranges
P. Lacy, Wiltron

U-5 Transmission Phase Measurements with a Single Six-Port
G. P. Riblet, MDL

U-6 A Dual Six-Port Automatic Network Analyzer
H. M. Cronson, L. Susman, Sperry

U-7 Optimizing the Design of the Six-Port Junction
M. Rafal, W. Joines, Duke Univ.

U-8 A Least Squares Solution for Use in the Six-Port Measurement Technique
Glenn F. Engen, NBS

V. FIELD THEORY
Chairman: L. Wilson Pearson

V-1 Frequency Selective Surfaces with Applications in Microwaves and Optics
R. Mittra, C. H. Tsao, W. L. Ko, Univ. Illinois

V-2 Calculation of Quasi-Static Characteristics of Microstrip on Anisotropic Substrate Using Mapping Method
M. Horno, Univ. Sevilla, Spain

V-3 Analysis and Application of a New Waveguide Structure with Dielectric Loading
A. Fukasawa, K. Hosoda, T. Sato, OKI, Japan

V-4 A Hybrid Method for Paraxial Beam Propagation in Multimode Waveguides
E. F. Kuester, D. C. Chang, Univ. Colo

V-5 Exact Analysis of Shielded Microstrip Lines and Bilateral FinLines
A. El-Sherbiny, Ain Shams Univ., Egypt

V-6 Microstrip Analysis on Anistropic and/or Inhomogeneous Substrate with the Finite Element Method
M. El-Said, A. A. Ahmed, Cairo Univ., Egypt

V-7 Waveguide Treatment of the Suspended Microstrip Line with Tuning Septums Using the Spectral Domain Approach & The Finite Element Method
K. Sachse, A. Sawicki, Univ. Wrodow, Poland

V-8 Attenuation in Microstrip Transmission Lines with Very Lossy Substrates
B. W. Jervis, R. M. Pannell, Dept. Comm. Eng., England

W. MICROWAVE IC COMPONENTS
Chairman: Ed Denlinger

W-1 A Spiral Microwave Directional Coupler for MIC Application
K. Shibate, Kitami Inst. Tech., Japan; K. Hatori, Res. Inst. of App. Elec., Japan; Y. Tokumitsu & H. Komizo, Fujitsu, Japan

W-2 Wideband High Directivity in MIC Proximity Couplers by Planar Means
F. C. DeRonde, LEP, France

W-3 Planar Multiport, Quadrature-Like Power Dividers/Combiners
A. Saleh, Bell Labs

W-4 The Traveling Wave Power Divider/Combiner
A. Bert, D. Kaminsky, Thomson-CSF, France

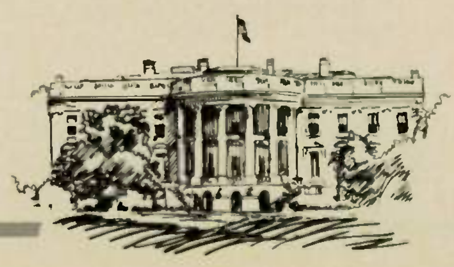
X. MICROWAVE SYSTEMS-2
Chairman: Gerald Schaffner

X-1 A Comprehensive Characterization of FET Power Amplifier Modules for Phased Array Applications
C. Wong, J. Bender, Raytheon

X-2 A 25W. 5 GHz GaAs FET Amplifier for MLS
Y. Takayama, K. Honjo, Nippon, Japan

X-3 Very Linear X-Band MIC Bipolar VCO with a 100 MHz FM Rate
R. G. Winch, J. L. Matson, Teledyne

X-4 Short-Range Microstrip Diplex Doppler Radar Sensor Using a Baritt Diode
B. M. Armstrong, R. Brown, E. J. Duffin, J.A.C. Steward, Queen's Univ., Belfast, Ireland



(from page 24) ATTENDING

7. *GaAs FET Circuits*. Eliot D. Cohen, 18 accepted/28 contributed
Come to learn about new technological advances with a very useful and practical device — the GaAs FET!
Noteworthy advances, many!
 - Super low noise packaged K_u-band devices.
 - Highly stable 9-14 GHz oscillator.
 - Ultra low chirp dual gate oscillator.
 - Optimum large signal design for fixed and varactor tuned oscillators.
 - CAD for ultra wideband MESFET power amplifiers.

 An exciting paper will be "Monolithic GaAs IF Amplifier for Integrated Receivers."

8. *Field Theory & Open Waveguides/Components*, Tatsuo Itoh, 16 accepted/28 contributed
Travel across the Country (Tatsuo circled the globe) to expose yourself to the state of the art and exchange information on dielectric waveguide, radiation from microstrip, and the analysis of both microstrip and films. Noteworthy advances have been made through more accurate analyses, design data and practical applications of dielectric waveguides. Exciting papers will be presented on "Trapped Image Guide," and "Dielectric Guides-Practical Uses."

9. *Millimeter Receivers & Components:* J. Whelchin, 4 accepted/8 contributed
This promises to be a good session on millimeter receivers and the noise characteristics of GaAs Gunn and silicon IMPATT oscillators. Exciting papers will be presented at 94 GHz, and above, on practical hardware implementation.

10. *Guided Wave Optics & Microwave Open Structure Interactions:* Thomas Giallorenzi, 8 accepted/10 contributed
Come to hear a new emphasis this year, as the title suggests, optics and microwave open wave structures share a common analysis base, not emphasized in previous meetings. This is a good forum for the microwave theoretician. Hear an exciting paper on "An Optimally Coupled Microwave Switch."

11. *High Power Solid State Sources:* D. Parker and H. Goldie, 7 accepted/12 contributed
Don offers the important tip that, if you're already in the Washington area, your trip to the MTT shouldn't take you across the Country; but do come, in any event, to see the power combining art find its way into practical applications. Advances of note include a form-factored, environmentally qualified solid-state missile transmitter; and exciting papers to be presented include: "Design of a High Power, X-band, Diode Amplifier and "X-band Pulsed Solid State Transmitters."

12. *Microwave & MM IC Components:* I. Loubeck, 15 accepted/28 contributed
Come to hear about low cost mm-wave finline components, as well as MIC couplers, mixers and amplifiers.

13. *Biologic Effects:* Elliot Postou and O. Gandi, 8 accepted/11 contributed
Come to Washington and first see the Smithsonian, because this session definitely can follow that act. Hear a paper about a "Dual Mode Microwave Radiometer that Detects Breast Cancer Early!", and in another paper, hear about the rationale behind the new (ANSI C95) recommended safety standard for human exposure to RF radiation.

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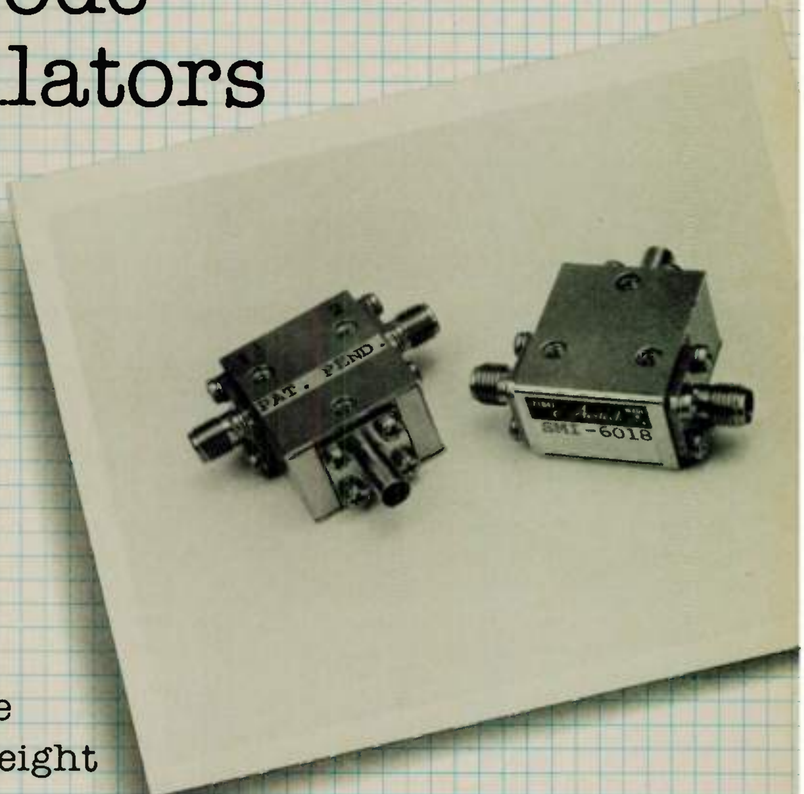

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6.0-18.0	SMI 6018	SMC 6018	14	.8	1.50:1	−40 to +60
6.5-18.0	SMI 6518	SMC 6518	15	.7	1.50:1	−40 to +60
7.0-18.0	SMI 7018	SMC 7018	16	.7	1.45:1	−40 to +60
8.0-18.0	SMI 8018	SMC 8018	17	.7	1.35:1	−40 to +60
8.0-20.0	SMI 8020	SMC 8020	16	.8	1.45:1	−40 to +60

*Patent Pending

†All specs guaranteed over stated temperature range.

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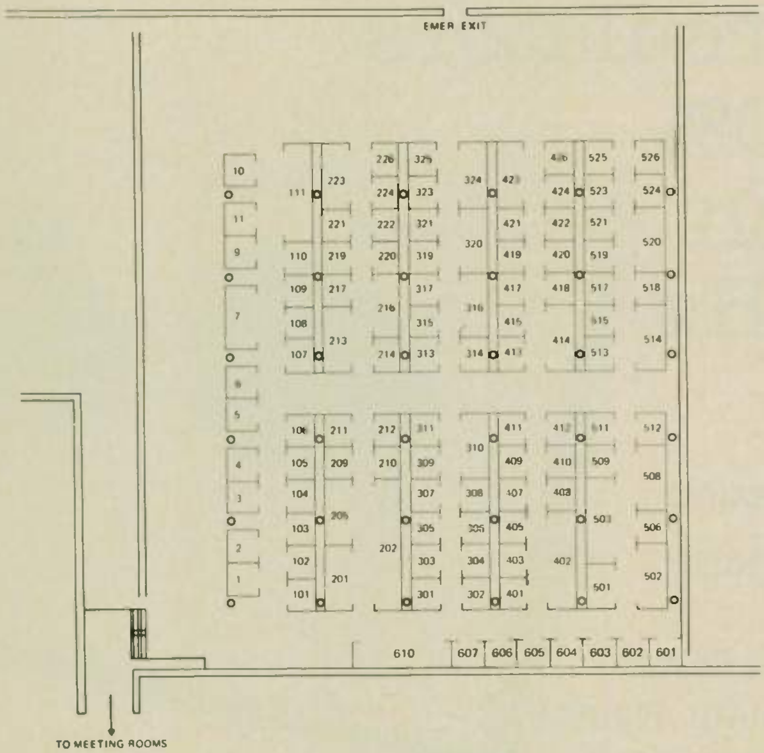

The 1980 Microwave Exhibition will be held in the Shoreham Exhibition Hall and, again, will be the largest Exhibition ever assembled for an MTT-S meeting. It will afford Symposium registrants the opportunity to meet with representatives of more of the principle microwave device, component, system and instrument manufacturers than is possible at any time during the year.

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ADAMS-RUSSELL 226
Anzac Div.
Burlington, MA
Mark Rosenzweig
Microwave amplifiers, mixers, hybrids, etc.

AERCOM INDUSTRIES 107
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Amplifiers, isolators/circulators, detectors

AERTECH INDUSTRIES 518
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Mike DiPrimo, Frank Dickison, Ted Britt, Joe LoSchiavo, Paul Csigi
Microwave assemblies

ALAN INDUSTRIES 511
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Bill Kennedy
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ALPHA INDUSTRIES, INC. 7
Woburn, MA
A. DeCarolis, J. Angus, C. Kamnitsis, J. Cotton, J. DelConte, D. Loger, M. Blustine, W. Reid, T. Chudzik, J. Diesso, A. Cardiasmenos, J. Roman, D. Sheldon, N. Knowlton, F. Leith, W. Ronis, R. Cayer, J. Ondria, G. Gill, N. Bishop
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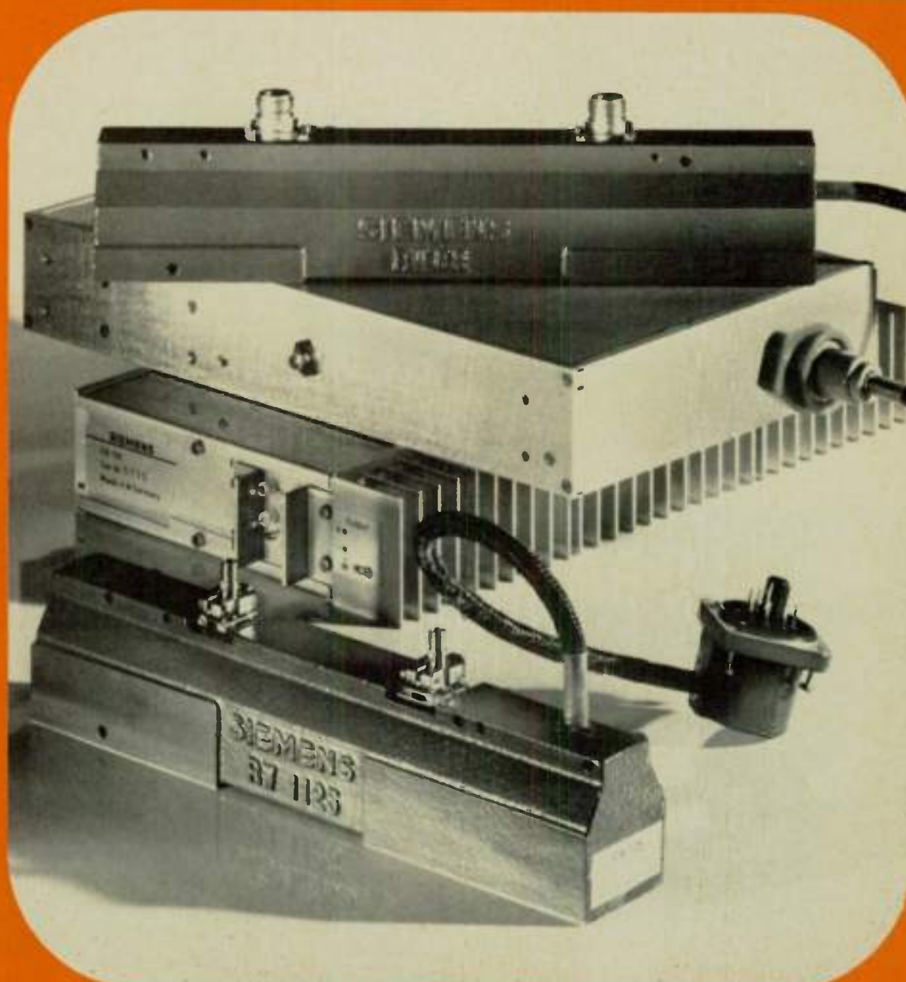

Siemens TWT Type	GHz	power W	efficiency %	intercept point dBm
RW 89	5.9– 7.2	15	34	45
RW 90	7.1– 8.4	15	34	45
RW 1125	10.7–11.7	20	37	46
RW 1126	10.7–13.2	10	10	51

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(continued on page 40)

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- Detector Mounts
- Harmonic Elements
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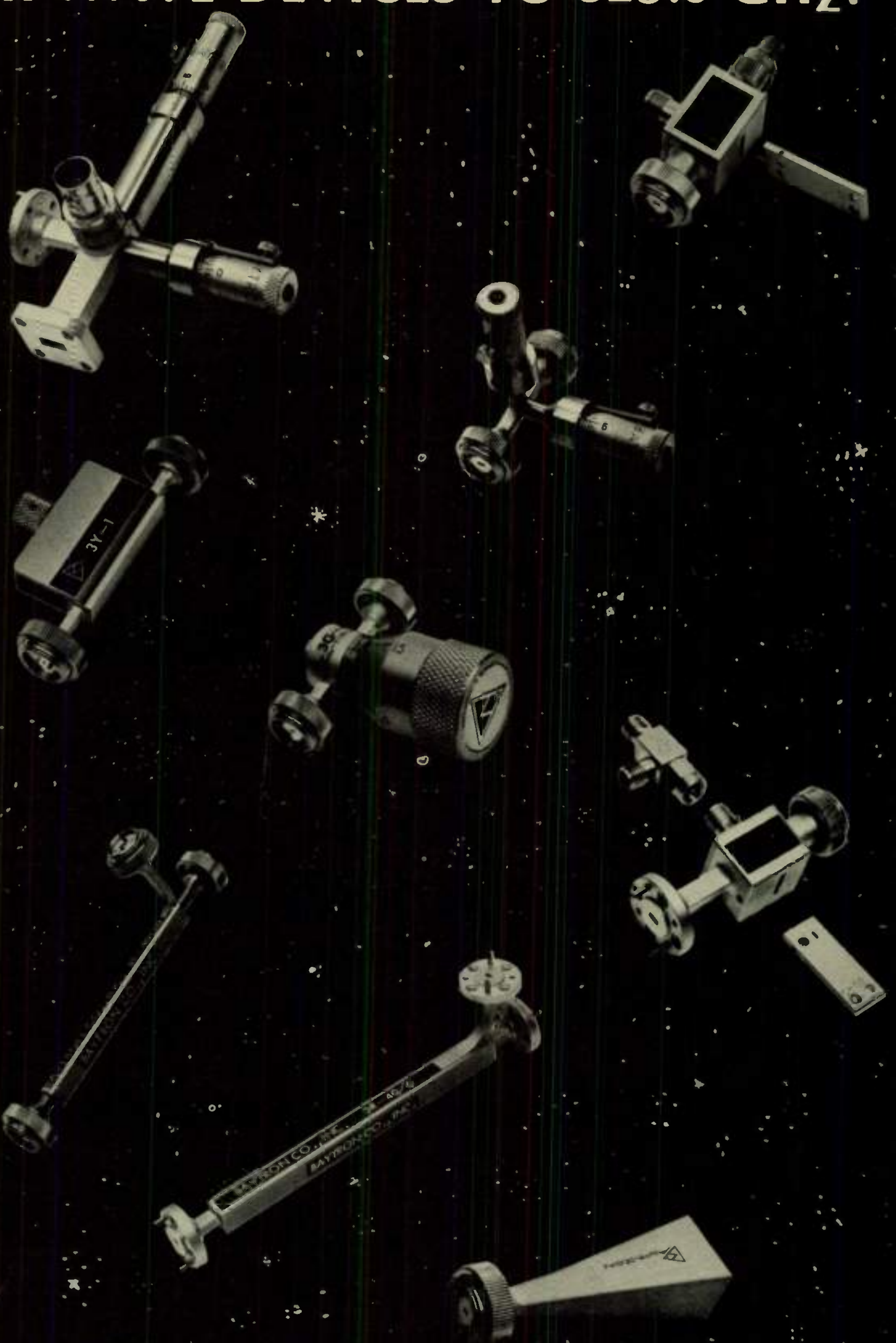

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CRYSTEK CORPORATION 307
Fort Myers, FL
Craig Irwin
Hybrid circuits

DELTA MICROWAVE 323
Westlake Village, CA
Richard Reid, Jim Muller
Small microwave components

DIAMOND ANTENNA & MICROWAVE CORP. 509
Winchester, MA
Rotary joints, antennas, transitions, ridged waveguide components, couplers etc.

DIELECTRIC LABORATORIES, INC. 109
Cazenovia, NY
Robert O. Baker, David Lupfer, John Tinkler, Stan Witlieb
Dicap single wafer precision parallel plate capacitors, monolithic capacitors – High-Q porcelain

DOSS ELECTRONICS, INC. 518
Ellicott City, MD
Herschell Doss, Renny Myers, Bruce Doran, Bob Eskanazy
representing Aertech Industries, Arra, Inc., Bendix Corp.

DYNATECH/UZ INC. 219
Culver City, CA
Bob Hamilton
Mechanical switches dc-18 GHz

EEV, INC. 502
Elmsford, NY
Various microwave electron tubes

EIP MICROWAVE 1
San Jose, CA
Howard Lurie, Rick Bush, Bob Loft, Bill Dentinger
Automatic microwave frequency counters

EMERSON & CUMING 424
Gardena, CA
D. W. Turi, Frank D. Campion, Bill W. Frasca
ECCOSORB® microwave absorbers, microwave anechoic chambers, ECCOSHIELD® RF shielded chambers

ENGELMANN MICROWAVE COMPANY 401
Montville, NJ
Carl Schraufnagl, Robert Hartwig, Herb Engelmann
Attenuators, terminations, power dividers, directional couplers, cavity oscillators, mixers, hybrids, PIN diode switches, stripline subassemblies

EPSILON LAMBDA ELECTRONICS CORP. 224
Batavia, IL
Gunn oscillators, microwave filters, millimeter transmitters and receivers

EPSCO MICROWAVE, INC. 2
Westwood, MA
Richard Strickland, Robert Peterson, Walter Currier, John Shalhoub
250 W CW, 40 kW pulse source, 5 kW IFF/TACAN simulator, assorted high power oscillators

FREQUENCY ENGINEERING LABS. 501
Farmingdale, NJ
A. F. Steinhauer, Bob Peterson
Diplexers, filters, amplifiers, multipliers, phase noise instruments, phase lock instruments, multiplexers

FREQUENCY SOURCES, INC. 420
Chelmsford, MA
West Division: *Tom Parkinson, Ed Brown*
Sources Division: *Gary Tamas, Bill Bruce, Joel Naidus, C. M. Jones*
Contours Division: *Leon Becker, Larry Jones, Joe Hendrickson*
GHz: *Bob Antonucci, J. W. Perkins*
Wavecom Division: *Joe Stevens*
VCO's, RF switches, multipliers, synthesizers, diodes, multiplexers/diplexers, filters, isolators, gain equalizers, directional couplers, military and telecommunication RF subsystems

FUJITSU AMERICA INC. 217
Santa Clara, CA
Microwave transistors

GAMMA-f CORP. 422
El Segundo, CA
Carl Goss, James Alford
Passive waveguide components fabricated utilizing the electroforming techniques including; custom designed band-pass and low-pass waveguide filters, custom fabricated microwave antenna feeds, custom fabricated

or fabricated microwave diplexers, catalogue waveguide bends, twists, transitions, terminations and antennas

GENERAL ELECTRIC CO. 315
Owensboro, KY
John Olson, Jim Rush, Paul Coomes, Jim Korcuba, Roy Berry, Bill Lupton
Bulk effect diodes, gridded tube circuit modules, solid state sources, microwave data link, microwave TV link, gridded vacuum tubes

GENERAL MICROWAVE 311
Farmingdale, NY
Sherman A. Rinkel, Moe Wind, Dr. Samuel Hopfer
PIN diode attenuators, PIN diode switches, digital phase shifters microwave signal sources, microwave radiation monitoring instruments, voltage variable attenuators, digitally controlled attenuators

W. L. GORE & ASSOCIATES, INC. 324
Newark, DE
Roger Kauffman, Don Slothour, Tom Whitten, Hugh Walling, Steve Kauffman
Gore-Tex® microwave coaxial assemblies and specification sheets on new assemblies using .290 diameter cable. A ten-foot assembly of this cable will provide typical insertion loss of 3.7 dB at 18 GHz.

A. I. GRAYZEL, INC. 304
Waltham, MA
Dr. A. I. Grayzel, William Emswiler
Frequency multipliers

HARSHAW CHEMICAL CO. 419
Cleveland, OH
John Chabria, Nanci Ensenat
Microwave crystals and materials: garnets, ferrites, dielectrics

HEWLETT-PACKARD CO. 202
Santa Rosa, CA
Automatic 18 GHz network analyzer, automatic 1.3 GHz network analyzer, automatic 22 GHz spectrum analyzer, precision automatic noise figure system, precision coax measurement system for 18-26.5 GHz, pulsed microwave counter

HORIZON HOUSE 213
Dedham, MA
William Bazzy, Claire R. Berman, Bernard Bossard, John Cotsworth, Howard I. Ellowitz, John Hartnett
Artech House, Intelcom, Journal of Electronic Defense, Microwave Journal, Telecommunications

HUGHES AIRCRAFT CO. 216
Electron Dynamics Div.
Torrance, CA
M. Talley, L. Forant, P. Crandell, R. Larson, M. Simonutti, H. Kuno, C. Sun, L. Casner, J. Paul, Y. Ma
Millimeter wave components, millimeter wave instruments

INTEGRA MICROWAVE 102
Santa Clara, CA
Microwave sweepers, spectrum analyzers, microwave filters, wavemeters etc.

ISOTRONICS 414
New Bedford, MA
Michael Frumento, William DiChiara, Sid Overall, Jim Pinac
Microwave circuit pkgs.

DIV., MuRata Corp. of America
Marietta, GA
Larry Valente, Ted MuRata

Microwave components

JOHANSON MFG. CO. 209
Boonton, NJ
Bob Kapner, John Conelius, Ed DiSuilian

Giga-Trim® variable capacitors, microwave tuning elements, air variable capacitors, Seal-Trim® capacitors, Thin-Trim® capacitors, high voltage quartz capacitors

JOURNAL OF ELECTRONIC DEFENSE 213
(see Horizon House)

KDI PYROFILM CORP. 301
Whippany, NJ
Albert D. Arfin, Patrick B. Daniels, Phil Levine, Doug McConnell, Barbara Russell, Herb Shinn
Passive resistor products for microstrip and stripline application, microwave chip and rod resistors, chip attenuators, power resistors and attenuators

K & L MICROWAVE INC. 105
Salisbury, MD
Dick Bernstein, Charlie Schaub, Bill Anthony, Norman Parker

Microwave tubular filters, cavity filters, tunable bandpass filters, tunable band reject, tunable diplexers, micro-miniature filters

KEENE CORP 308
Chase Foster Div.
Bear, DE
Ron Webb, Mike Norris, Bill Pritchett, Frank Yoerg
Stripline and microstrip laminate

KRYTAR 319
Sunnyvale, CA

Thomas Russell, Iva Russell, Carol Gentile
Directional couplers, directional detectors and detectors

LOGIMETRICS, INC. 309
Plainview, Nassau, NY
Murray Feigenbaum, Jerry Deutsch
Traveling-wave-tube amplifiers, signal generators

3M COMPANY 201
Electronic Products Div.
St. Paul, MN

Charles Bucci, Bob Applewhite, Bob Goff, Tom McCauley, Murry Olyphant, Joe Cesearo, Tom Nowicki

Full line of microwave products, including copper clad substrates, epsilam substrates, microwave design aids, bonding film

C. L. MALINOW & CO., INC. 219
Randallstown, MD

Nelson Slinkman

representing Dynatech/UZ Inc., Microwave Research Corp., Western Microwave Lab, Brandt Electronics, Inc., Nurad

MARCONI INSTRUMENTS 511
Northvale, NJ

Tony Ramsden

tors and sources

MAST MICROWAVE 415
Burlington, MA
C. Theophile
Rotary joints, double ridge components, adaptors and other waveguide components

MATERIALS RESEARCH CORP. 5
Orangeburg, NY
Mike Chmura, Tom Stensgard, Rosemary McPhillips, Mel Lipton, Vijay Borase, Teddi Theodoreu, John Irmen
Ceramic substrates — coated and uncoated, SUPERSTRATES®, high purity metals and alloys, sputtering targets — aluminum and precious metals

MAURY MICROWAVE CORP. 108
Cucamonga, CA
M. A. Maury, Jr., Marc Maury
Waveguide adapters, coaxial adapters, sliding loads, sliding shorts, other passive microwave components
On display will be such items as: 1) a new calibration kit for automatic network analyzers featuring APC3.5 connectors, covering dc to 34 GHz, 2) A 3mm precision sliding termination rated to 40 GHz, for use with SMA and OSSM type connectors, 3) lower SWR waveguide to coaxial adapters covering 18 to 40 GHz and 4) a WRD750 double ridged waveguide, full bandwidth, high performance circulator. Also to be displayed are: cryogenic terminations, high directivity couplers, adapters and a variety of coaxial and waveguide devices.

MEGAVOLT 415
Hackensack, NJ

Fred Cooper, Lenny Kahn

High voltage regulated power supplies for microwave tubes

MELCO SALES, INC. 525
Compton, CA
Joe Iizuka

GaAs FET

MERRIMAC INDUSTRIES, INC. 106
West Caldwell, NJ

Alan Egger, Joseph Cappucci, Vito Caruso, Gene Niemiec, Dan Loder, Mary Ann Sowa

Microwave components and subsystems

MICROLAB/FXR 513
Livingston, NJ

Harry Augenblick, Ray Vincent, Anne Vincent, Michael Bruno, Frank Stallone, Elissa DeTrolio

Coaxial and waveguide filters, couplers, samplers, dummy loads, switches, attenuators, hybrids

MICRONETICS, INC. 103
Norwood, NJ

Lon Edwards, Gary Simonyan, Kurt Stern, George Keskinyan

Microwave components — coaxial switches, waveguide switches, dummy loads, coaxial crystal detectors, bolometers, solid state noise sources and programmable noise generators

MICROPHASE 307
Cos Cob, CT
Floyd Parin
Filters, detectors

MICROTECK CO., LTD. 521
Bangkok, Thailand
Microwave ferrite isolators and circulators

MICRO-TEL CORP. 212
Baltimore, MD
Richard S. Finke, William Richardson, William Trussell, J. Wayne Brandt, Robert Biller, Wayne T. Gardner
Microwave receivers and test equipment

MICROWAVE APPLICATIONS GROUP 317
Chatsworth, CA
Dr. Charles Boyd, Dr. H. Clark Bell, Walter Reed
RF microwave components-precision ferrite phase shifters for lab use and phased array antennas, RF filters, multiplexers, integrated assemblies

MICROWAVE ASSOCIATES INC. 402
Burlington, MA
Tom Rose, Dan Gallagher, Joe Saloom, Jim Bunker, Dr. Frank Brand
Semiconductor device capability, ferrite devices, solid state sources and amplifiers, control devices, transmission line products, radar and missile products

MICROWAVE JOURNAL 213
(see Horizon House)

MICROWAVE POWER DEVICES, INC. 101
Hauppauge, NY
Daniel Mazziota, Bill Liebman, Richard Sheloff
Solid state RF & microwave amplifiers and related subsystems for military, space and industrial applications.

MICROWAVE RESEARCH CORP. 219
North Andover, MA
James Herrmann
Waveguide components, rectangular and double ridge

MICROWAVE SEMICONDUCTOR CORP. 223
Somerset, NJ
Microwave power transistors, MIC power amplifiers, solid state noise sources, microwave diodes

MICROWAVE SYSTEMS NEWS 519
Palo Alto, CA
Jim Fawcette, Anthony Yaconetti, Harry Eustace, Kimberley Hanson

MICROWAVES 508
Rochelle Park, NJ
Stacy Bearse, Howard Bierman, Diane Berkman, Sid Moskowitz, Hap Bojsza, Harry Dolan, Ian Hill

MILITARY ELECTRONICS COUNTERMEASURES 524
Santa Clara, CA
Leigh Hartley, Sam Greenberg

MITEQ 413
Hauppauge, NY
A. Kiiss, Helle Kiiss
Microwave components and subsystems

MOTOROLA SEMICONDUCTORS 520
Mesa, AZ
Stene Lazar, Paul Sanders, Alan Wagstaffe, Rick Potyka
RF transistors, hybrid modules

NARDA MICROWAVE CORP. 6
Plainview, NY
John Coppola, Art LeMay
Portable microwave multimeter – 2 to 18 GHz, 6 GHz to 18 GHz GaAs FET amplifier, broadband radiation monitors – 10 MHz to 26 GHz, in-phase power dividers – 2 and 4 way up to 33 GHz, components covering up to 26 GHz

NORSAL IND., INC. 421
Brentwood, NY
Norman Spector, Jerry Cohen, Tony Mendoli
Mixers, 6-port reflectometer, directional couplers, power dividers

NURAD 219
Baltimore, MD
Dr. George Rappaport
Antennas

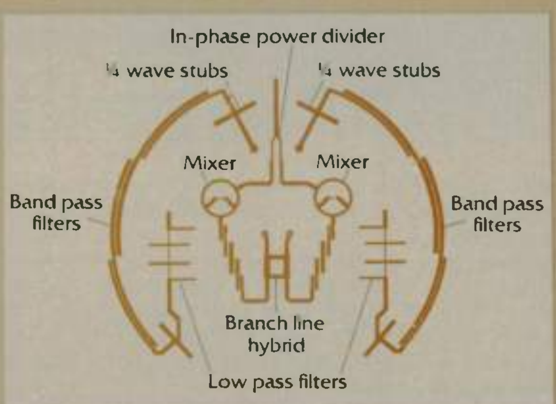
OMNI SPECTRA, INC. 408
Burlington, MA
Philip Cox
Microwave connectors, components, subsystems

(continued on page 44)

We've built a better mousetrap.

It's Keene's new Di-Clad 810 Teflon® ε10 low loss laminate and you can print any microwave circuit on it.

Our "cat" is proof of that. Remove the ears and grin, and you're looking at what is a complex working circuit.



* DuPont registered trademark

New Di-Clad 810 has other advantages. It gives you a dielectric constant of 10 ±.25; it's flexible; it's far easier to work with than ceramics. Available in several thicknesses, this new ceramic-loaded Teflon soft substrate can be processed through your printed circuit board shop. Its uniformity and consistency result in repeatable reliability for your microwave applications.

We think Di-Clad 810 is the new cat's meow for the microwave industry. For more information, write us at P.O. Box 308, Bear, DE 19701. Or call (302) 834-2100.

KEENE
CORPORATION
CHASE-FOSTER DIVISION

(from page 42) GUIDE

PACIFIC MEASUREMENTS INC. 9
Sunnyvale, CA

Tom Fry, Ed Mendel, Ralph Britton, Scott Wetenkamp, Bruce Anderson, Dean Armann, Bob Genin

Power meters, swept measurement systems

PARAMETRIC INDUSTRIES, INC. 526
Winchester, MA

Robert T. Fallon, Louis Covino, George R. Sotiropoulos

Tuning varactors, harmonic generator varactors, PIN and PN junction switching diodes, limiter diodes, parametric amplifier varactors, point contact mixer and detector diodes, Schottky barrier mixer and detector diodes, noise diodes, military approved point contact mixer and detector diodes, diode chips

PLESSEY OPTOELECTRONICS AND MICROWAVE 412
Irvine, CA
Malcolm R. Weatherhead, Abe Ruben
GaAs FET's – low noise GaAs FET's, power GaAs FET's; 1.3 µm emitters, detectors Gunn devices – pulsed Gunn oscillators, electronically tuned Gunn oscillators, fixed frequency Gunn oscillators, Gunn diodes Doppler modules – X and K-Band Doppler modules, X and K-Band antennas IMPATT oscillators – millimeter wave IMPATT oscillators, X-Band IMPATT oscillators, fiber optic sources – high radiance emitters at 0.9 µm with integral fiber pigtails or connector mounted

POLARAD ELECTRONICS, INC. 104
Lake Success, NY

Edward F. Feldman, Sol Abrams, Eugene Kushner, Joe Schindler
Microwave signal generators, RF/microwave spectrum analyzers

PREMIER MICROWAVE CORP. 321
Port Chester, NY
Jules Simmonds, Richard Snyder, Leonard Kardon, William Callas

Passive m/w components – filters, diplexers, rotary joints, antenna feeds, ferrite devices from 400 MHz – 40 GHz

Q-BIT CORPORATION 407
Palm Bay, FL

Gary Callaway, Mary Rogers, Don Harney, Hansel Mead, Ken Cox
RF amplifiers, hybrid TO-8 amplifiers, heterodyne receiver

RAYTHEON CO., 503
Microwave and Power Tube Div.
Waltham, MA

R. Manson, J. Vega, W. Mitten, B. Silberman, A. Maier, S. Ameen, B. Wood, F. Paik, F. Heintz, J. Stabile, J. Hieber, A. Yarranton, F. Regalado, J. Simpson, M. Rubin, L. Cook, W. Jones, I. Meyers, R. Langley, C. Bowness, H. Perreault, W. Boyd, T. White, A. Vacaro, J. Vishinski, K. Lambert, G. Callahan, E. Chin, T. Rogala, G. Greenstein, T. Griffin

Microwave tubes; solid state microwave devices and components; microwave test equipment

ROCKLAND SYSTEMS CORP. 610
Rockleigh, NJ

Richard N. Ridgewell

Filters for signal processing programmable "Brickwall"™ filters, frequency synthesizers, FFT real-time spectrum analyzers, IEEE INTERFACES

SAGE LABORATORIES, INC. 325
Natick, MA

Tony Cieri, Ted Saad, Carl Marguerite, Harry Chapell, Ken Paradiso, Don George, Dick Keyes
Amplifiers, attenuators, directional couplers, filters, hybrids, instruments, mixers, phase-shifters and line-stretchers, power dividers, rotary joints, switches, terminations, video detectors and diode holders, plus WIRELINE series

SANDERS ASSOCIATES, INC., 302
Microwave Div.
Manchester, NH
James Schack, Kenneth Klimas, Richard Wood

Antennas, couplers, noise figure test set, power dividers, switches, M/W components

SOLID STATE MICROWAVE, Div. 405
of Thomson-CSF Components Corp.
Montgomeryville, PA

Don Kupinewicz, Robert Tyson, John Walsh, Jeff Holmquest, Romesh Gulrajani

RF and microwave power transistors, microwave diodes, microwave power tubes and RF and microwave connectors
(continued on page 46)

Circle 31 on Reader Service Card

STANDARD DESIGNS

FERRITE ISOLATORS AND CIRCULATORS

POPULAR OCTAVE BANDS — STANDARD DESIGNS

These units are internally terminated circulators (isolators) with SMA female connectors and are available from stock*

Frequency (GHz)	Model No.	Isolation (dB min.)	Insertion Loss (dB max.)	VSWR (max.)	Size Height	Width	Thickness
1.0 - 2.0	T-1S63T-18	18	0.5	1.30:1	2.75	2.75	0.88
2.0 - 4.0	T-2S63T-6	17	0.5	1.35:1	1.63	1.63	0.75
2.6 - 5.2	T-2S63T-44	17	0.5	1.35:1	1.25	1.25	0.70
4.0 - 8.0	T-4S63T-10	17	0.4	1.35:1	1.06	1.00	0.76
4.5 - 9.0	T-4S63T-13	17	0.5	1.35:1	1.13	0.95	0.76
5.2 - 10.4	T-5S63T	17	0.5	1.35:1	1.06	1.00	0.76
8.0 - 16.0	T-8S63T-18	17	0.5	1.35:1	0.75	0.63	0.40
10.0 - 20.0	T-10S63T-5	17	0.7	1.35:1	0.68	0.51	0.56

S-T-R-E-T-C-H OCTAVE BANDS — STANDARD DESIGNS

Both circulators and isolators are available with either SMA-male or female connectors. Model Nos. shown are isolator versions with SMA-female connectors.

Frequency (GHz)	Model No.	Isolation (dB min.)	Insertion Loss (dB max.)	VSWR (max.)	Size Height	Width	Thickness
1.7 - 4.2	T-1S83T-2	16	0.7	1.50:1	1.70	1.63	0.76
2.0 - 4.5	T-2S73T-4	16	0.6	1.40:1	1.70	1.56	1.10
3.7 - 8.2	T-3S73T-2	16	0.7	1.40:1	1.06	1.00	0.76
4.4 - 10.0	T-4S73T-2	16	0.7	1.40:1	1.13	0.95	0.76
5.9 - 13.0	T-5S73T-1	17	0.6	1.35:1	0.81	0.63	0.80
7.6 - 18.0	T-7S83T-20	16	0.8	1.50:1	0.76	0.63	0.62

POPULAR NARROW BAND — STANDARD DESIGNS

Frequency (GHz)	Model No.	Isolation (dB min.)	Insertion Loss (dB max.)	VSWR (max.)	Size Height	Width	Thickness
.95 - 1.225	T-0S23T-2	20	0.5	1.25:1	1.20	1.20	0.75
1.2 - 1.6	T-1S23T-7	17	0.5	1.35:1	1.25	1.25	0.70
1.9 - 2.3	T-1S13T-2	20	0.4	1.30:1	1.25	1.25	0.75
2.2 - 2.3	T-2S03T-2	20	0.4	1.35:1	1.00	1.00	0.62
3.7 - 4.2	T-3S13T-9A	25	0.25	1.10:1	0.75	0.75	0.50
4.4 - 6.5	T-4S33T-1	17	0.5	1.35:1	0.75	0.75	0.50
5.9 - 6.4	T-5S03T-3A	26	0.3	1.10:1	0.75	0.75	0.69
7.0 - 11.0	T-7S43T-6	28	0.4	1.10:1	0.85	0.75	0.60
8.0 - 12.4	T-8S43T-1A	17	0.4	1.35:1	0.78	0.63	0.70
12.4 - 18.0	T-12S43T-8	18	0.5	1.30:1	0.68	0.51	0.56
18.0 - 26.5	T-18S33T-7	16	1.0	1.50:1	0.68	0.51	0.53

SPECIAL DESIGNS

- Multi-Junction 4, 5, 6 or more Ports
- Stripline Tab Drop-Ins
- Special RF Power Requirements
- N or TNC Connectors (lower frequency units only)

TELEDYNE MICROWAVE

1290 Terra Bella Ave., Mt. View, CA 94043 (415) 968-2211 TWX (910) 379-6939

OTHER PRODUCTS: • RF Coaxial Switches • SPDT • Transfer • Multithrow • Multiplexers and Integrated Components • VCOs

(from page 44) GUIDE

SOLITRON/MICROWAVE 4
Port Salerno, FL
Ray Sulzer, Jerry Fenex
RF connectors, resistive film products

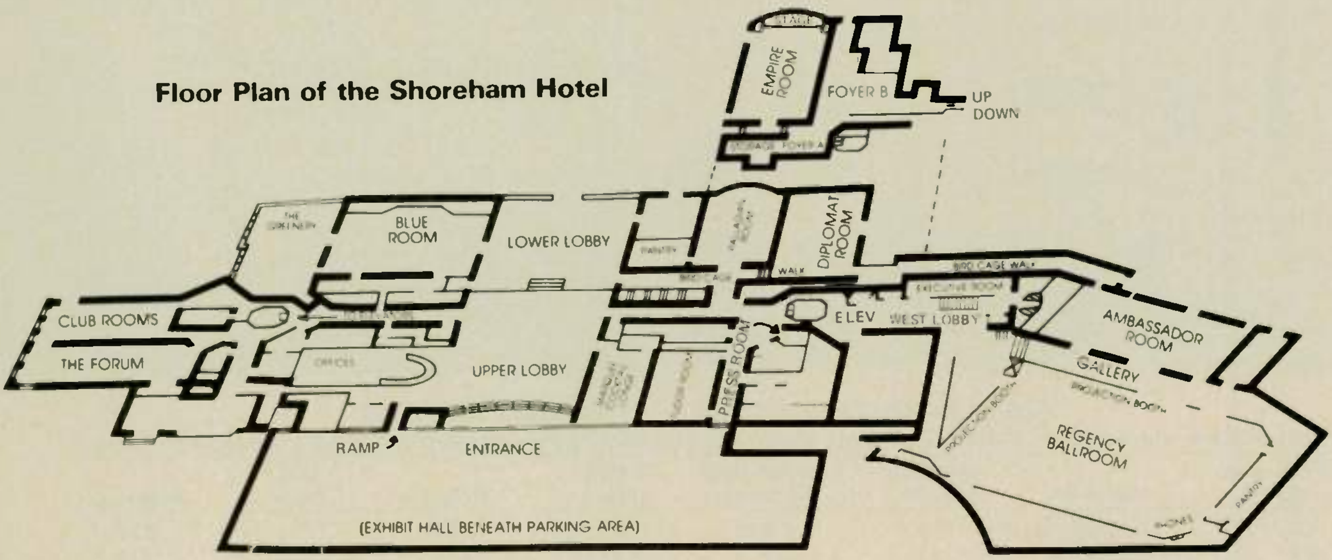
SPACE MICROWAVE LABS., INC. 110
Santa Rosa, CA
Jack Paul, Frank Miller, Jim Tarber
High power microwave amplifiers, radar transmitters, threat platform simulators, wideband test systems

SUMMIT ENGINEERING 517
Bozeman, MT
Radio frequency components — mixers, transformers, switches, diode assemblies, hybrids

SYSTRON-DONNER CORP. 314
Concord, CA
YIG devices, oscillators, filters and varactor-controlled oscillators; microwave test equipment — spectrum analyzers, sweep generators, frequency synthesizers, signal generators, counters

TEKFORM PRODUCTS COMPANY 221
Anaheim, CA
Marjorie Byrnes, Barry Gaunt
Microelectronic packages for microwave circuits

Floor Plan of the Shoreham Hotel



(continued on page 48)

BROADBAND FLATPACK DOUBLE BALANCED MIXER DBM-700

L.O. and R.F. Ports: 1-3500MHz, I.F. Port: 5-2500MHz

VSWR (typical): 2.0:1

Conversion Loss (typical): 7.5dB

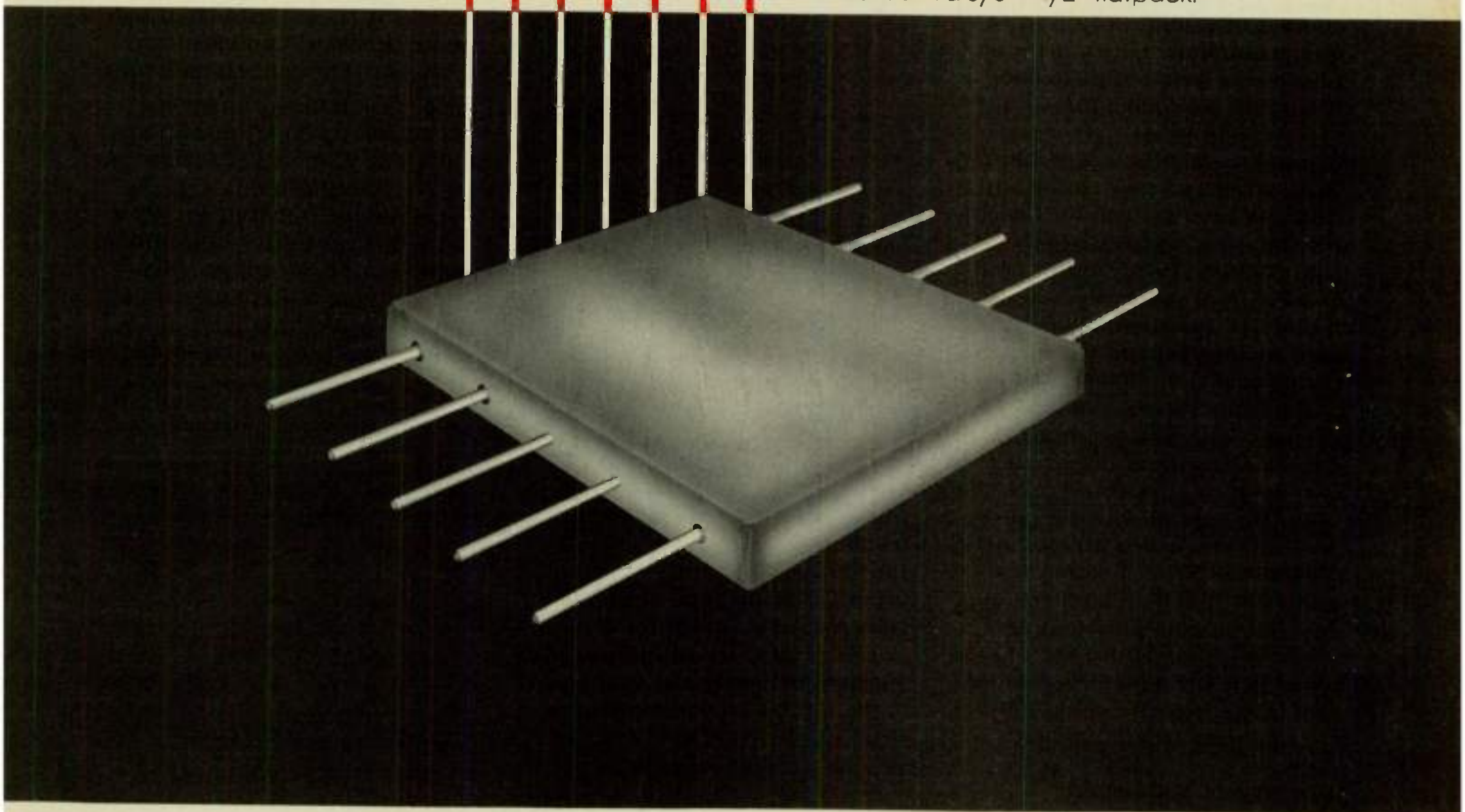
Isolation (typical all ports): 25dB

1dB Desensitization (typical): +5dBm

3rd Order Intercept Point: +20dBm

Price: $250.00 (1-9)

The new VARI-L DBM-700 is insensitive to X-port mismatches. The DBM-700 can be directly interfaced with filters on all ports with minimal change in 3rd order intermodulation products across the entire bandwidth. The DBM-700 is ideal for up converting or down converting. The mixer is housed in a 3/8" × 1/2" flatpack.



The recognized industry leader for twenty-six years, VARI-L leads the way in state-of-the-art engineering. For fast, personal assistance, just call (303) 371-1560

VARIL

VARI-L COMPANY, INC. 11101 EAST 51ST AVENUE, DENVER, COLORADO 80239 (303) 371-1560, TWX: 910-932-0311

Circle 35 on Reader Service Card

TEKTRONIX INC. 512
Beaverton, OR

Bill Rutherford, John David, Ken Andrews, Ed Browning

492P Programmable Spectrum Analyzer, 4052 Controller, 4631 Hard Copy Unit, microwave comb generator

TELECOMMUNICATIONS 213
(see Horizon House)

TELEDYNE MICROWAVE 220
Mountain View, CA

Alan Campbell, Pat Gruver, Nam Han, Paul Kovacich, John Matson, Pat McLaughlin, Ken Mills, Jim Mongillo

Broad range of circulators and isolators, electromechanical coaxial switches, integrated switchable filter arrays, and MIC voltage-controlled oscillator systems: continuous slide presentation showing variety products for space vehicle, ECM communications, radar and avionics communication

TEXSCAN CORPORATION 313
Indianapolis, IN

Bob Jackson

Attenuators, filters, oscillators, sweep generators, spectrum analyzers

THINCO 306
Div. of Hull Corp.
Hatboro, PA

Chip capacitors and inductors

TRAK MICROWAVE CORP. 10
Tampa, FL

George Pate, Tom Roberts, Mort Lader, Jerry Stanley, Charlie Stackhouse

Circulators, isolators, IF amplifiers, GaAs FET amplifiers, oscillators, comb generators

TRANSCO PRODUCTS, INC. 3
Venice, CA

Ray Williams, Jerry Fricke, Norm Feigenbaum, John Underhill, Joe Belcher, Bill Lyman

RF switches, components, antennas

TRW RF SEMICONDUCTORS 411
Lawndale, CA

Jim Humphrey, Roger Debloois, Mark Williams, Les Kilpatrick

Silicone bipolar RF power transistors — non-matched and internally matched — for use in both pulse and CW applications from 2 MHz to 4.2 GHz

A. J. TUCK COMPANY 4
Brookfield, CT

Tore Andersen, Alvin J. Tuck IV

Precision electroforming

UNIFORM TUBES, INC. 418
Collegeville, PA

Dr. Robert A. Schafer, Lloyd Deery

Semi-rigid coaxial cable, filters

UNI-TEL LTD. 403
Scarborough, Ontario

G. G. Cooper, B. H. Griffiths, J. K. Wallace

Microwave fault alarm, remote control, local orderwire, service channel bridges, amplifiers and filters

VARIAN ASSOCIATES, EDG 607
San Carlos, CA

Modulators, microwave transistors, millimeter wave components, klystrons, TWTs

VARI-L 307
Denver, CO

Carol Kiser

Double balanced mixers

WATKINS-JOHNSON CO. 111
Palo Alto, CA

S. L. Erickson, D. L. Henry, A. T. Isaacs, R. V. Jackson, D. G. Killen, G. L. Koker, D. J. Sheehan, W. T. Smith, V. D. Varenhorst, S. B. Witmer

Microwave amplifiers, oscillators, filters, mixers, front ends and test equipment

WAVETEK 610
Beech Grove, IN

Ed McDonald, John Duval, Jost Ladwig, Bruce Malcom, Lou Abbott, Tony Reuter, Henry Reinecke, Kurt Zubin, Tad Ofuji, John Roth, Ron Gross, Curt Ball, Jim Reeve

Sweep generators, signal generators

WEINSCHEL ENGINEERING 320
Gaithersburg, MD

Ron Ramirez, Barry Server, Gary McNamara, Jerry Spiro, Harmon Banning

VM-4A Attenuator and Signal Generator Calibrator — microprocessor-based instrument provides fully automated (IEEE-488) insertion loss measurement of 120 dB in a single step 0.01 to 18 GHz, 4,310 A/K multi-band sweep oscillator with IEEE-488 bus compatibility-covers 0.01 to 18 GHz, RF power calibration system — 0.1 to 18 GHz, RF attenuators — fixed, continuously variable step and programmable, dc-26.5 GHz, OEM programmable attenuators — dc-22 GHz and up to 127 dB/1 dB steps

WESTERN MICROWAVE LAB. 219
Sunnyvale, CA

George Elsaesser

Ferrites, isolators, circulators

WILTRON 310
Mountain View, CA

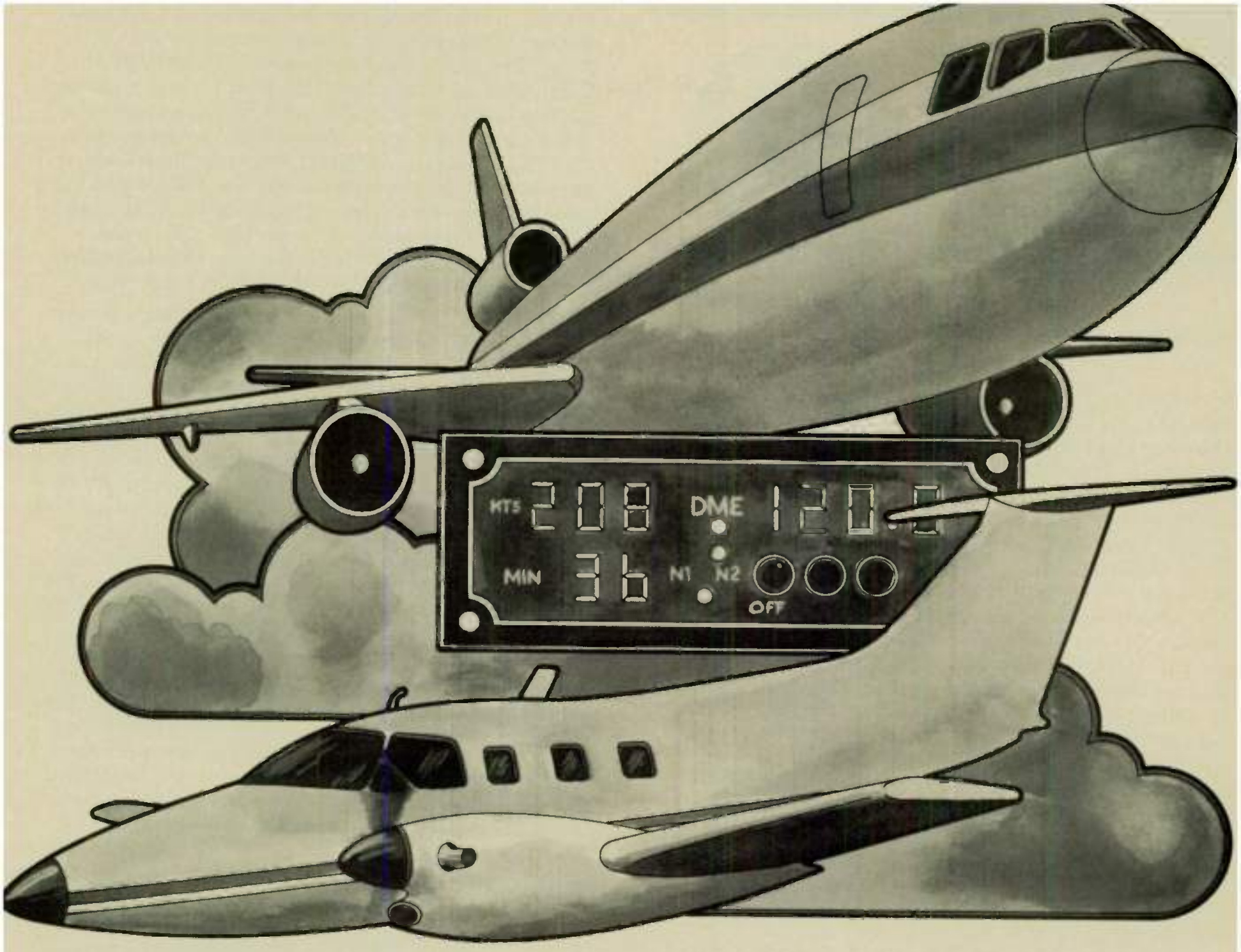
Ed Daw, Dr. Peter Lacy, Walter Baxter

Microwave test equipment

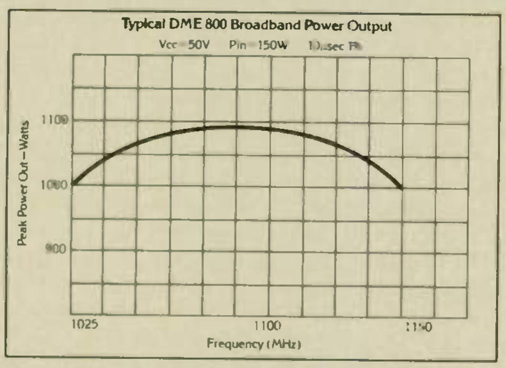
ZETA LABS., INC. 214
Santa Clara, CA

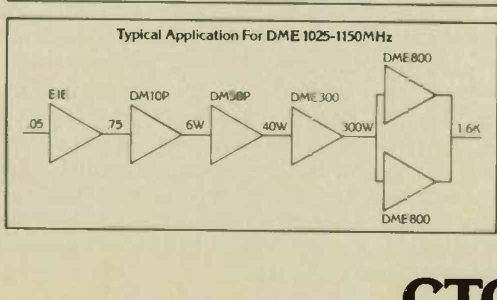
Chuck Frank, Austen Terry

Frequency synthesizers, multipliers, crystal controlled oscillators, telecommunications oscillators, IF amplifiers, electronic subsystems



800 Watts P_{OUT} DME





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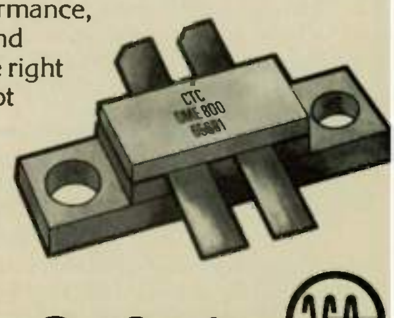

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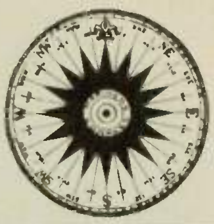
Around the Circuit



PERSONNEL

Allen E. Rosenzweig was named National Sales Manager for Aertech Industries. . .Alpha Industries TRG Div. named Dr. **Apostle G. Cardiasmenos** as Asst. Div. Mgr. and Manager of its Millimeter Subsystems Organization. . .In Bunker Ramo Corp.'s Amphenol N. America Div., **Allen Nemetz** was appointed V.P., Product Marketing of the Danbury, CT. plant. . .After a major internal management reorganization at California Eastern Laboratories, Inc. **Hugh A. White** remains Chief Exec. Officer; **Carl A. Petersen** becomes President; **Jerry A. Arden** is V.P. Marketing and **Brian L. Jones** becomes V.P. of Engineering. . .**Joseph P. Engeman** was named Deputy General Mgr. of Eaton Corp.'s Electronic Instrumentation Div.'s L.I. operation. . .Merrimac Ind. appointed **Dan Loder** as Eastern District Sales Mgr. . .**Kent E. Keller** joined Racal-Dana Instruments Inc.'s staff as Corporate Mgr. of Marketing Services. . .At Collins Transmissions Systems Div. of Rockwell Int'l. Corp., **Joe C. Culp** was named V.P. and General Mgr. . .Sanders Associates, Inc. announced the appointment of **Donald A. Bond** as General Mgr. of its Microwave Div. . .**William G. White** joins Sealectro Corp. as Dir. of Marketing. . .**Don Salom** heads the new Fairfax, VA Scientific Communications Inc. COMINT receiver operation. **Britt Vincent** was named SciComm's V.P. of Engineering. . .At Systron-Donner's Instrument Div., **Gail M. Dishong** was appointed Product Dir. of Microwave Instrumentation. . . **Frederick G. Suffield** joins Teledyne Micronetics as Mgr. of Marketing. . .Tecom, Inc. appointed **Tom Koster** as National Sales Manager. . .**Jerry Fricke** has been promoted from Sales Manager to Director of Marketing at Transco Products, Inc. . .**Bruno O. Weinschel**, President of Weinschel Engineering Co., was appointed Chrmn. of the Engrg. Affairs Council of the American Assoc. of neering Co., was appointed Chrmn., Engrg. Affairs Council, American Assoc. of Engrg. Societes (AAES).

WILLIAM J. KENNEDY

William J. Kennedy, associated with Sage Laboratories, Inc. of Natick, MA as Sales Manager and Vice President of Marketing from 1959-1975, died on April 8, 1980 at age 54.

Prior to his affiliation with Sage Laboratories, Mr. Kennedy held positions at Sperry Gyroscope Company and H. L. Hoffman Company. At the time of his death, he was Marketing Manager for Bertan Associates of Syosset, NY.

CONTRACTS

American Electronic Laboratories, Inc. was awarded a $3M contract by ERADCOM for counter-microwave communications simulation equipment and a $190K overseas contract for multi-octave antennas. . . **California Microwave, Inc.** received a $2.1M award from the Dept. of the Air Force for a portable calibration van (PCV). . .An $11M contract was granted to **Lockheed Missiles & Space Co.** for a radar antenna for the US Army Stand-Off Target Acquisition System (SOTAS). . . **Loral Corp.** received a $35M contract for additional production quantities of its AN/ALR-56 radar warning receiver for USAF F-15's. . .M/A-COM, **Inc.** announced that its operating co., **Digital Communications Corp.** was awarded a $15M-plus contract for over 200 transmit/receive 4.6-meter earth stations. . .**Scientific-Atlanta, Inc.** received a $1M order from **Exxon Int'l. Co.** for 20 MARISAT terminals a $2M order from **Mobil Shipping and Transportation Co.** for 50 MARISAT terminals.

INDUSTRY NEWS

Alpha Industries completed construction of its Woburn, MA plant housing millimeter-wave testing laboratories, microelectronics assembly areas and processing/technical support areas. . .**Bunker Ramo Corp.** announced the acquisition of **B & W Associates** of Burlington, MA, a connector/cable assembly manufacturer; B & W will function as part of Bunker Ramo's Amphenol RF operations. . .**Isotronics**, an Augat, Inc. subsidiary which manufactures all-metal packages for the hybrid microcircuit industry, opened a 45,000-square-foot plant in New Bedford, MA. . .**M/A-COM, Inc.** and **Aetna Life & Casualty** will form a partnership, LDC, to provide transmission equipment for the local distribution of business communications. . .**Materials Research Corp.** will open a $4.5M facility in Orangeburg, NJ in 1981. . .**Scientific Communications Inc.**'s commercial satellite communications operations recently were sold to **Gardiner Communications** of Houston and a new SciComm facility at Fairfax, VA has been opened to produce a communication surveillance receivers. . .An added 44,000 sq. ft. of manufacturing space is nearing completion at the **Sealectro** plant in Watertown, MA.

FINANCIAL NEWS

Aydin Corporation reported results for the year ended December 31, 1979 of net sales of $64M, net income of $4.0M or $1.78 per share. This compares with 1978 sales of $47M, net income of $2.6M or $1.20 per share. . .For the year ended December 31, 1979, **Electromagnetic Sciences, Inc.** reported net sales of $5.0M and net earnings of $263K or 30¢ per share as compared with 1978 yearly results of $3.7M sales and earnings of $214K or 25¢ per share. . .**California Microwave** will report a net loss for the third quarter ended March 31, 1980 due to a write-down of inventory to current market value expected to approximate $1M. . .**M/A-COM, Inc.** reported results for the first quarter ended January 31, 1980 of net sales of $32.5M, net income of $2.0M or 36¢ per share. In the same quarter last year, net sales were $27.0M, net income was $1.5M or 27¢ per share. . . **Sanders Associates, Inc.** had second quarter FY80 results of net sales of $70M, net income of $4.0M or net 70¢ per share. In 1978, the quarterly net sales were $38.8M, net income was $3.6M or 60¢ per share. . .Midyear results were reported by **Scientific-Atlanta, Inc.** for the period ended December 31, 1979 of net sales of $86M and net earnings of $5.2M of primary earnings per share of $1.12. For the 1978 period, net sales were $57.2M, net earnings $3.4M or primary earnings per share of 83¢. . .**Sealectro Corp.** reported annual results for the year ended Dec. 28, 1979 of sales of $35M and net income of $2.5M or $2.21 per share. This compares with 1978 year-end sales of $27.1M and net income of $1.3M or $1.15 per share.

Your brains.

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WIDEBAND DESIGNS

Model No.	Frequency (GHz)	Gain (dB) Min.	Gain Variation (±dB) Max.	Noise Figure (dB) Typ.	Noise Figure (dB) Max.	VSWR Max. Input	VSWR Max. Output	Dynamic Range: 1 dB Gain Comp. Output (dBm) Min.	Dynamic Range: 3 rd Order Inter. Pt. (dBm) Typ.
AMF-1B-2040-3	2-4	10	0.5	3.0	3.5	2:1	2:1	7	17
AMF-2B-2040-3	2-4	20	0.75	3.0	3.5	2:1	2:1	10	20
AMF-3B-2040-3	2-4	30	1.0	3.0	3.5	2:1	2:1	10	20
AMF-4B-2040-3	2-4	40	1.5	3.0	3.5	2:1	2:1	13	23
AMF-1B-3060-3	3-6	9	0.5	3.0	4.0	2:1	2:1	7	17
AMF-2B-3060-3	3-6	18	0.5	3.0	4.0	2:1	2:1	10	20
AMF-3B-3060-3	3-6	27	0.75	3.0	4.0	2:1	2:1	10	20
AMF-4B-3060-3	3-6	36	1.5	3.0	4.0	2:1	2:1	13	23
AMF-5B-3060-3	3-6	45	1.5	3.0	4.0	2:1	2:1	13	23
AMF-1B-4080-3	4-8	8	0.5	3.5	4.5	2:1	2:1	7	17
AMF-2B-4080-3	4-8	16	0.75	3.5	4.5	2:1	2:1	10	20
AMF-3B-4080-3	4-8	24	1.0	3.5	4.5	2:1	2:1	10	20
AMF-4B-4080-3	4-8	32	1.5	3.5	4.5	2:1	2:1	13	23
AMF-5B-4080-3	4-8	40	1.5	3.5	4.5	2:1	2:1	13	23
AMF-1B-0510-3	5-10	7	0.5	5.0	6.0	2:1	2:1	7	17
AMF-2B-0510-3	5-10	14	0.75	5.0	6.0	2:1	2:1	10	20
AMF-3B-0510-3	5-10	21	1.0	5.0	6.0	2:1	2:1	10	20
AMF-4B-0510-3	5-10	28	1.5	5.0	8.0	2:1	2:1	13	23
AMF-5B-0510-3	5-10	35	1.5	5.0	8.0	2:1	2:1	13	23
AMF-1B-0612-3	6-12	6	0.5	5.5	6.5	2:1	2:1	7	17
AMF-2B-0612-3	6-12	12	0.75	5.5	6.5	2:1	2:1	10	20
AMF-3B-0612-3	6-12	18	1.0	5.5	6.5	2:1	2:1	10	20
AMF-4B-0612-3	6-12	24	1.5	5.5	6.5	2:1	2:1	13	23
AMF-5B-0612-3	6-12	30	1.5	5.5	6.5	2:1	2:1	13	23
AMF-1B-8012-3	8-12	6	0.5	5.5	6.5	2:1	2:1	7	17
AMF-2B-8012-3	8-12	12	0.75	5.5	6.5	2:1	2:1	10	20
AMF-3B-8012-3	8-12	18	1.0	5.5	6.5	2:1	2:1	10	20
AMF-4B-8012-3	8-12	24	1.5	5.5	6.5	2:1	2:1	10	20
AMF-2B-8016-3	8-16	8	0.75	7.0	8.0	2:1	2:1	10	20
AMF-3B-8016-3	8-16	12	0.10	7.0	8.0	2:1	2:1	10	20
AMF-4B-8016-3	8-16	16	1.5	7.0	8.0	2:1	2:1	10	20
AMF-5B-8016-3	8-16	20	1.5	7.0	8.0	2:1	2:1	10	20
AMF-2B-1218-3	12-18	8	0.75	7.0	8.0	2:1	2:1	10	20
AMF-3B-1218-3	12-18	12	0.75	7.0	8.0	2:1	2:1	10	20
AMF-4B-1218-3	12-18	16	1.0	7.0	8.C	2:1	2:1	10	20
AMF-5B-1218-3	12-18	20	1.5	7.0	8.0	2:1	2:1	10	20
AMF-6B-1218-3	12-18	24	2.0	7.0	8.0	2:1	2:1	10	20
AMF-7B-1218-3	12-18	28	2.0	7.0	8.0	2:1	2:1	10	20

AMPLIFIER UPDATE

NOISE FIGURE OPTIMIZED DESIGNS

Model No.	Frequency (GHz)	Gain (dB) Min.	Gain Variation (±dB) Max.	Noise Figure (dB) Typ.	Noise Figure (dB) Max.	VSWR Max. Input	VSWR Max. Output	Dynamic Range 1 dB Gain Comp. Output (dBm) Min.	Dynamic Range 3 rd Order Inter. Pt. (dBm) Typ.
AMF-2A-1617	1.6-1.7	25	0.5	1.4	1.6	1.25	1.5	5	15
AMF-3A-1617	1.6-1.7	35	0.5	1.4	1.6	1.25	1.5	10	20
AMF-2A-2223	2.2-2.3	22	0.5	1.5	1.7	1.25	1.5	5	15
AMF-3A-2223	2.2-2.3	35	0.5	1.5	1.7	1.25	1.5	10	20
AMF-2A-2124	2.1-2.4	20	1.0	1.6	1.8	1.25	1.5	5	15
AMF-3A-2124	2.1-2.4	33	0.75	1.6	1.8	1.25	1.5	10	20
AMF-2A-1720	1.7-2.0	20	0.75	1.7	2.0	1.35	1.5	5	15
AMF-3A-1720	1.7-2.0	30	0.75	1.7	2.0	1.35	1.5	10	20
AMF-2A-2729	2.7-2.9	20	0.5	1.7	1.9	1.25	1.5	5	15
AMF-3A-2729	2.7-2.9	30	0.5	1.7	1.9	1.25	1.5	10	20
AMF-2A-2931	2.9-3.1	20	0.5	1.8	2.0	1.25	1.5	5	15
AMF-3A-2931	2.9-3.1	30	0.5	1.8	2.0	1.25	1.5	10	20
AMF-2S-3742-3	3.7-4.2	20	0.5	1.5	1.7	1.25	1.5	7	17
AMF-3S-3742-3	3.7-4.2	30	0.5	1.5	1.7	1.25	1.5	13	23
AMF-4S-3742-3	3.7-4.2	40	0.5	1.5	1.7	1.25	1.5	13	23
AMF-2S-4550-3	4.5-5.0	20	0.5	1.7	2.0	1.25:1	1.5:1	7	17
AMF-3S-4550-3	4.5-5.0	30	0.5	1.7	2.0	1.25:1	1.5:1	13	23
AMF-4S-4550-3	4.5-5.0	40	0.5	1.7	2.0	1.25:1	1.5:1	13	23
AMF-2S-7278-3	7.2-7.8	17	0.5	2.5	3.0	1.25:1	1.5:1	5	15
AMF-3S-7278-3	7.2-7.8	26	0.5	2.5	3.0	1.25:1	1.5:1	10	20
AMF-4S-7278-3	7.2-7.8	35	0.5	2.5	3.0	1.25:1	1.5:1	10	20
AMF-2S-8596-3	8.5-9.6	16	0.5	3.0	3.5	1.25:1	1.5:1	5	15
AMF-3S-8596-3	8.5-9.6	24	0.5	3.0	3.5	1.25:1	1.5:1	10	20
AMF-4S-8596-3	8.5-9.6	30	0.5	3.0	3.5	1.25:1	1.5:1	10	20
AMF-2S-109-117-3	10.9-11.7	14	0.5	3.5	4.0	1.25:1	1.5:1	5	15
AMF-3S-109-117-3	10.9-11.7	21	0.5	3.5	4.0	1.25:1	1.5:1	10	20
AMF-4S-109-117-3	10.9-11.7	28	0.5	3.5	4.0	1.25:1	1.5:1	10	20
AMF-2S-117-122-3	11.7-12.2	14	0.5	3.5	4.0	1.25:1	1.5:1	5	15
AMF-3S-117-122-3	11.7-12.2	21	0.5	3.5	4.0	1.25:1	1.5:1	10	20
AMF-4S-117-122-3	11.7-12.2	28	0.5	3.5	4.0	1.25:1	1.5:1	10	20
AMF-2S-140-145-3	14.0-14.5	12	0.5	4.0	5.0	1.25:1	1.5:1	5	15
AMF-3S-140-145-3	14.0-14.5	18	0.5	4.0	5.0	1.25:1	1.5:1	10	20
AMF-4S-140-145-3	14.0-14.5	24	0.5	4.0	5.0	1.25:1	1.5:1	10	20

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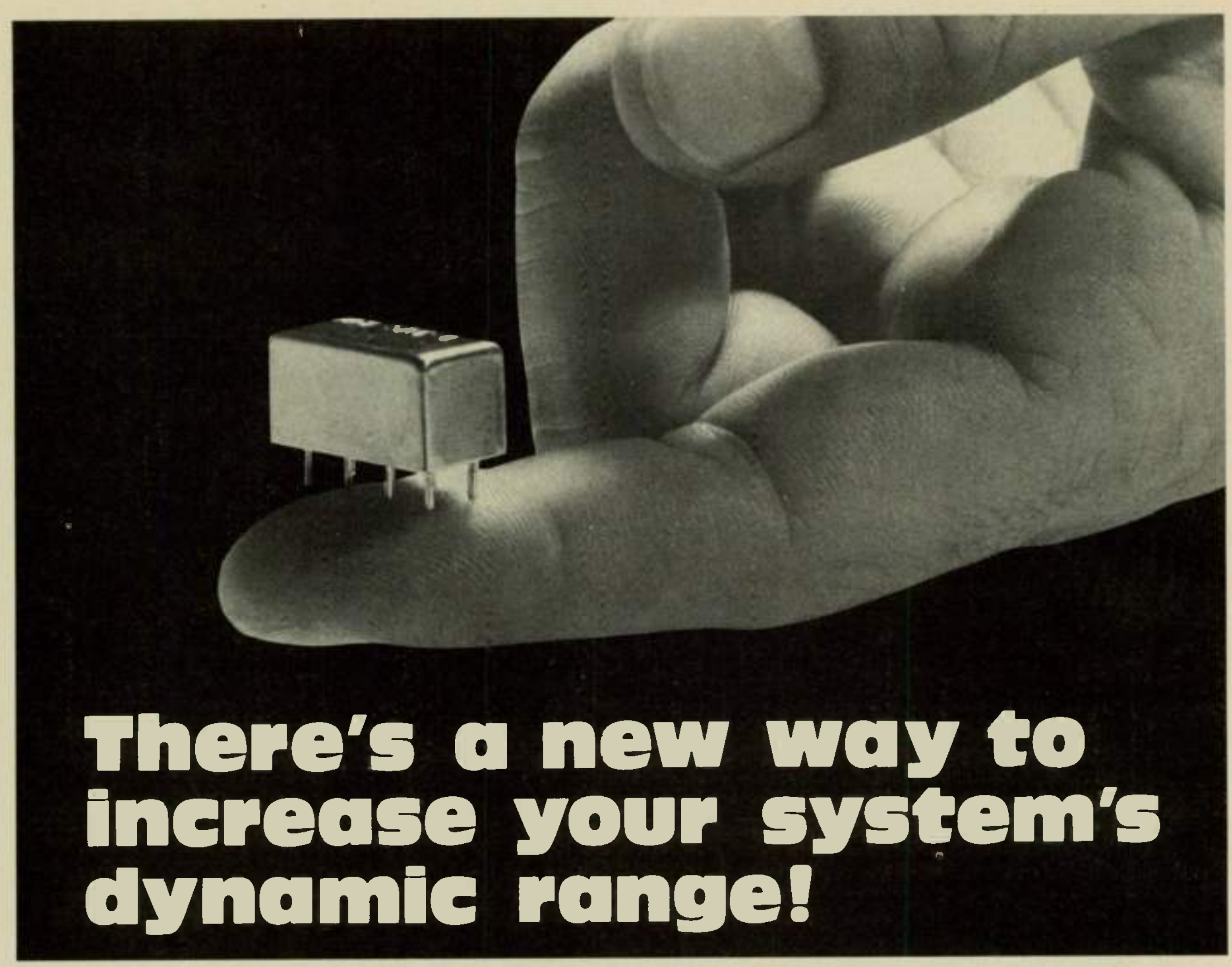

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SAY-1	0.1-500	7.5	+20	8 pins	0.4x0.8x0.4	$54.95
SAY-2	0.1-1000	9.5	+20	8 pins	0.4x0.8x0.4	$59.95
SAY-11	10-2400	10.0	+18.5	8 pins	0.4x0.8x0.4	$64.95
ZFY-1	0.1-500	7.5	+20	*BNC, TNC, SMA, N	1.25x1.25x0.75	$74.95
ZFY-2	0.1-1000	9.5	+20	*BNC, TNC, SMA, N	1.25x1.25x0.75	$79.95
ZFY-11	10-2400	10.0	+18.5	*BNC, TNC, SMA, N	1.25x1.25x0.75	$84.95

Impedance 50 ohms. Isolation 20 dB min.
*BNC standard. TNC on request. Type N and SMA $5.00 additional.
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38 REV. A

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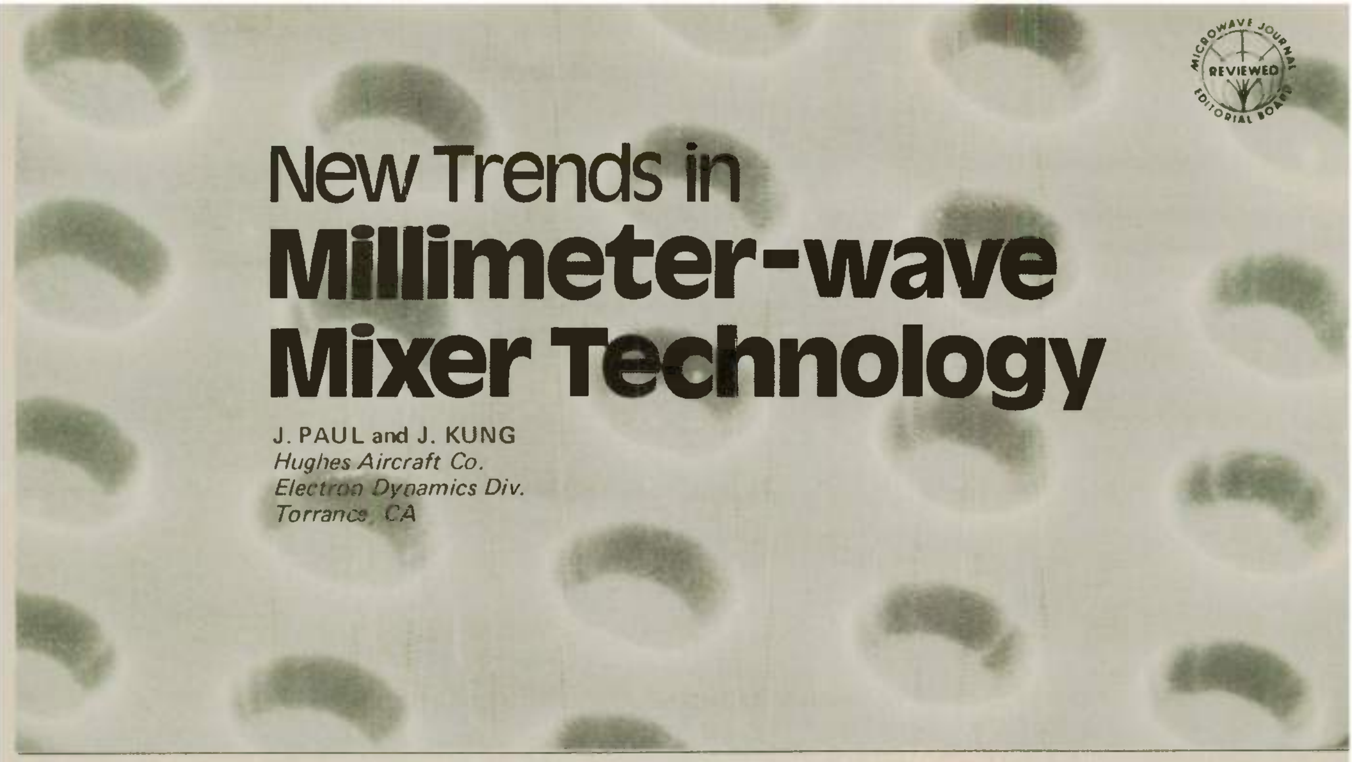

New Trends in Millimeter-wave Mixer Technology

J. PAUL and J. KUNG
Hughes Aircraft Co.
Electron Dynamics Div.
Torrance, CA

INTRODUCTION

One of the key reasons behind the successful development of millimeter wave systems is the availability of receiver front ends with outstanding performance characteristics. Substantial efforts have been under way to develop new mixer diodes and circuit technologies in the upper millimeter wave frequency range. In this paper we cover the new mixer technologies under active consideration for the frequency range from 60 GHz to 340 GHz. First we examine three types of GaAs Schottky barrier mixer diodes: honeycomb, notch front and beam lead. Four types of mixers involving different circuit technologies are than presented: waveguide, suspended stripline, dielectric guide and quasi-optical. The design and performance trade-offs of both mixer circuits and diodes are analyzed as a function of frequency and instantaneous bandwidth.

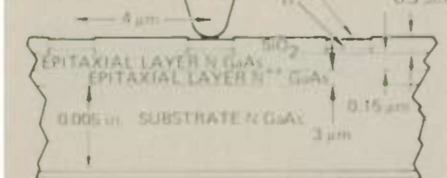

Fig. 1a Cross sectional view of GaAs honeycomb Schottky diode.

MILLIMETER WAVE GaAs MIXER DIODES

Three different types of Schottky barrier mixer diodes have emerged as suitable candidates for use with the new circuit technologies: honeycomb, notch front and beam lead. Honeycomb diodes are best suited for waveguide and quasi-optical circuits; notch front diodes for suspended stripline circuits and beam lead diodes for both suspended stripline and dielectric waveguide circuits. In the following paragraphs we describe the fabrication techniques, performance and design trade-offs of these three types of diodes.

Honeycomb Diodes

The structure of a typical honeycomb type of GaAs Schottky barrier diode is shown in Figures 1a and 1b. The fabrication procedure starts by epitaxially growing an n^{++} buffer layer on a n^{+} GaAs substrate wafer, followed by an n-type active layer. These GaAs epitaxial layers can be grown by using various techniques such as vapor phase epitaxy, liquid phase epitaxy and molecular beam epitaxy. The epitaxial layer is then covered with a layer of silicon dioxide approximately 5000 Å thick. The honeycomb pattern is registered on the SiO_2 surface with a layer of photoresist by standard photolithographic techniques. The pattern can also be formed by X-ray or electron beam lithography, which can extend the dimension control below 0.1 µm. The next step is to open windows through the SiO_2 layer according to the photoresist pattern by using either chemical etching or ion beam milling techniques. Schottky barrier junctions are then formed on the exposed GaAs surface by evaporation, sputtering or electroplating. A layer of gold is then deposited onto the Schottky metallization to facilitate electrical

Fig. 1b Honeycomb diode pattern.

contact to the device. At this stage, the GaAs surface is thinned from the n^+ substrate side to approximately 5 mils and a Au-Ge-Ni based metallization layer is deposited on the surface and then alloyed to form a good ohmic contact on the back side of the wafer. The finished wafer is then diced into chips for circuit application. Dependent upon the Schottky barrier contact and chip size, a chip will typically have hundreds and sometimes thousands of individual Schottky barrier diodes. However, only one diode will be electrically contacted and used in the circuit.

An etched metal wire or a whisker is used to provide a reliable low-loss electrical contact to the Schottky barrier diode. Due to the small dimensions of the whisker tip and the diode diameter, the contact is sometimes made by using a Scanning Electron Microscope.

A high performance honeycomb diode for the 100 GHz to 300 GHz region has the following device parameters:

- Junction Diameter: 2 μm
- Active Layer Doping Density: 2.5×10^{17} cm^{-3}
- Active Layer Thickness: 0.15 μm
- Series Resistance: 6 ohms
- Reverse Characteristic: 1 μA @ 4.5 volts

Notch Front Diodes

The special geometries associated with suspended stripline mixer circuits suggest a variation on the design of honeycomb mixer diodes. The notch front diode is one method of altering the honeycomb configuration to fit the package requirements of stripline. This device configuration has the added advantage of inherently reducing the skin effect loss.

The basic notch front diode is shown in Figures 2a and 2b. The device fabrication procedure is very similar to that of the honeycomb diode described above. However, instead of applying a back ohmic contact to the diodes as in the honeycomb process, an ohmic contact to the side of the diode is made. This is done by first sawing notches about 100 μm deep into the front of the GaAs wafer to form 75 μm x 75 μm squares. Using a photoresist layer to protect the Schottky barrier contact on the front surface of the wafer, a Au-Ge-Ni based metallization layer is sputter-deposited into the notch. The wafer is then alloyed to have ohmic contacts formed on the four sides of each square chip. The wafer is then lapped from the back surface until notches are broken through and chips separated. This process results in a diode chip that has the ohmic contact metallization closer to the Schottky junction. This reduces the skin effect resistance simply by reducing junction-to-contact distance. Electrical contact to the notch front diodes is made by using a whisker in a way similar to the honeycomb diodes.

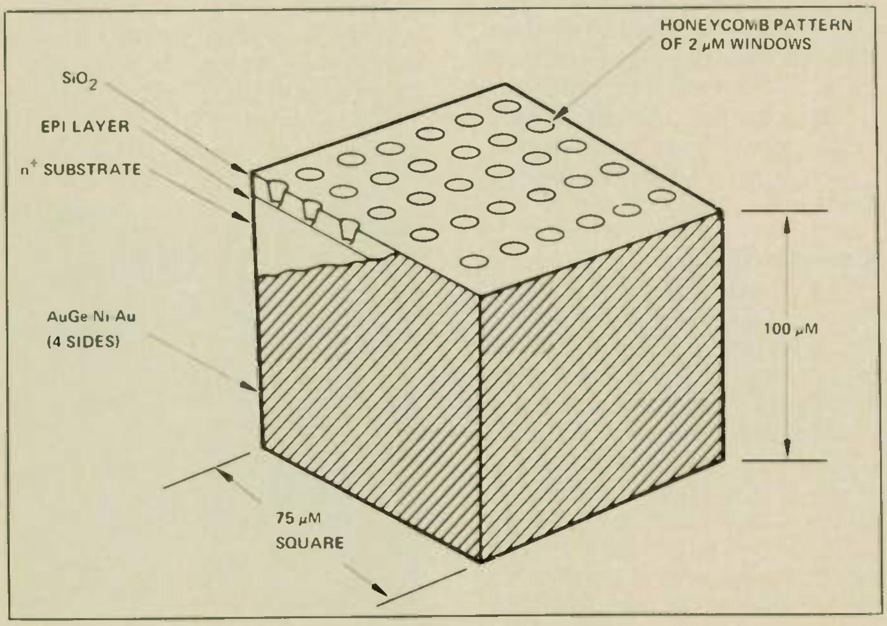

Fig. 2a Notch front diode geometry.

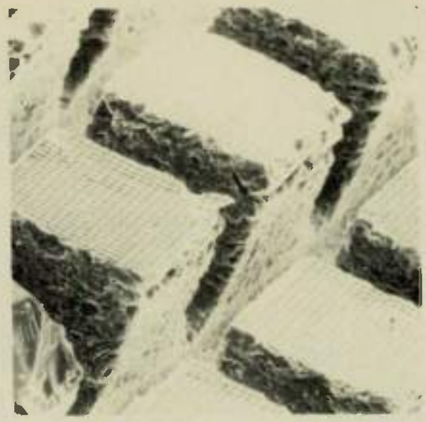

Fig. 2b Electron photomicrograph of notch front diodes.

Beam Lead Diodes

The beam lead diode configuration is drastically different from those of the honeycomb and notch front diodes. Instead of an axial diode to which a whisker must make contact, this device has a surface-oriented configuration from which two beams extend for contact to an RF circuit. Figure 3 shows a photograph of a beam lead device. The Schottky junction is under the long narrow finger. The narrow strip junction geometry has both advantages and disadvantages relative to the circular dot geometry. The strip geometry advantages include a reduced series resistance and a reduced thermal resistance. The disadvantages relate to the large junction periphery for a given junction area, and hence increased edge leakage effects.

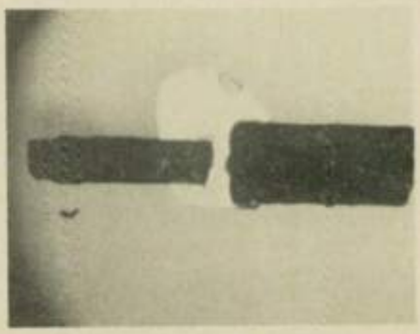

Fig. 3 GaAs beam lead diode.

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The beam lead diode fabrication is an order of magnitude more difficult than either honeycomb or notch front axial diodes. The GaAs material structure is similar to that of the honeycomb diode except that the two epitaxial layers are grown on semi-insulating GaAs substrates. The first layer (n^{++}) has an n-type carrier concentration higher than 1×10^{18} cm^{-3} and is 3 μm thick. The top n-layer has the same parameters as the honeycomb diodes since the material design trade-offs for honeycomb diodes also apply to beam lead diodes. Ohmic contact pads which consist of a Au-Ge-Ni metallization layer are then formed on the epilayer surface by using photolithography, metal evaporation and lift-off techniques. The metallized pads are then alloyed into the GaAs surface to form good ohmic contacts. With the ohmic contact pads and the Schottky contact area properly shielded, the wafer is subject to proton bombardment to convert the n and n^{++} layers into semi-insulating material. After removal of the bombardment shield, the Ti-Au-based Schottky barrier contact pattern is defined on the wafer by again using photolithography, metal evaporation and lift-off techniques. The gold beams are formed by either selectively plating Au into beam forms or by plating Au over the whole wafer and then etching away the Au from selected areas. A passivating glass layer is then deposited selectively over the active device area to protect the diodes. Photoresist patterns in the form of 250 μm x 250 μm squares are then formed on the backside of the wafer, registered with the devices on the front side. The wafer is subsequently etched from the backside until the devices are separated.

MIXER CIRCUITS

Conventional rectangular waveguide balanced mixers have been in existence since the early days of millimeter waves. They perform competitively at frequencies up to 140 GHz for narrowband (up to 10%) applications. Other circuit technologies offer advantages at selected frequency ranges for specific applications. Here we present results on three other circuit technologies in addition to the waveguide. In some instances we find that a combination of circuit technologies provides the best performance trade-offs.

Waveguide Mixers

The advantages provided by balanced mixers over single-ended mixers (LO noise suppression and LO to RF isolation) have made them the almost universal choice over single-ended mixers for systems applications.

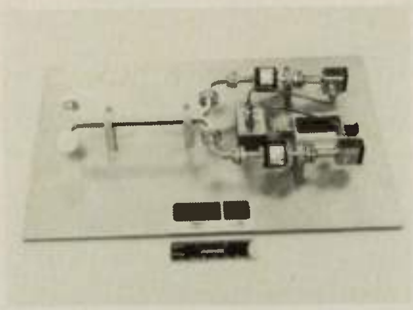

Fig. 4 Wideband scanning LO balanced mixer.

The RF circuit can be implemented with magic Tees, short-slot hybrids, 3 dB directional couplers or rat-race hybrids. **Figure 4** shows a balanced mixer with instantaneous 50 GHz to 75 GHz frequency coverage designed for use with a scanning LO for plasma diagnostic applications.

Typical mixers operating in the 94 GHz window can be reproducibly manufactured with better than 5 dB DSB noise figure, including a 2.5 dB NF contribution from an IF preamplifier with a 10 MHz to 1010 MHz bandwidth. These mixers incorporate whisker-contacted honeycomb diodes with demonstrated reliability under military and space environmental conditions. For example, **Figure 5** shows a 94 GHz balanced mixer/IF preamplifier which was designed and tested for 10,000 G centrifugal acceleration on all three axis.

Fig. 5 W-band shock hardened balanced mixer.

To further improve the noise figure of waveguide balanced mixers, it is necessary to implement equivalent circuit modeling techniques and to verify their validity by experimental RF measurements. **Figure 6** shows a simplified schematic diagram of a 94 GHz balanced impedance bridge capable of measuring the complex impedance of mixer diodes and their embedding circuits. Through methodic measurements of a variety of diode mounting configurations, the pertinent equivalent circuit elements (whisker inductance, junction capacitance, series resistance, etc.) are measured directly at the operating frequency (94 GHz). Once measured, the circuits may be improved and optimized.

Suspended Stripline Mixers

Suspended stripline mixers naturally lend themselves to sub-

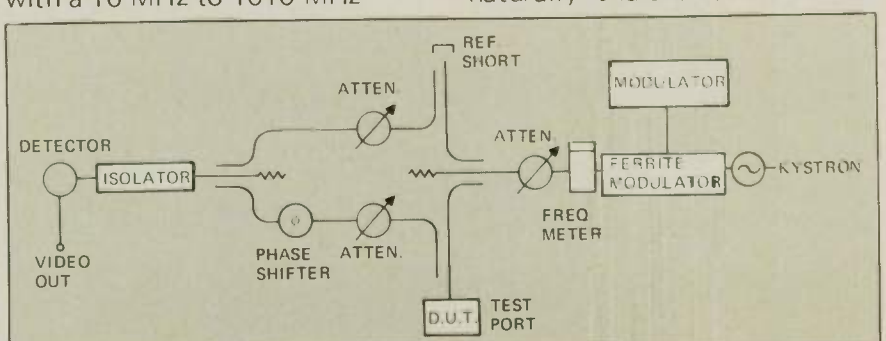

Fig. 6 Simplified schematic of complex impedance bridge.

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harmonic pumping techniques which are useful for many applications where LO power is at a premium. Subharmonic pumping is a technique which is, by comparison to fundamental pumping, a relatively new approach to mixer design. It allows the local oscillator frequency to be chosen at one half or one quarter of the RF frequency thereby making it easier to design high frequency mixers where fundamental low noise solid state oscillators are either difficult to make or nonexistent.

In order to design millimeter wave suspended stripline circuits, stripline models at S and X bands were fabricated to optimize waveguide to stripline transitions before scaling to the millimeter wave bands. Transmission line characteristics were measured experimentally and compared to a theoretical computer model to facilitate computer aided design without the need for low frequency modeling. Excellent agreement has given us a valuable design tool for filter design in the stripline mixers.

Two mixer designs have been considered for comparison at 60 GHz, 94 GHz and 140 GHz. One design incorporates mixer diodes mounted in the stripline channel while the alternate design uses diodes mounted in the reduced height RF waveguide on the end of the stripline. Figures 7 and 8 show the two mixer configurations. Although notch front and honeycomb diodes have been used, beam lead devices are much easier to mount and make for a more practical mixer design. The use of quartz striplines and beam lead diodes make fabrication

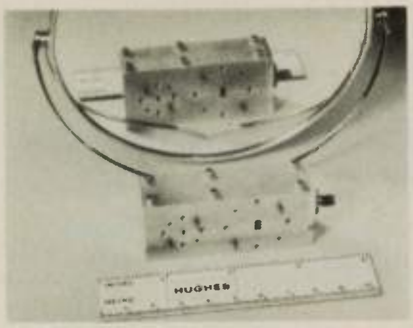

Fig. 7 Subharmonically pumped suspended stripline mixer.

much easier than waveguide mixers, drawing upon established photolithographic and device bonding techniques. It is easy to imagine mixers such as these being naturally suited for mass production and capable of performing in a variety of adverse environmental conditions.

Dielectric Guide Mixers

A novel mixer incorporating waveguide, dielectric loaded waveguide, and TEM transmission lines is being developed at 60, 94 and 140 GHz. This fundamentally pumped mixer uses beam lead diodes mounted on a dielectric slab terminating a dielectric loaded waveguide. Dielectric loading eliminates the need to reduce the waveguide height in order to match the diode impedance. For the dielectric loaded waveguide, the diodes appear in series resulting in an overall higher impedance which is easier to match. A low loss transition into the dielectric loading material, such as Teflon, is made through a long linear taper from air-filled waveguide. An adjustable backshort serves to tune the RF circuit for achieving optimal performance.

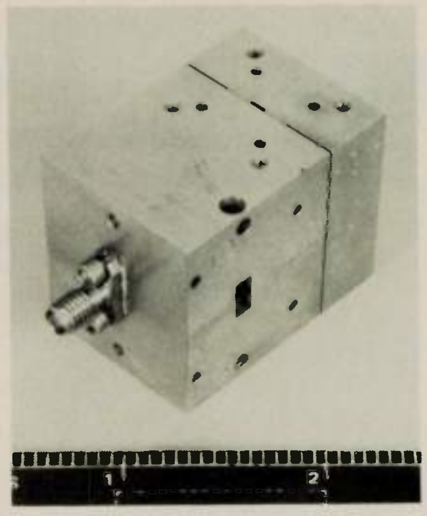

Fig. 8 Suspended stripline mixer with diodes mounted in RF guide.

Two beam lead diodes are mounted on a thin metallized dielectric slab oriented in the E-Plane. Local oscillator and IF connections to the diode slab are made in the H-Plane from TEM lines realized by coax or suspended stripline. The local oscillator transmission line couples the LO signal via a probe in the LO waveguide and the two mixer diodes appear in parallel with the LO line. Similarly, the IF output sees the diodes in parallel, which

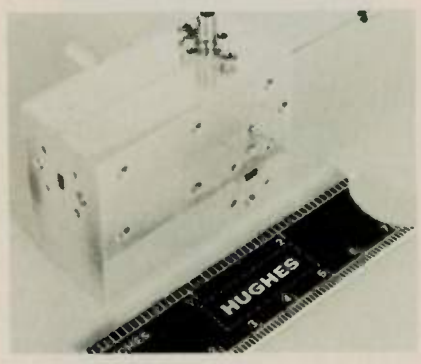

Fig. 9 60 GHz balanced mixer using dielectric guide, stripline and coax.

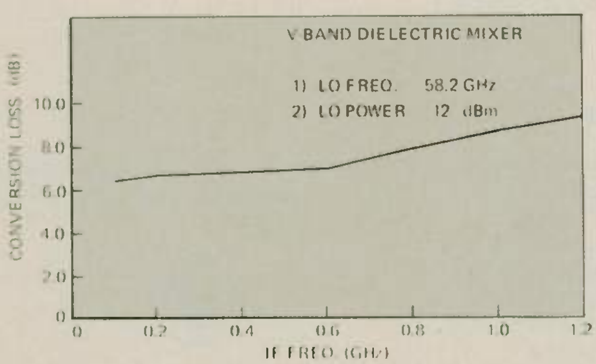

Fig. 10a Conversion loss of V-band dielectric mixer.

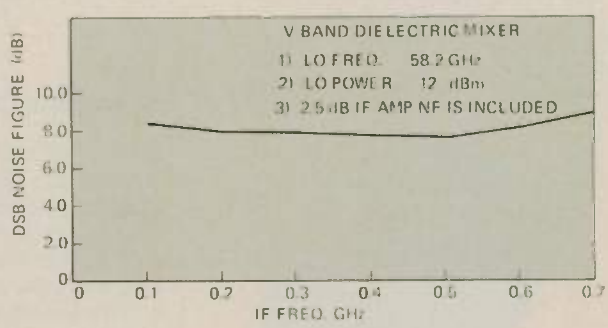

Fig. 10b DSB noise figure of dielectric guide mixer.

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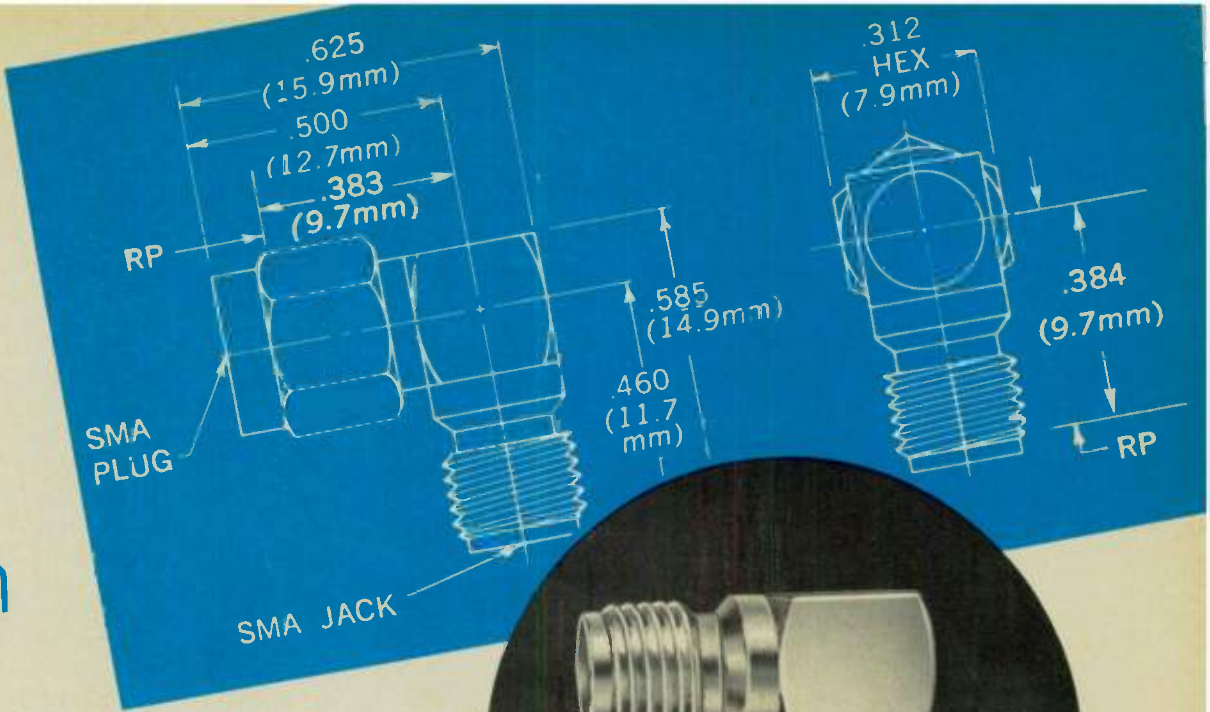

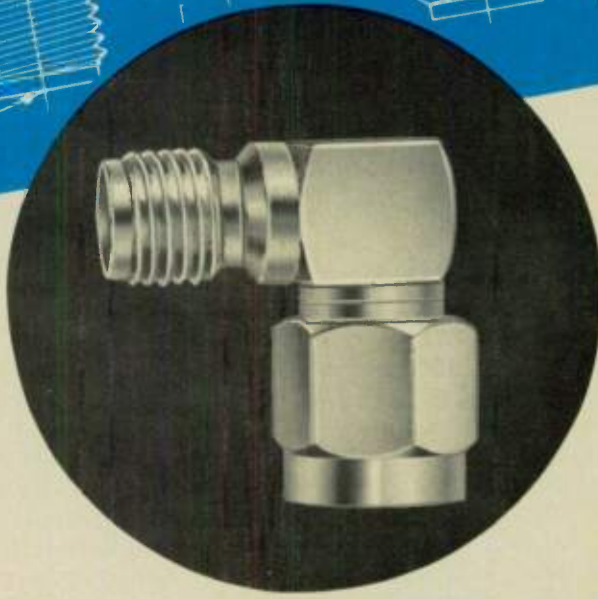

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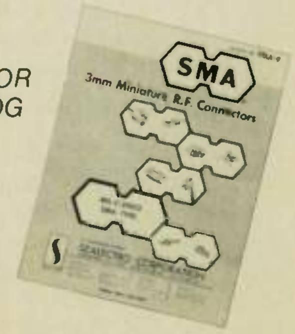

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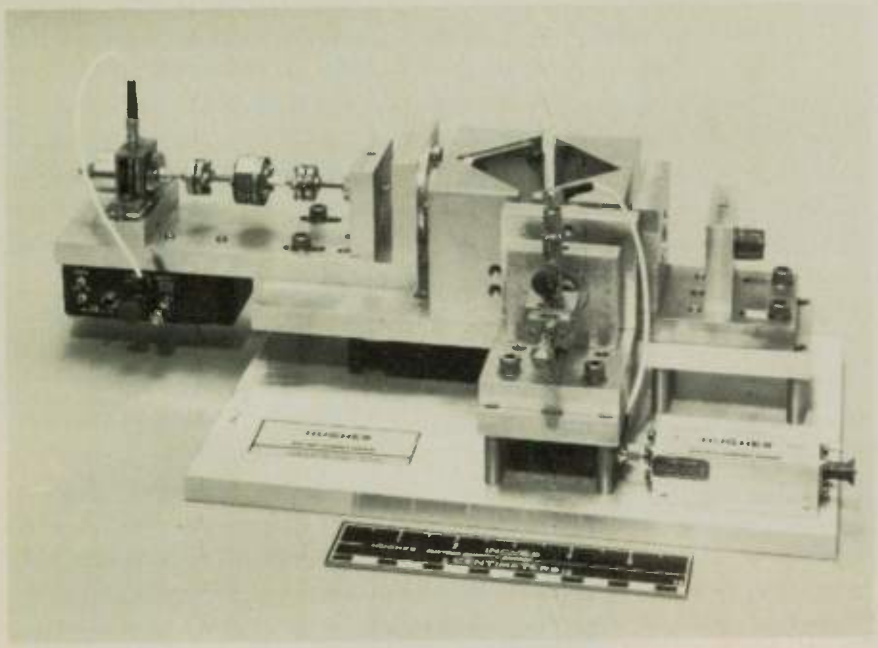

Fig. 11 217 GHz quasi-optical mixer.

makes for a good match to the IF amplifier. A low-pass filter in the IF transmission line prevents LO leakage into the IF line. **Figure 9** shows the prototype design of this mixer.

Because the mixer does not require a hybrid for balanced operation, the structure is inherently broadband, limited primarily by the IF parasitics. High LO to RF isolation is also inherent to the design since the LO TEM mode does not couple to the RF TE_{10} waveguide mode for well-matched diodes. Test results on this mixer are shown in **Figures 10a** and **10b**.

Quasi-Optical Mixers

At frequencies beyond 140 GHz, increasing losses and tighter mechanical tolerances preclude the use of conventional metal waveguide circuits. Subharmonic pumping at one-half or one-fourth the RF frequency permits the use of lower frequency Gunn oscillators as local oscillators; combinations of conventional circuit techniques to handle LO requirements and quasi-optical techniques for the RF makes for considerable flexibility in high frequency mixer design.

Although fundamentally pumped mixers are feasible, their performance is somewhat limited when pumped with IMPATT oscillators. The first such mixer at Hughes was designed for operation at 217 GHz. **Figure 11** shows how a diplexer/filter realized by a Fabry-Perot resonator allowed the use of an IMPATT local oscillator for a mixer with an IF bandpass from 1 to 2 GHz. Horn/lens combinations were used to form Gaussian beams and transition to or from rectangular waveguide. A conversion loss of 10.5 dB has been achieved with this mixer.

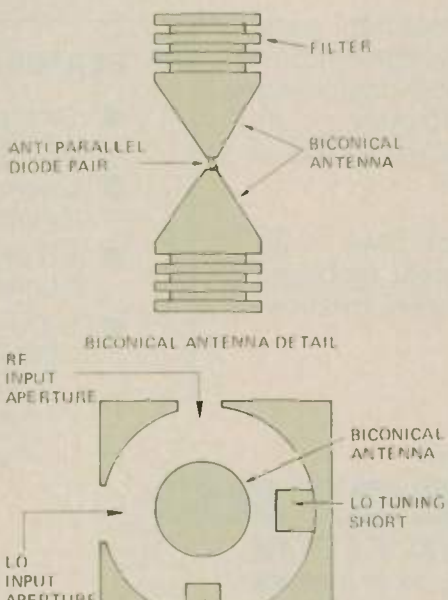

Fig. 12 Subharmonically pumped quasi-optical mixer concept.

Designing practical, high frequency mixers requires some alternate techniques to reduce size and weight while still maintaining high performance. One such approach is the use of the biconical antenna with mixer diodes mounted as an antiparallel pair at the apices as shown in Figure 12. The biconical antenna is mounted in either a closed resonator as shown or in an open resonator. Input apertures couple the RF and subharmonic LO into the resonator which in turn couples the signals to the biconical antenna. Separate adjustable tuning shorts allow for optimization with minimal interaction due to the orthogonal orientation of LO and RF fields. Filters to prevent leakage into the IF circuit are easily provided by ribs machined into the upper part of the conical antenna sections. Optimization of this structure is being accomplished by scale models at a lower frequency (94 GHz) where a wider variety of instrumentation is available.

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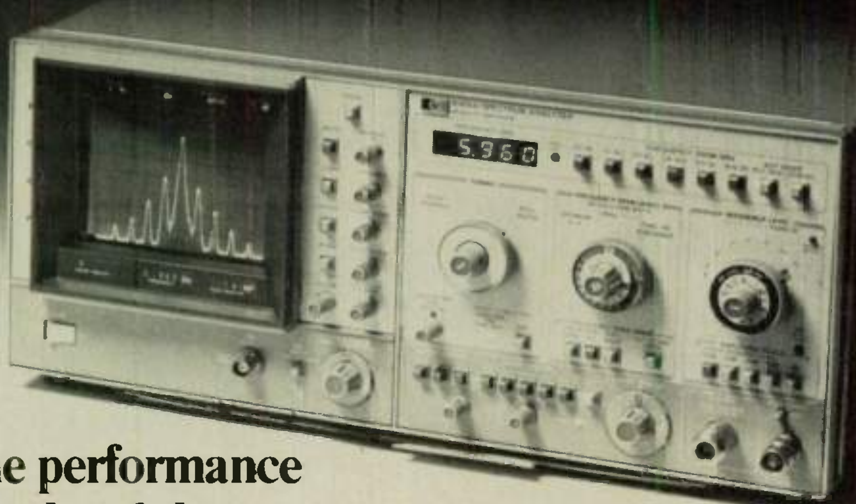

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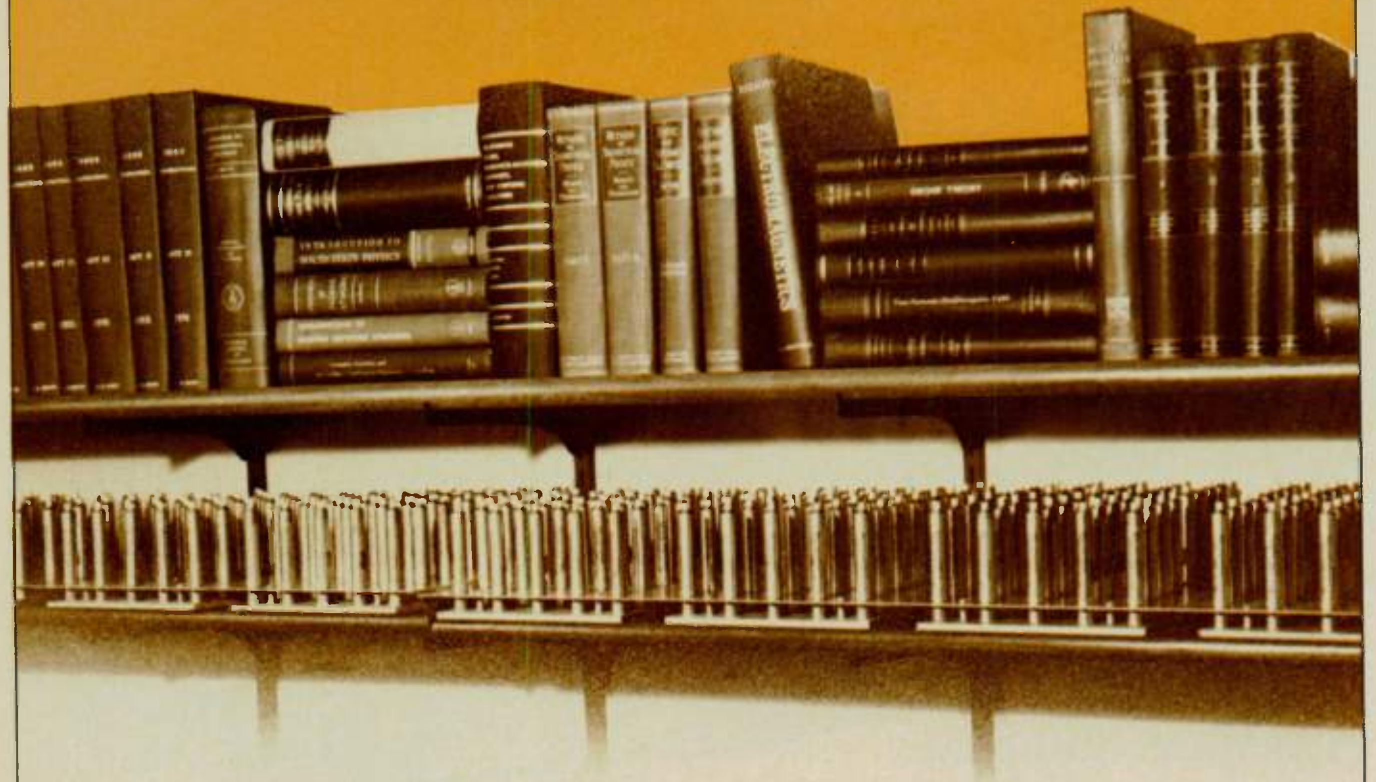

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DESCRIPTION OF THE NEW TECHNOLOGY

The era of high-performance, low-cost, light, compact microwave integrated circuits is rapidly approaching through GaAs monolithic microwave integrated circuit (MMIC) technology. This new technological approach to microwave circuitry is based on the unique capabilities of GaAs material in conjunction with ion implantation for precise control of active region doping.[1] The insulating properties of GaAs semi-insulating substrates with resistivities as high as 10^9 ohm cm allow monolithic integration of active devices, bias networks, and microwave circuitry on a single GaAs chip. Ion implantation doping technology facilitates control of multiple doping densities for optimization of active devices and also permits fabrication of highly planar circuits to achieve superior yields.*

The types of circuitry which can be realized within the new technology range from simple functional modules at the lowest level of integration to complex multi-functional subsystem components at higher levels of integration. Examples of simple functional components that may be achieved at the first level of integration include low-noise amplifiers, mixers, oscillators, power amplifiers, switches and other microwave functional components. At the next highest level of integration, the functional components may be combined to produce specific system building blocks such as receiver front ends, modulators and demodulators, transceivers, binary phase shifters, etc. An even higher level of integration is conceivable at which the circuitry would provide relatively complete functionality for frequency agile receivers and transmitters including modulation and demodulation as well as beam steering in the case of phased array systems. In fact, it is foreseeable that an entire hierarchy of MMICs will be created to fulfill component, subsystem, and system needs for circuitry with the following attributes are exclusively inherent in the monolithic technology:

- small size
- light weight
- low cost
- reproducible performance
- broad bandwidth capability
- multi-functional performance

These attributes derive directly from the technology utilized to design and construct these circuits. Small size is intrinsic to the monolithic approach. However, minimal size is a design objective which is required to achieve the advantages of high yield and low cost. Light weight is an adjunct to the small size and integrated functionality of the monolithic circuitry. Low cost derives from the batch fabrication of many circuits on each wafer and is directly impacted by circuit size and yield. The reproducible performance of MMICs is a result of the high-resolution capability of the lithography used to define the active device and circuit geometries in conjunction with the highly reproducible doping profiles attainable with ion implantation doping. Capability of broad band performance in monolithic circuitry arises from the elimination of parasitic elements such as wire bond inductances and bonding pad capacitances which tend to limit the bandwidth in conventional MIC circuitry. Finally, one of the most important features of MMICs is the capability of providing several circuit functions integrated onto a single chip, e.g.: the receiver on a chip which offers extraordinary advantages in terms of size, weight, and cost.

Details of the material and process technology which make possible the fabrication of GaAs MMICs will be covered in the next section. A discussion of circuit design philosophy and some examples of current circuit designs will be given in the succeeding section. The final section will summarize the properties of GaAs MMICs and attempt to project the direction of future advances in this field.

MATERIAL AND PROCESS TECHNOLOGY FOR MMICs

The MMIC technology can only be practical utilizing a simple, highly reproducible device process technology. Thus, ion implantation (I.I.) techniques are preferred over the traditional GaAs epitaxial approaches due to their simplicity and improved device reproducibility.[2] However,

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the preparation of active device layers using ion implantation (I.I.) requires a high temperature anneal cycle to activate the implanted dopants and remove radiation damage. This process places stringent requirements on the quality of the semi-insulating material as the intrinsic properties must remain unchanged during the anneal. Unlike the case with high resistivity silicon wafers, the Cr compensated semi-insulating (S.I.) GaAs can be selected for stable resistivity over the range of temperature excursions necessary to fabricate microwave devices (up to 850-900°C).[3] A high temperature test is used to assess the stability of the semi-insulating substrate with respect to its electronic properties. This objective may be accomplished by a two-step qualification procedure. A reactively sputtered Si_3N_4 cap is employed in the first test to furnish a protective layer for the substrate surface. The second test utilizes bombardment with krypton ions to simulate the disorder introduced during the implantation of the dopant. The bombarded sample is then capped with Si_3N_4. Good reproducibility of device doping profiles has been found when the resistivities of both samples remain above $1 \times 10^6 \Omega$ cm after anneal at 850°C for 30 minutes in a hydrogen gas ambient. This substrate material is then referred to as "qualified" semi-insulating GaAs suitable for MMIC fabrication.[4] Experience has shown that all slices from an ingot can be considered qualified if samples from the front end and the back end of that ingot pass the qualification tests. Commercial sources have yielded qualified ingots with up to 300 slices.

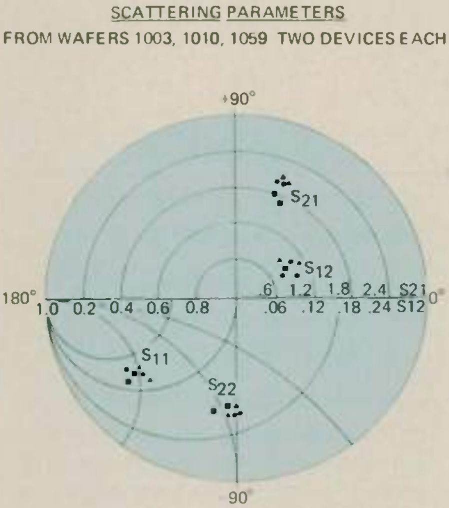

Fig. 1 S-parameters at 10 GHz for randomly selected ion implanted FETs from three wafers.

A high degree of device uniformity and reproducibility of electrical parameters are characteristic of the ion implanted GaAs FETs. The scattering parameters of two randomly selected discrete one micron long, 300 micron wide ion implanted FET from each of three wafers measured at 10 GHz are shown in **Figure 1**. The device uniformity as shown by the tightness of this distribution suggests that no circuit tuning will be necessary in a given MMIC application. The wafers #1003 and #1059 were processed approximately four months apart. This observation further illustrates the reproducibility of the ion implantation process. For MMIC fabrication, the implantation doping may be performed either uniformly across the S.I. GaAs wafer with mesa etching being used for device isolation or, preferably, selectively implanted to achieve simultaneous optimization of a variety of devices and a highly planar surface topology for best circuit yield. The localized ion implantation (I.I.) process pioneered at Rockwell International uses photoresist or Si_3N_4 as implantation masks. Silicon, S, and Se are commonly used dopants for n-type GaAs device layers. The localized implantation of dopants is followed by the encapsulation of the slice in Si_3N_4 and annealing at 850°C in H_2 atmosphere. The undoped areas between active devices and substrate areas for circuit matching elements.

Figure 2 depicts a cross sectional view of an MMIC device fabricated by the planar, localized I.I. process. In this circuit, a double implant process is used to fabricate the FET active chan-

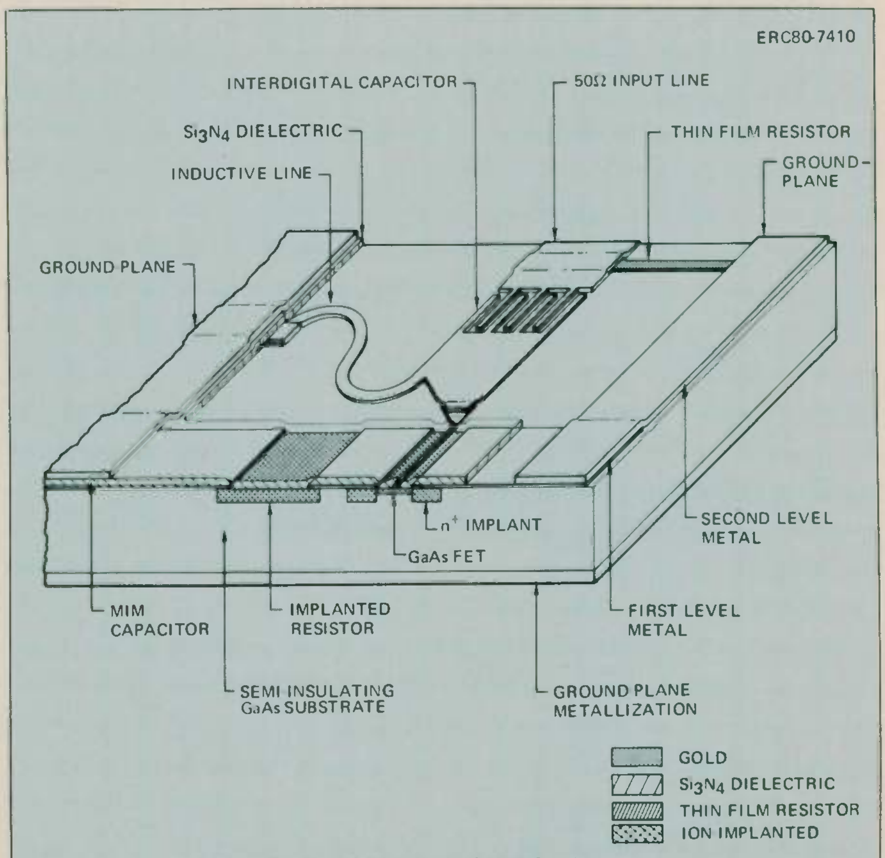

Fig. 2 Cross section of MMIC chip.

TABLE I

Useful Circuit Elements for MMIC Technology

Planar FET	Planar Schottky Diode	Planar Gunn Diode
(a) Low noise	(a) Mixer	(a) Power source
(b) Power	(b) Varactor	
(c) Switch	(c) Level shifting	
Resistors	**Capacitors**	**Transmission lines and inductors**
(a) Implanted	(a) Interdigitated	(a) Tuning elements
(b) Thin film	(b) MIM	

nel, ohmic contacts, and bias resistors. Both implanted and thin film bias resistors are used for the on chip bias networks. Interdigitated and metal-insulator-metal (MIM) capacitors are included as routine circuit elements. An all gold based two level device and circuit metallization system is used for optimum circuit performance and reliability.

Delineation of device geometries and circuit topography is accomplished via the standard lithographic processes. Both photolithography and electron beam lithography (EBL) are currently in use for the fabrication of MMICs. The resolution capability of electron beam lithography (EBL) is only required for the submicron gates of the highest frequency circuits presently being fabricated. Therefore, a composite process using photolithography and EBL is desirable for improved throughput. However, EBL has been used in our laboratory as a versatile tool for fast reconfiguration of circuits by variation of interconnection patterns during the early circuit design stages. The lithographic techniques used to define the circuit elements of MMICs are the same as are used to define the one micron FET gates. The degree of control of elemental circuit dimensions is, thus, far beyond that of the standard MIC technology. Therefore, once an MMIC is designed and circuit refinements are incorporated on the mask set, the fabricated components will not require the labor intensive tweaking that MIC technology typically does.

The planar, localized I.I. circuit technology described can be utilized to simultaneously fabricate a variety of active and passive devices desirable for a spectrum of advanced MMIC components. A list of useful circuit elements for MMIC components is shown in Table I. All of the elements, with the exception of the I.I. Gunn diode have been demonstrated by the planar I.I. process.

MMIC CIRCUITS AND COMPONENTS

Implementation of a particular microwave circuit design mono- ... choices in the areas of transmission mode configuration, grounding of active devices, chip dimensions and layout. Naturally, these choices interact with one another so that a consistent design philosophy is required in order to weigh all variables simultaneously. The choice of transmission mode appears preeminent since it has the largest impact upon the other choices which must be made. The types of transmission modes possible with MMICs include microstrip, coplanar, and suspended stripline circuitry as well as many other configurations. Measured values of transmission line attenuation versus frequency for coplanar and microstrip lines on GaAs are compared to coplanar line on alumina in Figure 3. One basic choice is whether or not to provide a ground plane on the back side of the GaAs substrate. The presence of a ground plane can improve isolation of circuit elements by providing a shielding function. Also, for power circuitry, a ground plane will be useful for thermal dissipation. Coplanar circuitry, on the other hand, can provide somewhat

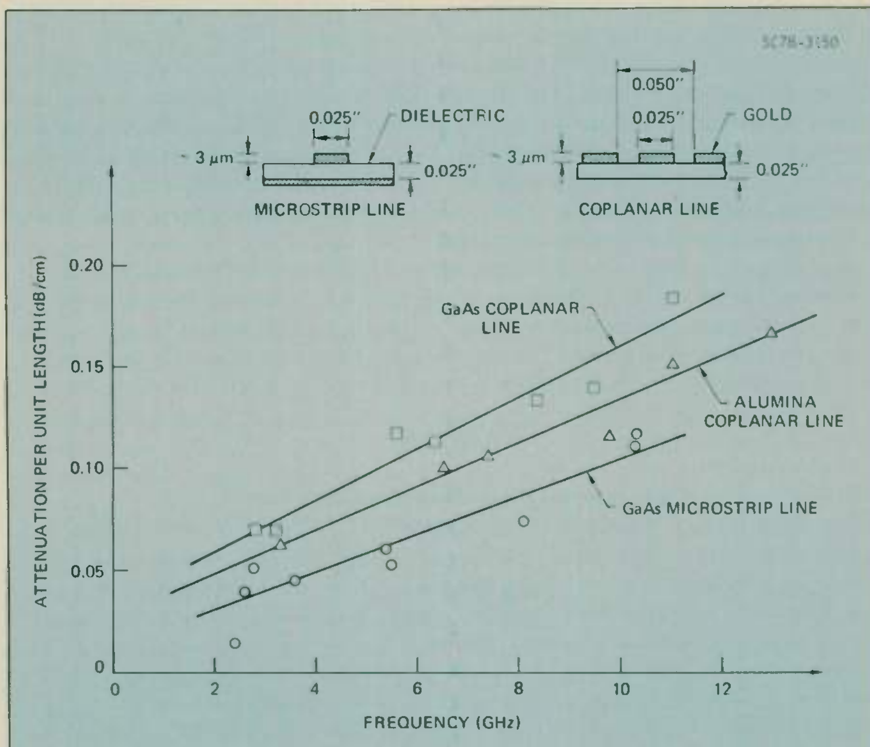

Fig. 3 Transmission line attenuation versus frequency.

Fig. 4 Photograph of MMIC broadband amplifiers and receiver front end component chips.

higher line impedances and improved grounding for higher frequencies where even via grounding through the substrate may represent unacceptably high inductance.

A comparison of monolithic circuit implementations utilizing coplanar and microstrip transmission modes is shown in the photograph of **Figure 4**. The two top circuits are 2-stage and 3-stage broadband amplifiers of coplanar configuration. The bottom three circuits are a preamplifier, mixer, and I.F. amplifier, from left to right, which are the separate components of a complete 8 GHz receiver front end. It has been possible to reduce the size of the microstrip circuits compared to the coplanar circuits for an equivalent level of complexity.

Once the transmission mode has been chosen, active device grounding can be considered. The types of grounding available can be broadly classified as wrap-around grounds and via grounds. For wrap-around grounds the active devices must be kept close to the circuit edge to minimize grounding inductance. For via grounding, the substrate must be thin enough to permit via processing without sacrifice of substantial chip area. The edge ground approach offers significant advantages in terms of process simplicity and yield. However, the via process offers significant performance improvement particularly at higher frequencies (above X-band) and for more complex circuits. It is anticipated that both grounding techniques will continue to be used in MMIC circuitry with the choice depending on trade-offs between factors such as process complexity, cost, and yield versus performance and circuit complexity.

Design of MMICs is approached just as is MIC design — through the use of computer models for both active and passive circuit elements. The development of accurate circuit models for all constituent elements of the circuit is an important aspect of the design process. Actual circuit design is accomplished by a combination of analytical techniques in conjunction with CAD using software such as the COMPACT program including optimization techniques. The accuracy of the device and circuit element modeling will be reflected in the performance of the completed monolithic circuit, since no final "tweaking" of the circuit is possible or desirable as it is for MIC circuitry.

The elimination of extensive, passive matching networks in the design of broadband monolithic amplifiers is an important consideration in maintaining minimal chip size.[5] Input and output matching of monolithic circuits is facilitated by the possibility of using common gate and common drain (source follower) stages respectively. The S-parameters of common source, common gate and common drain FETs are shown in **Figure 5**. The common

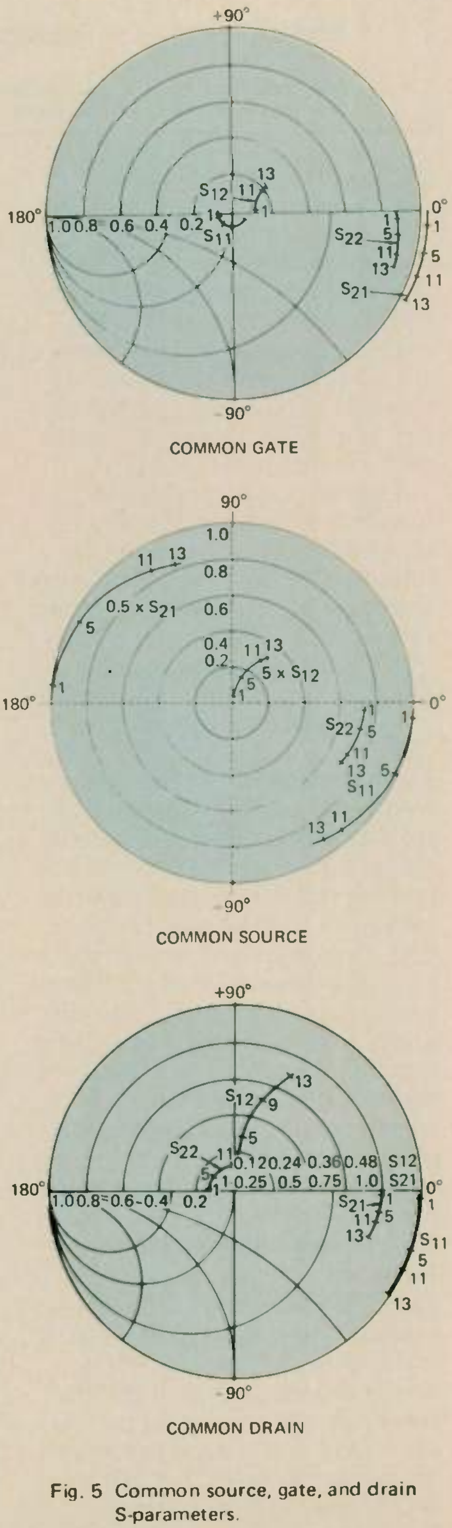

Fig. 5 Common source, gate, and drain S-parameters.

TABLE II

A comparison of broad band noise performance.
Noise Figure F and associated gain G are shown for each configuration in dB.

FREQ. (GHz)	COMMON SOURCE F	COMMON SOURCE G	COMMON GATE F	COMMON GATE G
3	3.4	11.5	1.53	6
7	2.8	9.7	2.0	5.8
11	2.55	8.5	1.91	8.0

(continued on page 72)

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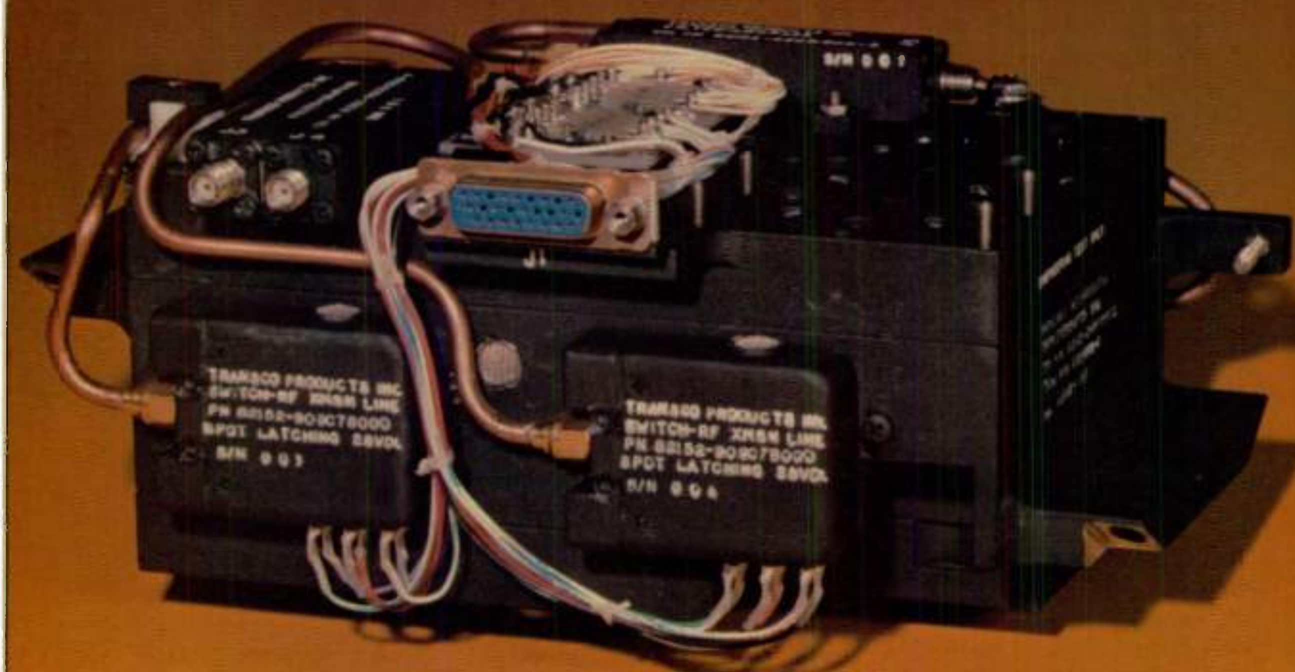

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gate configuration of a FET presents an input impedance approximately equal to the reciprocal of its transconductance up to frequencies approaching the f_t of the transistor. Thus, a FET with transconductance of 20mS is capable of providing an input match to 50 ohms over very broad bandwidth. The minimum noise figure of a common gate stage is about the same as that of a common source stage as shown in Table II and is attained for a source impedance which is close

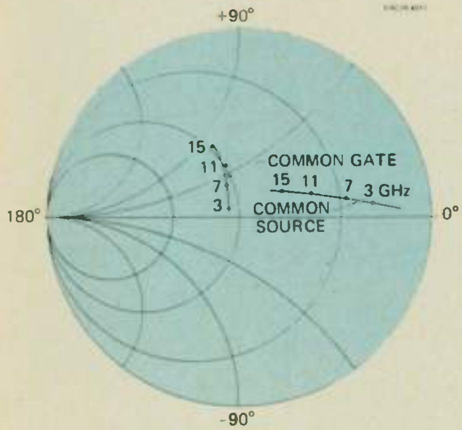

Fig. 6 Optimum source admittance for minimum noise of common source and common gate amplifiers.

to the matched value as shown in Figure 6. Therefore, not only is it possible to achieve low input SWR over broad bandwidths with this configuration, but it is also possible to simultaneously obtain near optimum noise performance across the same band. Incidentally, the common gate stage also provides moderate gain via the impedance transformation ratio between input and output although it has no current gain.

Use of the common drain or source follower connection for output matching and current drive capability is well established practice in bipolar transistor circuitry at low frequencies. Again, the output impedance of the common drain configuration is approximately equal to the reciprocal of the transconductance over a very wide bandwidth as seen in Figure 5. The width of the input and output transistors must be chosen to provide the appropriate value of transconductance to match the desired input and output impedances. For 50 ohm input and output, the required transconductance is 20 mS which can be realized using a FET width of about 250 to 300μ depending on doping profile. Therefore, application of these matching techniques is limited to use of FETs in this size range and is probably not appropriate for the output of power amplifiers.

The input and output match provided by the common gate (CG) and common drain (CD) stages is exceptional over very wide bandwidth as seen from the measured input and output return loss of the 3-stage CG-CS-CD amplifier shown in Figure 7. An improved version of this amplifier is presently under construction using microstrip circuitry and an additional common source gain stage. The predicted input and output SWRs of this amplifier are better than 2:1 across the band from 0.1 to 10 GHz.

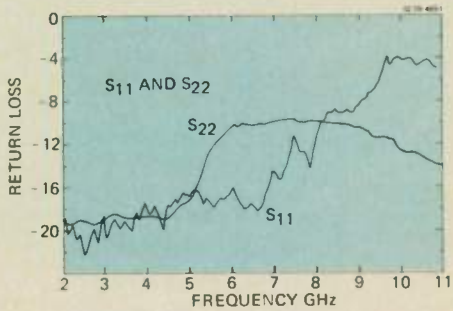

Fig. 7 Measured input and output return loss of CG-CS-CD amplifier.

The use of lumped versus distributed passive elements is determined by the requirements of minimal circuit size and accurate element modeling. Thus, wherever possible, circuit elements are designed to occupy as small an amount of chip area as possible. However, for circuit analysis, it is necessary to model all circuit elements using either equivalent circuits or distributed representations to obtain best accuracy. It is worth noting that inductors can be modeled as transmission lines and small MIM capacitors can be treated as simple lumped elements for most careful circuit layouts at frequencies at least through X-band. The element values that can be realized with monolithic circuitry are approximately as follows:

- Metal – insulator – metal (MIM) capacitors fabricated with silicon nitride dielectric ($t \approx 4000$ to 6000Å): $C/A \cong$ 100 to 150 pF/mm² useful capacitance range: .015 to 25pF
- Interdigital capacitors with 5μm gap: $C/P \cong 0.13$ pF/mm, where P = periphery in mm Useful capacitance range: .01 to 0.5 pF (through X-band)
- Inductive sections of transmission line: $L = (Z_0/\omega)\tan(\omega\ell/v_p) \cong Z_o\,\ell/v_p$ for $\ell << \lambda$, where v_p is the phase velocity of the transmission line. Useful inductance range: limited by Z_o to about 100 ohms of inductive reactance at $\ell = \lambda/8$
- Ion implanted bulk resistors: $R = \rho\ell/w$, where ρ = sheet resistivity in $\Omega/\square \cong 1000\ \Omega/\square$ useful resistance range: 10Ω to 10KΩ resistor size must be scaled for power dissipation requirement: inductance must be considered for long resistors.

Both broad and narrowband amplifiers have been constructed with the MMIC technology. The broadband circuits have been fabricated in several design configurations for evaluation of the matching concepts discussed above. One of the first amplifiers constructed consisted of two transistors configured for common gate (CG) input and common drain (CD) output. Also built at this time was a three stage amplifier configured as CG-CS-CD. These amplifiers were constructed using coplanar transmission lines in order to achieve as high as possible transmission line impedance for interstage matching. A photography of the two- and three-stage coplanar amplifiers was shown in Figure 4. The gain characteristic measured for a 3-stage broadband design of the CS-CG-CD configuration is shown in Figure 8.

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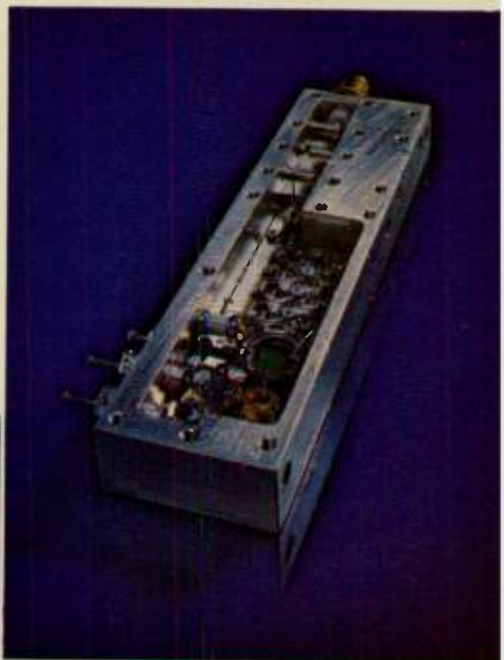

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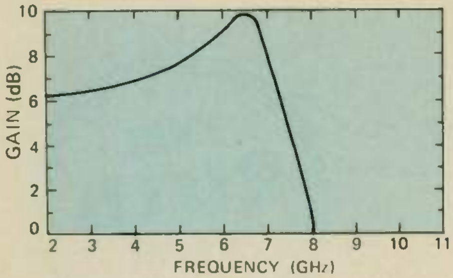

Fig. 8 Measured gain of CS-CG-CD amplifier.

Another type of broadband amplifier has been built for use as an I.F. amplifier in the band from 500 MHz to 1200 MHz. This I.F. amplifier was constructed using microstrip circuitry with one dual-gate FET plus a single gate output transistor and is shown in the photograph of Figure 4. The circuit configuration is CS-CG-CD. This amplifier was designed to be used in conjunction with an 8 GHz mixer circuit, so that input match to 50 ohms is not a requirement since the final version will be integrated with an interstage matching network. The measured gain of this amplifier is greater than 6 dB from 500 to 1200 MHz. The common drain output stage provided a return loss greater than 20 dB across the band.

The 8 GHz mixer circuit is configured using a dual-gate FET mixer followed by a common drain output stage. The local oscillator is input to the second gate and the signal is input to the first gate of the mixer. Initial results indicate satisfactory mixer performance, although no definitive performance data are yet available. A picture of this mixer chip is shown in Figure 4.

FUTURE POSSIBILITIES FOR MMIC TECHNOLOGY

The MMIC technology described in the previous sections is best adapted to medium to broadband components, since bandpass filters are much too large in the microwave frequencies and relatively low Q circuit components are available to the circuit designers. Thus, a narrowband low-noise, MMIC amplifier using half micron gate length FETs will exhibit bandwidth of ± 10% or more and will be competitive through 50 GHz. Power circuits utilizing 0.75 micron gate length FETs (with up to several watts power output capability at X band) will be possible through K_a band. These circuits will typically exhibit many times wider bandwidth capabilities than the comparable parts using the MIC technology. Yield considerations on high power output components may, at first, dictate that the driver stages and output stages be fabricated on separate chips. With high volume, in the long run, the entire component will probably be fabricated on a single GaAs chip.

For ECM and other types of systems desiring extremely wide band capabilities, the MMIC approach will be most welcomed. The 0-10 GHz type of low noise amplifier approach is basically limited only by the performance of the active devices available to the circuit engineer. Several octave bandwidth low noise amplifiers up through K_a band could be made into standard catalog components with present half-micron gate length devices.

Beyond the basic microwave low-noise and power amplifier circuits, components such as an entire microwave receiver front end on a chip as shown in Figure 9 will be fabricated. These integrated components should be less expensive to produce using MMIC technology as compared to current MIC technology provided that the volume requirements are sufficiently high. Home TV receivers for direct reception from satellites are such a volume product. Special component chips such as monolithic, frequency-agile VCOs and transmit/receive modules for communications and phased array systems are economically feasible within the next few years because of either large volume requirements (low priced chips) or unique performance capability (at a high price). Beyond this level of chip complexity, MMIC circuits incorporating both GaAs CCD signal processing capabilities and GaAs digital I.C. versatility are possible depending on system requirements and component budgets. Complex circuitry requiring chip sizes of up to 1 cm X 2 cm or larger may be economically feasible since most of the chip area in the MMIC approach is occupied by passive elements and, thus, the long range materials requirements are not overly restrictive.

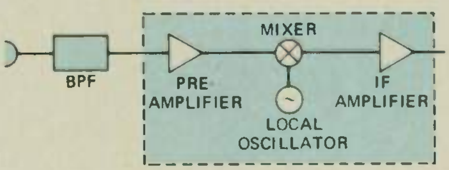

Fig. 9 Block diagram of receiver front end.

As frequency increases, the size of passive circuit elements shrinks proportionally. However, this advantage will be counter balanced by the increased coupling between circuit components. Thus, as the frequency of the MMIC chip is extended into the millimeter wave range, the chip size for a certain functionality may not continue to decrease beyond a certain physical limit. The incorporation of 1000 GHz cut off-frequency Schottky barrier diode and planar Gunn diode technologies should push the monolithic approach into the millimeter wave frequencies. Such a monolithic approach could be a great step forward to this region of the spectrum. Solid state power sources at 100 GHz and above are more difficult to realize as the output power increases. It is likely that a better approach to solid state power in the millimeter wave range will be to utilize a large array of medium powered devices on a monolithic circuit with synchronized reference phase.

The typical cost analysis of silicon digital circuitry in terms of dollars per unit chip area must be modified in order to predict the cost of GaAs MMIC circuits. As in the case of silicon chips, we assume that a GaAs MMIC chip is tested after completion of fabrication and if it functions as designed, it is kept, otherwise it is discarded. No attempt at "tweaking" will be permitted due to cost considerations. The Si chip, however, is very densely occu-

(continued on page 78)

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(from page 74) **MONOLITHIC**

pied by active devices and circuitry, and the GaAs MMIC chip is extremely sparsely populated by active circuit elements. Most of the GaAs real estate will be covered by passive tuning circuitry, thus, much larger physical chip size may be fabricated with acceptable chip yields. Circuits with extremely large volume requirements and large chip sizes could be made at low cost. For example, it is projected that a complex T/R chip for a phased array of 1 cm X 2 cm in size requiring 10^5 units/year or more could be made at a cost of approximately \$10-\$100/chip.

CONCLUSION

In summary, the benefits that the MMIC technology can offer are (1) higher frequency capabilities, (2) wider bandwidth low noise and power components, (3) smaller size components, (4) higher system reliability and (5) lower component costs. These features will make possible microwave systems that were not heretofore feasible using the present day technologies. In addition, the GaAs MMIC chip technology is compatible with the anticipated next generation of communication systems using optical-electronics technology in which modulation of the optical signals will be in the microwave range. Also, the MMIC chip fabrication technology is compatible and in many ways similar to the GaAs CCD and GaAs digital I.C. technology. Advanced MMIC components and subsystems incorporating both GaAs CCDs and digital circuitry for on-chip signal processing and frequency synthesis will utilize the ultimate potential of the emerging technology.

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D. R. Decker received a B.S., Physics, from North Carolina State U.; a M.S., Physics and a Ph.D., E.E. from Lehigh U. Since joining the Rockwell International Electronics Research Center in 1978, Dr. Decker has been active in the research and development of GaAs microwave devices. In 1976, he joined the National Radio Astronomy Observatory in Charlottesville, VA, where he was engaged in research and design of low noise millimeter wave receivers. He joined Hewlett Packard Co. in Palo Alto, CA in 1975, where he worked on low noise and high power GaAs FETs and circuits. In 1972, he joined the corporate research lab. of Varian Associates in Palo Alto, CA. and in 1961 he joined the staff of Bell Telephone Labs in Allentown, PA, where he worked on harmonic generator circuitry. Dr. Decker has two patents in GaAs FET technology.


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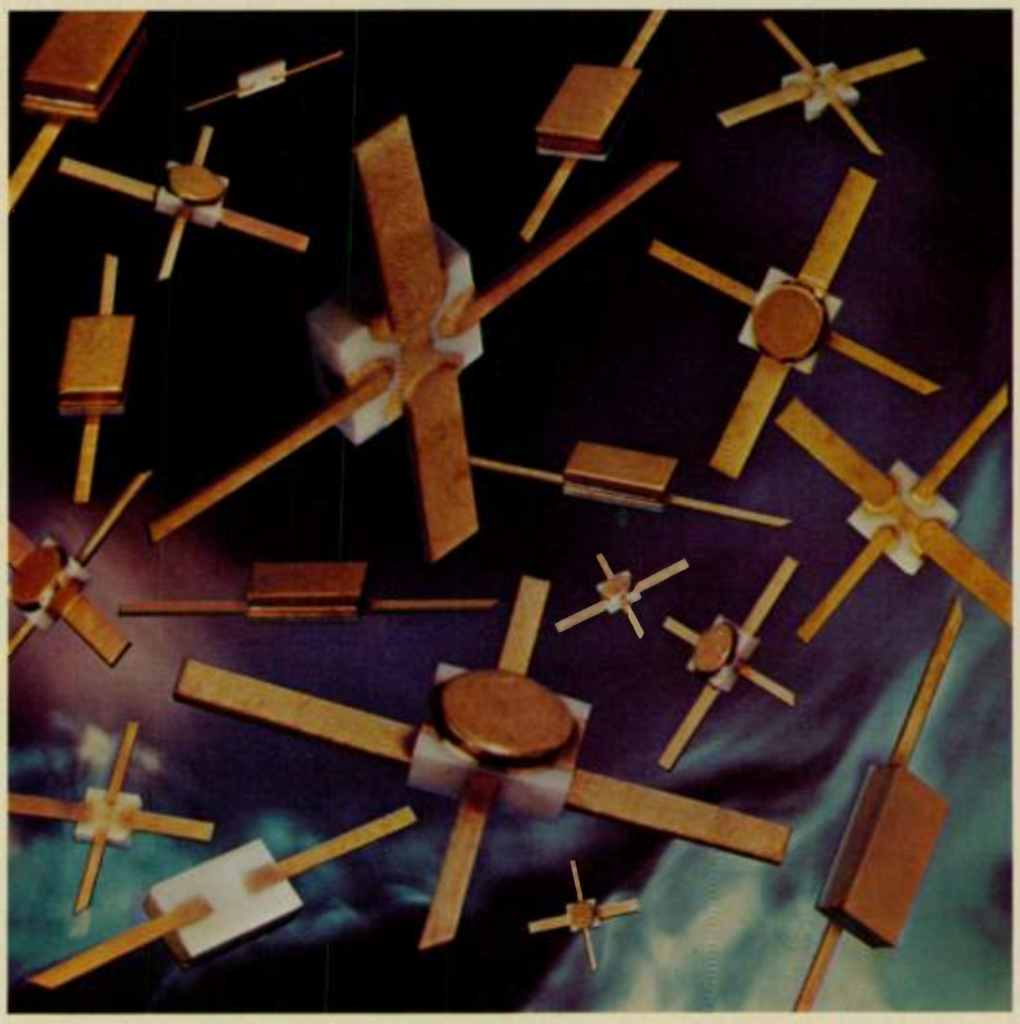

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Microstrip-Slotline Components for Microwave IC's

RYSZARD VOGEL
Technical University of Gdansk
Poland

In microwave circuits, and in microwave integrated circuits in particular, microstrip coupled lines are commonly used, enabling realization of directional couplers and filters. However, the usefulness of those lines is limited by the difficulties of achieving tight couplings. For this reason new structures and constructions are needed. A very interesting construction of a directional coupler based on a combination of slotline and microstrip was proposed by de Ronde[1] and analyzed by Schiek.[2] From this analysis, it can be stated that the theoretical properties and frequency characteristics of this coupler are identical to the coupled transmission line (CTL) coupler. Thus, t the microstrip-slotline coupler can be used instead of the microstrip CTL coupler in situations demanding a tight coupling i.e., 1.5 to 4 dB. Such a requirement exists in the construction of multi-element proximity couplers and filters.

This paper presents examples of new microwave passive components which directly follow from the idea of the microstrip-slotline coupler.

The first circuit proposed is the three-section maximally flat 3 dB coupler and the second one is the filtering section obtained as a result of opening the coupled and through ports of the microstrip-slotline, four-port.

BASIC COUPLER

The structure of microstrip slotline coupler de Ronde has suggested[1] and its two wire equivalent circuit are shown in **Figure 1**.

In a simplified analysis done by Schiek,[2] equality of the electrical length of microstrip and slot lines ($\theta_m = \theta_s$) creating the coupling section had been assumed. It was also presumed that both shunting lines are non-dispersive and no coupling exists between them.

Under such assumptions perfect match and directivity can be obtained if the following impedance condition is fulfilled:

$$z_s = \frac{2z_m}{z_m^2 - 1} \qquad (1)$$

where

$$z_s = \frac{Z_s}{Z_o}, \quad z_m = \frac{Z_m}{Z_o}$$

= normalized characteristic impedances of slot and microstrip lines respectively (**Figure 1**).

Z_o = loads impedance and characteristic impedance of the main through going lines.

The scattering matrix describing the coupler properties is found to have the form:

$$[S] = \begin{bmatrix} 0 & c & 0 & t \\ c & 0 & t & 0 \\ 0 & t & 0 & c \\ t & 0 & c & 0 \end{bmatrix} \qquad (2)$$

where

$$c = \frac{k}{1 - j\sqrt{1 - k^2}\,\mathrm{ctg}\,\theta}$$

$$t = \frac{-j\sqrt{1 - k^2}}{k \sin\theta}$$

$$k = \frac{z_m}{z_m + z_s} = \frac{1}{\sqrt{1 + z_s^2}}$$

$\theta = \theta_m = \theta_s$ - electrical length of the lines.

As it was pointed out,[2] the frequency characteristics of the coupler are the same as in the case of the CTL coupler. The microstrip-slotline couplers main advantage in comparison with the CTL cou-

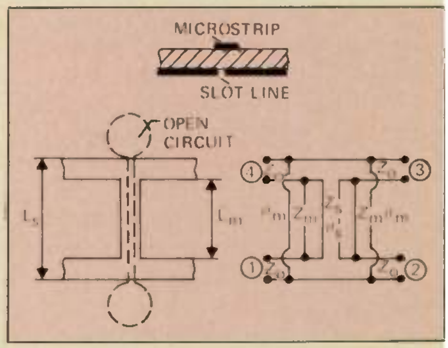

Fig. 1 Microstrip-slotline coupler.
a) structure of the coupler
b) equivalent circuit

pler is that it is relatively easy to realize tight coupling values. This fact is illustrated in Figure 2, where the characteristic impedances of microstrip and slot lines are plotted as a function of coupling at the center frequency ($\theta = \pi/2$). The latter parameter is defined as follows:

$$C_o = 10 \log_{10} \frac{1}{k^2} = 10 \log_{10} \quad (1 + z_s^2) \quad (3)$$

If the coupling coefficient $k = 10^{-C/20}$ is given, then the characteristic impedances can be calculated by:

$$z_m = \sqrt{\frac{1+k}{1-k}}$$

$$z_s = \frac{1}{k} \sqrt{1 - k^2} \quad (4)$$

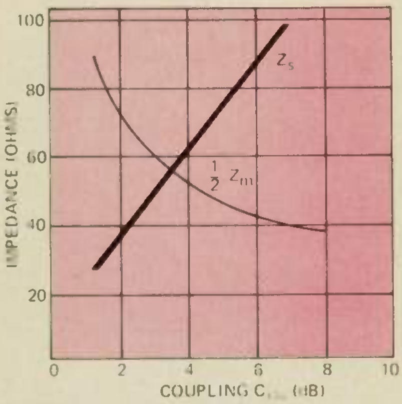

Fig. 2 Characteristic impedances of the coupler lines as a function of coupling.

Determining the microstrip and slot line dimensions which ensure the proper values of impedances, and taking into account technological MIC possibilities, it may be shown that the microstrip-slotline coupler enables realization of couplings in the range of 1.5 to 4 dB. Such values are unattainable in the case of microstrip CTL couplers.

The scattering matrix (2) given above is valid only if the electrical lengths of the coupling lines are equal. The expressions to determine the frequency properties of the coupler in the more general case $\theta_m \neq \theta_s$ are given in the Appendix.

Microstrip and slot line quarter-wavelength distances depend on the center frequency as well as on all other coupler dimensions including substrate thickness. The equivalent circuit of the microstrip-slotline T-junction has not yet been determined, nevertheless an approximate estimation can be carried out.

Neglecting the slot influence on the microstrip T-junction, the length l_m (Figure 1) of the microstrip section can be approximately determined with respect to the inner edges of the microstrip through lines. In turn, the slot line length l_s (Figure 1) is determined as the distance between the outer edges of these lines.

In practice it seldom happens that both lengths l_s and l_m are simultaneously one-quarter wavelength long at the center frequency.

There are two ways to equalize microstrip and slotline quarter-wavelength sections. One solution is based on application of dielectric overlay loading the electrically shortest line. The second method is to shunt the end of the microstrip or slotline section by lumped reactance elements. The capacitive loading of the slotline[3] can be used if $\theta_s < \theta_m$. On the other hand, if $\theta_s > \theta_m$, then shunting elements at the ends of the microstrip should be applied.

An analysis of a microstrip-slotline coupler with compensating reactance elements is presented in the Appendix. The expressions determining the coupler and reactance element parameters are found to be:

A) $\theta_{s_o} < \theta_{m_o}$ (Figure 3a)

$$\theta_{m_o} = \frac{\pi}{2} \quad l_m = \frac{\lambda_{m_o}}{4}$$

(at the center frequency)

a) $\theta_m > \theta_s$ b) $\theta_m < \theta_s$

$$z_m = \sqrt{\frac{1+k}{1-k}}$$

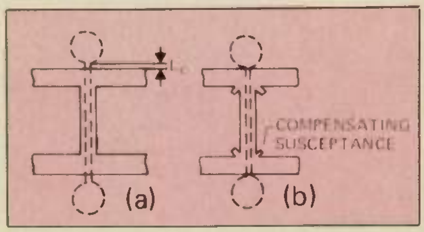

Fig. 3 Compensated microstrip-slotline couplers.

$$z_s = \sqrt{\frac{1-k^2}{k \sin \theta_{s_o}}} \quad (5)$$

$$x_c = \frac{X_c}{Z_o} = -\sqrt{\frac{1-k^2}{k \cos \theta_{s_o}}} \quad (6)$$

if the compensating stubs with characteristic impedances $z_c = z_s$ and phase constant $\beta_c = \beta_s$ are used[3] then:

$$\tan \beta_c l_c \cong \beta_s l_c = \cot \theta_{s_o} \quad (7)$$

B) $\theta_{s_o} > \theta_{m_o}$ (Figure 3b)

$$\theta_{s_o} = \frac{\pi}{2} \quad l_s = \frac{\lambda_{s_o}}{4}$$

at the center frequency

$$z_m = \frac{1}{\sin \theta m_o} \sqrt{\frac{1+k}{1-k}} \quad (8)$$

$$b_c = B_c Z_o = \sqrt{\frac{1-k}{1+k}} \cos \theta m_o \quad (9)$$

if the compensating stubs with characteristic impedances

$$z_s = \frac{\sqrt{1-k^2}}{k}$$

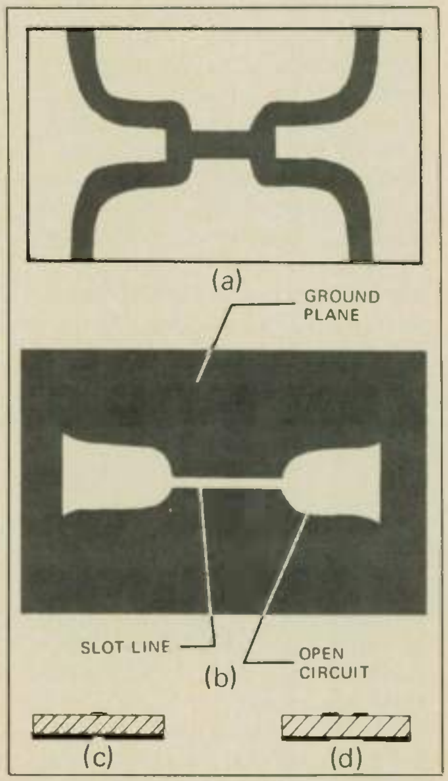

Fig. 4 Three-section 3 dB microstrip-slotline coupler.
a) top view; b) bottom view; c) cross-section of the middle section; d) cross section of the outer section.

(continued on page 86)

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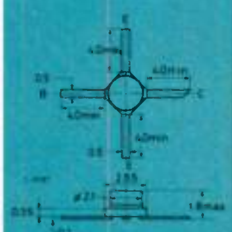

TYPE	Polarity	f_T (GHz)	S_{21e} (dB)	Gmax (dB)	GAIN V_{CE} (V)	GAIN I_C (mA)	GAIN f (GHz)	NOISE NF (dB)	NOISE Ga (dB)	NOISE V_{CE} (V)	NOISE I_C (mA)	NOISE f (GHz)
BFQ86	NPN	4	13	15	8	10	0.5	1	–	6	3	0.14
BFQ88	NPN	5	12	15	10	15	1	2.5	12.5	10	5	1
BFQ88A	NPN	5	11	14	5	30	1	2.5	10	5	5	1
BFQ88B	NPN	4.5	9.5	11	8	40	1	4.5	9	8	40	1
BFQ89	NPN	6	9.5	14.5	10	10	2	2	11	10	6	2
BFQ89A	NPN	6	9	14	10	15	2	5	11	10	15	2
BFQ98	PNP	5	12	15	10	15	1	2.5	12.5	10	3	1
BFQ98B	PNP	4.5	9.5	11	8	40	1	4.5	9	8	40	1

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$z_c = z_m$ and phase constant
$\beta_c = \beta_m$ are used then

$$\tan \beta_c l_c \cong \beta_m l_c = \cot \theta_{m_o} \quad (10)$$

Determining the preliminary coupler impedances from the expressions (4) and calculating microstrip and slotline dimensions with the use of the well known papers collected in Reference 3, it can be concluded which type of compensation (case A or B) should be applied.

THREE-SECTION MICROSTRIP-SLOTLINE COUPLER

It is known (e.g. Reference 5) that a three-section 3 dB coupler with maximally flat characteristic demands the coupling values of the middle and outer sections to be equal to 2 and 20 dB respectively. That is why the middle section of the coupler is unrealizable with the use of conventional coupled microstrip lines. However, as has been mentioned above, there is no serious technological problem to realize the microstrip-slotline 2 dB coupler. As it is known that the open circuits at the both ends of slotline have to be etched, the coupled lines creating the outer sections are of the form (**Figure 4d**) discussed in the papers.[6-8] The data given in these works are taken as a first approximation in the designing of proximity 20 dB coupler. The final dimensions of this coupler were obtained as a result of experimental optimization of its parameters. Independently evaluated 2 dB and 20 dB couplers were finally integrated, creating the three-section 3 dB coupler. The coupler was made on a substrate of 0.7 mm thick alumina, having a dielectric constant of 10. The nominal center frequency was 4 GHz.

The measured frequency characteristics of the coupler parameters (SWR, coupling, isolation) are presented in **Figure 5** showing a good agreement with the theory. The SWR and isolation characteristics are mainly dependent on transition (microstrip - SMA) parameters and discontinuities between the sections of the coupler.

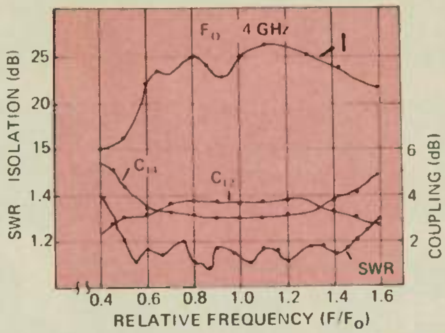

Fig. 5 Frequency characteristics of the three-section microstrip-slotline coupler.

BANDPASS FILTERS

The second circuit evaluated was a filtering section which is presented in **Figure 6(a)**. The idea of this filter results from the equivalence between the CTL and microstrip-slotline couplers. One can expect that in the case of structures obtained as a result of opening the coupled, and through ports, the similar equivalence will exist. The properties of this filter can be determined by carrying out an analysis of its equivalent circuit shown in **Figure 6(b)**. As a result the transducer loss function is obtained

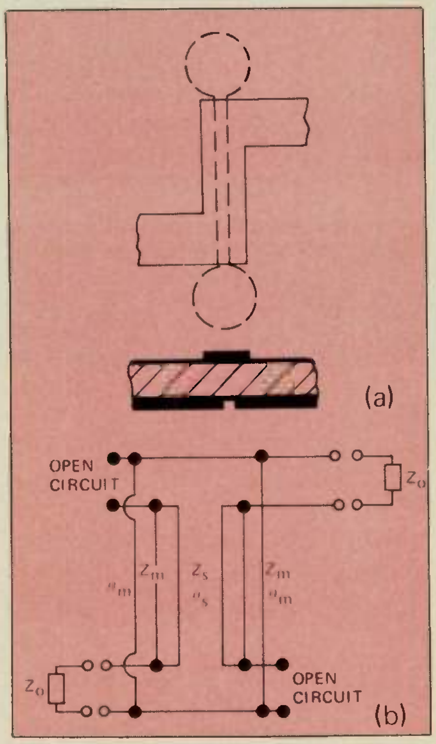

Fig. 6 Microstrip-slotline filtering section.

a) structure of the filter
b) equivalent circuit

$$L = 1 + \ldots \frac{[(A^2 B-1) \tan^2\theta + A(A-2)]^2}{4 A^2 B \tan^2\theta(1+\tan^2\theta)} \quad (11)$$

where

$$A = 2 + \frac{z_s}{z_m}$$

$$B = \frac{1}{z_m^2}$$

If the characteristic impedances of microstrip and slotline are appropriately related the filter exhibits an equiripple or maximally flat behaviour.
The equiripple characteristic will take place if

$$z_s < z_m (z_m - 2) \quad (12)$$

In the case of reverse unequality

$$z_s > z_m (z_m - 2) \quad (13)$$

the transducer loss characteristic will be flat, and become maximally flat for

$$z_s = z_m (z_m - 2) \quad (14)$$

In particular, the conditions (12)-(13) can be also fulfilled if the impedances are related by the expression (1), ensuring directional properties of the four-port prototype. In this case the expressions (4) are also valid, and in order to fulfill the condition (12), the coupling coefficient k should be greater than $1/\sqrt{2}$. If $k < 1/\sqrt{2}$ then the condition (13) is satisfied, and condition (14) leads to $k = 1/\sqrt{2}$.
It can be shown that values of characteristic impedances fulfilling the required conditions are easily realizable in the case of microstrips and slotlines. In order to check the possibility of realization of such filters, the bandpass (f_o = 3 GHz) maximally flat section was designed in agreement with the expressions (1), (4) and (14). As in the coupler case, the alumina substrate (h = 0.7 mm) was used.

In **Figure 7** the transducer losses of the filter are plotted in comparison with the theoretical characteristic calculated from the expression (11). Above about 2.5 GHz, theoretical and experimental characteristics are nearly idenfrequency region in which a slotline doesn't propagate, since the wave is very weakly coupled with the slot.

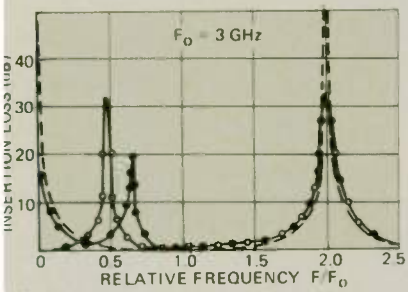

Fig. 7 Frequency characteristics of the filtering section o-o-o experiment slotline opening circuits are surrounded by the ground plane (without dc isolation between outputs), ●-●-● experiment splitted package and ground plane (dc isolation between outputs) - - - theory.

The proposed filter section can be used independently or as a part of multi-element filters. This last application is presented in **Figure 8(a)** which shows the structure of a multi-section filter with maximally flat characteristic in the 15 percent passband and with the attenuation level higher than 30 dB for frequencies outside of the 30 percent band.

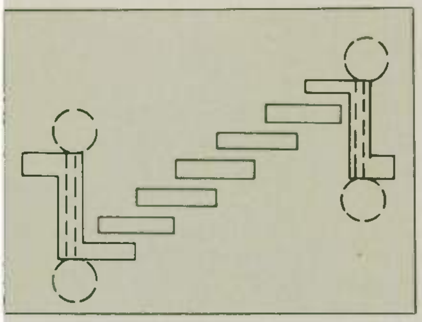

Fig. 8 Multi-element microstrip-slotline filter.

The realization of such a filter with the use of coupled microstrips only, is impossible because the required coupling coefficient of the edge sections is quite impractical (k ≅ 0.6). However, microstrip-slotline sections with such coupling are easily achievable. The inner sections can be realized in a common way using microstrip coupled lines.

The measured frequency characteristic of the filter (**Figure 9**) is in a good agreement with the theoretical one. The existing differences are caused by losses in slotline and microstrips.

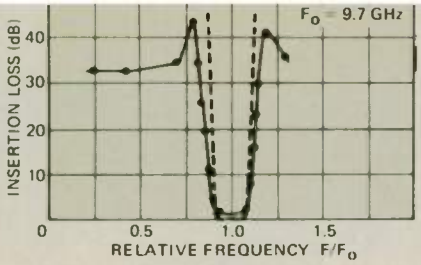

Fig. 9 Frequency characteristic of the multi-element microstrip slotline filter.

CONCLUSIONS

Microstrip-slotline coupler sections enabling achievement of tight coupling (1.5 - 4 dB) are found to be useful in the construction of multi-element, wideband couplers and bandpass filters. The advantage of the structures proposed is the ease of their realization when MIC technologies are used.

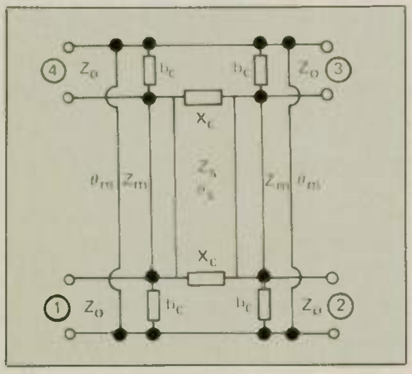

Fig. 10 Equivalent circuits of the microstrip-slotline coupler with compensating elements.

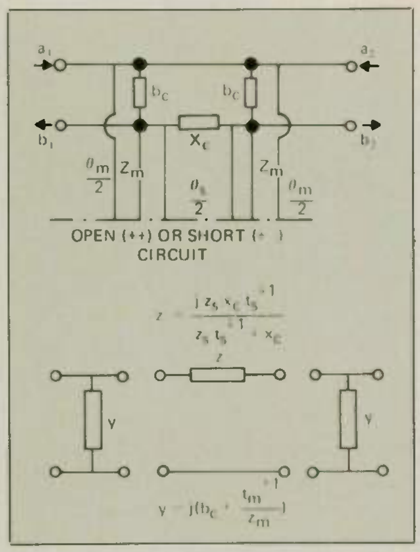

Fig. 11 Equivalent two-ports for the even (++) and odd (+ -) excitations.

Analysis of Microstrip-Slotline Coupler

A symmetrical four port, microstrip slotline coupler (**Figure 10**) can be analyzed using even and odd excitation method.

Figure 11 shows two port circuits which are equivalent to the four-port under consideration.

Let us introduce a wave transfer matrix defined as

$$\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = [T] \begin{bmatrix} b_2 \\ a_2 \end{bmatrix} \qquad (A.1)$$

Where a_i, b_i, are incident and reflected waves at the ports i respectively (**Figure 11**).

The transfer matrix of the two-port circuits for the even and odd excitation can be expressed as

$$[T_{e,o}] = [T_{1e,o}]\,[T_{2e,o}]\,[T_{3e,o}] \qquad (A.2)$$

where

$$[T_{1e,o}] = [T_{3e,o}] = \frac{1}{2}\begin{bmatrix} (2 + j\alpha e_o) & (j\alpha e_o) \\ (-j\alpha e_o) & (2 - j\alpha e_o) \end{bmatrix}$$

$$T_{2e,o} = \frac{1}{2}\begin{bmatrix} (2 + j\beta e_o) & (-j\beta e_o) \\ (j\beta e_o) & (2 - j\beta e_o) \end{bmatrix}$$

$$\alpha e_o = b_c \pm \frac{t_m^{\pm 1}}{Z_m} \qquad \beta e_o = \frac{x_c Z_s}{Z_s + x_c t_s}$$

$$t_m = \tan\frac{\theta_m}{2} \qquad t_s = \tan\frac{\theta_s}{2}$$

When the component matrices are multiplied out, the elements of matrix $T_{e,o}$ are found to be

$$T_{11e,o} = 1 + \alpha e_o \beta e_o + j\left[\alpha e_o + \frac{1}{2}\beta e_o \times (1 - \alpha e_o^2)\right]$$

$$T_{12e,o} = j\left[\alpha e_o - \frac{1}{2}\beta e_o\,(1 + \alpha e_o^2)\right] \qquad (A.3)$$

$$T_{21e,o} = T_{12e,o}$$

$$T_{22e,o} = T_{11e,o}$$

The four-port scattering matrix coefficients can be expressed as

$$S_{11,44} = S_{22,33} = \frac{1}{2}\left(\frac{T_{21e}}{T_{11e}} + \frac{T_{21o}}{T_{11o}}\right)$$

$$S_{12,13} = \frac{1}{2}\left(\frac{1}{T_{11e}} + \frac{1}{T_{11o}}\right) \qquad (A.4)$$

(continued on page 110)

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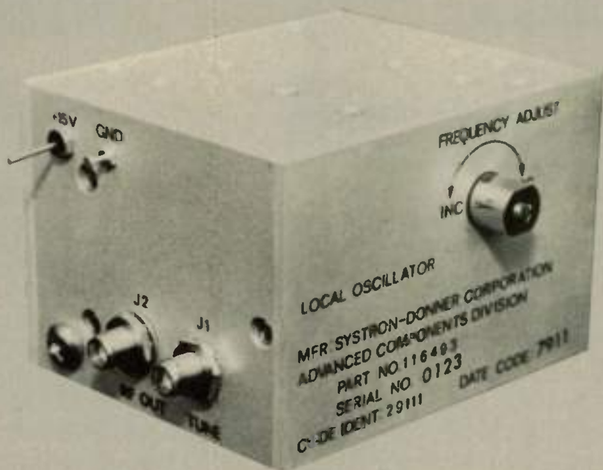

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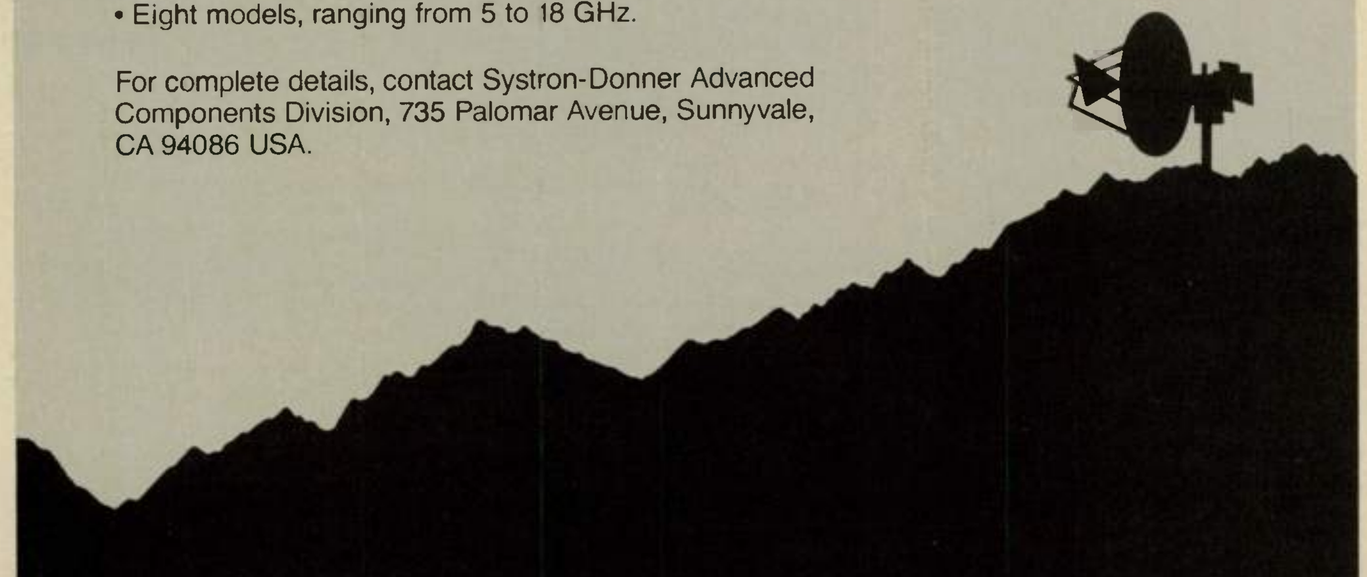

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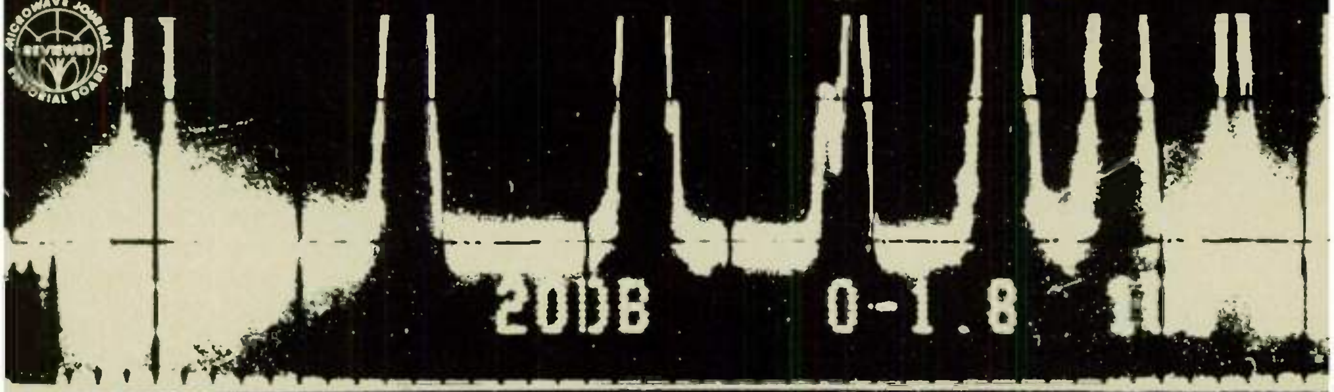

JOHN DAVID and CRAIG BRYANT *Tektronix, Inc. Beaverton, OR*

Many spectrum analyzer measurements need to be automated — for documentation, for data correction and analysis, or to eliminate laborious and time-consuming procedures and thus increase productivity. Because a programmable spectrum analyzer can be connected to a controller system, and possibly to other instruments, it opens up a new world of measurement possibilities. This article illustrates how a programmable spectrum analyzer such as the Tektronix 492P, which incorporates the ability to operate remotely under program control and provides powerful internal processing and language features, can greatly simplify automated measurements within its frequency range of 50 kHz to 220 GHz.

GPIB CAPABILITIES

A spectrum analyzer that implements all GPIB (IEEE-488 General-Purpose Interface Bus — 1977) interface functions is at home talking or listening to a wide range of controllers and other GPIB-compatible devices. Even without a GPIB controller, however, the "talk only" and "listen only" modes of the instrument can be used in a variety of controller-less applications including data logging, data display and automated instrument set up.

When connected to a GPIB controller, a programmable spectrum analyzer such as the 492P can accept commands to both set and interrogate all front-panel controls, and more. Some controls can be given expanded capability over the bus, such as two-significant-digit settability of frequency span per division, and vertical log calibration from 1 to 15 dB per division. Other commands can call up functions not available from the front panel. One such command that can be useful for automated set up applications is "SET?". This query returns all instrument settings to a controller or a GPIB listener in a format that can be sent back to the spectrum analyzer without changes.

After the front-panel controls have been set, and a measurement has been made, the data stored in the digital storage memory can be transmitted over the bus in one of two data formats ASCII coding can be selected for human readability, or when the listening device requires it. If transmission rate is important, the program can select binary coding. After processing, the waveform data can be sent back to the spectrum analyzer for display on the CRT. Similarly, the CRT readout characters can be interrogated, or replaced with a message selected by the operator.

LANGUAGE EASY TO USE

Since users of automated measurement systems interact with these systems at the keyboard of the controller, rather than at the front or rear panel of an instrument, it is important that instrument control language be as friendly to the user as possible. Software data formats that employ English-like commands, descriptive headers, and easily followed conventions for punctuation make it easier for the user to write or modify control programs. For example, commands to interface to the front-panel controls of a spectrum analyzer can consist of an English-like mnemonic (usually an abbreviation of the front-panel nomenclature), followed by an argument to set the control or a question mark to interrogate it. Several possible formats could be allowed to specify a setting by using a numeric argument. The numbers 5000, +5000.00, +50E +02, and 5K could all be allowable representations for five thousand. Units could be included following the number to aid in documentation, or the units could be omitted in favor of brevity on the bus.

When addressed to listen, a programmable spectrum analyzer should be able to accept multiple commands in a string, provided they are separated by symbols such as semicolons. Commands can even be used to instruct the instrument to execute a string of commands a specified number of times. An example of a multiple-command string in the language of the 492P would be "FREQ 7.4 GHz; REFLVL -43; SPAN 15M; VIDFLT WIDE."

INTERNAL WAVEFORM PROCESSING

A spectrum analyzer may also incorporate internal processing features which help to simplify automated measurements. In the 492P, for example, some additional commands allow the controlling program to deal with signals as entities, rather than having to deal with 1000-point waveforms. At the heart of these commands is a pattern recognition routine which is used to identify signal responses in the stored waveform. This routine compares each point value in the display to the median of the points within a window centered around the point in question. If the difference between the display value and the median value is larger than an internally set threshold, the point is flagged as a part of a signal. A group of points that is more than this threshold above the median is considered a signal. The routine picks the point at the center of such a signal as its peak.

With this pattern recognition routine, three commands can be defined to allow the spectrum analyzer to acquire the x-y coordinates of the data point at the peak of a signal. One command acquires the point at the peak of the largest signal on the screen; another acquires the point at the peak of the next signal to the left of the current point position; and a third acquires the point at the peak of the next signal to the right of the current point position. All three commands search for signals above a specified vertical threshold so that signals near the noise level can be ignored if desired. Once the peak point has been acquired, the spectrum analyzer can be tuned to the frequency represented by the horizontal position of the point with a single-word command. Similarly, the analyzer reference level can be changed to bring a signal peak to the top of the CRT and the coordinates of the data point can be obtained over the bus, by sending single-word commands.

If a single point from the display is desired, regardless of whether the data exhibits the characteristics of a narrowband signal, then one of three additional commands can be used. The point with the largest or smallest y value and the point with a specified x value can be acquired with single commands and their coordinates obtained.

Measurements using the internal preselector can also benefit from internal waveform processing commands. A command such as "PEAK AUTO" can be used to instruct the spectrum analyzer to take multiple sweeps while varying the center frequency of the preselector filter slightly, until the signal on the screen is maximized.

The problem of keeping a drifting signal on screen in a narrow frequency span per division can be used to illustrate the use of the waveform processing commands. A command string such as "FMAX; CENSIG; SIGSWP; WAIT; REPEAT 1E4" could tell the spectrum analyzer to perform this task with virtually no help from the controller. The "FMAX" command would acquire the data point with the largest vertical value, which is the signal peak. "CENSIG" would then tune the analyzer to center the signal associated with the point. "SIGSWP" would start a new sweep, and "WAIT" would hold up further processing until the sweep ends. The "REPEAT" command would cause this sequence to repeat 10,000 times. Thus, at a sweep time of 100 ms per division, the instrument would require no service from the controller for 10,000 seconds, or almost 3 hours. Larger arguments could be used to extend this time even further.

ENHANCED DATA PRESENTATION

One of the most immediate uses for the GPIB is enhanced presentation and documentation of spectral data. Using the GPIB, a spectrum analyzer can output a spectrum waveform such as that shown in **Figure 1** to a calculator, a computer, or a data-storage medium such as a tape or disk file. The data can then be graphed on a digital plotter, as shown by the output in **Figure 2**, or on a display screen, as shown in **Figure 3**. Since the original data is still available, operations such as calibration and correction can be performed by the controller before display. Data from several different frequency

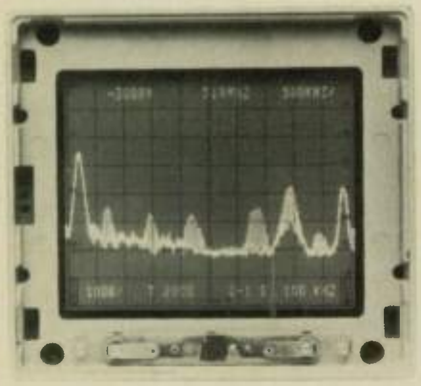

Fig. 1 UHF television signal spectrum displayed by Tektronix 492P Spectrum Analyzer.

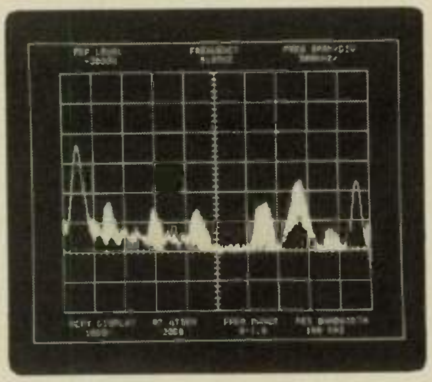

Fig. 2 Output of waveform shown in Figure 1 drawn by Tektronix 4662 Digital Plotter.

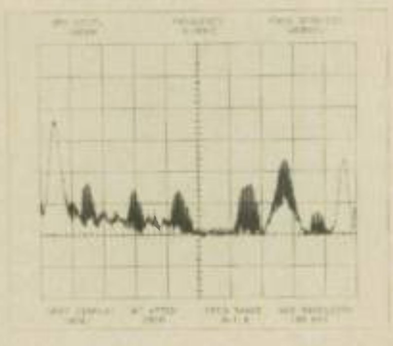

Fig. 3 Waveform shown in Figure 1 drawn on the display of a Tektronix 4052 Graphic System.

(continued on page 92)

spans can be combined to produce a composite plot, or mathematical operations can be performed to convert raw data into different units (for example, into watts or dBc).

A spectrum analyzer which has the ability to display the difference between two spectra in its digital storage can be used to view the difference between an incoming signal and a spectrum sent to the analyzer by the controller. The spectrum sent might be one previously acquired by the instrument or one generated in the controller. Instrument settings can be saved at the time of acquisition and returned to make sure the instrument set up is proper.

ANALYTICAL MEASUREMENTS MADE EASY

Whenever the power of automated data processing is available, difficult analytical problems can be solved quickly and easily. Some of these spectrum analysis measurements are:

- modulation %, deviation, or modulation index
- signal-to-noise ratio and noise figure
- power spectral density
- total harmonic distortion, total power
- amplifier gain and bandwidth

In all of these cases, some computation is done with parameters obtained from the raw data in order to come up with the desired result.

The measurement of total harmonic distortion can serve as an example of how the use of a programmable spectrum analyzer plus tne aid of a controller or computer can make measurement easier. Figure 4 shows the spectrum of the output of an RF oscillator having a fundamental frequency of 100 MHz and an output level of −20 dBm. To compute the total harmonic distortion of this output, the amplitudes of its harmonics must be determined as compared to the fundamental. An easy way to express these amplitudes is in terms of "dB below" the fundamental. Manual measurement of the total harmonic distortion would require reading each of these amplitudes off the screen in dBm, subtracting the amplitude of the fundamental, converting these values of dB below fundamental to power (i.e., taking the antilog of each), summing these numbers, and taking the square root of the sum. The result would then be multiplied by 100 to obtain the percent total harmonic distortion for the number of harmonics included. Obviously, if the raw data can be entered into a processor or computer by means of a GPIB interface, these calculations can be performed quickly and with little possibility of error.

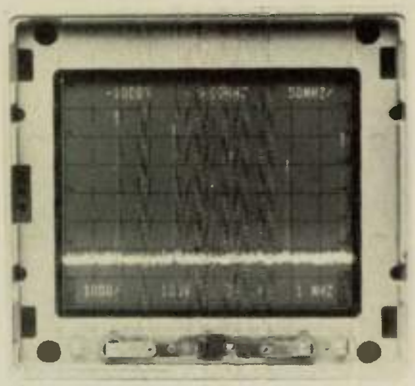

Fig. 4 Output of an RF comb generator as displayed by Tektronix 492P Spectrum Analyzer.

For the greatest accuracy, it would also be desirable to span down and locate each harmonic separately, and then position the signal at the top of the display and go into a high-resolution vertical mode of 1 or 2 dB per division in order to see the peak of each signal in detail. (The delta-amplitude mode in the 492P allows this technique to be used without input mixer overdrive.) Further measurement time would then be required to properly locate and measure each signal before the computation could begin. With the programmability and internal processing in a spectrum analyzer such as the 492P, however, such measurement refinements can also be automated. Figure 5 shows the output of a total harmonic distortion analysis program run on the RF oscillator output shown in Figure 4.

FREQUENCY	AMPLITUDE dBm	RELATIVE dB
1.0E+8	−20.8	0
2.0E+8	−25.64	−4.84
3.0E+8	−34.96	−14.16
4.0E+8	−38.16	−17.36
5.0E+8	−28.32	−7.52
6.0E+8	−37.64	−16.84
7.0E+8	−39.08	−18.28
8.0E+8	−35	−14.2
9.0E+8	−43.56	−22.76

TOTAL HARMONIC DISTORTION EQUALS 80 PERCENT
DO YOU WANT TO DO ANOTHER ANALYSIS (YES OR NO)?

Fig. 5 Output of a total-harmonic-distortion analysis program run on the RF comb generator output shown in Figure 4.

AUTOMATE TO SAVE TIME, REDUCE MEASUREMENT ERROR

A key advantage of a fully programmable spectrum analyzer is the ability to have some intelligence on the GPIB, not only do calculations, but also operate the measurement instrument. Programmability means that a device may be operated or controlled by digital instruction. While automated computation can always save time, a great part of the time required to make a measurement may be operator set up and acquisition time. In addition, errors or discrepancies frequently occur in the results obtained using manual methods because different operators do things differently, and some are more proficient than others. Full automation assures that all measurements are made in the same way and under the same conditions.

While programmability may be more or less important than computation in any given application, it almost always has a role to play. For example, the fairly straightforward task of searching a given portion of the spectrum for signals and cataloging them requires virtually no computation. However, such a task can be extremely laborious without the aid of automation.

The special intelligence incorporated in a programmable spec-

(continued on page 94)

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(from page 92)

trum analyzer such as the 492P makes tasks such as locating signals and cataloging them easy. For example, to record all signals above −50 dBm between 90 and 110 MHz in a 10 kHz bandwidth, the frequency span or window should be not much wider than 100 kHz per division, or 1 MHz full screen. If the first window covers from 90 to 91 MHz on the display, the program (written in Tektronix 4050-series Basic) would be as follows:

```
10  N = ϕ                     (initializes counter
                               variable)
20  PRINT@1:                  (positions POINT at left
    "POI 0;                    edge of screen; causes
    SIGSWP"                    single sweep)
30  PRINT@1:                  (causes spectrum analyzer
    "RGT 100"                  to automatically position
                               POINT at peak of next
                               signal to right above third
                               horizontal graticule line
                               —assume this is −50 dBm)
40  PRINT@1:                  (queries spectrum
    "POI?"                     analyzer for POINT
                               coordinates)
50  INPUT@1:X,Y               (inputs coordinates of
                               POINT to controller)
60  IF X > 1000,              (pointer is at right end of
    THEN 90                    display)
70  PRINT X, Y                (outputs signal coordi-
                               nates to controller dis-
                               play screen)
80  GO TO 30                  (look for next signal in
                               existing span)
90  PRINT @1:                 (causes spectrum analyzer
    "CEN"                      to tune up 500 kHz in
                               frequency as if to center
                               signal at right-hand edge
                               of display)
100 PRINT@1:                  (causes spectrum ana-
    "CEN"                      lyzer to tune up another
                               500 kHz)
110 N = N + 1                 (increments span counter)
120 IF N < 20,                (last 1-MHz span
    THEN 20                    covered?)
130 END                       (yes — finished)
```

A more elaborate version of this program was run on the spectrum shown in Figure 6, using 100 kHz resolution and 10 MHz full screen.

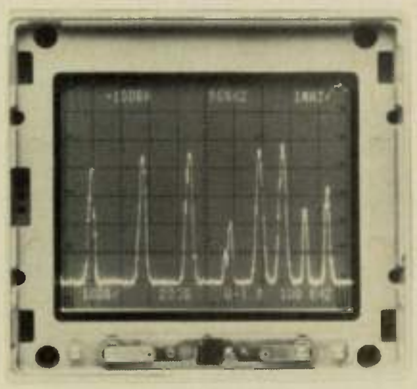

Fig. 6 Spectrum analyzed by signal cataloging program.

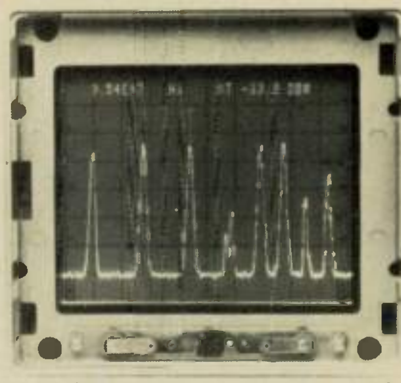

Fig. 7 CRT display showing signal identification by the cataloging program.

This program calculates the actual frequency in hertz and the amplitude in dBm from the x,y screen coordinates and prints this information in the CRT display, as shown by the photograph in Figure 7. The vertical index line showing which signal has been identified was generated by the program. Figure 8 shows the listing of signals for this display. Slight amplitude variations between Figures 6 and 7 are due to FM on these signals.

FREQUENCY		REFERENCE LEVEL
9.202E+7	Hz	at −35.6 dBm
9.381E+7	Hz	at −32.8 dBm
9.389E+7	Hz	at −38.4 dBm
9.54E+7	Hz	at −33.2 dBm
9.659E+7	Hz	at −66.8 dBm
9.679E+7	Hz	at −56.8 dBm
9.778E+7	Hz	at −32.8 dBm
9.858E+7	Hz	at −32.4 dBm
9.936E+7	Hz	at −54.8 dBm
1.0015E+8	Hz	at −44.8 dBm
1.0514E+8	Hz	at −46.4 dBm

Fig. 8 List of signals for the display of Figure 7.
(The signal listed at 105.14 MHz is in the next 10 MHz span and does not appear in Figure 7.)

CONCLUSION

GPIB compatibility of a spectrum analyzer usually provides the ability to enter raw spectral data into a controller, and clearly does much to save time in computation, data correction, and display enhancement. However, full programmability provides the power to completely automate measurements, adding set up and data acquisition time savings to computation time savings. Internal processing capabilities in the instrument and a conversational programming language ease the software development task and minimize program execution time. ■

Analysis and Synthesis of Coupled Microstrip Lines by Polynomials

Polynomial expressions for even and odd effective permittivities and characteristic impedances of unshielded pairs of coupled zero-thickness microstrip lines have been derived. They are valid for the combinations of dimensions and relative permittivities of the substrate most commonly encountered in practice. These expressions greatly facilitate the analysis and synthesis of coupled microstrip lines, especially when using computer-based optimization methods.

Ján Zehentner
Czech Technical University
Prague, Czechoslovakia

INTRODUCTION

Coupled microstrip lines on dielectric substrates, **Figure 1**, are used very often in microwave integrated circuits. Therefore, many authors concentrate on them, to describe the properties of their two zero cut-off frequency dominant modes (denoted as even and odd modes). Analysis and synthesis of a pair of coupled microstrip lines becomes difficult owing to the presence of the two dielectrics (air and the substrate) in the cross section of the transmission line. In the case of negligibly small dispersion of both dominant modes, the quasi-TEM approximation was found to be the most suitable way of characterizing the properties of the coupled microstrip lines in terms of the constants of propagation, β_e, β_o, wavelengths λ_e, λ_o, velocities of propagation v_e, v_o, effective permittivities K_{efe}, K_{efo} and characteristic impedances Z_{oe}, Z_{oo} of the even and odd mode, respectively. At the frequencies for which the dispersion can not be neglected but the supposition of the quasi-TEM approximation is valid, the description of the coupled microstrip lines can be modified, for example, using Getsinger's dispersion model.[1]

Most authors analyze the coupled microstrip lines using the quasi-TEM approximation as follows: Suppose that the field components in the direction of propagation are negligibly small in comparison with the perpendicular components. Then a solution to Laplace's or Poisson's equation can be found, from which it is possible to determine the per-meter capacitance of the line C, and then, from it, to calculate the other quantities describing the propagation of the even and odd quasi-TEM modes. C can be expressed by means of a series,[2] which leads to the solution of a set of linear equations.[3-5] Alternatively, it can be found by integration of the second order Fredholm's equation,[6] or by integrating the Fourier transform of the charge distribution function.[7] C can also be calculated through partial capacitances[8,9] or by means of conformal mapping.[10,11] Parameters of the coupled microstrip lines obtained in this way (static approximation) are frequency independent, and are valid when the dispersion effects can be neglected. More exact analyses of the coupled microstrip lines are based on the solution of the wave equation and this includes dispersive properties. The wave equation solution is obtained by difference equations,[12] by a direct application of the Fourier transform,[13,14] or by making use of the Galerkin's method.[15]

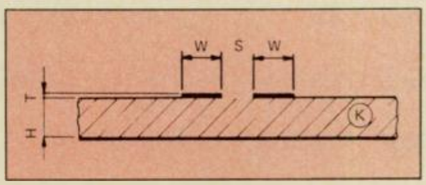

Fig. 1 Coupled microstrip lines.

Values of the parameters describing the propagation of the even and odd modes on the pair of coupled microstrip lines obtained by the various authors cited above differ. Likewise, they also vary to some extent from the measured values. Generally, it is accepted that the results given by Bryant and Weiss[6] agree with experimentally obtained values and therefore many authors cite them as a reference.

The calculation of the parameters of the coupled microstrip lines using analyses mentioned above[3-7,12-16] is involved since a quick and exact analysis or synthesis procedure has not yet been devised. If the dispersion can be neglected, then the analysis can be performed according to References 8-11. But Reference 11 quotes a maximum error in characteristic impedance of the odd mode of 6% and 14% for the even mode (compared to the values given in Reference 6).

In this article, power series expressions for the effective permittivity and characteristic impedance formulae of the even and odd mode of the coupled microstrip lines are presented. These were determined as approximations to a set of values calculated according to References 6 and 16 analogous to Reference 17. Approximation for each of the four quantities, with respect to W/H and S/H, keeping K constant, was obtained by least square approximation of the starting set of $K \times W/H \times S/H = 11 \times 20 \times 14 = 3080$ values using the modified Marquardt's method. Then, approximation with respect to K by least square approximation to the set of K x number of terms of polynomial=either 11x10 (Equations 3 and 4) or 11x15 (Equations 5 and 6) values using the dual method of conjugate directions according to Fletcher was done. If the dispersion effect of the both modes should be taken into consideration, then the frequency dependent relative permittivities should be calculated according to Reference 1 using the values of frequency independent relative permittivities calculated from Equations 3 and 4. The remaining frequency dependent parameters of the coupled microstrip lines can be determined according to Equations 7 through 10. Even and odd mode effective permittivities and characteristic impedances are expressed in closed form and are valid for ranges of dimensions: W/H (0.05 to 2.00), S/H (0.05 to 2.00) and relative permittivity of the substrate K (1 to 20) values encompassing those most usually met in practice. These formulas make possible calculations of the parameters of coupled microstrip lines which are easily performed by calculator or computer with precision sufficient for most engineering applications.

EVEN AND ODD MODE EFFECTIVE PERMITTIVITY AND CHARACTERISTIC IMPEDANCE

For the pair of coupled unshielded, zero-thickness ($T \doteq 0$) microstrip lines, **Figure 1**, having negligibly small losses, and with K=1, the effective permittivities $K_{efe} = K_{efo} = 1$ and the characteristic impedance of the even mode is:

$$Z_{oe} = (149.3360) - (162.5870)x - (37.9809)y + (17.6376)x^2 + (69.4057)xy + (1.9519)y^2 + (34.8733)x^3 - (10.3020)x^2y - (8.8147)xy^2 + (26.6284)y^3 + (12.9265)x^4 - (19.9102)x^3y + (20.9046)x^2y^2 - (19.5373)xy^3 + (11.4445)y^4 \qquad (1)$$

and characteristic impedance of the odd mode is:

$$Z_{oo} = (104.2580) - (99.8149)x + (44.3227)y + (14.9051)x^2 - (65.9082)xy - (11.2160)y^2 - (3.2273)x^3 - (2.5277)x^2y + (7.6415)xy^2 - (26.9063)y^3 - (2.4211)x^4 + (10.6035)x^3y - (13.4447)x^2y^2 + (13.5414)xy^3 - (9.6342)y^4 \qquad (2)$$

where $x = \log(W/H)$ and $y = \log(S/H)$.

Formulas 1 and 2 deviate from Z_{oe}, Z_{oo} calculated according to References 6 and 16 less than 1.5% and hold for $0.05 \leq W/H \leq 2.00$ and $0.05 \leq S/H \leq 2.00$.

Equations 3 and 4 can be written by introducing the column matrix:

$$(z) = \begin{pmatrix} 1 \\ K \\ K^2 \\ K^3 \end{pmatrix}$$

and row matrices $(A)_i = (a_{i1}\ a_{i2}\ a_{i3}\ a_{i4})$, i=1,2, . . . 10. K is the relative permittivity of the substrate, and a_{ij} (j=1,2,3,4) are the numbers in rounded brackets of Equations 3 and 4. If $K \geq 1$, the effective permittivity of the even mode can be written by means of a polynomial, whose individual terms are given by the products of matrices $(A)_i(z)$ and the proper power of x and/or y. For example, the seventh term of Equation 3 would be $(A)_7(z)x^2y = (9.629765 \times 10^{-4} - 3.900969 \times 10^{-4} K - 1.059613 \times 10^{-4} K^2 + 3.0324478 \times 10^{-6} K^3)x^2y$.

Therefore,

$$\begin{aligned} K_{efe} = {} & (+4.384481 \times 10^{-1} + 5.654027 \times 10^{-1} - 7.786037 \times 10^{-4} + 2.170123 \times 10^{-5})(z) + \\ & (-1.927090 \times 10^{-1} + 1.963063 \times 10^{-1} - 8.290811 \times 10^{-4} + 2.311680 \times 10^{-5})(z)x + \\ & (-4.341146 \times 10^{-2} + 4.465488 \times 10^{-2} - 2.469118 \times 10^{-4} + 6.822427 \times 10^{-6})(z)y + \\ & (+1.625815 \times 10^{-2} - 1.678040 \times 10^{-2} + 2.254192 \times 10^{-4} - 6.123393 \times 10^{-6})(z)xy + \\ & (+8.130743 \times 10^{-2} - 8.488870 \times 10^{-2} + 8.014258 \times 10^{-4} - 2.253715 \times 10^{-5})(z)x^2 + \\ & (+1.791596 \times 10^{-2} - 1.821545 \times 10^{-2} + 6.426116 \times 10^{-5} - 1.823700 \times 10^{-6})(z)y^2 + \\ & (+9.629765 \times 10^{-4} - 3.900969 \times 10^{-4} - 1.059613 \times 10^{-4} + 3.032448 \times 10^{-6})(z)x^2y + \\ & (-1.873500 \times 10^{-3} + 2.820664 \times 10^{-3} - 1.842717 \times 10^{-4} + 5.107836 \times 10^{-6})(z)xy^2 + \ldots \end{aligned}$$

$$(-1.366105\times10^{-3}+9.847058\times10^{-4}+7.177365\times10^{-5}-2.018744\times10^{-6})\,(z)x^2y^2+$$

$$(-1.684099\times10^{-2}+1.776884\times10^{-2}-1.974360\times10^{-4}+5.579338\times10^{-6})\,(z)x^3 \qquad (3)$$

and the effective permittivity of the odd mode is:

$$K_{efo} = (+5.013084\times10^{-1}+4.986675\times10^{-1}+1.137005\times10^{-5}-2.716794\times10^{-7})\,(z)+$$

$$(-3.078887\times10^{-3}+3.267818\times10^{-3}-5.178458\times10^{-5}+1.168559\times10^{-6})\,(z)x+$$

$$(-5.078874\times10^{-3}+5.222806\times10^{-3}-3.919275\times10^{-5}+1.085955\times10^{-6})\,(z)y+$$

$$(-4.870942\times10^{-2}+4.956467\times10^{-2}-2.106422\times10^{-4}+5.735316\times10^{-6})\,(z)xy+$$

$$(-1.546468\times10^{-2}+1.571308\times10^{-2}-3.073500\times10^{-5}+1.190300\times10^{-6})(z)x^2+$$

$$(-3.436739\times10^{-3}+3.535125\times10^{-3}-2.263527\times10^{-5}+6.439563\times10^{-7})(z)y^2+$$

$$(+9.686561\times10^{-3}-9.966367\times10^{-3}+9.576642\times10^{-5}-2.682815\times10^{-6})(z)x^2y+$$

$$(+9.868902\times10^{-3}-1.002012\times10^{-2}+6.554017\times10^{-5}-1.842724\times10^{-6})(z)xy^2+$$

$$(-9.562739\times10^{-4}+9.734051\times10^{-4}-2.793023\times10^{-5}+8.223064\times10^{-7})(z)x^2y^2+$$

$$(+2.279346\times10^{-3}-2.360689\times10^{-3}+3.531039\times10^{-6}-1.991800\times10^{-7})(z)x^3 \qquad (4)$$

where $x=W/H$ and $y=S/H$. Similarly for $K\geqslant1$ the characteristic impedance of the even mode has the form:

$$Z_{oe} = [-7.227500\times10^{0}+4.831881\times10^{-2}K+1.755011\times10^{2}/(K+2.929877\times10^{-1})^{0.4455830}]$$

$$+[7.306651\times10^{0}-4.819667\times10^{-2}K-2.132409\times10^{2}/(K+6.516210\times10^{-1})^{0.4534798}]\,x-$$

$$[1.194161\times10^{0}-8.487579\times10^{-3}K+4.506010\times10^{1}/(K+4.465563\times10^{-1})^{0.5488482}]\,y-$$

$$[4.287803\times10^{-1}+9.912341\times10^{-2}K-4.498870\times10^{2}/(K+7.522825\times10^{0})^{1.4473750}$$

$$-5.281605\ \log(K-0.5921654)]\,x^2+[7.086537\times10^{-1}-4.899064\times10^{-3}K+9.162004\times10^{1}/$$

$$(K+7.532529\times10^{-1})^{0.5127071}]\,xy-[9.726554\times10^{0}+1.097786\times10^{-1}K-2.644885\times10^{2}/$$

$$(K+8.289625\times10^{0})^{1.3146800}-8.914885\ \log(K-0.4522668)]\,y^2+$$

$$[1.039199\times10^{1}-1.098850\times10^{-1}K+1.608525\times10^{2}/(K+3.904932\times10^{0})^{1.1809130}]\,x^3-$$

$$[1.488784\times10^{0}-7.019496\times10^{-2}K+3.499848\times10^{2}/(K+8.334393\times10^{0})^{1.5973890}$$

$$+2.367744\ \log(K-0.6179666)]\,x^2y+[8.274227\times10^{-2}+7.147448\times10^{-2}K-3.000087\times10^{2}/$$

$$(K+8.291490\times10^{0})^{1.5274090}-3.127733\ \log(K-0.5196208)]\,xy^2+[1.033772\times10^{1}-1.253596\times10^{-1}K+8.297293\times10^{2}/$$

$$(K+6.894420\times10^{0})^{1.8983620}]\,y^3+[1.777133\times10^{0}-1.508959\times10^{-2}K+2.334689\times10^{1}/$$

$$(K+1.890813\times10^{0})^{0.6949306}]\,x^4-[2.019899\times10^{0}-1.517166\times10^{-2}K+3.467776\times10^{1}/$$

$$(K+1.855763\times10^{0})^{0.6299039}]\,x^3y+[3.302626\times10^{-1}-2.567510\times10^{-3}K+2.742376\times10^{1}/$$

$$(K+7.396667\times10^{-1})^{0.5187681}]\,x^2y^2-[1.869520\times10^{0}-1.355218\times10^{-2}K+3.411907\times10^{1}/$$

$$(K+1.872026\times10^{0})^{0.6230576}]\,xy^3+[2.564735\times10^{0}-2.426774\times10^{-2}K+2.979605\times10^{1}/$$

$$(K+2.767633\times10^{0})^{0.9105386}]\,y^4 \qquad (5)$$

and characteristic impedance of the odd mode is:

$$
\begin{aligned}
Z_{oo} = {} & [-1.541462\times10^{0}+1.047222\times10^{-2}K+1.392122\times10^{2}/(K+7.641871\times10^{-1})^{0.4836336}]- \\
& [5.811166\times10^{0}-4.282023\times10^{-2}K+1.550428\times10^{2}/(K+1.405116\times10^{0})^{0.5696270}]\,x+ \\
& [7.677150\times10^{-1}-5.361570\times10^{-3}K+5.209358\times10^{1}/(K+4.056875\times10^{-1})^{0.5253440}]\,y- \\
& [1.681961\times10^{0}-9.793748\times10^{-3}K-1.846503\times10^{1}/(K+3.173996\times10^{-1})^{0.3912342}]\,x^{2}- \\
& [2.116994\times10^{0}-1.558039\times10^{-2}K+9.197616\times10^{1}/(K+9.711925\times10^{-1})^{0.5388229}]\,xy+ \\
& [4.011319\times10^{-2}+8.238547\times10^{-2}K-2.479942\times10^{2}/(K+7.119761\times10^{0})^{1.3964730} \\
& -3.638965\,\log(K-0.7133899)]\,y^{2}-[5.707706\times10^{-1}-6.610225\times10^{-3}K+7.148432\times10^{0}/ \\
& (K+1.522619\times10^{0})^{1.0671150}]\,x^{3}+[3.226051\times10^{-1}-3.598921\times10^{-3}K-2.244685\times10^{1}/ \\
& (K+1.648527\times10^{0})^{2.1200900}]\,x^{2}y-[7.451796\times10^{-1}+7.293089\times10^{-2}K-2.998347\times10^{2}/ \\
& (K+8.453184\times10^{0})^{1.5399120}-3.402222\log(K-0.4819757)]\,xy^{2} \\
& -[9.605851\times10^{0}-1.148197\times10^{-1}K+3.384081\times10^{2}/(K+5.341414\times10^{0})^{1.6060860}]\,y^{3}- \\
& [2.738555\times10^{-1}-2.472218\times10^{-3}K+3.378718\times10^{0}/(K+8.452280\times10^{-1})^{0.7380907}]\,x^{4}+ \\
& [1.055974\times10^{0}-7.397372\times10^{-3}K+1.921203\times10^{1}/(K+2.035435\times10^{0})^{0.6290481}]\,x^{3}y- \\
& [4.328554\times10^{-1}-3.104664\times10^{-3}K+1.747946\times10^{1}/(K+7.202084\times10^{-1})^{0.5436921}]\,x^{2}y^{2}+ \\
& [3.705308\times10^{0}-3.608271\times10^{-2}K+4.988216\times10^{1}/(K+3.69888\times10^{0})^{1.0471590}]\,xy^{3}- \\
& [2.391575\times10^{0}-2.411365\times10^{-2}K+2.844322\times10^{1}/(K+2.917749\times10^{0})^{0.9992614}]\,y^{4}
\end{aligned}
\qquad (6)
$$

where x=log(W/H) and y=log(S/H). Equations 4 to 6 hold for $1 \leqslant K \leqslant 20$, $0.05 \leqslant W/H \leqslant 2.00$, $0.05 \leqslant S/H \leqslant 2.00$. They are obtained by approximation to the 3080 values of each of four quantities computed according to References 6 and 16. K_{efe}, K_{efo}, Z_{oe}, Z_{oo} calculated from Equations 4 to 6 deviate from the starting set of values less than 1.7% if K, W/H and S/H are found within the intervals specified above. There is no need for further reducing the errors of approximation, since, as demonstrated in Reference 6, the errors of measurements of Z_{oe}, Z_{oo} are of the same order. More over, the production accuracy with which the coupled microstrip lines can be realized is not better than 1-2%.

ANALYSIS OF COUPLED MICROSTRIP LINES

The wavelength, velocity of propagation and the constant of propagation of the even and odd mode can be determined as follows:

$$\lambda_e = \lambda/\sqrt{K_{efe}} \qquad \lambda_o = \lambda/\sqrt{K_{efo}} \qquad (7)$$

$$v_e = c/\sqrt{K_{efe}} \qquad v_o = c/\sqrt{K_{efo}} \qquad (8)$$

$$\beta_e = 2\pi/\lambda_e \qquad \beta_o = 2\pi/\lambda_o \qquad (9)$$

where $\lambda = c/f$. Substituting K_{efef}, K_{efof} calculated in accordance with Reference 1 making use of Equations 4 to 6 for K_{efe}, K_{efo} in Equations 7 to 9 the frequency dependent wavelengths λ_{ef}, λ_{of}, velocities of propagation v_{ef}, v_{of} and propagation constants β_{ef}, β_{of} of the even and odd mode can be found. Frequency dependent characteristic impedances Z_{oef} and Z_{oof} can be expressed by means of Equations 4 to 6 and Reference 1 as follows:

$$Z_{oef} = Z_{oe}\sqrt{K_{efe}/K_{efef}}$$

$$Z_{oof} = Z_{oo}\sqrt{K_{efo}/K_{efof}} \qquad (10)$$

SYNTHESIS OF COUPLED MICROSTRIP LINES

To design the dimensions of the pair of coupled microstrip lines on dielectric substrate of thickness H with given K at known frequency f with required characteristic impedances Z^{+}_{oef}, Z^{+}_{oof}, it is advantageous to minimize the following function:

$$F(W/H,S/H) = (Z^{+}_{oef} - Z_{oef})^{2} + (Z^{+}_{oof} - Z_{oof})^{2} \qquad (11)$$

in which Z_{oef}, Z_{oof} should be substituted from Equation 10 making use of Equations 4 to 6 and Reference 1. This way of the

(continued on page 110)

Exact Design of the **Marchand Balun**

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Published in Proceedings of the Ninth European Microwave Conference, Brighton, England, 17-20 September, 1979.

The Marchand, or compensated, balun[1-9] in **Figure 1** is widely used with multi-octave antennas such as the Archimedes spiral. This paper deals with three implementations of the Marchand balun. The first has the conventional second-order equivalent circuit consisting of a series open-circuit stub and a parallel short-circuit stub, both of quarter-wavelength at the center frequency. Oltman[6] analyzed the second-order balun and presented equations of element values intended to maximize the bandwidth. A 10:1 bandwidth design based on Oltman's equations was found to exhibit significant bandwidth contraction. In order to achieve a specified response the exact method described by Wenzel[10] was used. The method is straightforward and requires only simple calculations. The element values of a balun designed according to this procedure are given in **Table 1** and the frequency response in **Figure 2**.

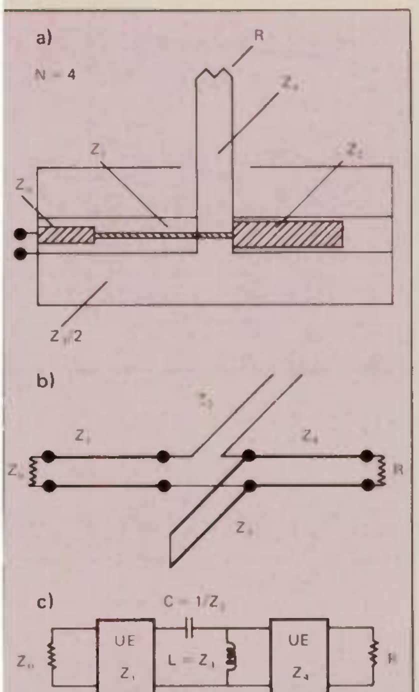

Fig. 1 The fourth-order Marchand balun.
a) Cross section through physical circuit.
b) Transmission line equivalent circuit.
c) Equivalent circuit using distributed element notation.

RESULTS

For applications when the load resistance is greater than approximately 75 Ω the second-order balun may provide inadequate impedance match. Although most authors[2,4,6-9] recognize the need for transformer action when dealing with such loads, and describe the use of various transformers with the second-order balun, only Laughlin[8] takes the interaction between the balun and transformer into account from the start. Failure to do this can lead to unacceptably degraded frequency response for broadband designs.

In the second implementation a quarter-wave line is inserted before the balanced load. The resultant third-order balun has been dealt with by Laughlin[8] who derived approximate equations for the element values. For this paper the element values for Tchebysheff passband response were computed using the exact, nonredundant method for the syntheses of commensurate length distributed networks described by Horton and Wenzel.[1] To simplify the design procedure, graphs of the element values as a function of passband reflection coefficient were produced for selected bandwidths. For example, **Figure 3** gives the graphs for 10:1 bandwidth ratio. A comparison with the second-order design is made in **Table 1** and **Figure 2**. A 0.2 to 2 GHz balun was constructed according to this design and **Figure 4** shows the agreement between the theoretical and measured responses.

For bandwidths up to approximately two octaves, the third-order balun offers marked improve

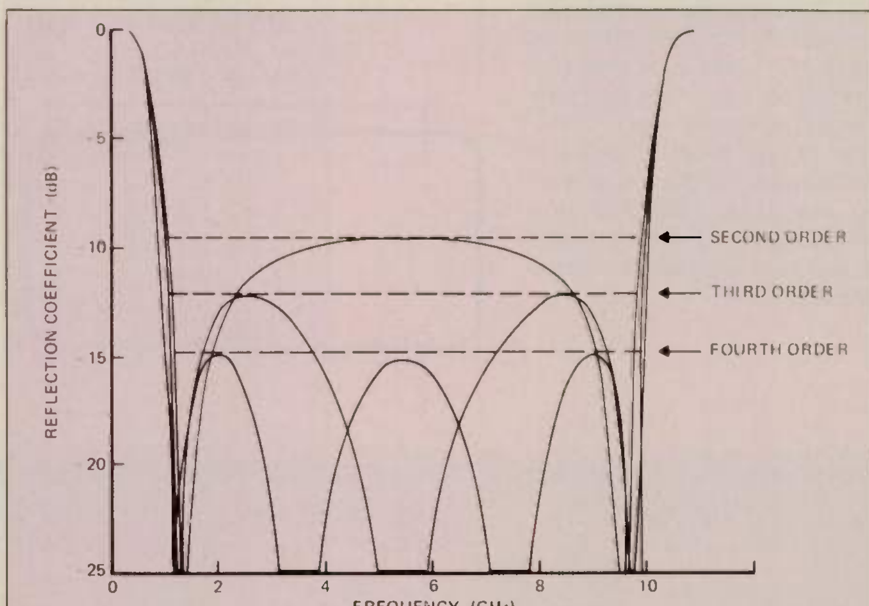

Fig. 2 Theoretical frequency response of the second, third and fourth order Marchand baluns with 50 Ω source resistance and 100 Ω load resistance.

(continued on page 102)

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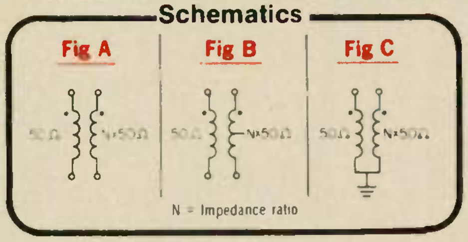

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Impedance ratio	1	4	9	16
Max. insertion loss	MHz	MHz	MHz	MHz
3 dB	8-300	8-350	2-90	7-85
2 dB	10-200	15-300	3-75	10-65
1 dB	25-100	25-200	6-50	15-40
Price (10-49 qty.)	$4.95	$4.95	$5.45	$5.95

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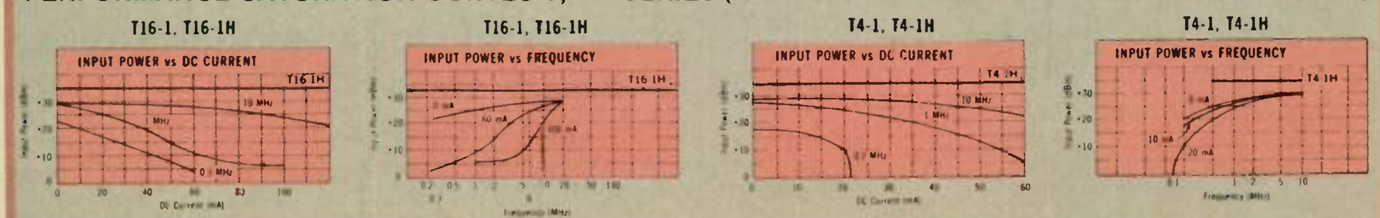

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CENTER-TAPPED DC ISOLATED PRIMARY & SECONDARY Fig B

Model	Metal case	TMO 1-1T	TMO 2-1T	TMO2.5-6T	TMO 3-1T	TMO 4-1	TMO 5-1T	TMO13-1T
	Plastic case	T 1-1T	T 2-1T	T 2.5-6T	T 3-1T	T 4-1	T 5-1T	T 13-1T
Freq. range, MHz		05-200	07-200	01-100	05-200	2-350	3-300	3-120
Impedance ratio		1	2	2.5	3	4	5	13
Max. inserton loss		MHz	MHz	MHz	MHz	MHz	MHz	MHz
	3 dB	.05-200	.07-200	01-100	.05-250	2-350	3-300	3-120
	2 dB	08-150	1-100	02-50	.1-200	35-300	.6-200	7-80
	1 dB	.2-80	.5-50	.05-20	.5-70	2-100	5-100	5-20
Maximum Amplitude Unbalance, MHz								
	.1 dB	5-80	1-50	.1-20	1-70	.5-100	10-100	5-20
	.5 dB	05-200	07-200	01-100	05-250	2-350	.3-300	3-120
Maximum Phase Unbalance Degrees, MHz								
	1°	5-80	1-50	1-20	1-70	5-100	10-100	5-20
	5°	05-200	07-200	01-100	.05-250	2-350	.3-300	3-120
Price (10-49)	Model TMO	$6.45	$6.75	$6.75	$6.45	$4.95	$6.75	$6.75
	Model T	$3.95	$4.25	$4.25	$3.95	$2.95	$4.25	$4.25

DC ISOLATED PRIMARY & SECONDARY Fig A

Model	Metal case	TMO 1-1	TMO 1.5-1	TMO 2.5-6	TMO 4-6	TMO 9-1	TMO 16-1
	Plastic case	T 1-1	T 1.5-1	T 2.5-6	T 4-6	T 9-1	T 16-1
Freq. range, MHz		.15-400	.1-300	.01-100	.02-200	15-200	.3-120
Impedance ratio		1	1.5	2.5	4	9	16
Max. insertion loss		MHz	MHz	MHz	MHz	MHz	MHz
	3 dB	.15-400	.1-300	.01-100	.02-200	.15-200	.3-120
	2 dB	.35-200	.2-150	.02-50	.05-150	.3-150	.7-80
	1 dB	2-50	.5-80	.05-20	.1-100	2-40	5-20
Price,	Model TMO	$4.95	$6.75	$6.45	$6.45	$6.45	$6.45
(10-49)	Model T	$2.95	$3.95	$3.95	$3.95	$3.45	$3.95

UNBALANCED PRIMARY & SECONDARY Fig C

Model	Metal case	TMO 2-1	TMO 3-1	TMO 4-2	TMO 8-1	TMO 14-1
	Plastic case	T 2-1	T 3-1	T 4-2	T 8-1	T 14-1
Freq. range, MHz		.025-600	.5-800	5-600	15-250	2-150
Impedance ratio		2	3	4	8	14
Max. insertion loss		MHz	MHz	MHz	MHz	MHz
	3 dB	.025-600	.5-800	2-600	15-250	2-150
	2 dB	.05-400	2-400	5-500	.25-200	5-100
	1 dB	.05-200	—	2-250	2-100	2-50
Price,	Model TMO	$5.95	$6.95	$5.95	$5.95	$6.75
(10-49)	Model T	$3.45	$4.25	$3.45	$3.45	$4.25

Common specifications: Primary impedance, 50 ohms Total input power, ¼ watt
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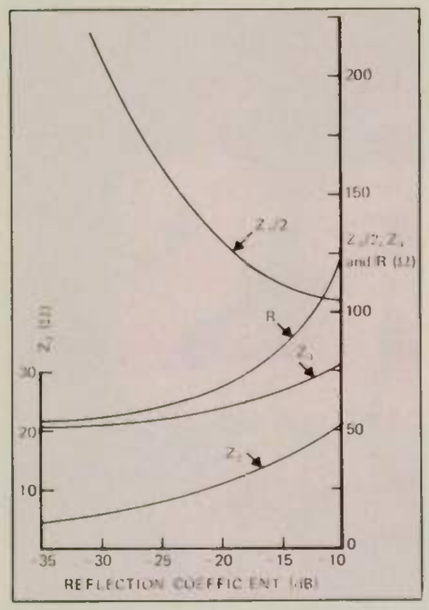

Fig. 3 Graphs of element values for the third-order balun with bandwidth ratio 10:1 and source resistance 50Ω.

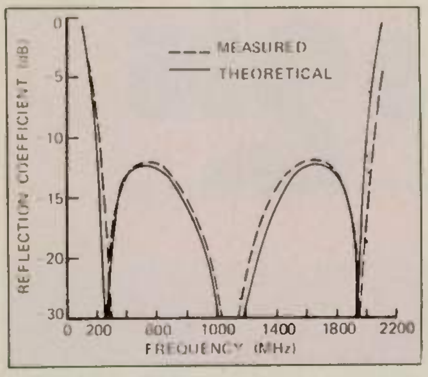

Fig. 4 Measured and theoretical response of a 10:1 bandwidth third-order Marchand balun with 50 Ω source resistance and 100 Ω load resistance.

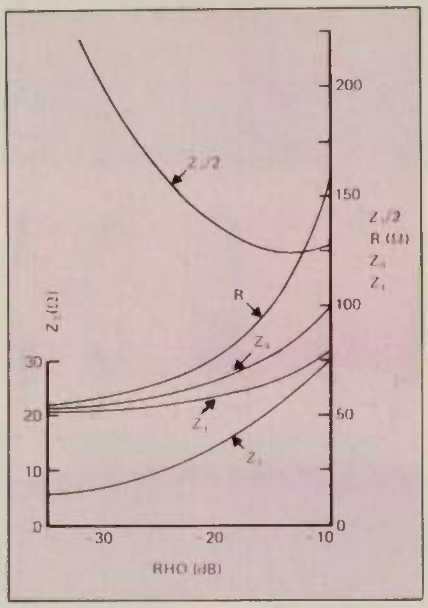

Fig. 5 Graphs of element values for the fourth-order balun with bandwidth ratio 10:1 and source resistance 50Ω.

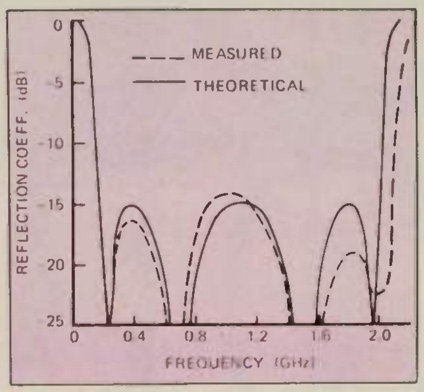

Fig. 6 Measured and theoretical response of a 10:1 bandwidth fourth-order balun with 50 Ω source resistance and 100 Ω load resistance.

ment over the second-order balun. However, effectiveness of quarter-wave lines decreases as bandwidth increases.[1] This trend is illustrated in **Figure 2** where the third-order balun offers only 2.9 dB improvement in reflection coefficient.

To counter this effect a new fourth-order implementation, shown in **Figure 1**, with quarter-wave lines included at both the balanced and unbalanced ports, was investigated. The element values for Tchebysheff response were computed using nonredundant synthesis[11] and, as for the third-order case, graphs of element values were prepared. For an example, see **Figure 5**. **Table 1** and **Figure 2** compare the fourth-order design to the previous two. **Figure 6** shows the agreement between the theoretical and measured responses of a fourth-order design. It is evident that there is no significant difference in realizability between the three circuits, but that an improvement of 5.4 dB in reflection coefficient over the second-order balun has been achieved.

The fourth-order design described here extends the operating range of the Marchand balun without compromising on its compact physical realization. For many practical applications the additional expense of manufacturing the input quarter-wave line will be justified by the improved performance.

Bandwidth ratio, B = 10 : 1
Source resistance, Z_0 = 50 Ω
Load resistance, R = 100 Ω

Order	Z_1 (Ω)	Z_2 (Ω)	Z_3 (Ω)	Z_4 (Ω)	Maximum passband reflection coefficient (dB)
2	–	21.0	241.0	–	–9.5
3	–	17.5	215.0	70.7	–12.4
4	65.0	20.0	250.0	76.0	–14.9

TABLE I Comparison of Tchebysheff Response Marchand Baluns

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	150BD	50-150	540	100	7	1.0
	200BD	150-250	550	110	7	0.7
	250BD	150-250	550	100	6	1.0
	300BD	250-350	550	110	7	0.7
	350BD	250-350	550	100	6	1.0
	400BD	350-500	560	100	6	0.7
*	450BD	350-500	560	80	5	1.0

* V measured at 500 µA I_R ** V measured at 3 mA I_F

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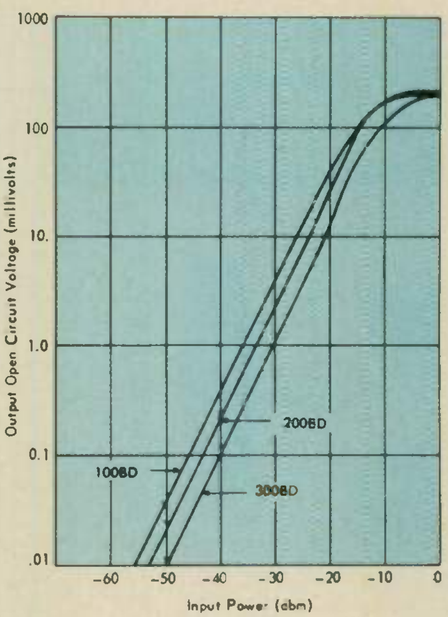
TYPICAL VALUES

DIODE TYPE	TEST FREQUENCY	TSS*	Figure of Merit $\gamma/\sqrt{R_v}$	Video Resistance R_v Ω
100BD	2 GHz	-58 dbm	300	400
	4 GHz	-56 dbm	750	400
	8 GHz	-52 dbm	75	400
	16 GHz	-47 dbm	40	400
150BD	2 GHz	-59 dbm	230	120
	4 GHz	-57 dbm	195	120
	8 GHz	-52 dbm	100	120
	16 GHz	-46 dbm	55	120
200BD	2 GHz	-55 dbm	110	80
	4 GHz	-54 dbm	100	80
	8 GHz	-51 dbm	100	80
	16 GHz	-45 dbm	85	80

*2MHz Bandwidth

TYPICAL DETECTOR RESPONSE CURVES



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An improved algorithm for handling arbitrary cross sections

M. van SLIEDREGT
Delft University of Technology
Delft, Netherlands

NTRODUCTION TO ALCULATION PROCEDURE

In microwave applications, a reat variety of cylindrical wave-uide cross sections are in use. he need for the estimation of ie cutoff frequencies associated ith these cross sections has lead the development of a number f methods for their calculations. s such, the finite difference ethod[1] and the finite element ethod should be mentioned in ie first place. Although they ad to accurate results, these ethods are computer time-con-uming. Therefore, there still ex-sts a need for methods which are ss expensive even if such meth-ds are less accurate. In this re-pect we mention the technique eveloped by Pyle and Angley.[2] his method, while simple, has ie disadvantage of assuming a onstant error allowance and re-uires a fine division of the cross ection.

Therefore in this paper, after a hort summary of the Pyle and ngley method, we will show ow this method can be improved.

The method described in Ref-rence 2 consists essentially of an pproximation of the arbitrary ross section by a number of par-llel strips as illustrated in Figure . The electrical length of a single ection is given by $\theta = 2\pi r/(N\cdot\lambda)$ vith r the radius of the cross sec-ion and N the number of sections.

The impedance of the parallel

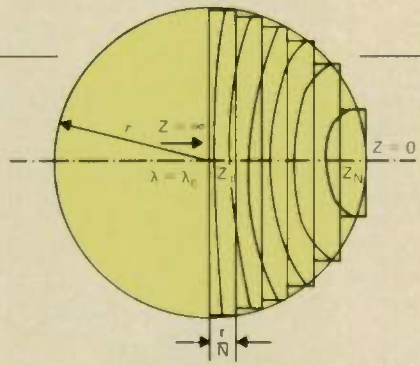


Fig. 1 Cross section of circular waveguide at cutoff wavelength λ_c.

strip transmission line Z is proportional to the distance between the strips. For the distance between the strips, and in contradistinction with the real distance as is taken in Reference 2 we have used the length of the electrical field line at the center of the strips. Physically this choice is justified by the fact that impedance is inversely proportional to the capacitance of the strips and therefore depends on the electrical field line. In an arbitrary cross section one must estimate the electrical field pattern and the electrical field line lengths. Further it will be shown that an accuracy of two digits is sufficient in practice.

One may characterize a single section (e.g. section g) by means of its ABCD-matrix, whereby Z_g is the impedance of section g.

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix}_g = \begin{pmatrix} \cos\theta & j Z_g \sin\theta \\ j \sin\theta / Z_g & \cos\theta \end{pmatrix}$$

$$= \cos\theta \left[\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} + j \tan\theta \begin{pmatrix} 0 & Z_g \\ 1/Z_g & 0 \end{pmatrix} \right]$$

$$= \cos\theta\ [\ (I) + j \tan\theta\ (M_g)]$$

The ABCD-matrix of the N cascaded sections is then found by matrix multiplication

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} =$$

$$\cos^N\theta\ [\ (I) + j \tan\theta\ (M_1)] \star \ldots$$
$$[\ (I) + j \tan\theta\ (M_2)] \star$$
$$[\ (I) + j \tan\theta\ (M_N)].$$

For $\begin{pmatrix} U_{in} \\ I_{in} \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} U_{out} \\ I_{out} \end{pmatrix}$

and the last stripline section short circuited, (i.e. $U_{out} = 0$)

$$Z_{in} = \frac{U_{in}}{I_{in}} = \frac{B}{D}.$$

Since Z_{in} should approach infinity for $\lambda \to \lambda_c$, the matrix element D is required to be zero at λ_c.

Noting that the matrix element D is partly formed by multiplication of the M-matrices, we observe that: $(M_1) \star (M_2) =$

$$\begin{pmatrix} 0 & Z_1 \\ \frac{1}{Z_1} & 0 \end{pmatrix} \star \begin{pmatrix} 0 & Z_2 \\ \frac{1}{Z_2} & 0 \end{pmatrix} =$$

$$\begin{pmatrix} \frac{Z_1}{Z_2} & 0 \\ 0 & \frac{Z_2}{Z_1} \end{pmatrix}$$

```
DATA ZK/0.9999,0.9994,0.9985,0.9970,0.9950,
     0.9925,0.9895,0.9859,0.9819,0.9773,0.9721,
     0.9663,0.9600,0.9531,0.9455,0.9373,0.9284,
     0.9187,0.9084,0.8972,0.8852,0.8722,0.8584,
     0.8435,0.8274,0.8102,0.7916,0.7715,0.7498,
     0.7262,0.7005,0.6723,0.6412,0.6066,0.5677,
     0.5232,0.4710,0.4076,0.3250,0.1956
```

Table I

$$(M_1) \star (M_2) \star (M_3) = \begin{pmatrix} \frac{Z_1}{Z_2} & 0 \\ 0 & \frac{Z_2}{Z_1} \end{pmatrix} \begin{pmatrix} 0 & Z_3 \\ \frac{1}{Z_3} & 0 \end{pmatrix} = \begin{pmatrix} 0 & \frac{Z_1 Z_3}{Z_2} \\ \frac{Z_2}{Z_1 Z_3} & 0 \end{pmatrix}$$

$$(M_1) \star (M_2) \star (M_3) \star (M_4) = \begin{pmatrix} 0 & \frac{Z_1 Z_3}{Z_2} \\ \frac{Z_2}{Z_1 Z_3} & 0 \end{pmatrix} \begin{pmatrix} 0 & Z_4 \\ \frac{1}{Z_4} & 0 \end{pmatrix} = \begin{pmatrix} \frac{Z_1 Z_3}{Z_2 Z_4} & 0 \\ 0 & \frac{Z_2 Z_4}{Z_1 Z_3} \end{pmatrix}$$

It is evident, that only the even products of matrices (M) contain a potentially, nonzero value for D, thus the number of stripline sections is restricted to be even. Furthermore we conclude that only the ratio of impedances is important.

The relationship of the characteristic impedances may be given as:

$$Z_g/Z_k = \ell_g/\ell_k,$$

where Z_g, ℓ_g and Z_k, ℓ_k are the impedance and the electrical fieldline lengths of section g and of section k, respectively.

The matrix element $D = \cos^N\theta\, [1 - s_1 \tan^2\theta [1 - s_1 \tan^2\theta + s_2 \tan^4\theta - s_3 \tan^6\theta \ldots s_{N/2} \tan^N\theta]$ where the coefficients s are functions of the impedance ratios of the sections.

To calculate the proper root of the higher-order polynomial, practically speaking, we may limit ourselves to the first 10 coefficients s, utilizing computer place accuracy (the contribution of the 11th and higher terms is smaller than 1.E – 16). We are thus required to solve for $\tan^2\theta$ from the equation:

$$1 - s_1 \tan^2\theta + s_2 \tan^4\theta - s_3 \tan^6\theta + \ldots - s_{10} \tan^{20}\theta = 0.$$

The cutoff wavelength is then given by $\lambda_c = 2\pi r/(N \cdot \theta)$.

The coefficients s can be written as:

$$s_1 = A_1 + A_2 + A_3 + \ldots A_{n-1}$$

where

$$A_1 = (Z_2 + Z_3 + Z_4 + \ldots Z_N)/Z_2$$

$$A_2 = (Z_3 + Z_4 + \ldots Z_N)/Z_2 \ldots$$

$$A_{N-1} = Z_N/Z_{N-1}$$

$$s_2 = B_1 + B_2 + B_3 + \ldots B_{N-3}$$

where

$$B_1 = \frac{Z_2}{Z_1} A_3 + \frac{Z_2 + Z_3}{Z_1} A_4 + \ldots \frac{Z_2 + Z_3 + Z_4 + \ldots Z_{N-2}}{Z_1} A_{N-1}$$

$$B_2 = \frac{Z_3}{Z_2} A_4 + \frac{Z_3 + Z_4}{Z_2} A_5 + \ldots \frac{Z_3 + Z_4 + \ldots Z_{N-2}}{Z_2} A_{N-1}$$

$$B_{N-3} = \frac{Z_{N-2}}{Z_{N-3}} A_{N-1}$$

$$s_3 = C_1 + C_2 + C_3 + \ldots C_{N-5}$$

where

$$C_1 = \frac{Z_2}{Z_1} B_3 + \frac{Z_2 + Z_3}{Z_1} B_4 + \ldots \frac{Z_2 + Z_3 + \ldots Z_{N-4}}{Z_1} B_{N-3}$$

$$C_2 = \frac{Z_3}{Z_2} B_4 + \frac{Z_3 + Z_4}{Z_2} B_5 + \ldots \frac{Z_3 + Z_4 + \ldots Z_{N-4}}{Z_2} B_{N-3}$$

$$C_{N-5} = \frac{Z_{N-4}}{Z_{N-5}} B_{N-3}$$

The algorithm for rapid calculation of the coefficients s is given in the appendix.

APPLICATION ASPECTS

This method has been verified for the case of the calculation of the cutoff wavelength of the fundamental mode of a circular waveguide. In this case expressions of the radial and tangential electrical field components are known. Starting from a point on the wall of the waveguide we take a small step in the direction of the tangent of the electrical fieldline. At the point we calculate the electrical field components and take, once again a small step in the direction of the tangent of the electrical fieldline and so on.

The length of the electrical fieldline is equal to the sum of all steps including the residue (that is smaller than the length of one step) to the center line. In this way the length of 40 electrical fieldlines with four-place accuracy have been calculated and are given in Table I.

By means of interpolation one can easily calculate the fieldline lengths, when the number of sections is changed.

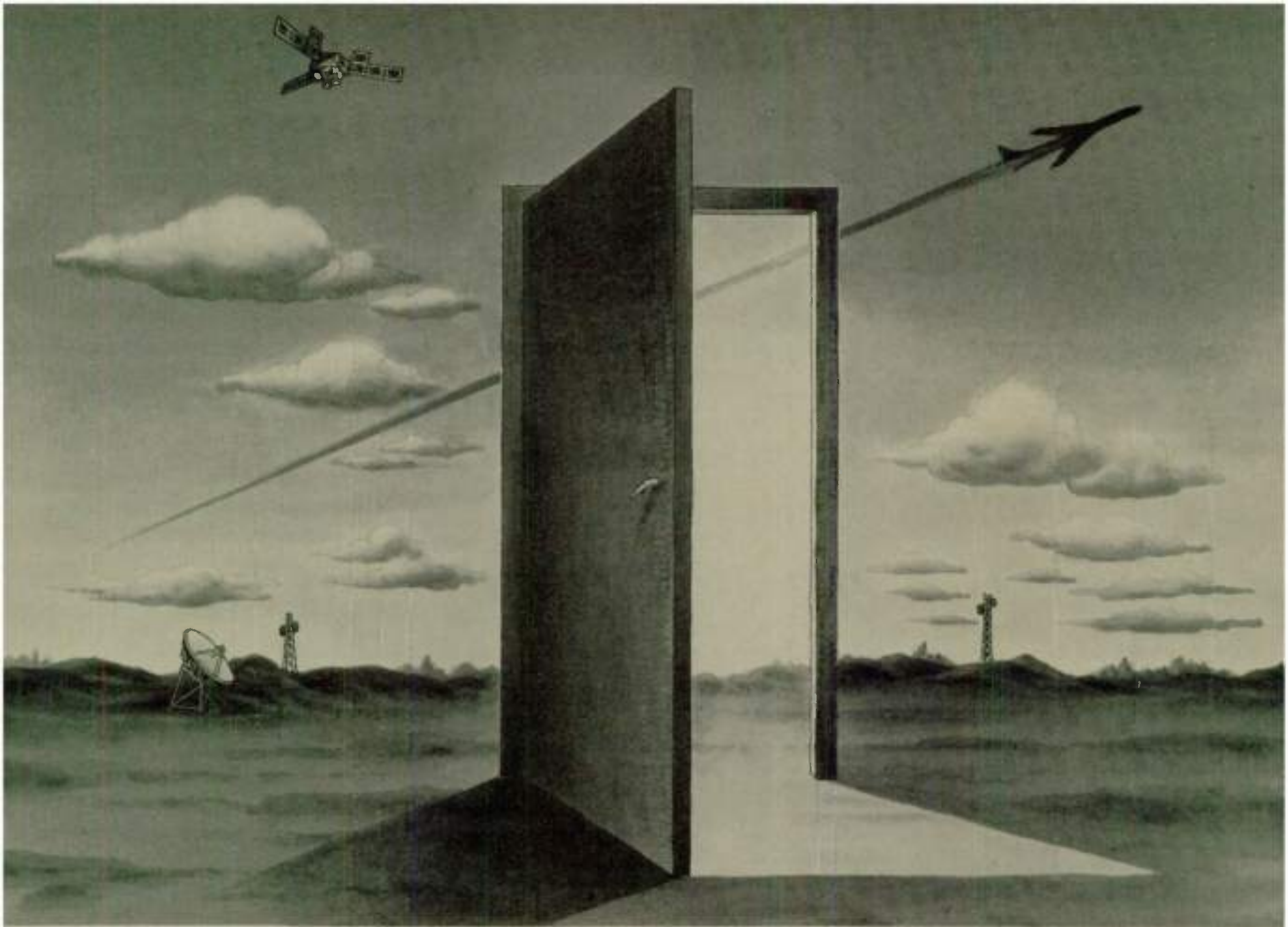
Comparison of the calculated cutoff wavelength with the exact value $\lambda_c = 3.412579r$, while varying the accuracy of the electrical fieldline lengths (by decreasing the number of digits) and doubling the number of sig

(continued on page 108)

$$\frac{\lambda_{c\ exact} - \lambda_{c\ calculated}}{\lambda_{c\ exact}} \star 100\%$$

	4 digits		3 digits		2 digits	
N	Real * 8	Real * 16	Real * 8	Real * 16	Real * 8	Real * 16
10	0.662%	0.662%	0.662%	0.662%	0.688%	0.688%
12	0.526%		0.521%		0.581%	
20	0.271%	0.271%	0.260%	0.260%	0.297%	0.297%
22	0.245%		0.245%		0.252%	
40	0.177%	0.177%	0.182%	0.182%	0.147%	0.147%
42	0.143%		0.144%		0.164%	
80	0.015%	0.015%	0.014%	0.014%	0.013%	0.013%
82	0.015%		0.015%		0.035%	
160	0.012%	0.012%	0.011%	0.011%	0.044%	0.044%
162	0.011%		0.012%		0.002%	

Table II



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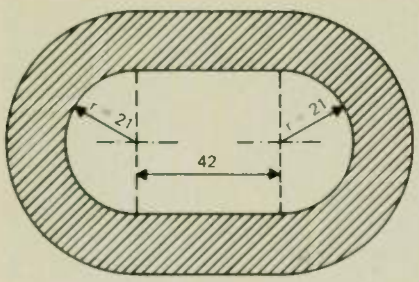

Fig. 2 Cross section of a detonation waveguide.

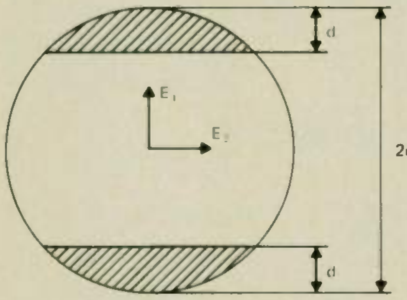

Fig. 3 Cross section of a circular polarizer.

nificant figures yields for several numbers of sections N the relative difference $\Delta\lambda_c/\lambda_c$ as given in Table II.

We note from Table II:

- The accuracy can be improved by increasing the number of sections. However, more than 80 or 160 sections are in this case unnecessary since the limiting factor is the accuracy of the fieldline lengths.
- Increasing the accuracy of the computer by doubling the precision of the reals from 8 bytes long in hexidecimal form (thus 16 significant figures in decimal form) to 16 bytes long in hexidecimal form (i.e. 33 significant figures in decimal form) does not improve the results. Calculating with 8 byte long reals would thus appear sufficient.
- Fieldline lengths accuracy of two digits are in practice sufficient. Using the IBM 370/158 computer the calculation time per column of Table II with 8 byte long reals was 10 seconds.

Separate calculation of the sensitivity with respect to fieldline length of the cutoff wavelength for the cases N = 10, 20, 40, 80 and the fieldline length specified to two digits shows a

N	f_c in MHz
20	1954.1
40	1956.3
80	1956.5
160	1957.4
320	1958.2

Table III

change in λ_c of 0.2%/0.01 absolute change in all the fieldline lengths (in case r = 1). Because of the rounding off in two digits of the fieldline lengths we can expect a discrepancy in the calculation of the cutoff wavelength of about 0.1% or less.

The described method is thus applicable in those situations, in which the field pattern over the cross section can only be estimated. The method has been applied to calculate the cutoff frequency of a detonation pipe used a waveguide. The cross section, which is found from mechanical strength consideration, is shown in Figure 2. The cross section consists of two parallel plates connected by semi-circulator parts at each end. The field pattern in the rectangular section has been roughly approximated by straight electrical fieldlines, while the circular waveguide fundamental mode solution has been adapted for the semi-circular parts at each end.

The results of the calculated cutoff frequency are given in Table III as a function of the number of sections using two digit accuracy as above.

The measured value of the cutoff frequency was 1967.9 MHz, corresponding within 0.5% with the calculated value. The total calculation time for the values given in Table III was 23 seconds.

Another application of the method is the polarizer mentioned in Reference 1 and 2. A drawing of such a polarizer is given in Figure 3. The cutoff wavelength was calculated by using N = 80 sections and the length of the electrical fieldlines expressed in only 2 digits. For the vertical polarization the electrical fieldlines meet a discontinuity in the boundary.

It is assumed that the electri-

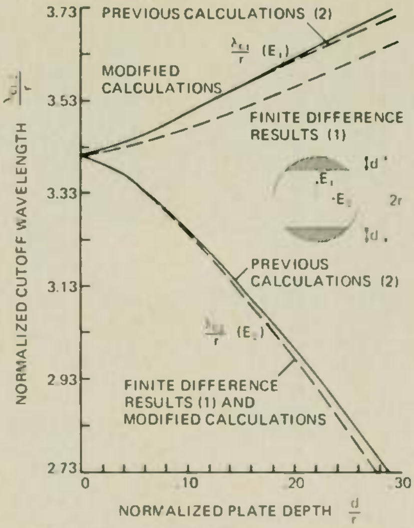

Fig. 4 Cutoff wavelengths for circular polarizer.

cal fieldlines between the parallel-plates are for the most part straight lines while the electrical fieldlines ending on the circular boundary are for the most part coincident with those of the circular waveguide. In the neighborhood of the discontinuity it is assumed that the curve of the fieldline lengths varies smoothly from the constant value between the plates to values belonging to the fieldline length of the circular waveguide.

For the horizontal polarization it has been assumed that the electrical fieldlines are the same as those of the circular waveguide up to the plates, where the electrical field is set zero.

A comparison has been made with the results for this cross section as given by Pyle and Angley[2] and also with those obtained by the finite difference solutions as given by Sinnott et al.[1] The results are given in Figure 4;

The calculation time per curve in Figure 4, consisting of 12 points, was 8 seconds.

An electroformed polarizer with one end short circuited has been constructed and the cutoff wavelength for the two polarizations precisely measured. The measured values are for d/r = 0.267, λ_c/r = 3.6282 and λ_c/r = 2.7697 respectively and are marked in Figure 4. For the horizontal polarization our calculations and measurements are consistent with the finite difference method. For the case of vertical

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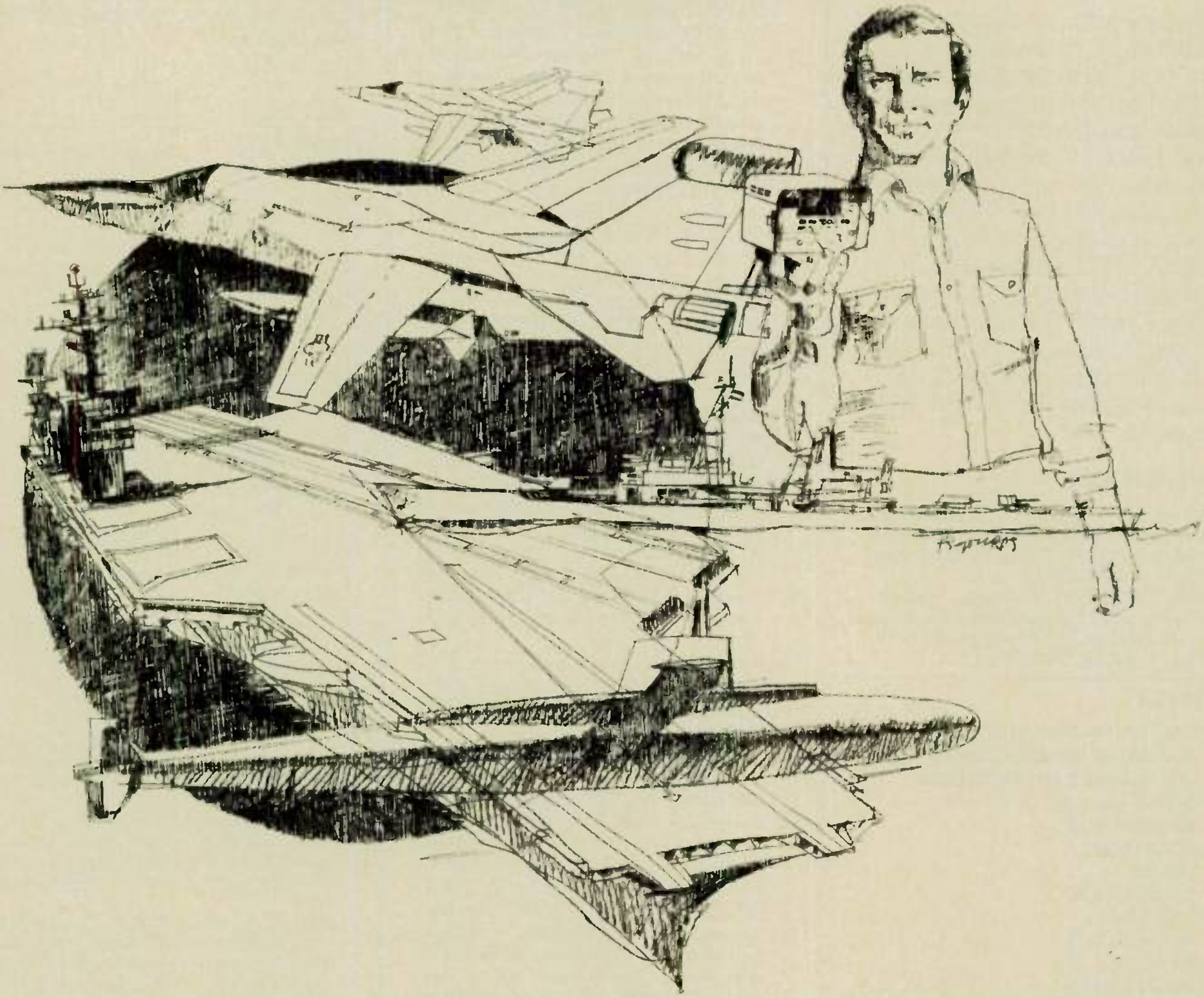

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polarization, our measurement is more consistent with the finite difference result than with our own calculations there being a discrepancy of 1.7% between the two. The probable cause lies in the difficulty of accurately estimating the field pattern in a case with a discontinuity at the boundary.

CONCLUSION

The cutoff wavelength of the fundamental mode of an arbitrary cross section, given electrical fieldline lengths estimated with an accuracy of only two digits, can easily and quickly be calculated for most practical purposes using an improvement to the method given by Pyle and Angley i.e. that the real electrical field pattern instead of straight lines are used. The given method converges as the number of sections increases and doesn't require an assumed constant error allowance.

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APPENDIX

```
    DIMENSION SOM (10),
    Z(NUMBER OF SECTIONS),
    A(2, NUMBER OF SECTIONS)
    DO 10 K=1, 10
    SOM(K)=0.D0
10  CONTINUE
    S=0.D0
    DO 20 K=2,N
20  S=S+Z(K)
    A(1,1)=S/Z(1)
    N1=N-1
    DO 30 K=2,N1
    A(1,K)=(A(1,K-1)* Z(K-1))/Z(K)-1.D0
30  CONTINUE
    DO 40 K=1,N1
40  SOM(1)=SOM(1)+A(1,K)
    DO 70 M-2,10
    NM1=N-2*M+1
    NM2=N-2*M+2
    DO 60 L=1,NM1
    S1=0.D0
    S2=0.D0
    L1=L+1
    DO 50 K=L1,NM2
    S1=S1+Z(K)
50  S2=S2+S1/Z(L)*A(1,K+1)
    A(2,L)=S2
60  SOM(M)=SOM(M)+A(2,L)
    DO 80 MM=1,NM1
80  A(1,MM)=A(2,MM)
70  CONTINUE
```


design of coupled microstrip lines is very quick, easy and sufficiently exact.

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To obtain a backward coupler with perfect match $S_{11} = 0$ and directivity $S_{13} = 0$ the following conditions have to be fulfilled

$$T_{11e} = T_{11o} \quad ; \quad T_{12e} = -T_{12o} \quad \text{(A.5)}$$

If $\theta_m = \theta_s$ ($t_m = t_s$) one can assume $b_c = 0$; $x_c = \infty$ and (A.5) directly leads to the expression (1) and in consequence to the scattering matrix given by (2).

If $b_c = 0$ and $x_c \neq \infty$ the conditions (A.5) leads to

$$\frac{2 z_m}{z_s (z_m^2 - 1)} = \frac{\sin\theta_s}{\sin\theta_m}$$
$$\frac{1}{x_c} = \frac{1}{z_s} \quad t_s - t_m \frac{\sin\theta_m}{\sin\theta_s} \quad \text{(A.6)}$$

This expression can be useful when $\theta_m > \theta_s$.

In the case of $x_c = \infty$; $b_c \neq 0$ the conditions (A.5) will be fulfilled if

$$\frac{z_m}{z_s}\left(\sqrt{1 + z_s^2} - 1\right) = \frac{\sin\theta_s}{\sin\theta_m} \quad \text{(A.7)}$$
$$b_c = \frac{1}{z_m}\left(\frac{1}{t_m} - \frac{1}{t_s}\frac{\sin\theta_s}{\sin\theta_m}\right)$$

In turn, the expressions (A.7) are employed in the case of $\theta_m < \theta_s$.

Assuming $b_c = 0$; $x_c = \infty$, the expressions (A.3), (A.4) can be also used in the case of real coupler without compensating elements.

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Synthesize Lumped Element In-Phase Power Dividers

MANLEY J. HEAD
Rockwell International
Electron Devices Div.
Dallas, TX

INTRODUCTION

A lumped element two-way in-phase equal-amplitude power divider can provide a viable alternative at UHF frequencies to iron/air-core transformers employed at lower frequencies and transmission line dividers (notably the Wilkinson) at GHz frequencies. In addition to simple power division, the lumped element approach can be employed to transform from one impedance level to another, while isolating the two output ports.

DESIGN PROCEDURE

The divider is illustrated schematically in **Figure 1**, and consists of a matching network in each arm to match resistive input impedance $2R_A$ to resistive output impedance, R_B with the requirement that the network phase shift equal 90°. Pi and Tee, in either high pass or low pass form, are two networks that may be used to accomplish this. The design equations[1] for the networks shown in **Figure 2** are:

1) *Pi Network*

$$X_1 = j\,\frac{R_1 R_2 \sin\theta}{R_2\cos\theta - \sqrt{R_1 R_2}} = \pm j\sqrt{R_1 R_2}$$

$$X_2 = j\sqrt{R_1 R_2}\sin\theta = \pm j\sqrt{R_1 R_2}$$

$$X_3 = j\,\frac{R_1 R_2 \sin\theta}{R_2\cos\theta - \sqrt{R_1 R_2}} = \pm j\sqrt{R_1 R_2}$$

$$R_b = 2R_2$$

Upper sign = low pass
Lower sign = high pass

2) *Tee Network*

$$X_1 = -j\,\frac{R_1\cos\theta - \sqrt{R_1 R_2}}{\sin\theta} = \pm j\sqrt{R_1 R_2}$$

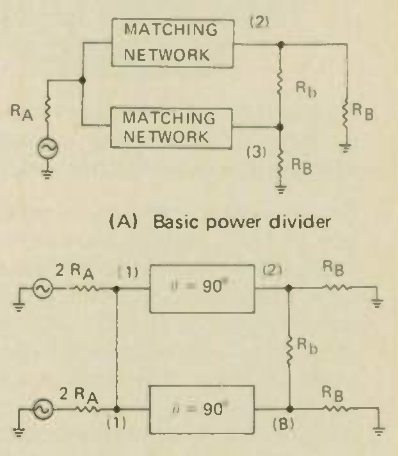
$$X_2 = -j\,\frac{\sqrt{R_1 R_2}}{\sin\theta} = \pm j\sqrt{R_1 R_2}$$

$$X_3 = -j\,\frac{R_2\cos\theta - \sqrt{R_1 R_2}}{\sin\theta} = \pm j\sqrt{R_1 R_2}$$

$$R_B = 2R_2$$

Upper sign = low pass
Lower sign = high pass

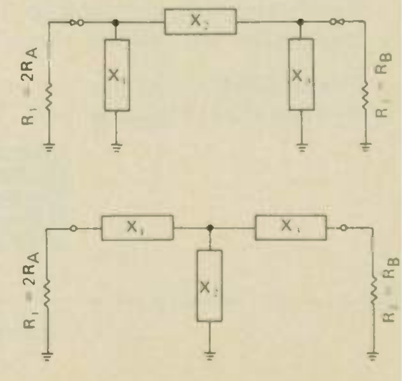
Fig. 1



(A) Basic power divider

(B) Equivalent even mode network

Fig. 2



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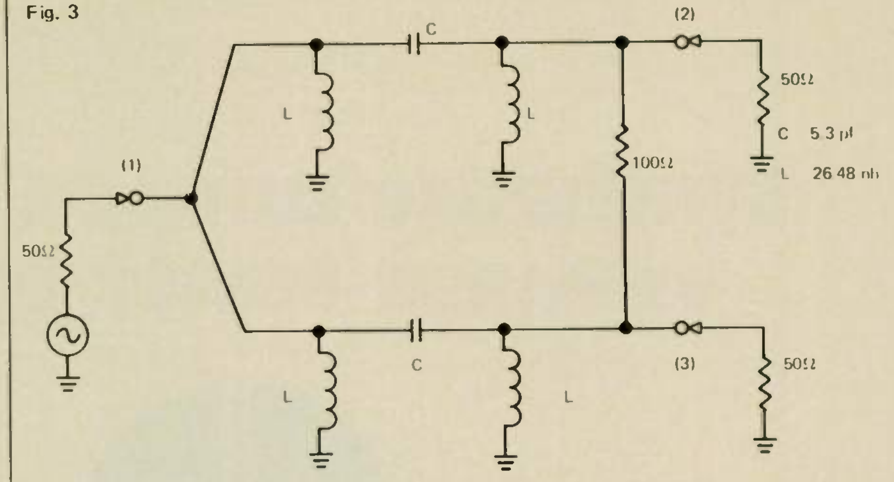
1. F. E. Terman, *Electronic and Radio Engineering*, McGraw Hill, 4th Edition, 1955, pp. 113-115.

A negative value of X indicates a capacitor, while a positive value an inductor. Note that R_1 does not have to equal R_2.

EXAMPLE

A 50 ohm divider was designed for the 400 to 450 MHz frequency range with the matching section a Pi network of the high pass type. The complete divider with calculated element values is shown in **Figure 3** along with its performance. The series capacitors employed were ceramic chips, and the shunt inductors were realized as short sections of 107 ohms transmission line on G-10 type fiberglass board. The total area of the device is approximately one square inch. It was found that most of the loss shown is due to dielectric loss under the shunt inductor. The same circuit built on teflon or ceramic substrate has about 3.1 or 3.2 dB loss in each arm.

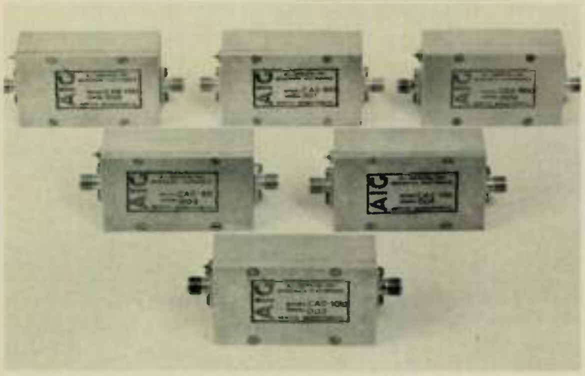
Fig. 3



FREQ.	I.L (1-2)		I.L (1-3)		ISO (2-3)		PHASE DIFF.
(MHz)	MEAS.	CAL.	MEAS.	CAL.	MEAS.	CAL.	DEG.
400	3.85	3.04	3.65	3.04	22.6	25.3	0
410	3.65	3.02	3.50	3.02	21.5	30.0	0
420	3.60	3.01	3.40	3.01	19.8	40.1	0
430	3.57	3.01	3.42	3.01	18.3	39.6	0
440	3.63	3.02	3.43	3.02	17.3	30.5	0
450	3.85	3.03	3.50	3.03	16.4	26.4	1

Since 1973, Manley J. Head has worked in the Hybrid Microelectronics Div. of Rockwell International, first as a design engineer in the RF Products Dept. and more recently as Project Engineer, UHF/MW Product Development, RF Products. Here he has designed the receiver, AGC functions, IF and detector modules for a narrow-band spread-spectrum packet radio for ARPA as well as a waveguide-to-microstrip transition for the 18-26 GHz band. Mr. Head served as Design Engineer at Electro-Data, Inc. from 1970-1973, where he helped to develop a 2-18 GHz spectrum analyzer and 2-4 GHz input octave-band doubler as well as amplifier modules for the 1 MHz to 1 GHz frequency band. From 1961 to 1970, Mr. Head was employed at Rockwell's Collins Radio Group as a technician. He is co-owner of a patent for coplanar to slot line transistion.

Multiplier Chains Do-it-yourself



A. I. GRAYZEL, INC.
Waltham, MA

Cascadable frequency doubler and tripler modules allow the system engineer to assemble his own multiplier chains. Modules are available with output frequencies from 20 MHz to 2 GHz. They are unconditionally stable, uneffected by load impedance and operate from –40° to + 85°C.

The basic module consists either of a frequency doubler or a frequency tripler followed by an amplifier. The doublers have 35% bandwidths and the triplers 15% bandwidths. The amplifier acts as a buffer so that the performance of the multiplier is not affected by the load impedance. Minimum module gain is 7 dB and minimum output power is 50 mW at the desired harmonic with an input power of 10 mW. Maximum module input power is 50 mW. The output of the modules is unfiltered and a filter must be used at the cascade output to define the desired bandwidth and to reject the undesired harmonics. The 7 dB module gain allows for a significant filter insertion loss.

Figure 1 shows the output power of the CA2-25 frequency doubler module at room temperature. The module has a nominal input frequency range of 21 to 29 MHz. The output power at the second harmonic is shown together with the output levels of the fundamental and third harmonic.

Modules may be specified to operate at any dc voltage between 15 and 24 V. Price: frequency doublers, $500. triplers, $550. Delivery: 30-45 days.

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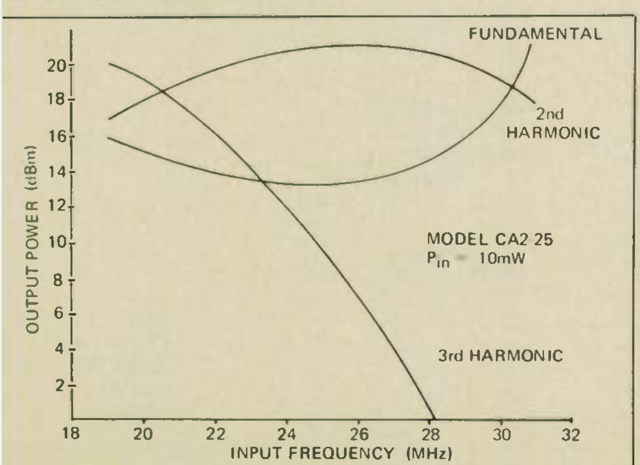

A Versatile 7-11 GHz Signal Generator

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San Diego, CA

The WAVETEK Model 907 Signal Generator for the 7-11 GHz band is the first in a series of microwave generator designs which will find wide application. The combination of solid state microwave components with digital control techniques provides operating features and characteristics which suit the instrument to a wide variety of test jobs.

A 3 1/2 digit LCD indicates the output frequency of the 7-11 GHz YIG oscillator source with an accuracy of ± 1% and a resolution of 10 MHz. Harmonics are at least -30 dBc and spurious are -55 dBc, maximum at the output. An external 0 to +5 V ramp at up to 15 Hz may be used to generate a full 7-11 GHz swept output. Isolators at the oscillator and instrument outputs eliminate frequency pulling and protect against reverse powers to +30 dBm.

Output level, also show on a 3 1/2 digit LCD, ranges from +1 to -135 dBm. Level indication accuracy ranges from ± 0.5 dB at 0 dBm to ± 6 dB at levels of -80 to -127 dBm (see **Table I**).

A PROM-based control system for the PIN attenuator leveler yields automatic output leveling to ± 1 dB in the 0 to -40 dBm range. This performance is achieved by individual tailoring of PROM's to compensate for the frequency response anomalies of the attenuator with which each is supplied. Leveling specifications over the full output range are shown in **Table I**.

A full complement of modulation modes is built into the generator. The pulse modulator offers transition times under 35 ns for pulse widths from 200 ns to 100 μs at rates from 10 Hz to 10 kHz and pulse delays from 3 μs to 1 ms. On-Off ratio is greater than 80 dB at 0 dBm output. Frequency modulation at 10 Hz to 10 kHz with 5 MHz maximum deviation and square wave amplitude modulation are available as well.

Provision is also made for external pulse, frequency and amplitude modulation and simultaneous AM and FM may be employed.

The instrument is particularly suited to radar receiver testing. Its excellent pulse modulation capabilities eliminate the need for a separate pulse generator for the vast majority of radar receiver test jobs.

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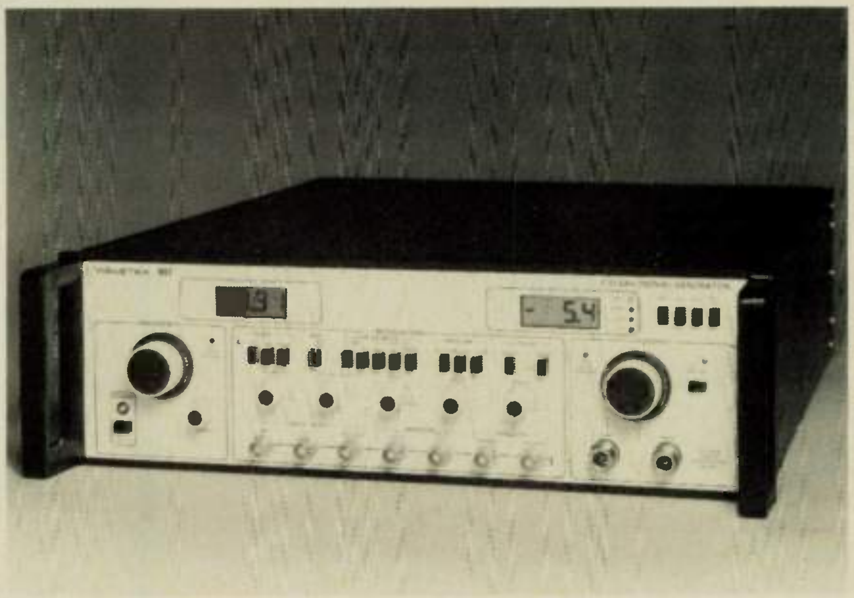

TABLE I

Model 907 – Selected Specifications

Frequency:			7-11 GHz
Resolution:		10 MHz	
Accuracy:		± 1%	
Output Level:			+1 to –135 dBm
Accuracy:	0 dBm	± 0.5 dB	
	+1 to –40	± 1.0	
	–40 to –80	± 3.0	
	–80 to –127	± 6.0	
Flatness:	0 to –40 dBm	± 1 dB	
	–40 to –80	± 2	
	–80 to –100	± 3	
	–100 to –127	± 5	
Impedance:			50 Ω
SWR:		< 1.5	
Internal Modulation:			
Pulse			
Width:	200 ns to 100 μs		
Transition Time:	< 35 ns		
Frequency:	10 Hz - 10 kHz		
On-Off Ratio:	> 80 dB at 0 dBm		
Frequency			
Maximum Dev.:	5 MHz p-p		
Frequency:	10 Hz - 10 kHz		
Weight:			40 lb.
Dimensions:			17" W. x 5¾" H. x 20¼" D.
Power:			120 W
Price:			$6795

Military Users

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

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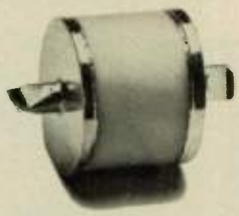
M-OV's development and environmental test laboratories are now working on the next generation of magnetrons. The smallest, most rugged and most reliable of tubes are emerging for the 80's. And beyond!

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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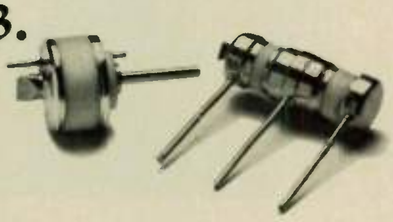

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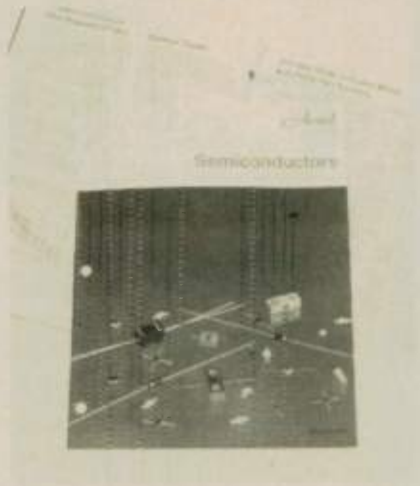
CATALOG UPDATE

1980 CATALOG

Catalog for 1980 will be the new industry standard on RF and Microwave Signal Processing Devices. This 272-page catalog offers over 200 products in the areas of amplifiers, mixers, power dividers, hybrids, attenuators and directional couplers. Includes detailed specifications which are guaranteed over temperature, typical performance curves on each device with S parameters and Smith charts) and small quantity pricing. Features new products including termination insensitive mixers, thin film amplifiers and passive devices. **Adams-Russell Co., Inc., Anzac Division, 80 Cambridge Street, Burlington,** MA 01803. (617) 273-3330.
Circle 106.

PRODUCT LINE BROCHURE

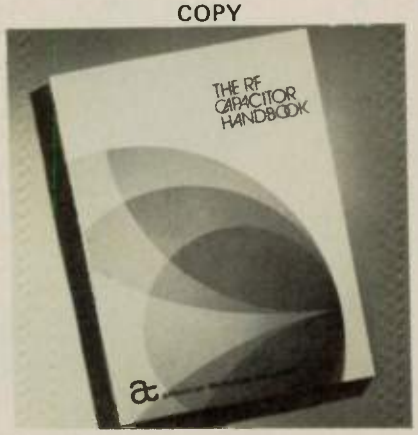


A 52-page brochure contains complete information on Aertech Industries' tunnel, Schottky barrier, PIN, NIP, and step recovery diode product lines. Included are electrical specifications, performance curves, outline drawings and an interchangeability guide, as well as a selection chart for each diode family. Of special interest are sections containing applications information and a description of diode parameters. **Aertech Industries, 825 Stewart Drive, Sunnyvale, CA 94086.**
(408) 732-0880. Circle 107.

ATTENUATORS AND OTHER COMPONENTS

Catalog features step attenuators operated by dials, TTL logic, toggle-switch, pushbutton or rockerswitch. Also included are fixed attenuators and precision loads, both low and high power; terminations, RF fuses, detectors, resistive dividers, return loss bridges, matching pads and reactive power dividers/combiners. The comprehensive catalog 79-10 contains specifications, diagrams and ordering information. **Alan Industries, Inc., P.O. Box 1203, Columbus, IN 47201. Bill Kennedy, (812) 372-8869.** Circle 108.

RF HANDBOOK: DESCRIPTIVE COPY



The RF Capacitor Handbook presents over 190 pages of detail for design considerations and uses for miniature chip and leaded RF capacitors. Includes theoretical and empirical high-frequency circuit design equations, characteristics of capacitor dielectrics, actual test data at frequencies from 100 MHz to 3 GHz, and practical design methods for increasing gain and power, dc to RF conversion efficiency, bandwidth, transistor lifetime, circuit MTBF and low-noise performance. **American Technical Ceramics, One Norden Lane, Huntington Station, NY 11746. (516) 271-9600.** Circle 109.

MICROWAVE ANTENNA SYSTEMS PLANNING

This bulletin (1080D) provides detailed mechanical data for use in planning the shipping and installation of Andrew microwave antennas. Included are shipping weights and dimensions, windload data, environmental considerations, tower interface requirements, feed clearance measurements, and an antenna system planning work sheet to facilitate system design. **Andrew Corporation, 10500 W. 153rd St., Orland Park, IL 60462.** Circle 110.

SMA RF CONNECTORS

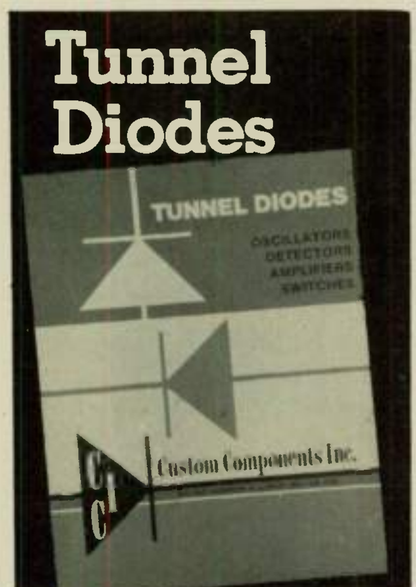
A new 16-page catalog describes a complete line of SMA coax connectors. It features over 100 standard SMA designs, most now available in low cost passivated stainless steel, as well as the gold plated units. It complements MIL-C-39012 SMA brochure describing MIL Spec QPL connectors. **Automatic Connector, Inc., Subsidiary of ASU Industries, Inc., 400 Moreland Road, Commack, New York, NY 11725. Edward S. Selig, (516) 543-5000.** Circle 111.

STANDARD RF AMPLIFIER

Catalog includes specifications and related product application and information pertaining to five (5) basic series of single and multi-stage amplifiers and typical cascaded amplifier combinations. These amplifiers are standard modular, plug-in hybrids and are available in 4 Pin DIP, TO-8 and TO-12 packages. Specifications for voltage variable attenuators are also included. All standard products are screened to MIL-STD-883B. **Aydin Vector Division, Newtown, Industrial Commons, P.O. Box 328, Newtown, PA 18940. (215) 968-4271.** Circle 112.

RF WATTMETER BROCHURE

Introduction of a new series of multipurpose digital RF directional wattmeters is the subject of a new brochure by THRULINE® designer. The microprocessor-based model 4381 RF Power Analyst™ offers measurement of several signal parameters in addition to bi-directional power, and the brochure (PA4381-1179) highlights application of SWR, return loss, % modulation, dBm, peak envelope power functions. Full specifications are included. **Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), OH 44139. (216) 248-1200.** Circle 113.



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CAPACITOR CATALOG

This catalog describes fixed, parallel plate, ceramic dielectric, uncased, single wafer, microwave chip style capacitors. These capacitors are intended for use in microcircuits, hybrids, and spacecraft equipment as by-pass, coupling, tuning and filtering elements. These capacitors are capable of operating over the temperature range of −55°C to +150°C and frequency ranges of up to 36 GHz. **Dielectric Laboratories Inc., 69 Albany Street, Cazenovia, NY 13035. John Tinkler, (315) 655-8710.** Circle 114.

AUTOMATIC FREQUENCY COUNTER APPLICATION NOTE

An eight-page application note provides in-depth information on the Model 451 microwave frequency counter characteristics and theory of operation. Counter allows measurement of signals covering 300 MHz to 18 GHz, frequency range, with pulse widths as narrow as 100 nanoseconds, without external gating or manual tuning. Note also describes measurement techniques generally associated with pulsed RF and time-varying CW signals. **EIP, 3230 Scott Blvd., Santa Clara, CA 95051. Howard Lurie, (408) 244-7975.** Circle 115.

1980 ENGELMANN CATALOGS

These two catalogs describe a complete line of passive and active RF and microwave components in the DC-18 GHz frequency range. Included are 4 and 8 pin plug-in, flat packs and the common SMA, type N, BNC, and TNC connector versions.

The complete line includes attenuators, terminations, couplers, hybrids, power dividers, bias tees, diode switches, oscillators, mixers, monitors, and tuners.

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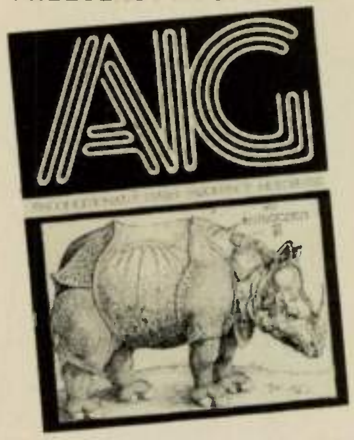
FREQUENCY MULTIPLIERS



This catalogue describes a complete line of varactor frequency multipliers from 10 MHz to 10 GHz. In addition the catalogue describes a line of mod-ule-pliers which are cascadable frequency doublers and triplers. This is a new product line presently available from 10 MHz to 2 GHz. The catalogue items include multiplication factors to 16 and bandwidths from single frequency to 35%. Passive and active multiplier chains are available at low, medium and high power. Full specifications are included. A. I. Grayzel, Inc., **3 Common St., Waltham, MA 02154. (617) 893-4210.**

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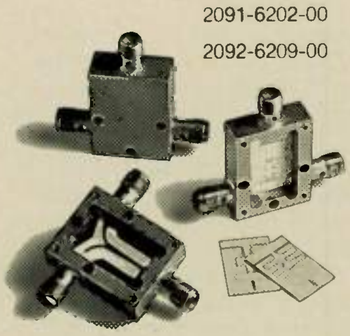
2091-6202-00	2.0 - 4.0	1.35:1	20	0.6
2092-6209-00	4.0 - 18.0	1.70:1	16	0.1 + 0.08f

(f expressed in GHz)
*Loss measured above 3dB Power Split.



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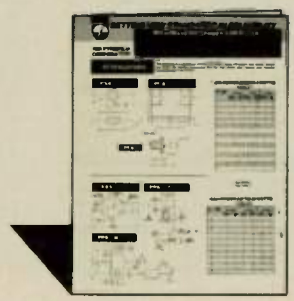
PYROFILM SHORT FORM CATALOG



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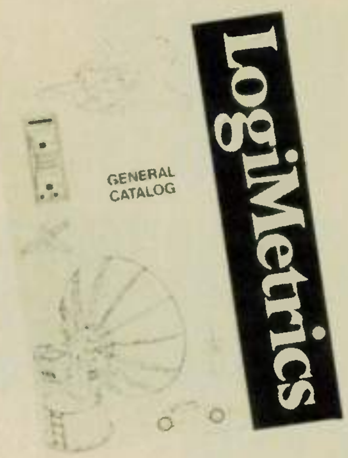
REVISED NC4 BROCHURE

An 8-page 4 GHz Low Noise Amplifiers brochure provides technical information, applications data, and specifications for the complete series of NC4 Low Noise Amplifiers for LNR. Includes data for LNR's newest Models NC4-51 and NC4-61 LNA's designed specifically for continuous operation in unattended terminals. Amplifiers are ideal for use in any size satellite earth terminals. An extensive description of the Ultra-Low Noise Models NC4-33 and NC4-38 is also included. **LNR Communications, Inc., 180 Marcus Blvd., Hauppauge, NY 11787. Jeannie Piotrowski, (516) 273-7111.** Circle 119.

GENERAL CATALOG



This 48-page catalog features a full line of power amplifiers operating over the frequency range of 500 MHz to 18 GHz at power levels of 1 watt to 1000 watts for both CW and pulse amplifications. This publication also includes a description of LogiMetrics' Broadband Amplifier Systems for use in EMI-RFI test systems, EW simulators, radar platform simulators, and communications systems. **LogiMetrics, Inc., 121-03 Dupont St., Plainview, NY 11803. (516) 349-1700.** Circle 120.

(continued on page 120)

MERRIMAC INDUSTRIES CATALOG

This comprehensive 320-page catalog describes complete line of signal processing components and integrated networks employing lumped element designs, in the frequency range of dc to 4 GHz. Catalog M-80 has also been designed to provide customers with reliability data in the form of MTBF calculations for each different product area and consists of numerous calculations under the guidelines of MIL-Handbook-17. **Merrimac Industries, Inc., 41 Fairfield Place, West Caldwell, NJ 07006. (201) 575-1300.** Circle 122.

CATALOG 30

Microlab/FXR's Catalog 30 provides full information on extensive line of microwave coaxial and waveguide components. New product areas include double ridge waveguide couplers, samplers, dividers and loads. Broadband and high power coaxial couplers are featured. **Microlab/FXR, Ten Microlab Road, Livingston, NJ 07039. Raymond Vincent, (201) 992-7700. Circle 123.**

DUAL-MODE PHASE SHIFTERS

Forty-eight page brochure includes selected information on dual-mode phase shifter applications data, RF circuit design considerations, driver considerations, and cost trade-off info. Appendices include three baseline technical articles from IEEE transactions on design and manufacture; dual-mode latching reciprocal ferrite phase shifters; and application of latching ferrite phase shifters to light weight electronically scanned phased arrays. A highly technical dissertation covering both applications and theory. **Microwave Applications Group, 10019 Canoga Ave., Chatsworth, CA 91311. (213) 882-7333. Circle 121.**

TWO NEW CATALOGUES FROM MICRONETICS

Catalogue #MC/180 features coaxial switches, waveguide switches, dummy loads, crystal detectors, bolometers, and RF micropotentiometers. Catalogue #SSN5/679 offers a broad line of solid state noise components. Included are: RF noise sources – coaxial & waveguide, standard noise modules, noise generators custom modules, RF noise source with directional coupler, high level noise instruments and broadband noise sources. **Micronetics, Inc., 36 Oak Street, Norwood, NJ 07648. (201) 767-1320. Circle 125.**

MINIATURE (OSM) ATTENUATORS AND TERMINATIONS

Eight-page catalog covers a line of miniature (OSM) microwave attenuators and terminations. The fixed, coaxial attenuators and miniature terminations are typically broadband devices with frequency ranges up to dc-18 GHz (attenuators) and dc-26.5 GHz (terminations). Attenuators and terminations meet MIL-E-5400 and MIL-E-16400 environmental requirements. Attenuators offered in 1 dB steps up to 20 dB. **Microwave Components Div., Omni Spectra, Inc., 21 Continental Blvd., Merrimack, NH 03054. John C. Callahan, (603) 424-4111. Circle 128.**

PRODUCT BOOKLET

Our latest product information, the Spectrum Update, describes MPD's latest achievements in solid state high power RF amplifiers covering the 2 MHz to 8.4 GHz frequency spectrum. Featured are 1 kilowatt amplifiers for various applications. Microwave Power Devices, Inc., 330 Oser Avenue, Hauppauge, NY 11787. Bill Liebman, (516) 231-1400. Circle 118.

MRC CATALOG

Latest catalog will show you the way to better system performance. One of our specialties is broadband components with optimum match for ECM applications. Our product line features state-of-the-art components in double-ridge and rectangular waveguide, coax and slabline. Typical examples include absorption filters, adapters, antennas, bends, ultra-flat couplers, delay lines, ferrite devices, hybrids, power dividers and combiners, samplers, pressure windows and terminations. Microwave Research Corporation, 1429 Osgood Street, North Andover, MA 01845. (617) 685-2776. Circle 126.

GUIDE TO SIGNAL PROCESSING COMPONENTS

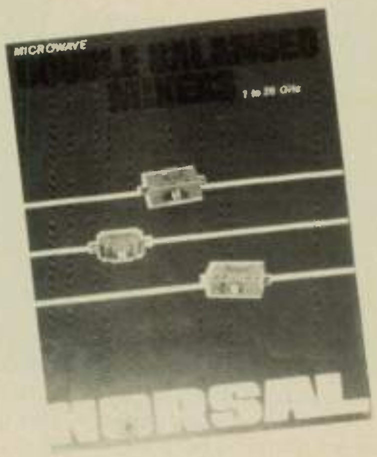
Mini-Circuits Laboratory will provide its free 205-page catalog, giving over 1,000 performance curves, technical application notes, reliability data, environmental specifications, frequence selection guides, features of each components, temperature ratings, schematics and dimensions, as well as pricing information. Mini-Circuits Laboratory, 2625 East 14th St., Brooklyn, NY 11235. Harvey Kaylie, (212) 769-0200. Circle 124.

(continued on page 122)

SYSTEM COMPONENTS SUBSYSTEMS

This catalog describes a comprehensive line of microwave system components and subsystems. Among the standard components listed are IF and video components, bipolar and GaAs FET amplifiers, mixers and mixer preamplifiers, voltage and mechanically tuned oscillators, crystal oscillators, phase-locked sources and integrated RF front ends. A full product line of frequency converters and receivers for use in satellite communication, meteorological satellite and telemetry applications are described. Miteq Inc., **100 Ricefield Lane, Hauppauge, NY 11787. (516) 543-8873.** Circle 104.

MIXER CATALOG



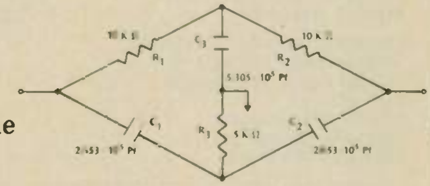
Product information on broadband microwave mixers to 26 GHz is described. Complete specifications and curves are given for microwave IF, biasable and standard double-balanced mixers. Applications include ECM receivers, OEM equipment as well as up/down converters. **Norsal Industries, Inc., 85D Hoffman Lane South, Central Islip, NY 11722. Norman Spector, (516) 231-4040.** Circle 127.

PACIFIC MEASUREMENTS, INC.

New from Pacific Measurements, Inc., is this four-page, two-color data sheet describing a more powerful version of its Model 1038 swept frequency measurement system. Identifying the updated version as the Model 1038/D-14, the data sheet describes the instrument in some detail, lising an Interface Bus option and a Refresh Memory as entirely new features. **Pacific Measurements, Inc., 488 Tasman Drive, Sunnyvale, CA 94086. (415) 734-5780.** Circle 129.

CIRCUIT DESIGN USING PROGRAMMABLE CALCULATORS

J. Lamar Allen, Ph.D. and Max Medley
260 pages. 8-1/2 x 11. Hardcover. June 1980. Price not set.



This revolutionary new book redefines the state-of-the-art in circuit analysis and design: now any engineer with a personal programmable calculator can slash design time, save money, and increase efficiency *without using large computer systems.* By following the simple instructions set forth in detail in this new volume, your TI-59 or HP 67-97 becomes an extremely powerful design tool — one which rivals the capabilities of large scale CAD programs.

FREQ (HZ)	GAIN (dB)
50	-25.62245078
60	-89.39062706
70	-27.35552292

The programs detailed herein show how difficult problems involving highly complex circuits need only be solved once; the solution can be programmed and used years later without investing any additional time and effort. In most cases, the user need only load the desired program, enter the necessary data, and begin execution.

Extremely powerful and simple to use, these programs offer fingertip convenience and pinpoint accuracy at significant cost savings. So take the drudgery out of circuit analysis and put the creativity back in!

CONTENTS: Introduction/Using the TI-59 & HP 67-97: Two-Port Analysis, Interconnections and Parameter Conversions, Lumped and Distributed Elements, Special Two-Ports, Mapping and Configuration Conversion, Ladder Network Analysis/HP-41C Compatibility/Design Examples/TI-59 Program Listings/HP 67-97 Program Listings.

ARTECH HOUSE BOOKS • 610 Washington Street • Dedham, Massachusetts 02026

MICROWAVE COMPONENTS HANDBOOK

A 36-page Microwave Components Handbook includes high power components, ferrite products, rotary joints, microwave front ends, filters, "majestic tees," signal samplers, pressure windows, circulators, isolators and attenuators. Eight pages are devoted to custom products and design checklists in the filter, front end and rotary joint sections. Has 100 photographs plus many graphs and extensive tables. Lists SWR, insertion loss, power, temperature ranges and frequency. **Premier Microwave Corp., 33 New Broad St., Port Chester, NY 10573. Jules Simmonds, (914) 939-8900. Circle 130.**

CATALOG SUPPLEMENT

A new supplement to a 240-page comprehensive catalog of microwave components, assemblies, amplifiers and instruments meeting requirements from dc - 50 GHz is now available. The contents include hundreds of models of amplifiers, attenuators, directional couplers, filters, hybrids, instruments, mixers, phase-shifters and line-stretchers, power dividers, rotary joints, switches, terminations, video detectors and diode holders, as well as the company's WIRELINE series. The supplement is issued in conjunction with Sage's 25th anniversary celebration and for the MTT-S symposium. There is no charge for either the catalog or its supplement. **Sage Laboratories, Inc., 3 Huron Dr., Natick, MA 01760. Tony Cieri, 617/653-0844. Circle 132.**

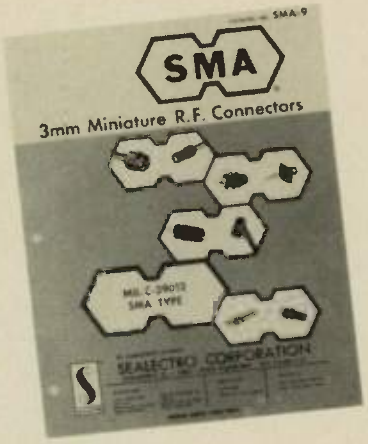
(continued on page 124)

IFM DISCRIMINATORS

SA
SANDERS
ASSOCIATES, INC.

A brochure describing a complete line of Instantaneous Frequency Measurements (IFM) discriminators, available in octave bands for frequency ranges between 2 - 18 GHz, is available from the Microwave Division of Sanders Associates, Inc. The booklet describes the units which are TTL or ECL compatible and feature miniaturized RF frequency discriminators which can be customized to specifications. Mean frequency resolution is 1.0 MHz. **Microwave Division, Sanders Associates, Inc.,** Manchester, NH 03103. (603) 669-4615. Circle 133.

SMA CATALOG FROM SEALECTRO



A new SMA catalog containing expanded listings of connector types is now off the press and ready for distribution. The SMA-9 catalog contains several new connectors in the SMA range. A complete line of hermetically sealed "spark-plug" connectors highlights the new additions. Additional tooling kits are also listed. **Sealectro Corporation, RF Components Division,** Mamaroneck, NY 10543. (914) 968-5600. Circle 134.

RF AND MICROWAVE POWER TRANSISTOR CATALOG

Solid State Microwave, a division of Thomson-CSF, has released its new catalog offering a complete line of RF and microwave power transistors for communications, radar, and avionics applications. These devices are characterized from 2.0 MHz to 2.0 GHz for most FM, AM, pulse, sideband and linear applications. Also many gold metalized broadband internally matched structures are offered. **Solid State Microwave, Montgomeryville Industrial Center, Montgomeryville, PA 18936. Jeff Holmquest, (215) 362-8500.** Circle 135.

1 GHz SIGNAL GENERATOR BROCHURE

A new 6-page brochure on Model 1702 synthesized signal generator that covers the range from 100 Hz to 999.9999 MHz in a single range with 100 Hz resolution. This signal generator meets the most demanding communications and system requirements for precise frequency generation. The Model 1702 can include optionally remote programming in accordance with IEEE-488 of frequency and output level. **Systron-Donner Corp., Instrument Div., 2727 Systron Drive, Concord, CA 94518. (415) 671-6629. Circle 136.**

1980 TRAK CATALOG

TRAK Microwave Corporation celebrates its 20th year with an exciting new 100-page catalog covering most microwave product needs. Included are technical data and application notes on oscillators, comb generators, multipliers, IF amplifiers, FET amplifiers, power amplifiers, super components, and ferrite devices. This updated catalog features the latest in technological advances in both active and passive components using many of TRAK's own advanced materials processing techniques. **TRAK Microwave Corporation, 4726 Eisenhower Blvd., Tampa, FL 33614. Tom Roberts, (813) 884-1411. Circle 138.**

NEW CATALOG

Transco announces its new 98-page Microwave Antenna Catalog. This document covers the entire product line including stub, blade, surface wave, telemetry, spiral horn and coplanar slot. Special sections are devoted to qualification and environmental test capabilities, with selection of the most frequently used nomographs and conversion charts. Detailed dimension information – including technical specifications with charts, tables and photographs – makes this a valuable aid for engineering and support activities. **Transco Products, Inc., 4241 Glencoe Avenue, Venice, CA 90291. Roy E. Williams, (213) 822-0800. Circle 139.**

(continued on page 128)

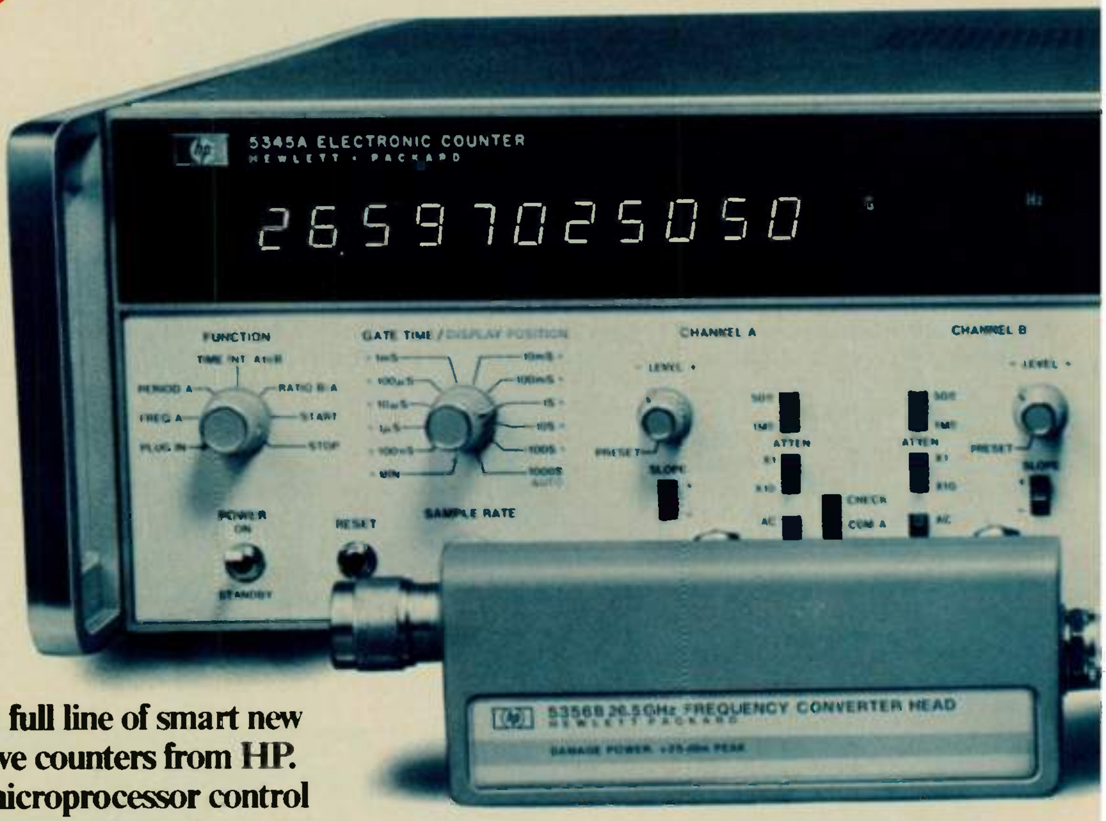
MICROWAVE COMPONENTS CATALOG

Catalog contents includes sections on standard, four-port and special designed circulators and isolators; microwave and waveguide filters; coaxial multiplexers; integrated components; SPDT miniature and coaxial switches; miniature and standard transfer switches; standard and miniature (3 to 8 position) multi-throw Switches, plus many photographs and schematic drawings for your reference. **Teledyne Microwave, 1290 Terra Bella Ave., Mt. View, CA 94043. Ken Mills, (415) 968-2211. Circle 137.**

HP: EXPERIENCE IN MICROWAVE TECHNOLOGY

NOW— PULSED or CW TO 40GHz

HP's Smart, New



Here is a full line of smart new microwave counters from HP. All use microprocessor control for added convenience from the front panel keyboards and for ease of automatic measurements.

These counters also have an optional HP-IB† interface for use in fully automatic measurement systems controlled by calculators or computers. Select the instrument that has the capabilities and performance to match your needs.

The first complete microwave counter—CW or Pulsed to 40 GHz.

The industry's highest performance microwave frequency counter is the new HP 5355A—it fulfills the frequency and time measurement needs of engineers and technicians working with pulse modulated and CW microwave signals.

With a single set up, using a single input, you can quickly measure these radar parameters:

- Average frequency in the pulse
- CW microwave frequency (STALO, magnetrons)
- Pulse repetition frequency
- Pulse width
- Pulse repetition interval

External gating enables profiling of frequency changes within the pulse—using sample sizes as small as 20 ns. Interchangeable frequency heads offer the flexibility of selecting the frequency ranges (to 40 GHz) and connectors (Type N, SMA, APC 3.5, waveguide) to match your present system. Higher frequency capability can be added later. HP 5345A mainframe, $4900.* HP 5355A plug in, $4150.* HP 5356A 18 GHz Head, $1300.* HP 5356B 26.5 GHz Head, $1800.* HP 5356C 40 GHz Head, $2400.*

HP 02923 C

†HP's implementation of IEEE Standard 488 and the identical ANSI Standard MC1.1

Microwave Counters:

The most capability in a CW counter for the price — CW to 26.5 GHZ.

HP's new 5343A Counter offers fully automatic CW frequency measurements to 26.5 GHz in a highly portable package. Wide FM tolerance is achievable along with high input sensitivity and automatic amplitude discrimination — allowing the counter to automatically measure the largest signal present within the counter's spectrum. Microprocessor controls provide the convenience of front panel keyboard entry. This includes an mx±b mode where the 5343A directly measures a receiver's local oscillator and displays the tuned receiver frequency. The microprocessor multiplies the LO frequency by the correct harmonic number and then offsets it by the receiver's IF. All of this in a highly portable package! $5200*

HP's 5342A features most of the 5343A's capabilities up to 18 GHz. An optional amplitude measurement capability automatically measures and simultaneously displays both the frequency and amplitude of the incident signal. Both frequency and amplitude offsets are conveniently entered from the front panel keyboards. FM tolerance of at least 50 MHz peak-to-peak allows you to confidently measure heavily loaded communications carriers on-line even with active traffic. $4500*

For more information on the smart new counters from HP contact your nearby HP sales office or write Hewlett-Packard, 1507 Page Mill Road, Palo Alto, CA 94304.

*Domestic U.S. prices only

HEWLETT PACKARD

(from page 125)

PRODUCT LINE CATALOG

Catalog describes line of passive and non-passive devices including: analog and digitally controlled PIN diode attenuators and phase shifters, diode switches, bi-phase modulators, bias tees, directional couplers, video detectors, dc blocks, polar and voltage discriminators, duplexers, 90° and 180° hybrids, diode limiters, mixers, power dividers, and generators. Also features integrated assemblies and sub-assemblies. Provides full specifications, outline drawings, ordering and information. Triangle Microwave, Inc., 11 Great Meadow Lane, East Hanover, NJ 07936. Martin Rabinowitz, (201) 884-1423. Circle 140.

DATA SHEETS

Western Microwave announces its new line of Thin Film Component Data Sheets covering RF amplifiers, double-balanced mixers/mixer-preamps, voltage variable attenuators and drop-in mixers. A dynamic new brochure displaying capability in MIC, and offering "The Western Microwave Solution" completes the set. Western Microwave, 1271 Reamwood Ave., Sunnyvale, CA 94086. (408) 734-1631. Circle 141.

WILTRON 1980 CATALOG

1980 Catalog describes complete line of microwave measurement systems, instruments, and components. New products include the 5610 Automated Network Analyzer, sweep generators (100 kHz - 40 GHz), scalar network analyzers (10 MHz - 34 GHz), SWR autotesters and bridges, RF analyzers, precision terminations, adapters, air lines, RF detectors, limiters, and digital phase meters. Also serves as a microwave measurements handbook. Notes recommend test procedures and instrumentation for making the most accurate measurements. Wiltron, 825 Middlefield Road, Mountain View, CA 94043. (415) 969-6500. Circle 142.

Showcase your capabilities at MTT-S 1981

Location: Los Angeles, California
Site: Los Angeles Bonaventure
Dates: June 15-17, 1981

The MICROWAVE JOURNAL will again provide exhibition management for the 1981 MTT-S Symposium/Exhibition.

Early participation will assure your choice of a preferred location at this, the most important annual microwave meeting to be held in the United States.

With the exhibitor list growing yearly, space is sure to be at a premium. Contact MICROWAVE JOURNAL headquarters now at (617) 326-8220. . .or visit the Journal booth at MTT-S 1980 for further details.

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Send me additional information on exhibiting at MTT-S 1981.

Name ____________________

Title ____________________

Organization ____________________

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State ____________ Zip ____________

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1980 MTT-S EXHIBITORS

123 organizations are scheduled to exhibit at Washington, D.C., May 28-30, 1980.

Adams-Russell
Anzac Div.
Aercom Industries
Aertech Industries
AILTECH
Airtron Div.
Alan Industries
Alpha Industries, Inc.
American Technical Ceramics
Amplica, Inc.
Anaren Microwave, Inc.
Andersen Laboratories
Arra, Inc.
Artech House
Automatic Connector, Inc.
Avantek, Inc.
Beacon North, Inc.
Bekr Industries, Inc.
Bendix Corporation
Brandt Electronics, Inc.
Cablewave Systems, Inc.
California Eastern Laboratories, Inc.
Cir-Q-Tel, Inc.
Com Dev Ltd.
Compac Development Corp.
Compact Engineering, Inc.
Crystek Corporation
Delta Microwave
Diamond Antenna & Microwave Corp.
Dielectric Laboratories, Inc.
Doss Electronics, Inc.
Dynatech/UZ Inc.
EEV, Inc.
EIP Microwave
Emerson & Cuming
Engelmann Microwave Company
Epsilon Lambda Electronics Corp.
EPSCO Microwave, Inc.
Frequency Engineering Labs.
Frequency Sources, Inc.
Fujitsu America Inc.
Gamma-f-Corp.
General Electric Co.
General Microwave
W.L. Gore & Associates, Inc.
A. I. Grayzel, Inc.
Harshaw Chemical Co.
Hewlett-Packard Co.
Horizon House
Hughes Aircraft Co.,
Electron Dynamics Div.
Integra Microwave
Isotronics
J.F.D. Electronic Components Div.
MuRata Corp. of America
Johanson Mfg. Co.
Journal of Electronic Defense
KDI Pyrofilm Corp.
K&L Microwave, Inc.
Keene Corp./Chase Foster Div.
Krytar
Logimetrics, Inc.
3M Company, Electronic
Products Div.
C. L. Malinow & Co., Inc.
Marconi Instruments
MAST Microwave
Materials Research Corp.
Maury Microwave Corp.
Megavolt
Melco Sales, Inc.
Merrimac Industries, Inc.
Microlab/FXR
Micronetics, Inc.
Microphase
Microteck Co., Ltd.
Micro-Tel Corp.
Microwave Applications Group
Microwave Associates Inc.
Microwave Journal
Microwave Power Devices, Inc.
Microwave Research Corp.
Microwave Semiconductor Corp.
Microwave Systems News
Microwaves
Military Electronics Counter-
measures
MITEQ
Motorola
Narda Microwave Corp.
Norsal Ind., Inc.
Nurad
Omni Spectra, Inc.
Pacific Measurements Inc.
Parametric Industries, Inc.
Plessey Optoelectronics and
Microwave
Polarad Electronics, Inc.
Premier Microwave Corp.
Q-Bit Corporation
Raytheon Co.
Rockland Systems Corp.
Sage Laboratories, Inc.
Sanders Associates, Inc.
Solid State Microwave, Div. of
Thomson-CSF Components
Corp.
Solitron/Microwave
Space Microwave Labs, Inc.
Summit Engineering
Systron-Donner Corp.
Tekform Products Company
Tektronix Inc.
Telecommunications
Teledyne Microwave
Texscan Corporation
Thinco
TRAK Microwave Corp.
Transco Products, Inc.
TRW RF Semiconductors
A.J. Tuck Company
Uniform Tubes, Inc.
Uni-Tel Ltd.
Varian Associates, EDG
Vari-L
Watkins-Johnson Co.
Wavetek
Weinschel Engineering
Western Microwave Lab
Wiltron
Zeta Labs, Inc.

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Microwave Products

Instrumentation

LINK ANALYZER FOR DIGITAL RADIO TESTING

A baseband plus sweep generator (HP 3707A BB + Sweep Generator) provide a test system usable with existing microwave link analyzer equipment to provide a more economical test system. This instrument is designed to drive an HP 8620C Up Converter to give a swept, FM source from 0.5 to 18 GHz. This source, when coupled with a standard IF/BB receiver, will measure transmission distortion in a radio link. Unit provides a single, low-frequency tone of 250 or 500 kHz (internally selectable) which allows measurement of linearity and group delay. Price: $1950. Del: 8 wks. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.** Circle 164.

WIDE-FREQUENCY SYNTHESIZER SPANS 10 MHz to 18 GHz

WJ-1292 is a frequency synthesizer which covers the 10 MHz to 18 GHz range and provides stable, clean, keyboard-selected signals with 100 kHz resolution. It can be programmed for digital sweeps over any portion of the range. With options, coverage can be extended up to 40 GHz. Computer or IEEE-488 interfaces can be specified. Unit comes in a single 5¼" H x 22" D rack mounting. **Watkins-Johnson Co., Palo Alto, CA. (415) 493-4141.** Circle 166.

MICROPROCESSOR-CONTROLLED POWER METER

A microprocessor-controlled power meter, Model 4200, stores calibration information for one-four interchangeable power sensors in non-volatile memory. Front panel entry automatically corrects the display using interpolated Cal Factors. Second channel option allows simultaneous use of two power sensors. Offers automatic zeroing and calibration against an internal 50 MHz power reference. Power range is 1 mW-100 mW, frequency range is 1 mW-100 mW, frequency range is 100 kHz to 18 GHz. Price: $1800, IEEE-488 bus option, $375, Second channel, $400. **Boonton Electronics Corp., Parsippany, NJ. Wallace F. White, (201) 887-5110.** Circle 163.

BROADBAND RF ABSORPTION MILLIWATTMETER

Model 6257 is a broadband TERMALINE® RF milliwattmeter which terminates and measures output of low power signal sources directly from 100 kHz to 1000 MHz. A front panel, range switch selects either 0-200 mW, 800 mW or 3W ranges, without a transfer of crystals. All ranges are field-calibratable and attenuator options can expand the maximum full-scale range. Model's diode detector also serves as a demodulator of AM transmission envelopes; the demodulated signal is available at a front panel jack. SWR of wattmeter is below 1.1 to 512 MHz and less than 1.15 to 1000 MHz in 50 Ω coaxial systems. Price: $265. **Bird Electronic Corp., Cleveland (Solon), OH. H. H. Heller, (216) 248-1200.** Circle 162.

SPHERICAL NEAR-FIELD ANTENNA ANALYZER

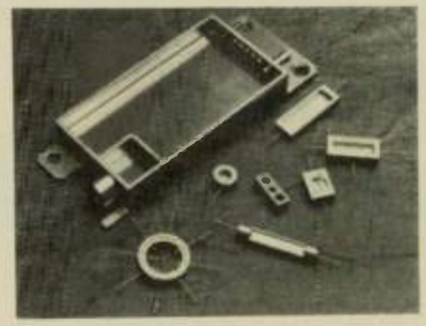
Model 2022 is a spherical near-field antenna analyzer which automatically collects near-field antenna data and transforms it to any measurement distance, including infinity. This data transformation capability is accomplished with the use of a spherical near-field software package. Once transformed, antenna parameters including gain, directivity, polarization and boresight can be automatically computed and displayed. Display capabilities include planar plots, three-dimensional plots, and line contours and complete data listings. Equipment may be operated in the conventional far-field data collection mode whenever near-field testing is not wanted. **Scientific-Atlanta, Inc., Atlanta, GA. Donald A. Pisarcik, (404) 449-2000.** Circle 165.

HIGH LEVEL NOISE INSTRUMENT SERIES

NOD 5100 series of noise instruments are intended for use as reference standards and as alignment sources for mixers, amplifiers, filters, etc. in place of sweep generators. Units are available with such options as inputs for external markers and high power levels (1 W). Frequency ranges are 10 Hz to 20 kHz to 300 MHz - 1 GHz; flatness is ± 0.5 dB; SWR is 1.5. Input power is 115 Vac at 60 cycles and operating temperature range is 0°C to +65°C. Temperature sensitivity is < 0.01 dB/°C and voltage sensitivity is < 0.1 dB/°DV. Attenuation range is 0-10 dB (1 dB steps); 0-100 dB (10 dB steps) and RF output is 10 dBm min. (10 mW). **Micronetics, Inc., Norwood, NJ. (212) 867-5464.** Circle 167.

Materials

SERIES OF PRIMARY-SEAL MODULES



A line of primary-seal microwave modules come in five basic configurations: circular, "T", rectangular, rectangular with ears, and coaxial. Modules are manufactured with primary seals in the body material itself. Body of the part is coined, rather than machined, to offer greater dimensional stability. **Isotronics, Inc., New Bedford, MA. Ralph Hickok, (617) 998-2000.** Circle 160.

BROADBAND ABSORBER SERIES

ECCOSORB® HT is a series of broadband microwave absorbers designed for use from −70°F to +750°F (−57°C to 399°C). Power handling of material is dependent upon heat transfer situation — typical value is 10-15 W/sq. in. allowing air to circulate at the back surface of the absorber. Product is supplied in the form of lightweight unicellular foamed ceramic bricks that have an array of conical holes drilled into them. Size: 12" x 18" (0.30 m x 0.46 m); nominal thickness is 2" (5.1 cm) or 3" (7.6 cm), depending upon frequency coverage. **Emerson & Cuming, Canton, MA. Jeanne B. O'Brien, (617) 828-3300.** Circle 161.

Components

WIDEBAND SOLID STATE SWITCH FOR 10-1200 MHz BAND

An all solid state SPDT switch, Model SW-1200-2, covers the 10-1200 MHz frequency range. Unit features terminated output ports in the "off" state, 1.5 dB maximum insertion loss in the "on" state and 50 dB minimum isolation in the "off" state. Impedance is 50 ohms, SWR is 1.15 max. and third order intercept point is + 55 dBm. Maximum RF power is 10 W and dc power requirement is ± 5V at 80 ma. Switching time is 5 μs max. and switching transients are below −60 dBm. Del: 60 days. **American Microwave Corp., Damascus, MD. (301) 253-6782.** Circle 172.

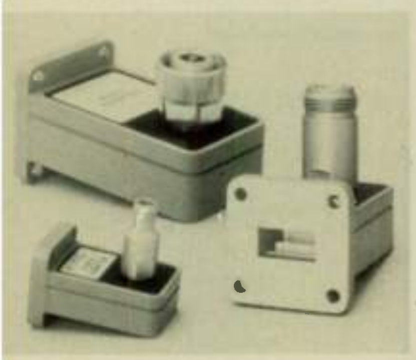
GaAs CW IMPATT SOURCE

The GaAs CW IMPATT source, Model AT-SC30, is suitable for use as an injection locked or free-running source of microwave power at 8-10 GHz. Power output is 1.5W ± 1 dB over the 0° to 60°C heat sink operating temperature range. Typical mechanical tuning range is ± 200 MHz. Source requires a constant current dc supply of 200 mA at 48 V; dc to RF efficiency is 15%, nominal. Frequency stability over temperature is ± 10 MHz, typ. Size: 3¼" L x 1" D. Weight: 3 oz. Price: $1100 (1-9 qty). Avail: 30-45 days. **Ad-Tech Microwave, Inc., Scottsdale, AZ. R. C. Havens, (602) 941-1290.** Circle 169.

10 GHz GUNN DIODE OSCILLATOR WITH ADJUSTABLE POWER

A Gunn diode oscillator, Model MT-A59, provides 10-100 MW of adjustable RF output power at 10 GHz. Unit provides level set tuning, with mechanical frequency adjustment to give a 5% screwdriver tuning range. Oscillator also features a frequency stability of 0.25 to 1%, depending upon output power level setting, over the temperature range of −30° to +85°C. Model includes an internal power supply regulator which accepts input voltages from +12 to +28 Vdc. Specified spurious responses are −60 dBc and harmonics are −20 dBc. Price: $275. Avail: 45 days, ARO. **Engelmann Microwave Company, Montville, NJ. Carl Schraufnagl, (201) 334-5700.** Circle 180.

SWR WAVEGUIDE/COAXIAL ADAPTER SERIES



Series 281C are waveguide/coaxial adapters which use a stepped-taper design for low SWR. Adapters are available in three frequency bands: Model X281C, 8.2-12.4 GHz, with SWR < 1.06; Model P281C, 12.4-18 GHz, with SWR < 1.06; and Model K281C, 18-26 GHz, with SWR < 1.07. Price: $250, No. X281C and No. P281C; $280, No. K281C. Del: 12 wks. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.** Circle 177.

ADJUSTABLE CAVITY FILTER

Model ACF400-512VD is an adjustable cavity filter designed for use in the 400-512 MHz range. Typical insertion loss and 1 dB bandwidth of the unit is 0.2 dB and 8 MHz; return loss is 30 dB (1.07 SWR). Capacitive coupling is used to give low frequency rejection with typical attenuation values of: at 300 MHz, 40 dB; at 200 MHz, 50 dB; and at 100 MHz, 75 dB. Unit is constructed from heavy-wall Cu tubing with all surfaces silver-plated; external surfaces are finished in grey enamel. Size: excluding tuning screw, 3 1/8" W x 3 3/16" H x 5" D. BNC connectors are standards and other combinations are offered. **Advanced Receiver Research, Burlington, CT.** Circle 170.

STAINLESS STEEL SMA ADAPTERS

The 901 Series of stainless steel adapters facilitate interconnection between Type N, BNC, and SMA coaxial connectors. These stainless steel adapters enable within-series interconnection with other SMA connectors as well as between-series interconnection with Type N and BNC plugs. Various configurations are offered in either gold-plated or stainless steel finish. **Amphenol North America Div., Bunker Ramo Corp., Oak Brook, IL. Art Morse or Don Zigament, (312) 986-2322.** Circle 173.

POWER ATTENUATOR DISSIPATES 200 W

Model PPA-200 is a power attenuator which will dissipate 200 W when the mounting range is maintained at 80°C. This conduction cooled power device is offered with attenuation values from 1-20 dB. Unit operates in the dc to 500 MHz band and attenuator has a SWR of 1.25 from dc to 200 MHz; 1.50, from 200-500 MHz. Size: 1" x 1 7/8". Price: $75, 1-9 qty. Avail: from stock to 10 wks. **KDI Pyrofilm, Whippany, NJ. Al Arfin, (201) 887-8100.** Circle 178.

SMA QUICK-DISCONNECT RACK AND PANEL CONNECTOR

An SMA quick-disconnect rack and panel plug connector, designated 705535-003, is designed for blind mating rack and panel applications. Unit has a spring-loaded float mount for .141" semi-rigid cable use. Its plug mates with a standard SMA jack. Connector meets all applicable portions of MIL-C-39012 and has a maximum SWR of 1.25 to 18 GHz. Price: $6.32 each, for 1000 pieces. **Cablewave Systems, Inc., North Haven, CT. Steven Raucci, Jr., (203) 239-3311.** Circle 174.

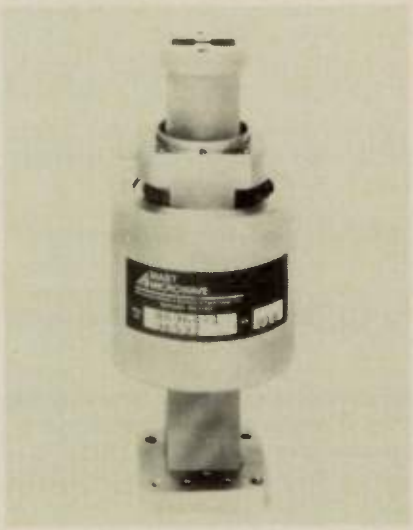
(continued on page 132)

(from page 131) NEW PRODUCTS

FLATPACK RF SWITCH FAMILY

Family of miniature, high-performance RF switches include models SS-80 (1-3000 MHz), SS-91 (10-500 MHz), and SS-92 (100-1000 MHz). All are housed in metal shielded flatpacks and series has a switching speed of 5 ns and typical third order intercept point (on state) of +30 dBm. Suitable for sampling, PM, monopulse IF switching, multiple LO switching and high-speed commutation. **Vari-L Company, Inc., Denver, CO. (303) 371-1560.** Circle 197.

DOUBLE RIDGE WRD750 ROTARY JOINT



Model RC15150 is a single channel I-Style waveguide rotary joint operating from 7.5-18.0 GHz. Unit has a maximum insertion loss of .5 dB, a SWR of 1.75, max. and an average power handling capability of 300 W CW. This unit can be pressurized up to 30 psig and rotates at 60 rpm with a torque of less than 20 oz.-in. Size: 4" L x 1.81" D. **MAST Microwave, Burlington, MA. Chris Theophile, (617) 273-4640.** Circle 184.

3mm SLIDING TERMINATIONS

Series 481 are 3mm precision sliding terminations which span the 8.2-4.0 GHz frequency band. They are supplied with interchangeable male and female connectors to mate with either SMA or OSSM connectors. Termination SWR ranges from 1.06 max. from 8.2-12.4 GHz to 1.04 max. from 12.4 to 40 GHz. Connector SWR is less than 1.02 + .0025 (GHz) (estimated). Units have nominal impedance of 50 Ω and airline impedance accuracy of ± 0.5 Ω. Power handling for series is 0.5 W CW, 0.25 kW peak and travel capability is > ½λ at 8.2 GHz. **Maury Microwave Corporation, Cucamonga, CA. (714) 987-4715.** Circle 185.

(continued on page 135)

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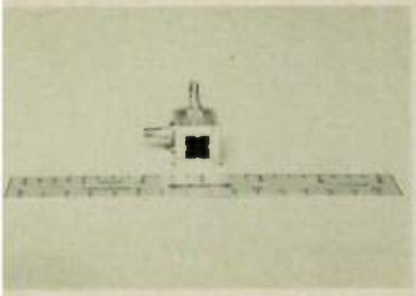
ꞁF SWITCHES COVER 0.5-4 GHz ꞁAND

ꞁP2T and SP4T RF switches operate n the 0.5-4 GHz frequency band, with).4 ms switching time and 50 ohms ermination. The family of two-throw ınd four-throw units can be ordered in :onnectorized or MIC Dual-Inline Pin :onfigurations. Line has TTL control ꞁF power rating of +10 dBm, mininum isolation of 40 dB, maximum inıertion loss of 1.6 dB, SWR of 1.4, naximum and 50 ohm impedance.)rive voltage is ± 5 Vdc. Price: for 10-24 qty., SP2T MIC, $242; SP2T Connectorized, $492; SP4T MIC, $378; SP4T Connectorized, $530.)aico Industries, Inc., Compton, CA. Jim Adamson, (213) 631-1143. Circle 175.

ꞁM-WAVE DUAL LINEAR HORN ANTENNA



ꞁ dual linear horn antenna, Model ꞁA-132, operates over the 18-40 GHz 'requency with azimuth and elevation ꞁeamwidths of 55°, nominal. Polarizaion is dual linear (horizontal and verical inputs), gain is +6 dBi minimum. Jnit has SWR of 1.5, typical, 3.0, naximum. The antenna is supplied vith connectors that mate with SMMA ꞁlugs and is offered with aperture 'lairing for other beamwidths. Weight: 2 oz. Size: 1.2" L x .75" square. Sanders Associates, Inc., Manchester, NH. (603) 669-4615. Circle 192.

DOUBLE-BALANCED MIXERS SPAN 2.9-5.5 MHz

Designed for use in the telecommunications band, two double-balanced mixers, Model 12019 (SMA connectors) and 12016 (module form) cover the 2.9-5.5 MHz band. IF range is dc to 750 MHz, conversion loss is 5.5 dB, typical and 6.0 dB, max. RF/LO SWR is 2.5, typical; LO/RF isolation is 20 dB min. and LO power range is from 5-10 dBm. Size: 12019, 1" x 1" x ½"; 12016, 1.10" x .46" x .125". Connectors: 12019, SMA Female; 12016, Kovar pins .012" D. x .140" L. Price: 12019, $225; 12016, $150. Del: stock to 8 wks. ARO. Norsal Industries, Inc., Brentwood, NY. (516) 231-4040. Circle 187.

FUNDAMENTAL PHASE LOCKED OSCILLATORS

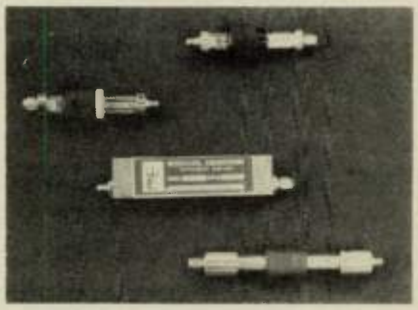
A series of phase locked oscillators cover the 0.2 to 5.6 GHz frequency range. Models have RF power output of +20 dBm between 0.2-2.0 GHz band and +13 dBm, typical 2.0 and 5.6 GHz. Internal reference stability is ±0.005% over operating temperature range of -30°C to 70°C. Harmonics are specified at -20 dBc and spurious at -80 dBc. Power supply requirements are -20 Vdc at 150 ma, typical. Size: 1.5" x 3.0" x 4.0", excluding projections. Del: 10 wks. RFD Inc., Tampa, FL. (813) 872-1502. Circle 190.

LINE OF MIC OMNIPAC GaAs FET AMPLIFIERS

Series of OmniPac MIC GaAs FET amplifiers span the 4.0-8.0 GHz frequency band and provide power output ranges of +20 dBm to +24 dBm. Gains range from 18 dB to 54 dB; input and output SWRs are 2.0 maximum. The third order intercept points are +24 dBm to +28 dBm, gain flatness is ±1.0 dB to ±2.0 dB and noise figures are 5.0 dB. Omni Spectra, Inc., Microwave Subsystems Div., Tempe, AZ. David Emerick or James Tominaga, (602) 966-1471. Circle 188.

(continued on page 136)

LOSSY-LINE ATTENUATORS GIVE FLAT RESPONSE TO 18 GHz



Series 960 are variable lossy-line attenuators designed for signal level control in the 2.5-18 GHz frequency range. Available in four basic groups, the 960, 961, 962, and 963 electrical and mechanical lengths of these attenuators remain constant with change in attenuation, resulting in a low phase change vs attenuation of 1°/dB x f(GHz). Series has a SWR of 1.6 input and 1.3 output; and an accuracy of ± 0.25 dB over the entire range. All attenuator groups possess a high degree of resolution and settability. Price: starts at $135, (US) for the series. Avail: stock to 30 days ARO. **Weinschel Engineering, Gaithersburg, MD.** (301) 948-3434. Circle 198.

LINEAR BROADBAND DROP-IN FET AMPLIFIER

A solid state linear broadband amplifier, Model 8049-1610, operates in the 2-6 GHz band. Unit is designed to function in pairs or groups of amplifiers and has a linear gain of 20 dB minimum, with power output of 18 dB minimum at the 1 dB compression point. Gain flatness plotted against frequency is ± 2 dB, maximum, and gain variation with temperature is ± 3 dB maximum. The unit-to-unit differential phase error is ± 30° maximum while differential gain error is ± 1.0 dB, maximum. Model operates at a supply voltage of +12 V at 250 mA and performance is guaranteed from −54° to +85°C. Unit is housed in a shielded enclosure with microstrip leads. Size: 3.25" x 1" x .3". Price: $3650. Del: 90 days ARO. **TRAK Microwave Corp., Tampa, FL. Thomas L. Roberts, (813) 884-33614.** Circle 195.

:MISSION

Лodel IRE-160FC is a pigtailed LED n a line of standard etched-well emit-ers using DuPont PFX-S120 fiber op-ic cable. Diode has a peak wavelength ›f emission of 790 nm (optimized at he minimum loss point of the)uPoint fiber) and typically yields ?00 μW optical power into the fiber :ore at 100 ma dc drive. Fiber is plas-ic clad silica with a N.A. of 0.27. Core ;ize is 200 μm with an O.D. of 600 μm. Typical rise and fall time is 10 ns, per-nitting digital data rates up to 40 Mbs. ›rice: $325, in single qty. Del: 2-4 vks. ARO. **Laser Diode Laboratories, nc.,** New Brunswick, NJ. 201) 249-7000. Circle 183.

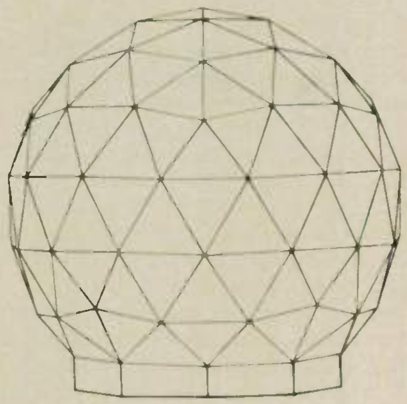
FREQUENCY AGILE PHASE LOCK ;OURCE

PLA-AA-4853 is a frequency agile ›hase lock source featuring low phase ıoise which covers the 4.8-5.32 GHz frequency band. Unit has a power out-›ut of +13 dBm; multiplication factor s x48; acquisition time is 100 ms, maximum, with locking to an input ;ignal at 0 ± 3 dBm. Alternate fre-quency ranges are offered as standard. Price: $1225, qty. of 1-4. Avail: 60-90 days del. **MITEQ, Inc., Hauppauge, NY. (516) 543-8873.** Circle 186.

L-BAND AMPLIFIER

Лodel A-1200-11-1 is a new L-band ;ingle-stage preamplifier using WIRE-LINE quadrature hybrids at the input ın output for low SWR. Frequency ·ange is 970-1450 MHz with input SWR less than 1.7 to 1 and output less than 1.5 to 1 over the band. Input or ›utput SWR is less than 2 to 1 over a full octave with or without power ap-plied. Gain is 11 dB, minimum, 12.5 dB maximum, noise figure is 2 dB, typ. Power requirement is < 25 mA at 15 V, negative ground, while power ›utput at 1 dB gain compression is 0 dBm, minimum. **Sage Laboratories, Inc.,** Natick, MA. Tony Cieri, (617) 653-0844. Circle 191.

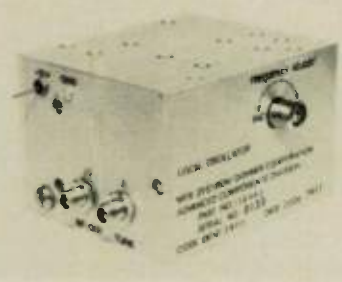
LIGHT WEIGHT RADOMES



A line of light weight radomes has models up to 15 feet in diameter and consist of 31 panels. A seven-foot radome weighs 70 pounds and can be shipped in a 3′ x 3′ x 1′ container. Units are monocoque structures so no metal or dielectric frame is required. Honeycomb sandwich panels are offered if needed. Ultra light microwave reflectors, sub-reflectors and polarizing antennas also available. **Custom Radomes and Reflectors, Inc., Santa Clara, CA. (408) 727-4777.**

Circle 159.

TUNED OSCILLATORS



A series of X and K_u-band voltage controlled oscillators feature both mechanical and voltage tuning and can be tuned to center frequency. Mechanical tuning ranges begin at 5.925-6.425 GHz band at the low end, with ranges up to 18 GHz. Voltage tuning bandwidths are 120 or 100 MHz, depending on the unit's frequency range. Internal voltage regulator eliminates tuning effects of noise on the bias line. Series has power outputs of 50 mW; second harmonics 30 dBc, non-harmonics 70 dBc, voltage tuning range 2-25 V, and dc power of 15 Vdc at 500 mA. Size: 2″ x 3″ x 2.5″. **Systron-Donner Corp., Advanced Components Div., Sunnyvale, CA. Ron Bowers,** (408) 735-9660. Circle 194.

(continued on page 138)

GaAs FET AMPLIFIER SERIES COVER 50-2000 MHz

APG-2050 is a series of GaAs FET amplifiers that cover the 50-2000 MHz frequency band and feature up to +27 dBm output power (1 dB gain compression) with +37 dBm typical third-order intercept point. Offer either 18 or 28 dB standard gain with ± 1.0 dB gain flatness, 6.0 dB noise and 2.0 max. input and output SWR in a 50 ohm system. Amplifiers operate from unregulated power sources supplying +15 Vdc nominal and 275 or 525 mA of current. Price: $1500, for single qty. orders. Del: 120 days ARO. **Avantek, Inc., Santa Clara, CA. Bob Jones, (408) 249-0700. Circle 179.**

SWITCHABLE FILTER SERIES — MULTI-MODE OPERATION

A switchable filter series comes packaged in half an ATR rack mount. A typical package (Model 1810) is switchable into modes A, B or C, using TTL-compatible logic. Mode A has an insertion loss of 0.7 dB over the 962-1212 MHz range; Mode B is a 7-pole filter with multiple capability of 1.5 dB insertion loss from 969 to 1008 MHz, 1053-1065 MHz, 1113-1212 MHz and 30 dB stopbands from 1025-1035 MHz and 1085-1095 MHz; Mode C is a 4-pole filter with 1.7 dB insertion loss from 966.5-971.5 MHz. Entire filter package can operate at 100 W CW and 1 kW peak with SWR of 1.3. **Premier Microwave Corp., Port Chester, NY. Jules Simmonds, (914) 939-8900. Circle 189.**

HIGH FREQUENCY COAXIAL RELAY

Model 401-230832 is a single-pole, double-throw coaxial relay designed for use up to 18 GHz and for operation in severe environments. Unit is a failsafe relay remotely actuated by a 28 Vdc, 475 ohm coil with maximum operation time of 20 ms at 20°C. Model carries up to 10 W of RF power at 18 GHz with isolation greater than -60 dB, insertion loss less than 0.5 dB and SWR of 1.5, maximum. At 1 GHz, SWR is 1.05, max., isolation is greater than 80 dB, insertion loss less than 0.1 dB and maximum operating power is 75 W. Maximum power rating is 200 W up to 200 MHz. Price: $140, 1-4 pieces. Avail: from stock. **DowKey, Div. of Kilovac Corp., Santa Barbara, CA. Jack Dysart, (805) 684-4560. Circle 176.**

MM-WAVE GUNN SOURCE WITH 20 mW OUTPUT

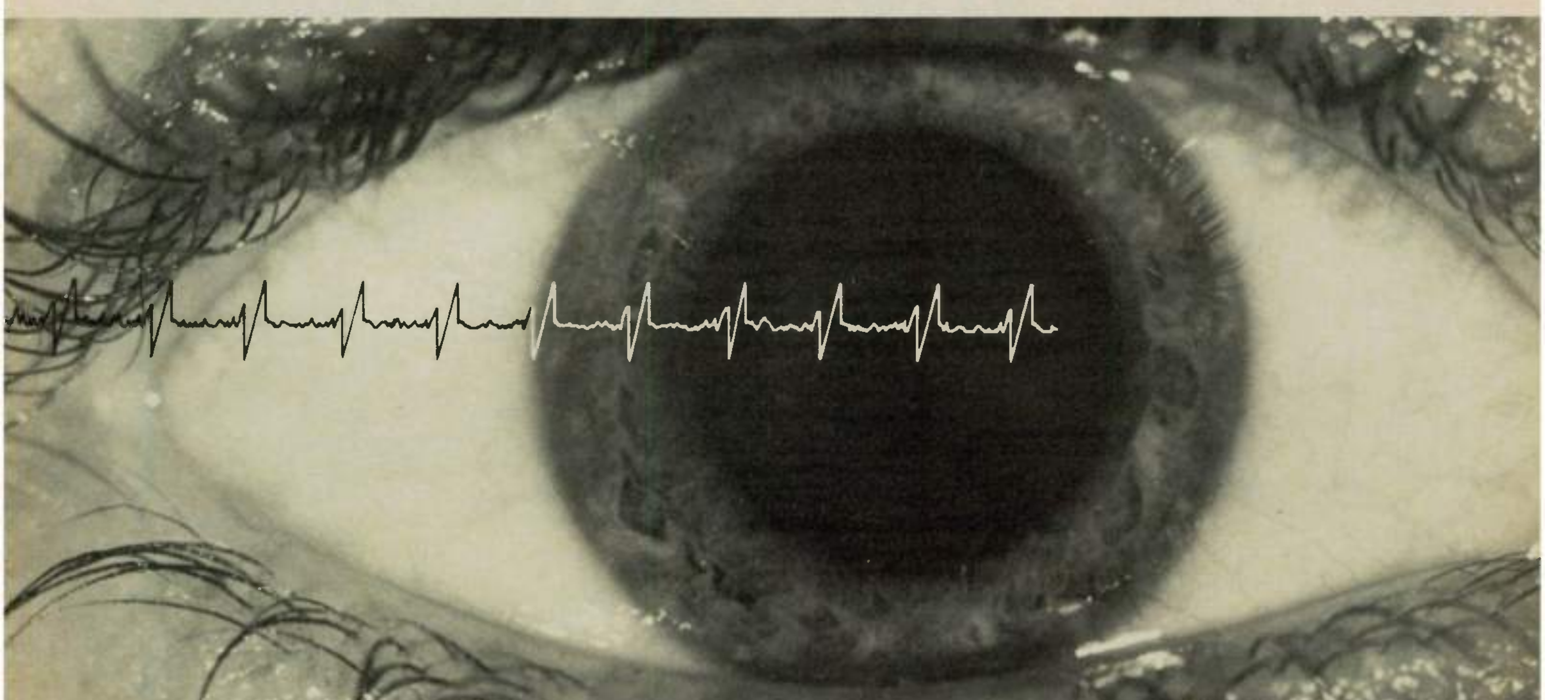
A series of Gunn oscillators, #4594C, offer typical power output of 20 mW at 95 GHz and 3 mW at 110 GHz. Units feature mechanical tuning of ±250 MHz (minimum), with no power output variation, and electrical tuning of ±60 MHz (minimum). Combination regulator/modulator unit provides electrical tuning for transmitter or AFC applications and 1000 Hz square wave modulation. A load isolator is also available as an option. Price: $3800-$5750, depending on model. Avail: 10-45 days. **Epsilon Lambda Electronics Corp., Batavia, IL. (312) 879-6006. Circle 181.**

LOW NOISE, FAST STEPPING FREQUENCY SYNTHESIZER

Model FS-100 is a low noise, fast switching frequency synthesizer with a frequency range of 97.75 MHz to 120.16454 MHz in 160 equally spaced steps. Frequency accuracy is ±0.004% and switching speed is less than 30 μs. Output power is +17 dBm ± 2.0 dB and FM noise at 1 MHz from the carrier is -142 dBc/Hz and -115 dBc/Hz at 2 kHz. Spurious output measured in a 100 Hz bandwidth is -91 dBc at 2 kHz and no greater at any point. Operating temperature range is -54°C to +71°C. Other models are available up to 110 GHz. **Frequency Engineering Laboratories, Farmingdale, NJ. A. E. Steinhauer, (201) 938-9000. Circle 182.**

MICROWAVE CHIP RESISTORS

A series of microwave chip thin film nichrome resistors are fabricated on 0.030" square substrates of inert glass, sapphire or alumina, with 0.004" square gold plated lead bond pads. Values range from 5 ohms to 500 k power rated to 40 mW. All parts 100% tested and are laser trimmed to standard tolerances of 1%, 5%, 10%, and 20%, with other tolerances available on special order. Stability is 0.1%/1000 hours at 125°C, with typical TCR of +100 ppm. Also available in custom miniature thin film resistor networks. **MICRO Service, Santa Monica, CA. Richard Balch, (213) 828-7496. Circle 168.**



New Literature

GaAs FET AMPLIFIER DATA SHEETS

Three data sheets describe a line of GaAs FET amplifiers. The first sheet covers units currently in production in the 2.0-4.0 GHz frequency range; the second sheet describes units in the 4.0-8.0 GHz range; and the third details units available from 8.0-12.4 GHz. Each data sheet presents electrical specifications, typical performance curves and outline drawings, as well as a description of standard and optional features. **Aertech Industries, Sunnyvale, CA. W. S. Patton, (408) 732-0880.** Circle 143.

SMA COAX CONNECTOR CATALOG

A 16-page catalog covers over 100 standard SMA coaxial connector designs. The two-color bulletin includes a series description, interface dimensions, RG cable chart, as well as cable assembly instructions and a connector index. Applications, specifications, and options for the product line are featured. **Automatic Connector, Inc., Commack, NY. Edward S. Selig, (516) 543-5000.** Circle 144.

BROCHURE ON SCHOTTKY DETECTOR DIODES

Product brochure B-4217A describes a new series of zero bias Schottky detector diodes. Features, applications electrical specifications and case styles are covered. These devices function as RF detectors without need of dc bias, have TSS values up to −58 dBm, come in various case styles and serve in waveguide, coax, stripline and microstrip circuits from L through K-band. **Microwave Associates, Burlington, MA. (617) 272-3000.** Circle 150.

W BAND GUNN OSCILLATOR DATA SHEET

A two-page four-color data sheet describes the CMF 1200 series Gunn oscillators which operate in the 90-110 GHz range. Three models offer power outputs ranging from 5-25 mW. Operating conditions and absolute maximum ratings are given on the data sheet. **Central Microwave Co., St. Charles, MO. James Caldwell, (314) 723-4700.** Circle 146.

MICROWAVE COMPONENTS CATALOG

Catalog No. MC/180 describes an extended line of coaxial switches, waveguide switches, dummy loads, crystal detectors, bolometers and RF micropotentiometers. The microwave components catalog includes product specifications, applications, illustrations and ordering instructions. **Micronetics, Inc., Norwood, NJ. (201) 767-1320.** Circle 149.

HP-IB (IEEE-488) INSTRUMENT BOOKLET

A 14-page booklet titled, "Do your Own System Design in Weeks, Instead of Months," describes 119 products which are compatible with the HP-IB (IEEE-488). Each product is shown with a color photograph and a short paragraph highlights its key features. This four-color publication, No. 5953-3846D, also includes a review of milestones that led to the development of the HF interface bus. A section that details support material for system designers concludes the booklet. **Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA. (415) 857-1501.** Circle 147.

MINI (OSM) ATTENUATOR AND TERMINATION CATALOG

An eight-page catalog covers a complete line of miniature (OSM) microwave attenuators and terminations. The two-color brochure includes illustrations, line drawings, performance curves, electrical characteristics and applications for the fixed, coaxial attenuators and miniature terminations. These typically broadband devices have frequency ranges up to dc-18 GHz (attenuators) and dc-26.5 GHz (terminations). They both meet MIL-E-5400 and MIL-E-16400 environmental requirements. **Omni Spectra, Inc., Microwave Components Div., Merrimack, NH. John C. Callahan, (603) 424-4111.** Circle 153.

(continued on page 140)

APPLICATION NOTE ON GENERATOR OUTPUT IMPEDANCE

A seven-page Application Note, No. 20, emphasizes that output impedance must be measured while a generator is operating at the frequency of interest to obtain meaningful results. Using only a line stretcher and sensitive RF millivoltmeter, a method is derived that yields both the complex output impedance and reflection coefficient. "Measuring Signal Generator Output Impedance" also provides two examples of the process. Boonton Electronics Corp., Parsippany, NJ. Wallace F. White, (201) 887-5110. Circle 145.

DATA SHEETS ON SWITCH MODULES

Single pole double and multi-throw solid state switch modules for applications from 0.1-18 GHz are described in four data sheets. A wide range of standard bandwidths includes models covering the full 0.1-18 GHz range. Reflective or absorptive, these hermetically sealed modules feature low loss and/or high isolation. High speed or higher power handling units with or without internal biasing circuitry are included. Microwave Semiconductor Corp./Diode Operation, North Billerica, MA. (617) 668-7700.

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FULL-LINE PRODUCT CATALOG

Number 21 is the latest edition of a full product line catalog. The 178-page, four-color document provides product features, technical information and applications data with specifications and outline drawings for a complete line of microwave components and instruments. Sections cover new GaAs FET amplifiers for EW, radar and communications, and recent products such as 2 and 4-way power dividers, solid state microwave oscillators and broadband isotropic radiation monitoring systems. Narda Microwave Corp., Plainview, NY. Robert E. Sowden, (516) 433-9000. Circle 152.

BROCHURE ON ANTENNA POSITIONING EQUIPMENT

A brochure on antenna positioner products describes a line of antenna positioners, controls, and position displays. Specifications and applications data for single and multi-axis positioners, antenna positioner control units, analog and digital angle displays are included. Scientific-Atlanta, Inc., Atlanta, GA. Donald A. Pisarcik, (404) 449-2000. Circle 156.

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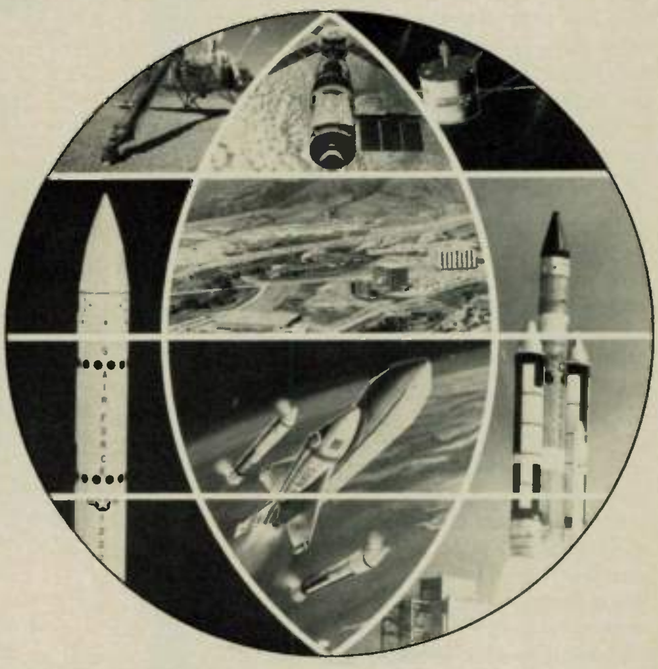

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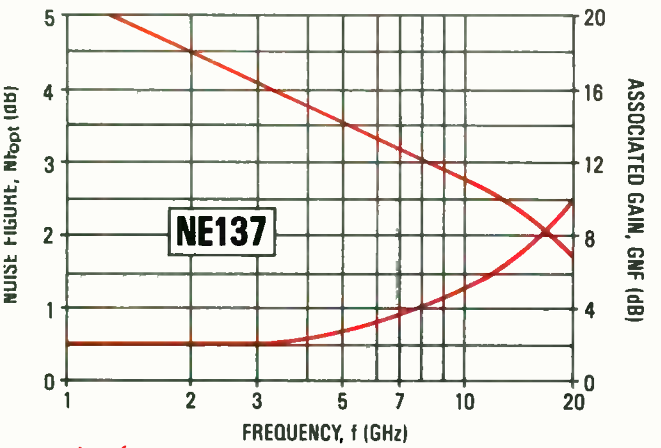

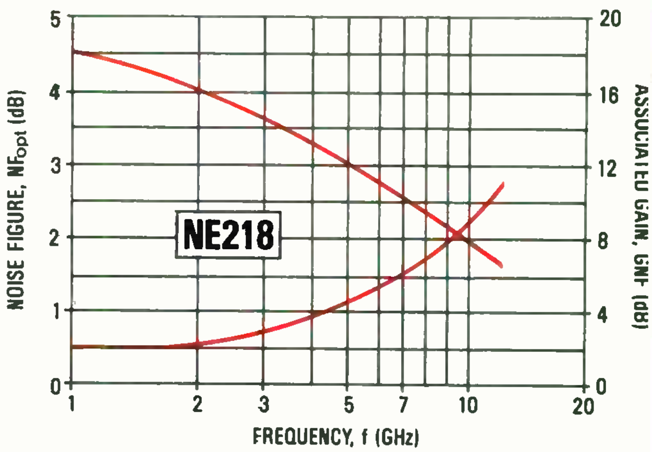

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