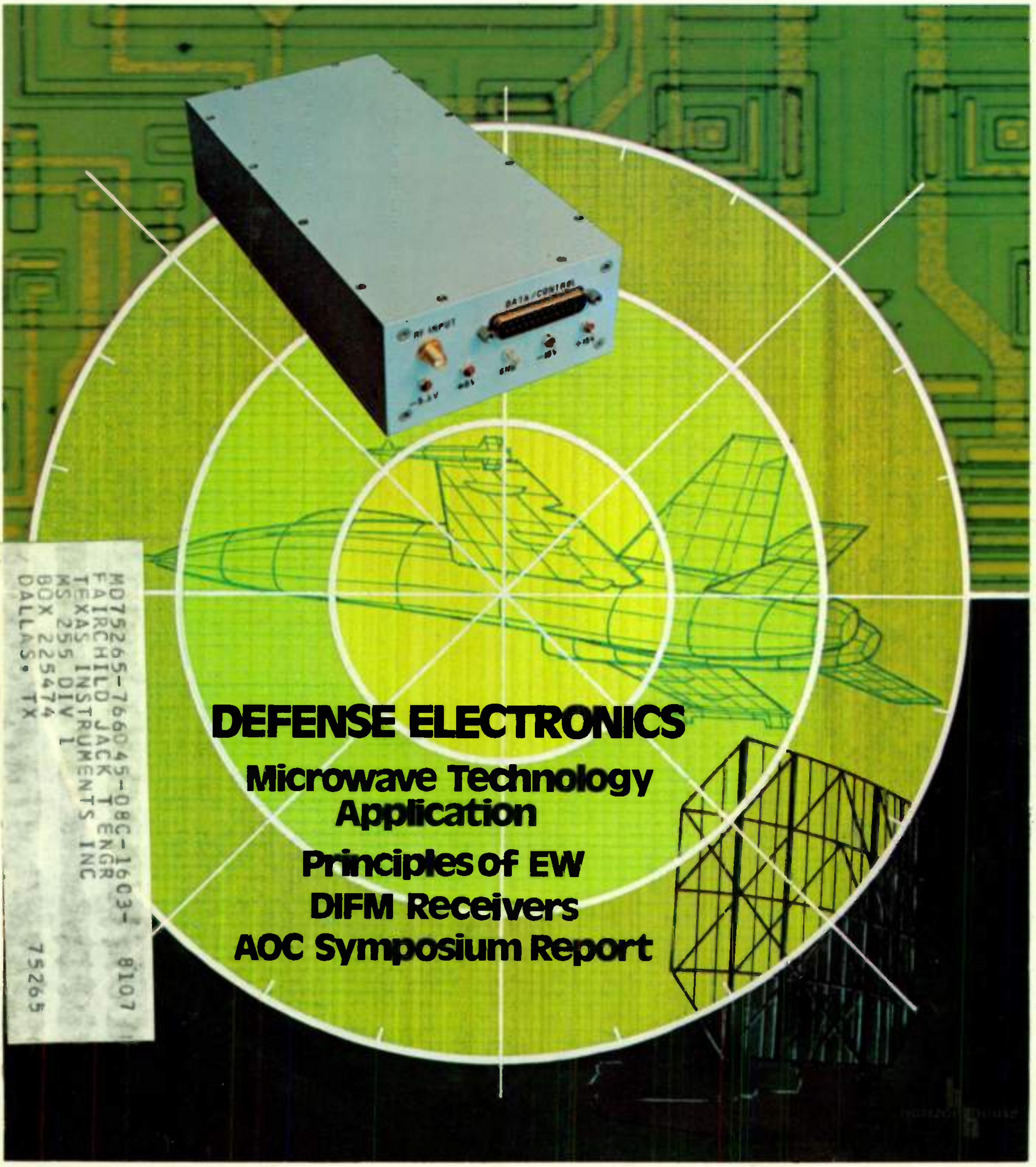
microwave
JOURNAL
INTERNATIONAL EDITION ☐ VOL. 23, NO. 2 ☐ FEBRUARY 1980



DEFENSE ELECTRONICS

Microwave Technology Application

Principles of EW

DIFM Receivers

AOC Symposium Report

NOW TAKE A NEW LOOK AT POLARAD

New Resources:

Polarad is now affiliated with the world renowned Rohde & Schwarz instrumentation family.

New Facilities:

Expanded production and engineering facilities at Lake Success. Worldwide service.

New Instrumentation:

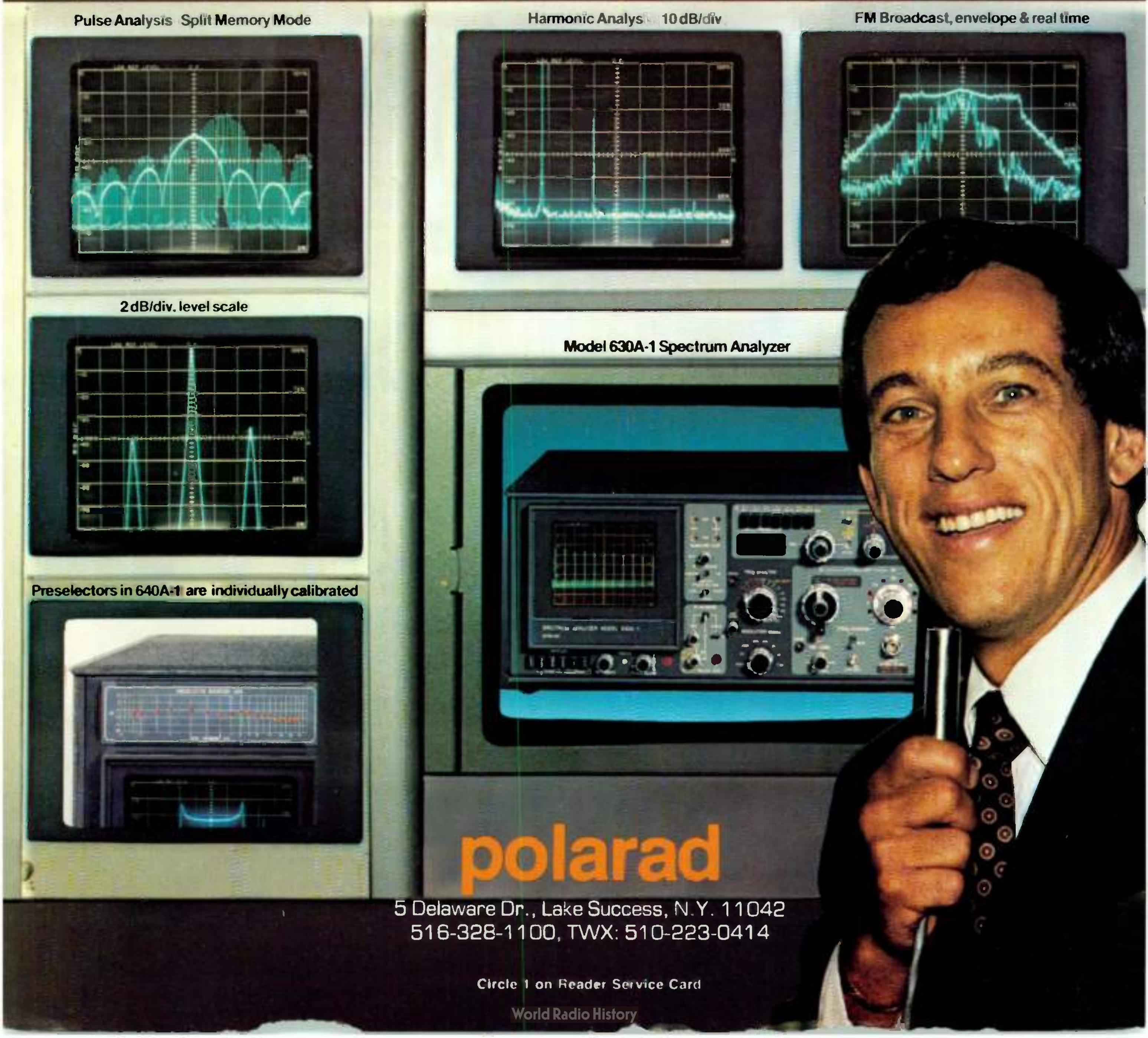
Solid-state Microwave Signal Generators and Spectrum Analyzers with IEEE-488 Bus Data Interface.

New Refined 600A Series:

RF/Microwave Spectrum Analyzers 100 kHz-40 GHz...

- easy to use
- exceptional performance
- greater sensitivity and dynamic range
- GPIB IEEE-488 Bus data interface capability; with Model 6488 Adapter
- All at lowest cost

Specifications and applications assistance on request. Call, TWX, or write for immediate action or use the Reader Service Card.



polarad

5 Delaware Dr., Lake Success, N.Y. 11042
516-328-1100, TWX: 510-223-0414

Circle 1 on Reader Service Card

TUNABLE FILTERS FEATURE VERSATILITY PLUS...

THE CHOICE IS YOURS!

TUNABLE BANDPASS DIPLEXER

K & L's TBD allows a receiver and transmitter to operate simultaneously from one antenna over a 225 400 MHz range.

TUNABLE BANDPASS FILTER

The BT series of tunable filters are capable of being tuned to any center frequency over the 24 to 4000 MHz range.

TUNABLE BANDREJECT FILTER

K & L's TND covers the frequency range of 225 to 400 MHz, featuring a Direct Read-Out with frequency resolution of 100 KHz throughout the range.

TUNABLE NOTCH FILTER

Six different models cover the 50 to 1000 MHz range in octave bands.

K&L
MICROWAVE INCORPORATED

408 Coles Circle, Salisbury, Maryland 21801
Phone 301-749-2424 • TWX 710-864-9683

Circle 4 on Reader Service Card

40 models to choose from,

It costs less to buy Mini-Circuits wideband RF transformers. The T-series (plastic case) and TMO series (hermetically sealed metal case) RF transformers operate with impedance levels from 12.5 ohms to 800 ohms and have insertion loss, 0.5 dB typ. High reliability is associated with every transformer. Every production run is 100% tested, and every unit must pass our rigid inspection and high quality standards. Of course our one-year guarantee applies to these units.

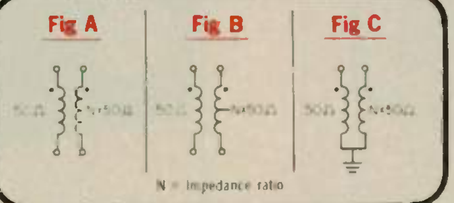
Designer Kits Available

2 TRANSFORMERS OF EACH TYPE

T 1-1, T 2-1, T 4-1, T 9-1, T 16-1
Specify TK-1 **$32.00**

TMO 1-1, TMO 2-1, TMO 4-1
TMO 9-1, TMO 16-1
Specify TMK-2 **$49.50**

Schematics



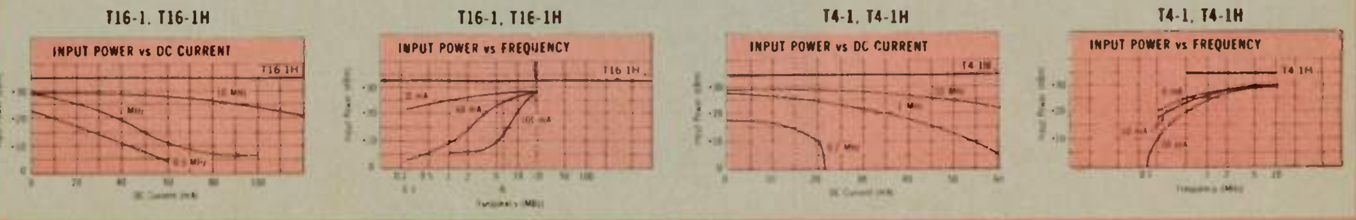
NEW MODELS

HIGH-LEVEL, PLASTIC CASE

Model	T1-1H Fig A	T4-1H Fig B	T9-1H Fig A	T16-1H Fig A
Freq. range, MHz	8-300	8 350	2-90	7 85
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

For complete specifications and performance curves, refer to 1979-80 Microwaves Product Data Directory pgs. 161 to 368 or 1979 EEM pgs. 2770 to 2974

PERFORMANCE SATURATION CURVES T, TH SERIES (RF POWER & DC CURRENT AT WHICH SIGNAL SATURATION BEGINS)



R41-1 Rev A

Circle 5 on Reader Service Card

10KHz-800MHz...

From $2.95 (10-49)

T-H Series
T-Series
(Plastic case)

TMO-Series
(Metal case, hermetically sealed)

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	$5.45	$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
TMO Series .25 cu. inches, .07 ounces T Series .02 cu. inches, .01 ounces

2625 East 14th Street Brooklyn, New York 11235 (212) 769-0200
Domestic and International Telex 125460 International Telex 620156

World's largest manufacturer of Double Balanced Mixers

Mini-Circuits
MINI-CIRCUITS LABORATORY
A Division of Scientific Components Corp

R41-2-Rev A

MICROWAVE JOURNAL is published monthly by Horizon House, 610 Washington Street, Dedham, MA 02026. Controlled circulation postage paid at Burlington, VT. Postmaster: Please send Form 3579 to MICROWAVE JOURNAL, 610 Washington Street, Dedham, MA 02026.

Circle 5 on Reader Service Card

microwave JOURNAL

contents

VOLUME 23, NUMBER 2
USPS 396-250
FEBRUARY 1980

GUEST EDITORIAL

BUSINESS/SPECIAL REPORTS

TECHNICAL/APPLICATIONS SECTION

DEPARTMENTS

* Euro-Global Edition Only

ON THE COVER: A digital instantaneous frequency measuring (DIFM) receiver is shown against an artist's rendition of a vehicle served by the equipment and representations of threats it is designed to identify. (Cover design by Jon Riddle, Aertech Industries.)

STAFF
Publisher/Editor
Howard I. Ellowitz
Consulting Editors
Theodore S. Saad
Dr. Joseph F. White
Managing Editor
Richard C. Howland
Senior Editor
Paul Backus
Assistant Editor
Claire R. Berman
Advertising/Production Manager
F. Lee Murphy, Jr.
Art Director
Tilly Berenson

IN EUROPE
Office Manager
Paul McGhee
Advertising Coordinator
Bronwyn Holmes
Editorial Assistant
Mary Earnshaw

CORPORATE OFFICERS
President
William Bazzy
Vice President Finance/Operations
Richard J. Briden
Vice President Corporate Development
John J. O'Neill, Jr.
Group Vice President
Bernard B. Bossard
Vice President
Theodore S. Saad

ASSOCIATE EDITORS
Dr. F. A. Brand
Dr. S. B. Cohn
V. G. Gelnovatch
Dr. R. C. Hansen
Dr. B. Lax
Dr. J. Wiltse

EDITORIAL REVIEW BOARD
Dr. F. Arams
Dr. R. C. Baird
D. K. Barton
Dr. F. A. Brand
D. J. Button
H. F. Chapell
Dr. S. B. Cohn
Dr. J. D. Dyson
M. Fahey
Dr. F. E. Gardiol
R. Garver
V. G. Gelnovatch
Dr. A. Gilardini
Dr. M.A.K. Hami
Dr. R. C. Hansen
J. L. Heathon
E. E. Hollis
J. S. Hollis
H. Howe
Dr. P. A. Hudson
A. Kelly
R. Knowles
Dr. B. Lax
Dr. L. Lewin
S. March
Dr. G. L. Matthaei
W. G. Matthei
Dr. R. L. Metivier
C.K.S. Miller
W. W. Mumford
Dr. N. S. Nahman
S. S. Oleesky
Dr. J. M. Osepchuk
N. H. Pond
W. L. Pritchard
J. J. Renner
Dr. L. J. Ricardi
Dr. L. Riebman
Dr. G. F. Ross
J. Rush
Dr. J. A. Saloom
H. Stinehelfer
Dr. H. E. Stockman
J. J. Taub
R. Tenenholtz
Dr. W.A.G. Voss
M. D. Waldman
Dr. B. O. Weinschel
Dr. P. Weissglas
Dr. J. Wiltse
Dr. E. Wolff

EDITORIAL OFFICES
EXECUTIVE EDITORIAL OFFICE
Tel: 617 326-8220 TWX: 710 348-0481
MICROSOL DEDM

WEST COAST EDITORIAL OFFICE
Suite 234, 1000 Elwell Court
Palo Alto, CA 94303
Tel: 415 969-3886

EUROPEAN EDITORIAL OFFICE
25 Victoria Street
London SW 1H OEX England
Tel: 01-222-0466 TELEX: 885744

BPA Horizon House also publishes Telecommunications and Journal of Electronic Defense.

Microwave Journal is issued without charge upon written request to qualified persons working in that portion of the electronics industry including governmental and university installation that deal with VHF through light frequencies. Other subscriptions, domestic, $25 per year, two-year subscriptions $45, foreign $30 per year, two-year subscriptions $54, back issues (if available) and single copies $2.50. Copyright © 1980 by Horizon House-Microwave, Inc.

World Radio History

POWER DIVIDERS

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

- **High performance microstrip construction**
- **Housed in rugged RFI-shielded aluminum case**
- **Available with BNC, TNC, SMA and Type N connectors**
- **Meets MIL-202E standards**
- **Also useful as power combiners at signal levels up to +10 dBm**

$39.95 1-9

Now you can specify and purchase state-of-the-art power dividers at ⅓ to ½ the price of competitive units, with immediate off-the-shelf delivery. . . from Mini-Circuits, of course.

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

So, if you are among the thousands of companies now using Mini-Circuits signal-processing units in your systems designs, add power dividers to the list of price/performance industry standards available from Mini-Circuits.

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

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

World's largest manufacturer of Double Balanced Mixers
Mini-Circuits
A Division of Scientific Components Corp.

2625 East 14th Street Brooklyn, New York 11235 (212) 769-0200
Domestic and International Telex 125460 International Telex 620156

International Representatives: ☐ **AFRICA:** Afra (PTY) Ltd., P.O. Box 9813, Johannesburg 2000, South Africa ☐ **AUSTRALIA:** General Electronic Service, 99 Alexander St., New South Wales, Australia 2065 ☐ **EASTERN CANADA:** B. D. Hummel, 2224 Maynard Ave., Utica, NY 13502 ☐ **ENGLAND:** Dale Electronics Ltd., Dale House, Wharf Road, Frimley Green, Camberley Surrey, United Kingdom ☐ **FRANCE:** S.C.I.E.-D.I.M.E.S., 31 Rue George Sand, 91120 Palaiseau, France ☐ **GERMANY, AUSTRIA, SWITZERLAND, DENMARK:** Industrial Electronics GMBH, 6000 Frankfurt Main, Kluberstrasse 14, West Germany ☐ **INDIA:** Gaekwar Enterprises, Kamal Mahal, 17 M.L. Dahanukar Marg, Bombay 400 026, India ☐ **ISRAEL:** Vectronics Ltd., 69 Gordon St., Tel Aviv, Israel ☐ **JAPAN:** Densho Kaisha, Ltd., Eguchi Building 8-1 1-Chome, Hamamatsucho Minato-ku, Tokyo, Japan ☐ **NETHERLANDS, LUXEMBOURG, BELGIUM:** B.V. Technische Handelsonderneming, COIMEX, P.O. Box 19, 8050 AA Hattem, Holland ☐ **NORWAY:** Datamatik As, Postboks 111, BRYN, Oslo 6, Ostensjoveien 62, Norway ☐ **SINGAPORE & MALAYSIA:** Electronics Trading Co. (PTE) Ltd., Suites C13, C22 & C23 (1st Floor), President Hotel Shopping Complex, 181 Kitchener Road, Singapore 8, Republic of Singapore ☐ **SWEDEN:** Integrerad Elektronik AB, Box 43 S-182 51, Djursholm, Sweden

U.S. Distributors: ☐ **NORTHERN CALIFORNIA:** Pen Stock, 105 Fremont Ave., Los Altos, CA 94022, Tel. (415) 948-6533 ☐ **SOUTHERN CALIFORNIA, ARIZONA:** Crown Electronics, 11440 Collins St., N. Hollywood, CA 91601, Tel. (213) 877-3550 ☐ **METROPOLITAN NEW YORK, NORTHERN NEW JERSEY, WESTCHESTER COUNTY:** Microwave Distributors, 61 Mall Drive, Commack, NY 11725, Tel. (516) 543-4771 ☐ **SO. NEW JERSEY, DELAWARE & EASTERN PENNSYLVANIA:** MCL Distributors, 454 Germantown Pike, Lafayette Hill, PA 19444, Tel. (215) 825-3177

34/REV/C ☐☐☐

SYSTRON-DONNER'S

Setting the standards for:

- Yig-tuned devices
- Voltage-tuned oscillators

YIG-TUNED OSCILLATORS are available in transistor and Gunn-diode types.

Specifications are given for typical standard models. In most cases, standard units with higher (100 mW) or lower (10 mW) power are also available.

MODEL:	Frequency Range (GHz)	Power Output Min. (mW)	Power Variation vs. Frequency	Spurious Signals:		Residual FM, 1 Hz—30 kHz	Frequency Stability:			
				Harmonic Min.	Non-Harmonic Min.		Vs. Temperature	Vs. Power Supply	Vs. Load Variation	Hysteresis
SDYX-3038	0.5—1.0	20	5 dB p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	2 MHz
SDYX-3034	1.0—2.0	20	5 dB p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	2 MHz
SDYX-3034-114	0.5—2	20	6 dB	12 dBc	50 dBc	10 kHz	0.03%/°C	1 MHz/V	1 MHz	4 MHz
SDYX-3036	2.0—4.0	20	5 db p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	4 MHz
SDYX-3036-125	1.0—4.0	20	7 dB	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	6 MHz
SDYX-3039-107	2.0—6.0	10	7 dB	12 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	4 MHz	7 MHz
SDYX-3000	8.0—12.4	25	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	10 MHz
SDYX-3001	12.4—18.0	25	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	15 MHz
SDYX-3001-111	8.0—18.0	10	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	25 MHz
SDYX-3003	18.0—26.5	10	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	25 MHz
SDYX-3004	26.5—40.0	5	6 dB p-p	20 dBc	60 dBc	10 kHz p-p	0.01%/°C	20 MHz/V	20 MHz	100 MHz

HARMONIC GENERATORS

Standard harmonic generators are available with fixed input frequencies of 100, 200, 500, or 1,000 MHz, and output frequencies up to 26.5 GHz. Generators may be ordered individually, with matched YIG drivers, or as part of a custom-designed subassembly meeting specific system application. Contact the factory for additional information and specifications.

YIG DRIVERS

Any Systron-Donner YIG device may be ordered with a matched YIG driver to provide accurate voltage/frequency conversion and to facilitate installation of the YIG device in a system. Two types of drivers are available: a standard version and a high-stability version. Both types operate with input power of ±15 V (±20 or ±12 V available with some frequencies on special order), control voltage of 0 to 10 V, and minimum input impedance of 10kΩ. Units meeting either commercial or military environmental requirements may be provided.

VOLTAGE-TUNED OSCILLATORS

MODEL:	Frequency Range (MHz):	Power, Min. (mW):				Spurious Signals:		Residual FM:	Amplitude Control:	
		Leveled	Power vs. Frequency	Unleveled	Power vs. Frequency	Harmonic Min.	Non-Harmonic Min.	in 1 Hz-30 kHz Band	Full Output	Down 40 dB
SDVX-2011	470-1030	20	<4 dB	30	<4 dB	20 dBc	60 dBc	2 kHz p-p	−5 V @ 30 mA	0 V @ 0 mA
SDVX-2012	940-2060	20	<4 dB	30	<4 dB	20 dBc	60 dBc	4 kHz p-p	−0.6 V @ 0 mA	+5 V @ 30 mA
SDVX-2013	1240-2060	20	<4 dB	25	<4 dB	20 dBc	60 dBc	4 kHz p-p	−0.6 V @ 0 mA	+5 V @ 30 mA
SDVX-2108	0.1-32	20	±0.3 dB[2]	25	<4 dB	20 dBc[1]	50 dBc	4 kHz p-p	−5 V @ 15 mA	0 V @ 0 mA
SDVX-2110	6-112	20	±0.1 dB[1]	30	<4 dB	30 dBc[1]	60 dBc	2.5 kHz p-p	−5 V @ 15 mA	0 V @ 0 mA
SDVX-2111	25-305	20	±0.2 dB[2]	30	<4 dB	30 dBc[1]	60 dBc	1.5 kHz p-p	−15 V @ 15 mA	0 V @ 0 mA
SDVX-2112	90-510	20	±0.2 dB[2]	30	<4 dB	30 dBc[1]	60 dBc	1.5 kHz p-p	−5 V @ 15 mA	0 V @ 0 mA
SDVX-2000	235-515			50	<4 dB	20 dB[3]	60 dB[3]	1 kHz p-p		
SDVX-2001	470-1030			50	<4 dB	20 dB[3]	60 dB[3]	2 kHz p-p		
SDVX-2002	940-2060			50	<4 dB	20 dB[3]	60 dB[3]	4 kHz p-p		
SDVX-2003	1340-2460			50	<4 dB	20 dB[3]	60 dB[3]	4 kHz p-p		
SDVX-2004	1.9-4.1 GHz			30	<4 dB	20 dB[3]	60 dB[3]	6 kHz p-p		
SDVX-2038	8-112			20	<4 dB	20 dBc	60 dBc	±1.5 kHz p-p	Linearized	
SDVX-2041	470-1030			20	<4 dB	20 dBc	60 dBc	±2 kHz p-p	Linearized	
SDVX-2042	0.94-2.06 GHz			20	<4 dB	20 dBc	60 dBc	±4 kHz p-p	Linearized	
SDVX-2043	1.34-2.46 GHz			20	<4 dB	20 dBc	60 dBc	±5 kHz p-p	Linearized	
SDVX-2044	1.9-4.1 GHz			10	<4 dB	20 dBc	60 dBc	±10 kHz p-p	Linearized	

1) @ 20 mW leveled　2) Internal Detector　3) below carrier

ADVANCED COMPONENTS

YIG-TUNED FILTERS

Systron-Donner SDYF-4000 Series reciprocal bandpass and bandreject filters are available in two, three, four, and dual-two stage versions in single bands from 0.5 to 40 GHz, and in one and three-stage multi-octave versions. These filters are ideal for use in receiver systems, frequency synthesizers, or test sets for preselection, signal sorting, or any other application in which a tunable filter must pass a desired signal or band of signals with minimal attenuation and reject undesired out-of-band signals.

SDYF-4000 Series filters may be ordered individually, with a YIG driver, as as part of a tracking filter/oscillator/driver assembly meeting specific system applications.

		MODEL:	Frequency Range *(GHz)*	Bandwidth *(MHz, Min.)*	Insertion Loss *(dB, Max.)*	O.R.I. *(dB, Min.)*	O.R.S. *(dB, Min.)*	PB Ripple & Spurious *(dB, Max.)*	Linearity *(MHz, Nom.)*	Hysteresis *(MHz, Nom.)*
BANDPASS	Two-Stage	SDYF-4021	0.5—1	12	6.0	40	25	2.5	±2	4
		SDYF-4022	1—2	20	3.0	40	25	3.0	±2	4
		SDYF-4023	2—4	20	3.0	50	25	3.0	±3	6
		SDYF-4024	4—8	25	3.0	50	25	2.5	±5	8
		SDYF-4025	8—12.4	30	3.0	50	25	2.5	±8	15
		SDYF-4026	12.4—18	30	3.0	40	30	2.5	±10	15
		SDYF-4027	18—26.5	35	4.0	40	30	2.5	±15	20
	Three-Stage	SDYF-4028	0.5—1	12	6.0	70	35	2.0	±2	4
		SDYF-4029	1—2	18	5.0	70	40	2.0	±2	4
		SDYF-4030	2—4	20	4.0	70	40	2.0	±3	6
		SDYF-4031	4—8	25	4.0	70	40	2.5	±5	8
		SDYF-4032	8—12.4	25	4.0	70	40	2.0	±8	15
		SDYF-4033	12.4—18	30	4.0	70	40	2.5	±10	15
		SDYF-4034	18—26.5	35	5.0	70	40	2.5	±15	20
	Four-Stage	SDYF-4035	0.5—1	10	8.0	70	40	3.0	±2	4
		SDYF-4036	1—2	15	6.0	70	50	3.0	±2	4
		SDYF-4037	2—4	15	5.0	70	50	3.0	±3	6
		SDYF-4038	4—8	20	5.0	70	50	3.0	±5	8
		SDYF-4039	8—12.4	20	5.0	70	50	3.0	±8	15
		SDYF-4040	12.4—18	25	5.0	70	50	3.0	±10	15
		SDYF-4041	18—26.5	30	5.5	70	50	3.0	±15	20
	Dual Two-Stage (Per Channel)	SDYF-4042	0.5—1	12	6.0	40	25	2.0	±2	4
		SDYF-4043	1—2	20	3.0	40	25	3.0	±2	4
		SDYF-4044	2—4	20	3.0	50	25	2.5	±3	6
		SDYF-4045	4—8	25	3.0	50	25	2.5	±5	8
		SDYF-4046	8—12.4	25	3.0	50	25	2.5	±8	15
		SDYF-4047	12.4—18	25	3.0	40	25	2.5	±10	15
		SDYF-4048	18—26.5	30	4.0	40	25	2.5	±15	20
	Multi-Octave	SDYF-4000	1.8—18	20	5.0	70	60	1.5	±10	15
		SDYF-4000-102	1.8—26.5	15	8.5	70	60	1.5	±20	20
		SDYF-4000-113	2—18	30	3.0	40	40	1.5	±10	15
BANDREJECT	Four-Stage	SDYF-4735	0.5—1	4	1.5	20*			±2	4
		SDYF-4736	1—2	6	1.5	25*			±2	4
		SDYF-4737	2—4	8	1.5	25*			±3	4
		SDYF-4738	4—8	10	1.5	30*			±5	8
		SDYF-4739	8—12.4	10	1.5	30*			±8	15
		SDYF-4740	12.4—18	10	1.5	30*			±10	15
		SDYF-4741	18—26.5	18	1.5	50*			±15	20

*Bandrejection

SYSTRON DONNER

ADVANCED COMPONENTS
DIVISION

735 Palomar Avenue, Sunnyvale, CA 94086
Phone (408) 735-9660

Circle 7 for information
Circle 61 for demonstration

Coming Events

EW SYSTEMS AND TECHNOLOGY
FEB. 11-12, 1980
LOS ANGELES, CA
MAR. 10-11, 1980
WASHINGTON, DC

Sponsors: American Institute of Aeronautics & Astronautics, Technical Marketing Society of America. Place: Hacienda Hotel, Los Angeles, CA and Ramada Inn, Rosslyn, VA. Fee: $355 individual, $335, member, $295 corporate group. Subject: unclassified forum lead by 16 experts discussing EW trends, issues, systems outlook and key technology needs. Contact: AIAA Conferences, P.O. Box 91295, Dept. EW, 5959 W. Century Blvd., Suite 1016, Los Angeles, CA 90009. (213) 670-2973.

1980 INT'L RADAR CONFERENCE
APR. 28-30, 1980

Sponsors: IEEE's Radar Panel and its British Professional Society. Place: Stouffer's National Center Inn, Arlington, VA. Contact: R. T. Hill, Naval Sea Systems Command, Conf. Office — Suite 917, 777 14th St., N.W., Washington, DC 20005.

IEE COLLOQUIUM ON HOLLOW WAVEGUIDES
MAY 8, 1980

Sponsor: Int'l Electrical Engineers, Microwave Devices & Techniques Group. Place: Savoy Place, London. Topic: Hollow Waveguides — Modern Problems in Attaining Low Loss, Light Weight and Low Cost. Contact: Dr. R. Baldwin, Int'l Aeradio Limited, Bailbrook College, London Road West, Bath, Avon, ENG.

1980 MTT-S INT'L MICROWAVE SYMPOSIUM/ EXHIBITION
MAY 28-30, 1980

Sponsor: IEEE MTT-S (Microwave Theory and Techniques Society). Place: Shoreham Americana, Washington, DC. Contact: B. Sheleg, Code 5733, Naval Research Laboratory, Washington, DC 20375. Tel: (202) 767-2297.

38TH DEVICE RESEARCH CONFERENCE
JUNE 23-25, 1980

Sponsor: Rockwell Int'l. Place: Cornell University, Ithaca, NY. Contact: Fred A. Blum, Conf Chrm, Rockwell International, P.O. Box 4761, Anaheim, CA 92803. Tel: (714) 632-2584.

2ND CONF. OF THE IEEE/EMBS
SEPT. 27-28, 1980

Call for Papers. Sponsor: IEEE Engineering in Medicine and Biology Society. Place: Washington Hilton Hotel, Washington, DC. (precedes the 33rd ACEMB meeting) Sessions on: instrumentation, bioelectric phenomena, microprocessors, noninvasive technology, clinical engineering, signal analysis, transducers, telemetry systems, standards and regulations, computers in medicine, etc. Submit papers for tutorials, technical sessions and workshops by April 1, 1980 to: Lee Ostrader, Ph.D., Program Chrm., EMBS Conf., Center for Biomedical Engineering, Rensselaer Polytechnic Institute, Troy, NY 12181.

“What you’ll need tomorrow is built into EIP’s 18, 26.5 and 40 GHz counters today.”

“EIP has a revolutionary new family of CW microwave counters able to satisfy all my requirements today and tomorrow.

“EIP’s Model 545 measures to 18 GHz. Their Model 548 goes to 26.5 GHz, with an option covering the range clear up to 40 GHz. And they built it to go even higher in frequency should my needs change a few years out.

“EIP’s performance? No contest! All their counters deliver minus 30 dBm sensitivity plus excellent amplitude discrimination, frequency selection and offsets. Full 5-watt burnout protection gives me real peace of mind.

“EIP’s new counters also have a power measurement option. For systems use they’ve got GPIB or BCD/remote programming.

“When I first saw these counters, I was afraid they’d be difficult to operate. But that wasn’t the case at all. Their built-in microprocessor does most of the work. Front panel keyboard diagnostic test routines and signature analysis make servicing really simple.

“The most pleasant surprise came when I compared prices. An EIP 545 goes out the door for only $4800.* The Model 548 with 26.5 GHz frequency coverage costs only $5700.*

“For demonstration or literature on these new counters, phone or write EIP. Believe me, I shopped around, but I couldn’t find a company or line of counters nearly as good. When it comes to microwave counters . . .

“I’m sold on EIP.”

EIP

EIP Microwave, Inc.
2731 North First Street, San Jose, CA 95134
Phone (408) 946-5700

In Europe
EIP International
Brussels, Belgium
Phone 2 660 48 70

*U.S. List Price

Circle 9 for literature

MICROWAVE TECHNOLOGY APPLICATION

The factors which will exert dominant influence on the application of microwave technology to electronic defense equipment in the coming decade are identified in this Staff Report. Based heavily on a series of interviews with DoD and industry senior scientists, it first discusses the increasing sophistication of technology which may be anticipated. It then dwells particularly on the proliferation of new sensors, the integration of their information and the data processing alternatives which are presently being explored. A wider use of the microwave spectrum together with a denser environment in the expanded spectrum are predicted. Deficiencies in the support of our R&D base over the past few years are discussed and the new climate designed to recover our losses is described. Additional second-order factors which will also have an impact on microwave technology application in the '80s are discussed.

ERADCOM ELECTRONICS TECHNOLOGY AND DEVICES

Material from the Army Advanced Planning Briefing presented by the Electronics Technology and Devices Laboratory of ERADCOM outlines the change in the planning strategy of that laboratory. Its classical mission of improving the technological base has been shifted to one of concentration on countering worldwide threats to the Army. The Briefing material lists the threats which have been identified and the responding program thrusts of ET&DL to develop counters to those threats. Allocation of the Laboratory resources to the funding of internal programs and outside contracts also is shown.

VCO LINEARIZATION

A technique which can be used to linearize a portion of the tuning characteristic of a VCO without external circuitry is discussed. Reactance compensation which alters the reactance slope of the oscillator resonance characteristic is employed. The absence of external circuitry minimizes size and reduces cost and complexity. Noise characteristics of the VCO are not altered and the tuning bandwidth is said to increase. Theoretical curves for different degrees of linearity are shown and performance curves for an X-band Gunn VCO linearized with the reactance compensation technique illustrate its practical application.

AOC EW SYMPOSIUM

The technical sessions at the Association of Old Crows Annual Symposium provide a coverage of current EW concerns as comprehensive as any program offered during the year. The report in this issue reviews the unclassified papers delivered at the October 1979 AOC meeting and offers some insight into the areas which will be of major interest to electronic warfare systems during the next few years.

PRINCIPLES OF ELECTRONIC WARFARE

In the second of his articles, the author describes the fundamentals of radar and associated counter and counter-countermeasure techniques. The relationship of this discussion to the operation and interception of and interference with communication links is pointed out. Basic radar principles are covered to introduce the characterization of various counter techniques.

Sum Up

A DIFM RECEIVER PRIMER

In a brief article, the author discusses the digital instantaneous frequency measurement receiver (DIFM). Its theory of operation, the form of its integrated RF assembly, its sensitivity and dynamic range characteristics and its ability to handle simultaneous signals are covered. The results of efforts to date to miniaturize this component are discussed as are the directions which future efforts in this area are likely to take. Requirements which are thought to have a significant impact on acquisition cost are clearly identified.

Howard Ellowitz

Workshops & Courses

PHASELOCK LOOPS COURSE

Sponsor: Gardner Research Company
Dates & Sites: March 31-April 4, 1980
Washington, DC
June 16-20, 1980
New York City, NY
October 6-10, 1980
Boston, MA
December 8-12, 1980
Los Angeles, CA
Fee: $495
Topics: Foundations, applications and implementation of PLLs.
Lecturer: Dr. Floyd M. Gardner
Contact: Gardner Research Co.,
1755 University Ave.,
Palo Alto, CA 94301
Tel: (415) 328-8855

RADAR TECHNOLOGY SEMINAR

Sponsor: Boston IEEE/AESS
Date: May 1, 1980
Place: Ramada Inn – Old Town, Alexandria, VA
Lecturer: Dr. Eli Brookner, Raytheon Co.
Topics: Radar, trends in signal processing, radar components, etc.
Contact: Duane Matthiesen,
MITRE Corp., Bedford, MA
Tel: (617) 271-2000, ext. 2300

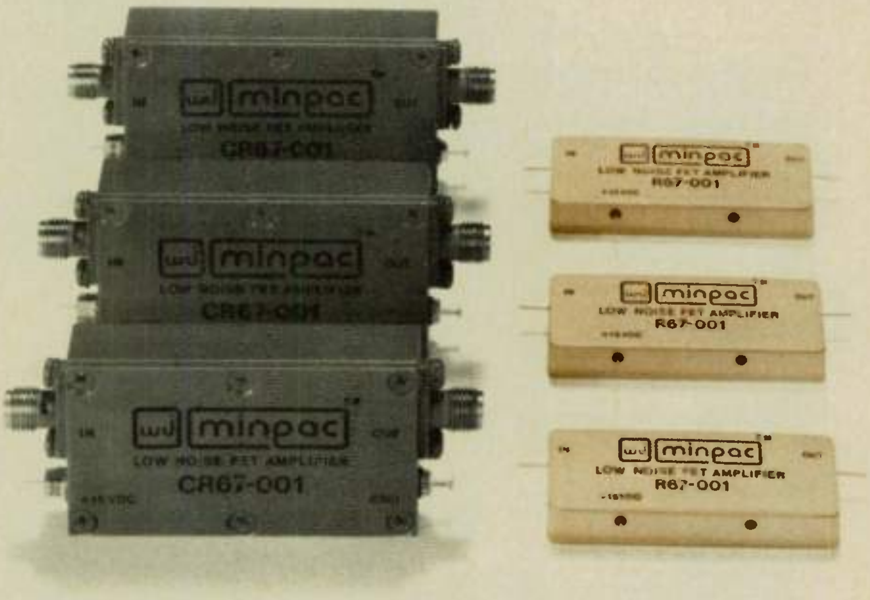
GEORGIA INSTITUTE OF TECHNOLOGY SHORT COURSES

Sponsor: GIT, Dept. of Cont. Ed.
Millimeter Wave Systems and Technology
Date: March 31-April 2, 1980
Topics: Design of communications and radar systems operating above 30 GHz.
Principles of Modern Radar
Date: May 5-9, 1980
Topics: Radar systems analysis, synthesis and evaluation.
Contact: Director, Dept. of Cont. Ed.,
GIT, Atlanta, GA.
Tel: (404) 894-2400

1980 ENGINEERING SUMMER CONFERENCE – U. OF MICHIGAN

Sponsor: College of Engineering, Cont. Engrg. Education
Date: June 23-27, 1980
Fee: $475
Chrm: Adam Kozma
Topic: Microwave Sensing Technology – Emphasis on SAR Systems.
Contact: Engrg. Summer Conf.,
800 Chrystler Cent.,
North Campus,
The University of Michigan,
Ann Arbor, MI 48109

Design Incredible Performance Into Your Radar System with Watkins-Johnson's new...



MINPAC™ low-profile amplifiers.

Watkins-Johnson's major breakthrough in packaging and circuitry makes designing incredible performance into your radar system easier than ever before.

Available with SMA connectors or in stripline-compatible packaging, these MINPAC low-profile amplifiers feature all-brazed assemblies, metal-to-metal hermetic seals, phase and gain matching, wide dynamic ranges, and state-of-the-art noise figures and power outputs.

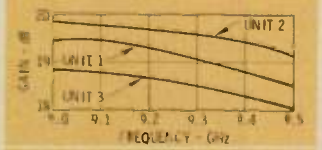
They also feature small size at very attractive, low prices.

Our WJ-R67 series, for the frequency range of 9.0–9.5 GHz, typically features a 3.3 dB noise figure, gain of 18 dB BH, VSWR of less than 1.5:1, and a power output of +12 dBm. Phase matching is less than or equal to 3 degrees while gain tracking is ±0.3 dB.

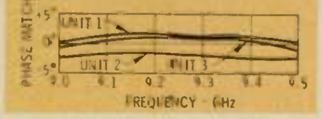
Production quantities meeting the most stringent military requirements have been delivered.

For more information on designing these exciting, new amplifiers into your radar system, contact the W-J Field Sales Office in your area or phone Solid State Applications Engineering in Palo Alto, California at (415) 493-4141, ext. 2327.

GAIN VS. FREQUENCY



PHASE MATCH VS. FREQUENCY



ACTUAL PERFORMANCE
FOR THREE WJ-R67 SERIES AMPLIFIERS

NOISE FIGURE VS. FREQUENCY

Noise Figure (dB)

Frequency (GHz)	9.0	9.1	9.2	9.3	9.4	9.5
Unit 1	3.04	3.02	3.04	3.08	3.13	3.20
Unit 2	2.84	2.83	2.85	2.90	3.00	3.15
Unit 3	3.08	3.08	3.10	3.17	3.22	3.30

WATKINS-JOHNSON

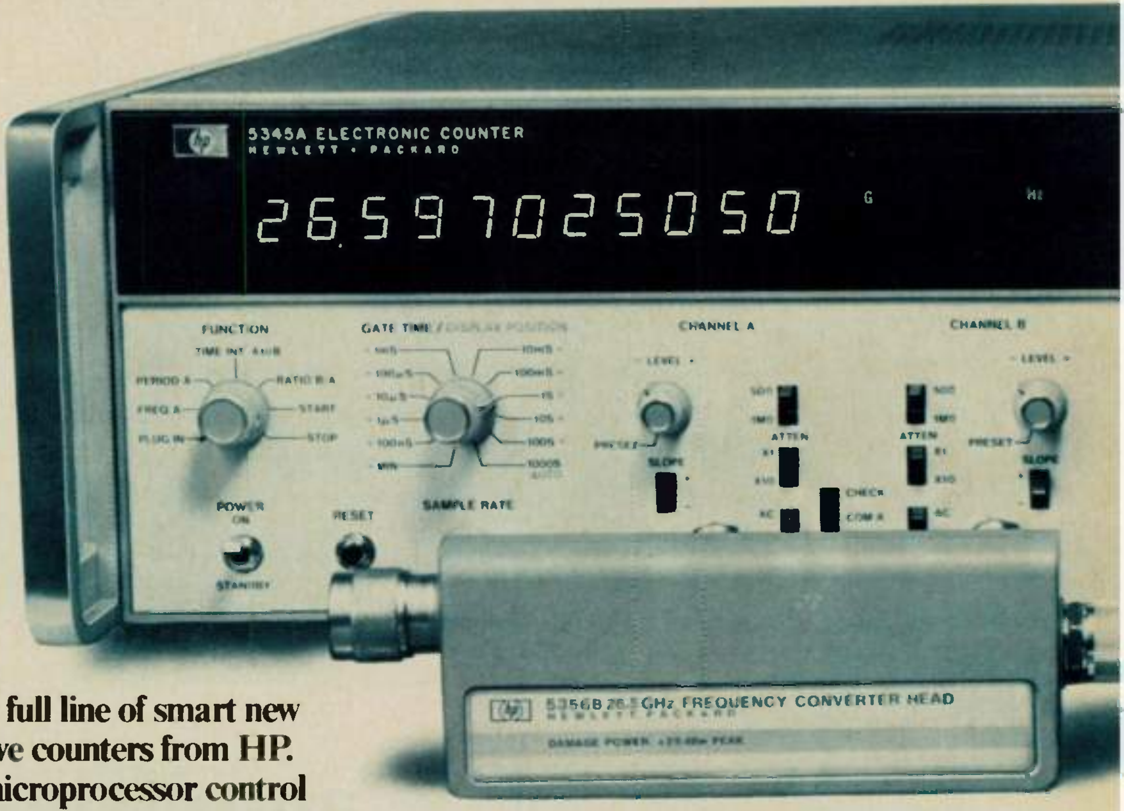
Watkins-Johnson—U.S.A.: • **California,** San Jose (408) 262-1411 El Segundo (213) 640-1980 • **Florida,** Altamonte Springs (305) 834-8840 • **District of Columbia,** Gaithersburg, MD (301) 948-7550 • **Massachusetts,** Lexington (617) 861-1580 • **Ohio,** Fairborn (513) 426-8303 • **Pennsylvania** Haverford (215) 896-5854 • **Texas** Dallas (214) 234-5396 • **United Kingdom:** Shirley Ave Windsor, Berkshire SL4 5JU • Tel Windsor 69241 • Cable WJUKW-WINDSOR • Telex 847578 • **Germany, Federal Republic of:** Manzingerweg 7, 8000 Muenchen 60 • Tel (089) 836011 • Cable WJDBM-MUENCHEN • Telex 529401 • **Italy:** Piazza G Marconi 25 00144 Roma-EUR • Tel 59 45 54 • Cable WJROM-I • Telex 612278

Circle 11 on Reader Service Card

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 Head, $2400.*

HP 02923 B

†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

Circle 12 on Reader Service Card

Microwave Challenges for EW Applications in the '80s

LYNWOOD A. COSBY
Naval Research Lab – Tactical EW Div.
Washington, DC

Mr. Lynwood A. Cosby *is currently Superintendent of the Tactical Electronic Warfare Division at the Naval Research Laboratory where he has worked since 1951. He received a B.Sc. from the University of Richmond in 1949 and a M.Sc. from Virginia Polytechnic Institute in 1951. Following graduation he served briefly as an Instructor in Physics at Virginia Military Academy. Most of his professional career has been in the field of EW. His early work includes contributions to the concept and development of the deception repeater, and many high power, broadband microwave sources. He was a principal contributor to the EW technology utilized in the defense of ships and aircraft in Vietnam. Mr. Cosby has received many commendations and awards, including the Navy's Distinguished Civilian Service Award, the American Society of Naval Engineers Gold Medal Award and the Department of Defense's Distinguished Civilian Award, the highest civilian award bestowed by DoD. He is a member of Sigma Pi Sigma, Sigma XI, is a Fellow of the IEEE and a past chairman of the Washington Chapter of the Professional Group on Electron Devices of the IEEE. He serves on numerous Navy and DoD advisory panels.*

Electronic warfare is a "war within a war" where one strives to detect and identify the enemy and to jam, deceive, or deny the usefulness of his guidance, detection, or communication electronic equipments. EW is clearly linked with survivability and has been aptly defined by some operators as "the ability to survive all those missiles shooting at you". The Department of Defense has increased the emphasis on EW in recent years to counter developments such as guided missiles and radar-controlled gun fire.

Microwaves and electronic warfare have been inexorably linked since World War II. Success or failure in the development of appropriate microwave devices has closely paced the evolution of successful EW equipments. Some will state with confidence that the defeat of the German submarine force in World War II was due to their inability to detect the Allied ASW radar which had moved into the 3- and 10-centimeter region. Their lack of an adequate electronic support measures capability at 10 cm and any at 3 cm ended their ability to operate undetected and resulted from the Germans' failure to anticipate that these spectral regions could be employed by the Allies. Their neglect of timely development of required basic technology to support the necessary warning receiver detector developments in these regions left vital gaps that persisted until the end of hostilities.

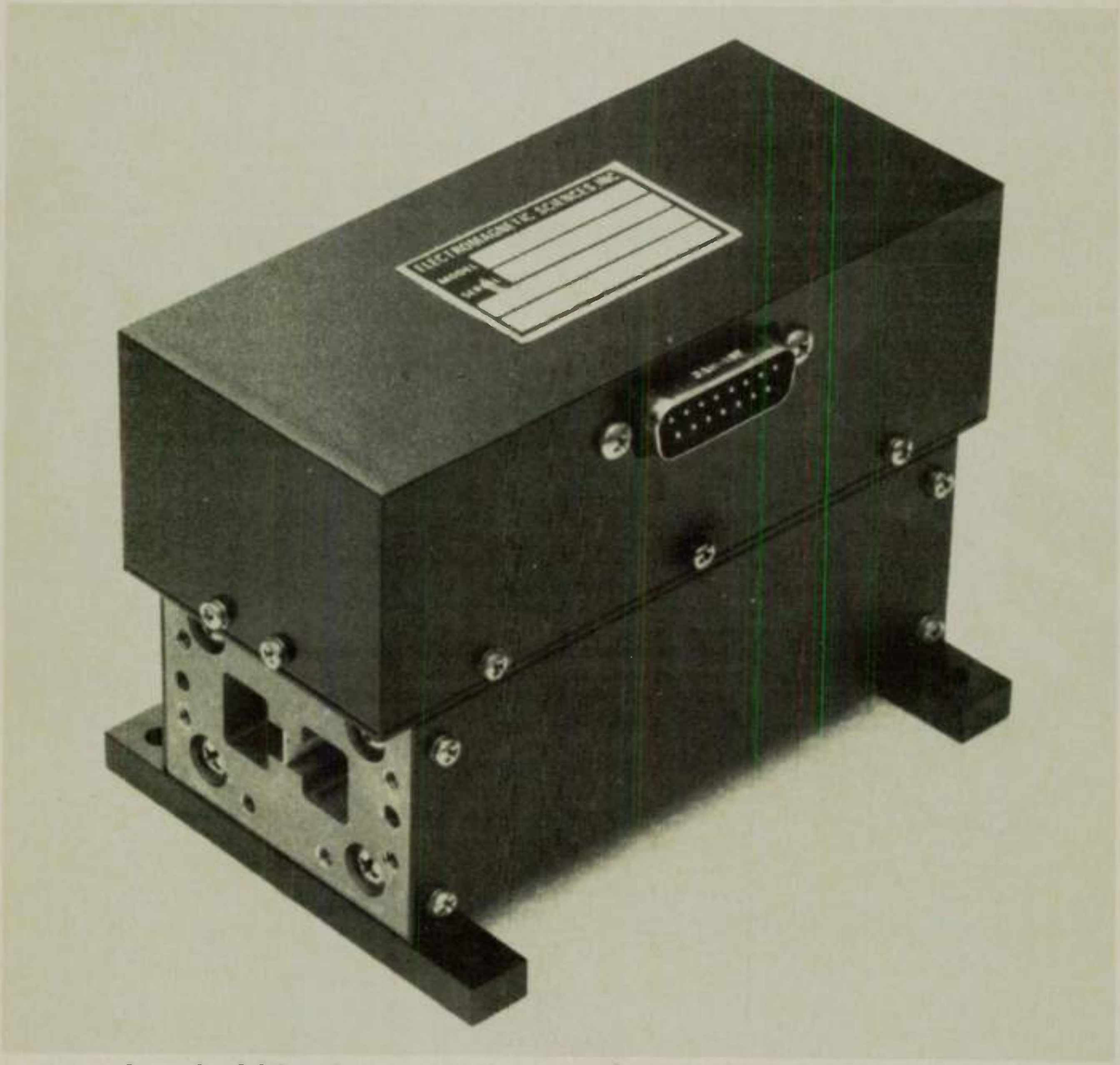
In a similar vein, the effectiveness of US jammers was limited for many years by the inherent modulation deficiencies of the only available noise generation devices then, i.e., magnetron oscillators. The ability to generate an optimum jammer spectrum with the required frequency agility was not achieved, even after large financial infusions to advance this particular microwave device development.

The above examples not only illustrate the mutual dependence of microwave device technology and electronic warfare but also are indicative of some lessons that should be projected forward as we view where electronic warfare and its close partner, microwaves, will have to go in the 1980s. The first lesson is simple. A broad technology base must constantly exist to support a wide range of equipment development options – even if they are not to be perceived as important today but may well be tomorrow. We must not fall in the trap of believing that electronic warfare is a "mature" technology, or that all currently required DoD R&D goals in supporting technology base development have been achieved. For example, detector and power generation or other related device capabilities must be extended to any part of the RF spectrum, regardless of current mentalities as to "usefulness," because so often it is too late to provide the required technology after the actual need is verified.

The second lesson is, perhaps, less clear but of even greater significance. It involves the choice of an end-product success-oriented applied R&D strategy. There are various common expressions that relate: technology "pull" vs technology "push," or technology "evolution" vs technology "revolution". In any case, the concern here is, at what point does one choose to terminate R&D on a particular approach when success is elusive? Is it better to take a new "high-risk longshot" R&D approach, or to stay with a tried and proven approach? History demonstrates in the example given for the early noise jammers that the deci-

(continued on page 21)

The views expressed are those of the author and do not represent the official position of the Naval Research Laboratory, the Department of the Navy or the Department of Defense.



octave bandwidth phase shifters and switches for ew applications

The latching nonreciprocal phase shifter can be designed to cover frequency bands up to at least one octave. In addition, these units in combination with appropriate power dividers and combiners form switches and variable power dividers operating over bands comparable with those of the phase shifters themselves.

Typical of the performance which may be obtained with such units is presented on the right.

Frequency Range: 8-18 GHz (also typical for 5.5-11)
Insertion Loss: 1.0 dB max.
Input VSWR: 1.4:1 max.
R.F. Power: 50 Watts cw
Phase Shift available: 0 to 180° in 128 1.41° steps
Phase Accuracy: 3° RMS
Phase Repeatability: 0.2° max.
Switching Time: 10 microseconds max. (7 µsec. typical)
Switching Rate: 1 KHz max.
Power Supply req'ts: ± 15 V, + 5 V
R.F. Connectors: WRD 750 D24 (Double Ridge Waveguide)
Input Command: 7-bit TTL phase data + strobe

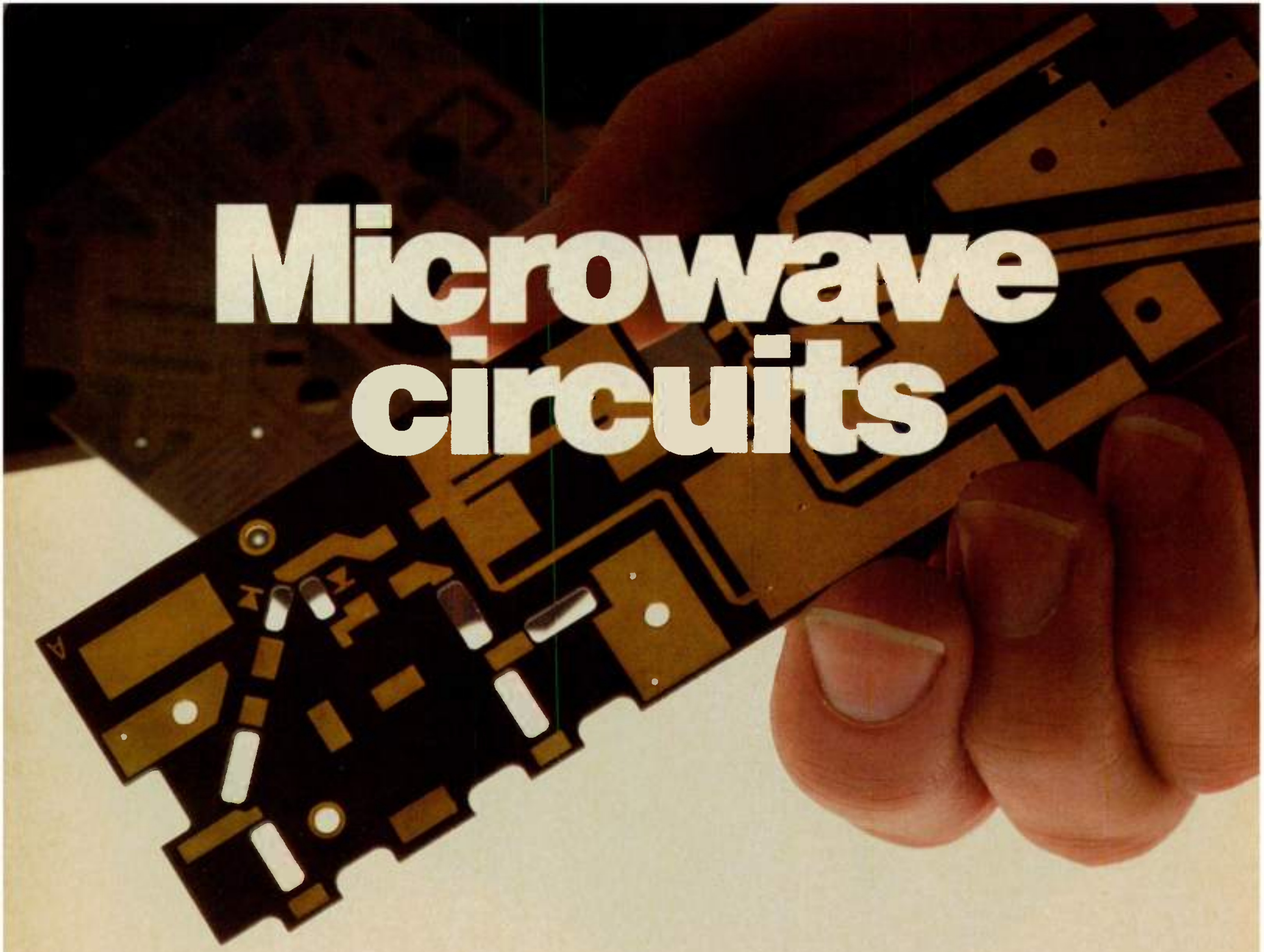
Starting our second decade of state-of-the-art ferrite devices for aerospace and communication systems.

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

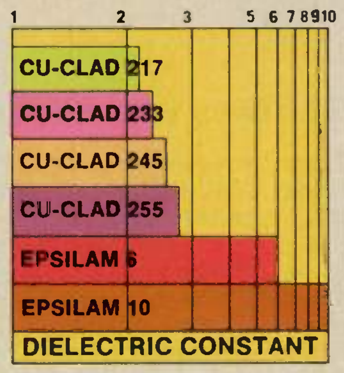
CANADA DATRON CANADA LTD Toronto Tel 416 233 2930
FRANCE DATRON Vincennes Tel 808 02 60
GERMANY MICROSCAN GmbH Ismaning b Muenchen Tel 089 96163
INDIA HIRMAL INTERNATIONAL New Delhi Tel 694089
ISRAEL DAGE ISRAEL Ltd Tel Aviv Tel 03 719191 6
ITALY TELECTRON SpA Roma Tel 591 07785
JAPAN NEW METALS AND CHEMICALS CORP Ltd Tokyo Tel 201 6585
SWEDEN ALGERS ELEKTRONIK AB Sundbyberg Tel 08 985475
THE NETHERLANDS DATRON B V Kortenhoef Tel 35 60834
U K C T LONDON ELECTRONICS London England Tel 01 527 5641

Circle 13 on Reader Service Card

World Radio History



Get 3M's help from start to finish.



No other single supplier can help you at all stages as well as 3M can. First, during your design and layout, there are 3M Microwave Design Aids, copper foil components on convenient transfer sheets. When you're breadboarding they save hours of time, make changes or tweaking quick and easy.

Next, we offer you the widest choice of high quality dielectrics for microstrip or stripline applications. In the dielectric constant (ϵ_r) range from 2.17 to 2.55, our CuClad Teflon-glass substrates deliver dependable characteristics within precise tolerances. In the 6 and 10 ϵ_r range, 3M's Epsilam series provide a remarkable combination of dielectric and physical properties.

When you move to production, our Bonding Film helps you still more. It's recognized as the most reliable and practical bonding agent for stripline or other multilayer circuit packages.

Most importantly, 3M's advanced research and superior manufacturing facilities assure you of consistent quality materials. In quantity. And delivered on time. It's the kind of quality and dependability that pays off in higher production yields and lower end costs for you.

For more information on any of our Microwave Products write us. Microwave Products, Electronic Products Division/3M, 223-4 3M Center, St. Paul, Minnesota 55101. Or if your need is urgent, call us now at 612-733-7408.

CuClad and Epsilam-10 are registered trademarks of 3M.
Teflon is a registered trademark of DuPont Co.

3M

Circle 14 on Reader Service Card

NUMBER 8 FEBRUARY 1980

E&C MICROWAVE BULLETIN

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

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

System Measurements in Anechoic Chambers

Much of E&C's production of microwave absorbers goes into the construction of anechoic chambers. Many of these chambers are designed and built by us, some by our customers.

Anechoic chambers simulate the properties of "free-space," as far as propagation of microwaves is concerned. Reflections in the chamber "quiet zone" may be reduced as much as 60 dB below the level of the incident signal.

The frequency range of chambers is from 30 MHz to 100 GHz. The low frequency limit requires pyramidal absorbers with thicknesses as great as 15 feet (4.6 m). Most chambers use a mix of absorber types and thicknesses to achieve optimum performance and low cost.

Chambers have ranged in size up to 52 feet x 52 feet (15.8 m x 15.8 m) in cross section and 175 feet (53.3 m) in length.

Although many chambers are shaped like rectangular rooms, others have a long end portion shaped like a funnel. They are called tapered chambers. The funnel shape minimizes direct reflection from walls, floor and ceiling which are the primary limitation on performance at low frequencies in room-shaped chambers, particularly at UHF frequencies.

Many chambers are built in shielded enclosures to prevent electromagnetic transmission into or from the chamber.

Measurements commonly made in chambers include: antenna patterns; radar-cross-sections; and measurements of system compatibility, susceptibility, vulnerability, sensitivity, effective radiated power-tracking ability, and boresight accuracy.

The most advanced chambers use computers to generate and move a variety of signals and targets to simulate system operation in a real-world environment.

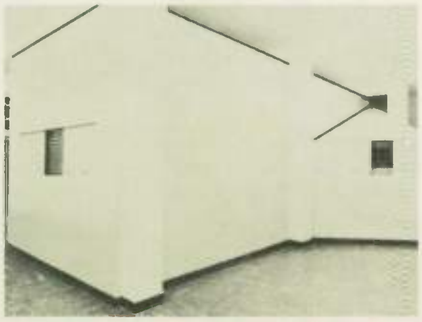
An expanding application is the measurement of a variety of electrical and electronic devices to establish that they meet requirements concerning electromagnetic emissions. Such devices include: microwave ovens, communication equipment, office equipment, computers, generators, lights, relays, tv sets, etc.

A number of chambers have been constructed to measure automobile ignition noise to show compliance with SAE standards.

Circle No. 51 on Reader Service Card

Versatile, Shielded Anechoic Chamber Provides for a Variety of Measurements

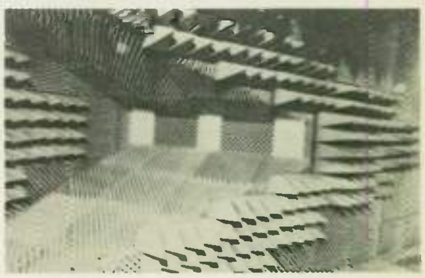
"Multi-faceted" may be the best one-word description of this interesting anechoic chamber built by Emerson & Cuming, Europe N.V. at the University of Naples, Naples, Italy. The chamber was constucted in an existing laboratory building. It includes a triangular, tapered annex at one side of the main chamber to permit bistatic measurements. The main chamber is 3 meters wide by 3 meters high by 8 meters long. The central quiet zone has a diameter of 60 centimeters and a length of 3 meters.



Chamber exterior. Transmitter wall at left; annex at right.

ECCOSORB HPY-12, HPY-30 and CV-6 were used to give anechoic performance in excess of the following specified values:

Frequency	Reflectivity	Antenna Gain
3 GHz	–40 dB	17 dB
6 GHz	–45 dB	17 dB
10 GHz	–50 dB	20 dB



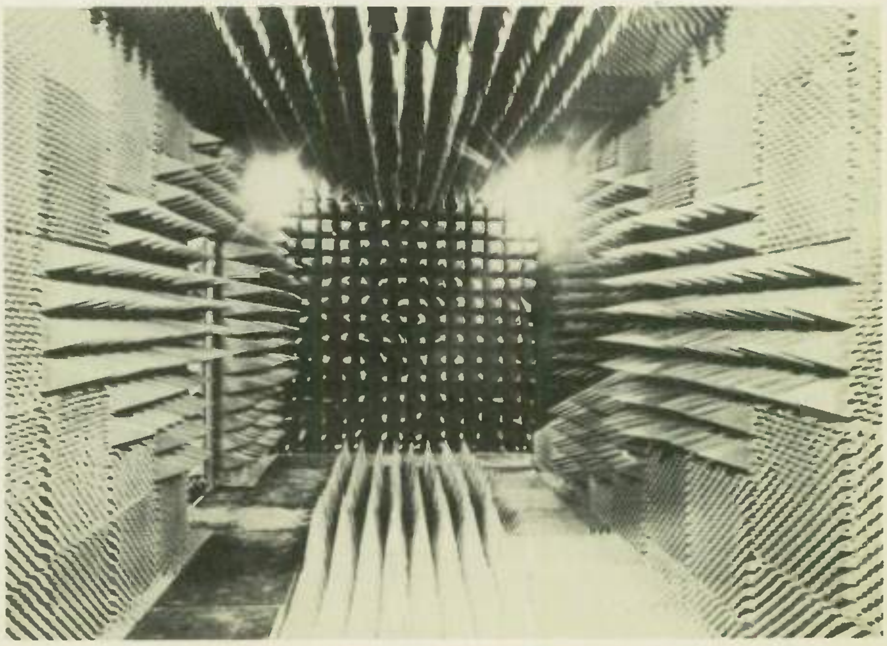
View looking into annex from back wall.

The chamber is being used in research programs involving measurements of radiation patterns, radar cross sections, and bistatic radar cross sections at wide angles.

ECCOSHIELD® CP shielding performance was demonstrated as follows: for magnetic fields, 40 dB at 15 kHz increasing to 60 dB at 100 kHz; for electric fields, 100 dB from 15 kHz to 100 MHz; for plane waves, 80 dB from 100 MHz to 10 GHz.

Here are the conclusions about microwave performance in a test report received from Italy:

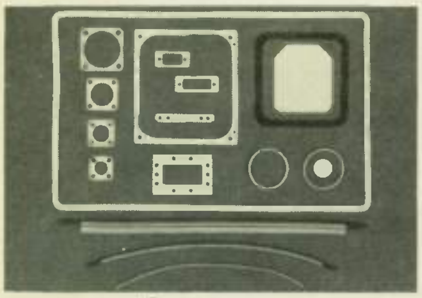
"All tested values exceeded specified values at all frequency bands. The chamber is very good at S-Band; it is excellent at X-band, and the quiet zone is larger than specified. The reflection of the East (annex) wall is lower than the West wall, indicating no decrease in performance of the chamber due to the angular annex."



Back wall from transmitter end. Annex is out of sight at right and forward of back wall.

For A Complimentary Copy of E&C MICROWAVE BULLETIN Circle No. 50 on Reader Service Card

Reliable, High Performance Conductive Plastic Gaskets



ECCOSHIELD® SV is a highly conductive plastic material with many applications in rf shielding. It is widely used for rf flat gaskets, O-rings and extruded gaskets. Based on vinyl resin and silver, its conductivity is close to the range of metals, yet it has the flexibility, toughness and versatility of an elastomer.

PROPERTIES

Density, g/cc	2.6
Elongation at Rupture, %	200
Tensile Strength at Rupture, psi (kg/sq cm)	1000 (70)
Hardness Shore A	65
Volume Resistivity, ohm-cm	0.002
Service Temperature, C	−65 to +125

Bonding Eccoshield SV to Waveguide

When formed into a gasket, ECCOSHIELD SV provides an hermetic seal as well as an rf seal. Insertion loss tests have shown that properly designed extruded gaskets of ECCOSHIELD SV are more effective than knitted metal gaskets. And they are much easier to use. Flat gaskets for waveguide are readily die cut from sheet stock. Sheet, tubing, or extrusions of ECCOSHIELD SV can be butt-joined to produce long lengths or continuous loops. Conductive adhesives are available for bonding to metals, glass, ceramics, and plastics.

Circle No. 52 on Reader Service Card

ENERGY PROPAGATION IN DIELECTRIC AND MAGNETIC MATERIALS

We'd like to send you a short, but very useful, technical note on this topic. It includes definitions and formulas relating to Complex Dielectric Constant, Complex Magnetic Permeability, Polarization, Interface Voltage Reflection Coefficient, Voltage Transmission and Reflection Coefficients, Metal-Backed and Open-Circuit Reflection Coefficients, and other subjects of interest to designers working with dielectric and magnetic materials.

Circle No. 53 on Reader Service Card

EMI Control of Digital Equipment

Strict government regulations concerning control of EMI may extend to the digital world according to an article in EDN magazine. The article notes that computers, peripherals, and other digital devices are both sources and receivers of broadband EMI. They are sources because they contain clock and other square-wave signals with high-frequency content. As computing speed rises, the spectrum of the EMI generated broadens, so digital circuits have great potential for interfering with other electronic equipment.

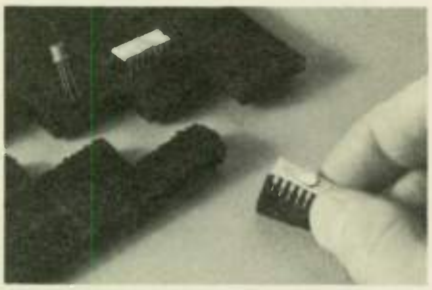
IC logic also can be affected by EMI, and this susceptibility will grow as the trend toward lower powered, lower voltage, and more sensitive VLSI circuits grows. Additional disturbances, such as high-voltage power-line transients or static discharged from personnel, can blow out ICs or wipe out memories.

Regulation in the US and other countries is becoming increasingly strict concerning the EMI generated from digital equipment. Manufacurers may need to redesign equipments as a result of these rules.

E&C can help in both learning about and correcting EMI conditions. Our EMI literature package includes information on shielding materials and techniques, shielding anechoic chambers for making precise emission measurements, and EMI shielding and measurement services. Send for it.

Circle No. 54 on Reader Service Card

CONDUCTIVE FOAM PACKAGING PROTECTS SOLID STATE DEVICES



ECCOSHIELD MOS-FET is a conductive foam sheet material which overcomes the dangers of static electricity in storing and handling MOS/FET, CMOS/FET, LST, MSI and other active solid state devices. Component leads are simply pushed into the semi-rigid foam like pins in a pin cushion, and they remain in place, safely cushioned from physical shock and protected from electrostatic discharges.

ECCOSHIELD MOS-FET now is available in pre-perforated sheets. Each sheet, 12 inches by 12 inches, contains 288 ½-inch by 1-inch rectangles which can quickly and easily be removed from the sheet for mounting individual components. Volume resistivity of the material is about 1000 ohm-cm.

Circle No. 55 on Reader Service Card

LOW LOSS DIELECTRICS FOR MICROWAVE TRANSMISSION LINES AND COMPONENTS

"Eccomax Hi-Q" is the designation for a variety of low-loss dielectrics selected from various Emerson & Cuming product lines and brought together in a single descriptive product folder.

Eccomax Hi-Q products include rod and sheet, casting resins, coatings, impregnants, and hi-k and lo-k foams. All are characterized by very low dissipation factors — typically 100 times lower than epoxy and urethane resins. They are designed for application in RF, UHF, VHF and microwave transmission lines (coax, waveguide, stripline) as well as components, such as capacitors and coils.

Microwave-transparent Blanket for outdoor use.

Dielectric constants range from 1.02 to 30. All materials are non-polar. Because they are crosslinked thermoset hydrocarbons, they will not creep or flow at elevated temperature of "gum" in machining, and show little variation in electrical properties with changes of frequency or temperature.

Circle No. 56 on Reader Service Card

SALES OFFICES

UNITED STATES	TELEPHONE
Gardena, CALIFORNIA 90248	(213) 321-6650
Winter Park, FLORIDA 32789	(305) 647-2602
Northbrook, ILLINOIS 60062	(312) 272-6700
Silver Spring, MD 20902	(301) 949-2777
Canton, MA 02021	(617) 828-3300
Philadelphia, PA. 19144	(215) 848-2040
Richardson, TEXAS 75081	(214) 235-7394
Seattle, WASHINGTON 98118	(206) 932-5855
AND OTHER CITIES	
CANADA	
Burlington, ONTARIO L7R 3Y2	(416) 632-9494
Ottawa, ONTARIO K1V 9A1	(613) 523-2377
Montreal, QUEBEC H9G 1P7	(514) 620-0172
EUROPE	
Westerlo, BELGIUM	(014) 589326
London, ENGLAND	01-922-6692/4
Scunthorpe, ENGLAND	0724 63281/3
Paris, FRANCE	(1) 366-59-86
Cologne, GERMANY	(0221) 58 20 37
Milan, ITALY	02-548 35 25
JAPAN	
Kuriyama, JAPAN	01237-2-3432
Yokohama, JAPAN	045-681-6677

EMERSON & CUMING

Dewey and Almy Chemical Division
W. R. Grace & Co.
Canton, Massachusetts 02021 U.S.A.
Telephone (617) 828-3300

sion to take the high-risk, oscillator-power amplifier approach had considerable success while the power-oscillator-alone approach has all but disappeared in EW systems. One can argue whether the latter success had to do with the relative merits of the alternative system design or whether it related specifically to the electron device choice, e.g. a magnetron, or the choice of a traveling wave tube as was the final outcome.

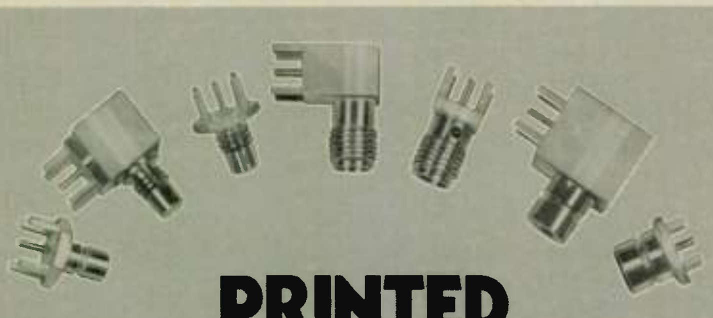
It is suggested that the important lesson here is not that TWTs are fundamentally better than magnetrons, but that there are factors, sometimes not too obvious, that cause certain device types to be selected for particular applications. The EW community must be constantly aware of relevant characteristics of newly developed microwave components and potentially available for equipments under current development, and the microwave community must be quick to understand the forces which drive choices of microwave devices for EW applications. One difficulty here is that not all of us in either the EW or the microwave device communities have (or perhaps deserve) the stature or judgment that is required to convince those responsible for the decision to take the high risks necessary to develop and field a really new microwave device. The high costs coupled with the long development cycles, and the uncertainties/instabilities of the marketplace, are negative factors opposing the enthusiasm for, and promise of, revolutionary breakthroughs in microwaves. All of us are aware that the development cycle for a new EW equipment is reaching 7 to 12 years. When an obsolescence period of less than 10 years is coupled to a 5 through 10-year lead R&D cycle for key microwave components that must be "state-of-the-art" before the EW equipment development can be initiated, there is indeed a real equipment acquisition problem for an area as volatile as EW has been over the last 25 years.

How can one best apply the lessons illustrated by these historical examples of a mismatch between microwave device capabilities and EW needs to the current environment characterized by a protracted procurement cycle, with its multitudinous checks and balances? Some think a return to QRC (Quick Reaction Capability) is the answer – whereby certain normal procurement and fielding procedures are handled in an expedited fashion, shortening the period of development and deployment. Another approach favored by others is to apply more discipline at the beginning of an EW equipment development, allowing for more modularizing and standardizing of components. This will provide greater versatility in the ultimate performance capability of the equipment and avoid a high rate of major replacement because of the premature obsolescence that has been experienced in the past.

Both of the above are important strategies for realizing conventional EW equipments such as on-board warning and surveillance receivers or jammer equipment, but the future has reserved an important place for another factor that has not been so widely debated. This relates to an old EW concept, i.e., "chaff" or "window;" where the central idea is expendability, providing prospects for a whole new set of EW R&D and acquisition possibilities. We should now extend this idea by developing receivers, jammers or decoys based on microwave devices which would be expended from the platform to be defended, or as a means of forward projection to intercept, deceive, or deny the use of a particular part or parts of the electromagnetic spectrum in a specific geographic area.

Not only is the capability for a flexible response provided, but the problems of rapid deployment of new capabilities and inherent high obsolescence rates of installed equipments are greatly reduced. Other important benefits accrue, but the risks are high: projected development costs are hard to estimate, there are challenging requirements for new concepts in devices, packaging, manufacturing technology, and T&E. While there is not yet the general acceptance at all levels – from tactical forces to Executive and Congressional echelons – necessary to achieve a significant program initiation, the viability of this new thrust is beginning to be examined in very serious terms in many quarters.

We are then led to a number of important interrelated questions. What might be the impact of new EW system requirements on the microwave industry? Can one conceive of producing a range of microwave passive and active devices, circuits, and power sources compatible with a hostile but short-operating environment in the quantities required at the necessary unit costs? Is there the level of imagination left in this "mature" technology area to make it happen? Where does the investment capital come from? What is the Government role? What level of incentives are required for the industrial sector? Can one get started, and who will lead? Solutions of the problems behind these questions could well be the most significant microwave industry challenge of the 80s. ■



Circle 15 on Reader Service Card

Introducing the 5610 Automated Network Analyzer System...

Fast, Automatic and Accurate from 10 MHz to 18 GHz.

It's a Wiltron.

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.

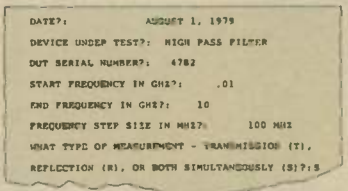
Test antennas to make precise return loss measurements with 40 dB directivity accuracy and memory-corrected test data.

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.

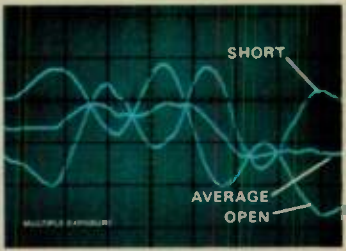
For an early demo or full data, phone Walt Baxter, (415) 969-6500, or address Wiltron, 825 East Middlefield Road, Mountain View, CA 94043.

Easy 4-step operation

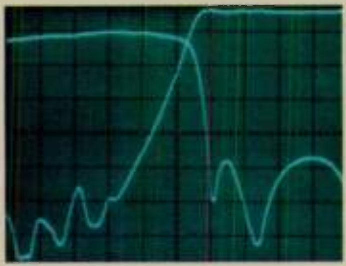


```
DATE?:                AUGUST 1, 1979
DEVICE UNDER TEST?:  HIGH PASS FILTER
DUT SERIAL NUMBER?:   4782
START FREQUENCY IN GHZ?:      .01
END FREQUENCY IN GHZ?:    10
FREQUENCY STEP SIZE IN MHZ?:       100 MHZ
WHAT TYPE OF MEASUREMENT - TRANSMISSION (T),
REFLECTION (R), OR BOTH SIMULTANEOUSLY (S)?:S
```

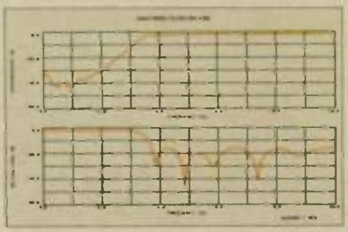
Enter test parameters on controller



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



Initiate automatic measurements and hard copy printout

WILTRON

Circle 16 on Reader Service Card

Some Trends in the Application of Microwave Technology

GOVERNMENT INDUSTRY VIEWS – FIVE FACTORS

As we enter a new decade, it is helpful to identify some of the major factors which will influence the development and acquisition of microwave equipment (broadly speaking, we'll include wavelengths below 1 foot, i.e., frequencies from 1000 MHz through visible light) by the Department of Defense over the next five to eight years. To help us read the tea leaves, we consulted several senior scientists both in DoD organizations and industry as well as reviewed numerous recent reports and news releases. The results follow.

Some four major factors and a number of lesser ones will influence the application of microwave technology in the coming decade. These are:

- Increasing Sophistication of Technology through Solid State
- Increasing use of the Microwave Spectrum – MM Waves
- Increased Government – Industrial Cooperative R&D
- Development of Directed Energy Beam Weapons
- Special, Second Order Trends

Most sources we interviewed agree that the technology being applied to the microwave spectrum is becoming both more sophisticated and more complex and that this trend will continue. During the 1970s the development of solid state devices and their introduction into microwave circuits moved ahead very rapidly. While vacuum tubes generate power at microwave frequencies orders of magnitude higher than do individual solid state devices, a shift to solid state is occurring. For example, one hundred watt peak power pulses can be generated using cavity combiners to sum the output of ten diodes (even the magnetron this replaces has a power output which is the combination of many individual cavities within one vacuum tube). The motive for this shift is to achieve the lighter weight of the solid state approach, particularly that of its lower voltage, simpler modulator.

Whatever the vehicle, or whatever the medium in which it operates, more sensors will be utilized for its operation. The trend is in the direction of creating sensor systems which have different front ends for each sensor regime but which share a common signal processor.

In fact, some signal processing circuits will be incorporated in the design of all new microwave systems. Increasingly, the design, documentation and standardization of software will become the controlling factors in the acquisition of microwave systems. One of the difficult design decisions that will remain is how to handle the processing – centrally, or, in a distributed fashion? Today there is no generalized solution applicable to all cases. The key trend: *Sensors will tend toward integration of their outputs and correlation in a central processor.*

There are some significant efforts going on to integrate functions into "standard" modules, a synergism whereby the integration offers greatly enhanced capabilities compared with the simple aggregate of the subsystems. In the case of surveillance from space, the Air Force is evaluating at least three different processing concepts. One postulates that a new surveillance system will operate from independent, self-sufficient satellites. Another suggests that data will be processed centrally from distributed space platforms and the third, proposes that the processing will be central but data will be collected from a distribution of sensors suspended from very large mechanically linked structures orbiting in space. *Today decisions about central versus distributed processing are being developed on a case by case basis.*

Many engineers believe that the portion of the microwave spectrum below 18 GHz region represents a relatively mature technology, a region in which incremental increases in performance capabilities require disproportionate investments of time and money. On the other hand, the millimeter-wave region has had little development; more payoffs in performance capabilities can be expected for the R&D dollar. This may be also true, to a lesser extent, for the E-O wavelengths; but there are reservations. In some Navy circles, it is felt that for electronic warfare (EW), research on electro-optics has been over-emphasized at the expense of millimeter-waves.

In the Soviet Union research in this region appears to have been better supported for many years. As a result, the gyrotron represents a development that has progressed very rapidly there. The Soviet gyrotron oscillator development apparently is ahead of what we are doing here. Soviets are using these devices with cryogenic magnets for plasma re-

(continued on page 26)

Solid State Microwave can solve your pulsed power transistor problems

- GOLD METALLIZATION
- RUGGED BALLASTED DESIGNS
- BROADBAND, INTERNALLY MATCHED STRUCTURES
- HIGH VOLUME PRODUCTION CAPABILITY
- BROAD SELECTION OF POWER/GAIN/PACKAGE AND SUPPLY VOLTAGE COMBINATIONS
- LOW COST PACKAGING AVAILABLE

For over a decade Solid State Microwave* has been a leading supplier of RF power transistors to the land mobile, aircraft and marine communications equipment industries. Consistent performance in delivering high volume, high quality, cost effective devices has earned us an enviable reputation unsurpassed in the industry.

We are now equipped to meet your most critical microwave pulsed power transistor requirements with a full line of devices designed for DME; TACAN; IFF; Weather Radar and Phased Array Radar applications.

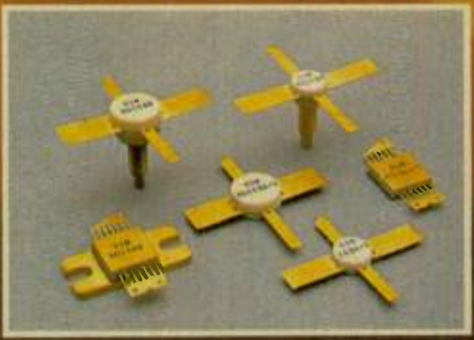
For fast action on your next microwave pulsed power transistor problem, call John Walsh at (215) 362-8500. After all . . . our name *is* Solid State Microwave.

**Formerly the RF Division of Solid State Scientific Inc.*

Weather Radar

DME; TACAN

IFF



SSM

SOLID STATE MICROWAVE

a division of Thomson-CSF Components Corporation

Montgomeryville Industrial Center, Montgomeryville, PA 18936 • (215) 362-8500 • TWX: 510-661-6548

Circle 17 on Reader Service Card

search. Recently, there has been gyrotron amplifier development in this country (see MJ cover, Aug. 78). But according to one senior Government laboratory scientist, it will be a long time before gyrotron amplifiers are available here for application to production equipment.

The military is attracted to the microwave region because it can get the bandwidth to modulate signals so that they have a lower probability of intercept, and better anti-jam and encryption characteristics. Furthermore, the potentials of much higher resolution, and passive operation in much smaller packages are available. Accordingly, military use will increase, as will the sophistication of the signals emitted.

The United States, however, is not the only nation which is using and expects to use the microwave spectrum. All of the developed nations make heavy use of it now and will continue to do so. Moreover, Third World nations served notice recently at the World Administrative Radio Conference (WARC) in Geneva that they want allocations of, and expect to use, certain microwave frequencies. Representatives of the US were pleased, by the way, to see that controversial issues about allocations were resolved for the most part on the basis of their technical merits and not by bloc votes. Nevertheless, the US lost out on two key issues. These included the US desire for allocation of the 3.4 to 3.6 GHz band for "radio location" on a primary basis and the use of a 20 MHz band centered at 2450 MHz for experimentation and possible future use to return power to the earth from an orbiting satellite solar generator.

Of particular concern is the allocation of the 3.4 to 3.6 GHz band. The Navy shipboard AEGIS system, the Air Force E-3A (AWACS) and the British Nimrod airborne radars are affected. Radar use was given primary status in Regions 2 and 3 (Western Hemisphere and Asia) and secondary status in Region 1 (Europe/Africa) except for Britain, Norway and Denmark. In these three countries it was given equal status with fixed terminal satellite communication service. Furthermore, WARC added the proviso that it wants "all administrations operating radio-location systems in this band — to cease operations by 1985". The US proposal for the use of a 20 MHz band centered at 2450 MHz for the possible return to earth of solar satellite generated power, received almost no support. To reiterate, it is clear from the results of the WARC and other masses of evidence that *both the signal density and signal sophistication throughout the microwave spectrum can be expected to increase steadily throughout the world in the 80s.*

Increased sophistication, better reliability and lower costs for microwave devices stem from the ever widening application of integrated circuits (ICs). The DoD has unique needs for ICs. These needs, however, represent no

more than about 7% of the current market. This is not a large enough market segment to attract the industrial research dollar. As a consequence, DoD has instituted a major research program to develop improved capabilities to produce by the mid-1980s very high speed integrated circuits. About $12 million per year, per service will be spent on this program through FY 1984.

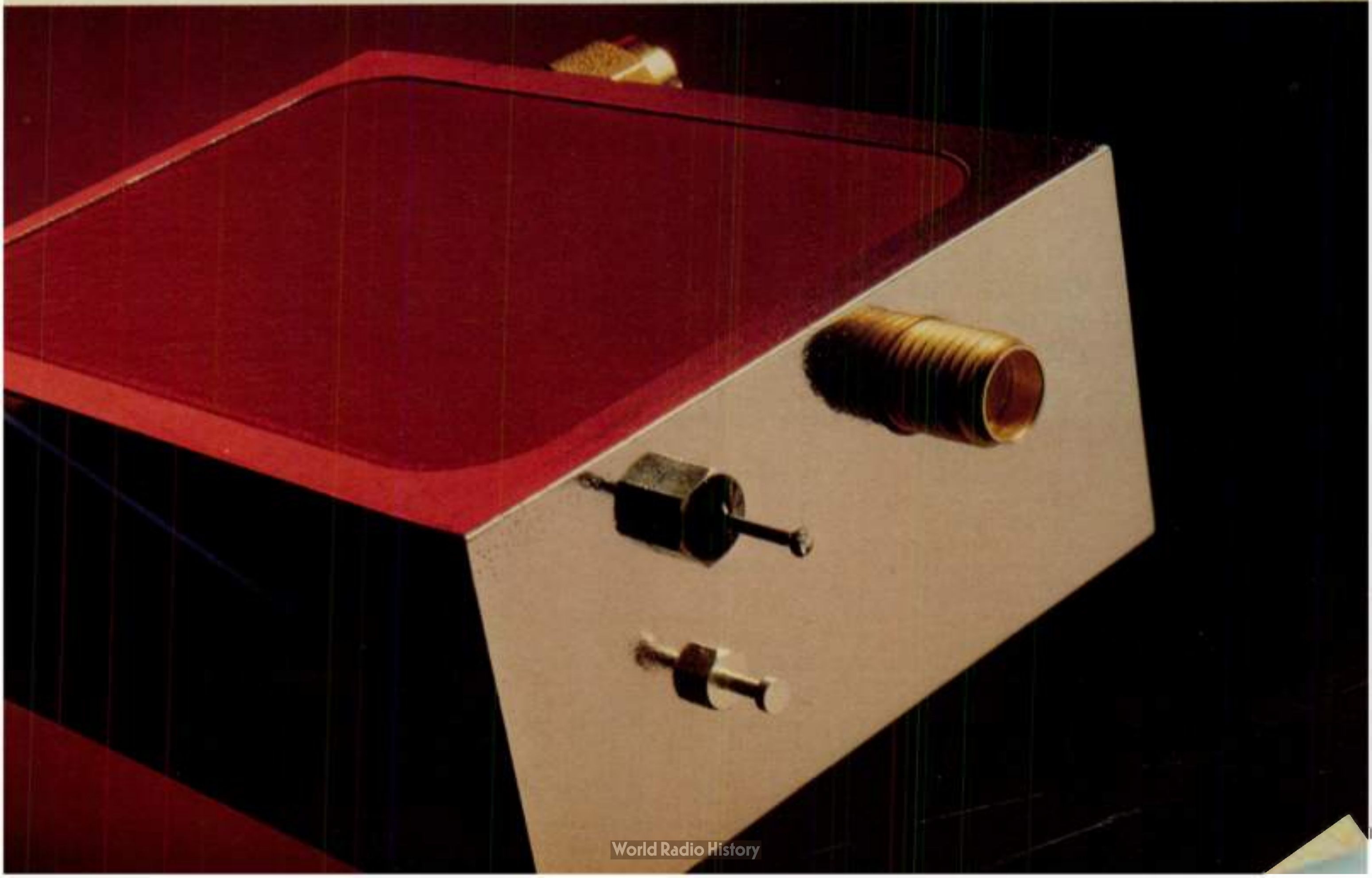
Of course, complexity is being added at the chip level by combining functions. This trend will advance with great speed. A current example of the results of the application of this technology is the 4-inch diameter, staring focal plane array seeker developed by Hughes for the Army for possible use with tactical missiles. This sensor includes more than 1000 charge coupled devices (CCDs) that combine memory and multiplexing read-out functions. Their use reduces greatly the number of wires which otherwise would be needed to store and process signals from the detectors which also are mounted on the same chip.

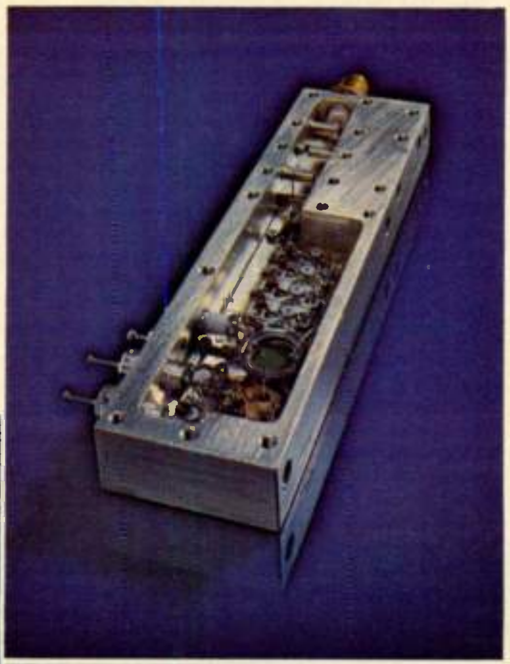
At the system level, R&D emphasis has shifted to the millimeter wave and electro-optics regions; since, as mentioned, technological advances are expected to offer a payoff more quickly and to be of greater operational significance in these regions. Production funding, on the other hand, will continue to be committed but in even greater amounts to the lower frequency (below 18 GHz) region. Additionally, production funds will be allocated in ever increasing amounts to thermal imaging devices for the acquisition of equipment for individual infantrymen and tank drivers, as well as for surveillance and fire control systems.

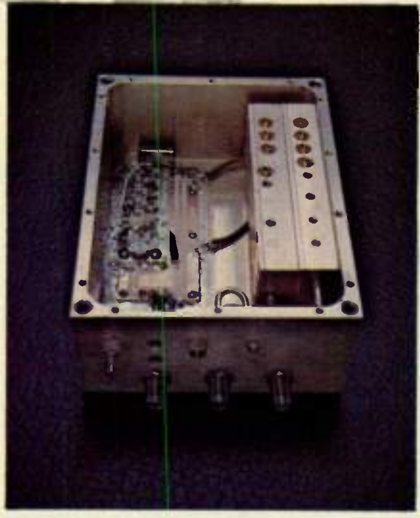
Use of the entire microwave spectrum by the United States will increase, and the increased signal density will not be limited only to the region below 30 GHz. The immediate emphasis in the millimeter-wave region will be for greatly increased research and development. Production systems will be following in the near future. Even in the E-O region, while the primary emphasis is on R&D, nevertheless, there will continue to be IR production systems in the field for all of the services, with more to follow shortly. Low power laser devices such as range finders and target designators are already being manufactured, but here too the primary emphasis is on R&D.

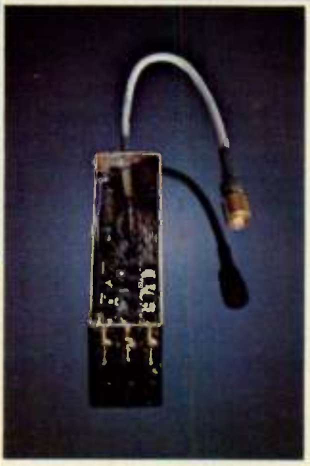
Here at home, the environment for spending for Defense has changed. Now there appears to be at least a partial commitment to playing catch-up by emphasizing hardware procurement and at least staying even in developing the technical base. The FY 80 and 81 budgets do increase procurement budgets for hardware above the inflation rate. This will continue for at least another year or two if the present level of tension in the international environment remains about the same. A similar situation ex-

(continued on page 29)









ists for the technical base. There seems to have been a general realization that we have not been investing enough in research to maintain our so-called technological lead, to increase productivity at any meaningful rate and to develop cost-effective substitutes for critical materials.

According to one very senior Service scientist, this is the first year (FY 80) that the "tech base budget" has increased faster than the inflation rate. Also, it is being more solidly supported by the Services than heretofore. Moreover, statements to the Congress by the Secretary of Defense, the Undersecretary for Research and Engineering, the Deputy Undersecretary for Research and Advanced Technology and the Director, Advanced Research Projects Agency (DARPA) all repeat the theme of increased emphasis on research.

The areas of Defense application of microwave technology can be broken out as Communications, Surveillance, Weaponry, and EW. The concensus of experts indicated that the order in which these areas are listed reflects the amounts of money which will be invested in them in the United States each year for the next several. The investment in EW, however, is increasing rapidly. It might move up.

Communication applications include both ground-based point-to-point systems and a rapidly increasing number of satellite systems. Surveillance applications cover all forms of active and passive systems, both atmospheric and exoatmospheric. Search, warning, intercept, fire-control, tracking and security systems are among those included. Weaponry encompasses not only guidance (including seekers) and fuzing systems but destructive applications (lasers) as well. Electronic warfare equipment includes receivers, direction finders, jammers, signal analyzers and all varieties of counter-countermeasure fixes to communication, surveillance and weapon systems.

Another major factor directly influencing the application of microwave technology is the increasing use of space platforms. While all the DoD officials consulted expressed serious reservations about the survivability of space platforms, they acknowledged that both the military and civil use of them would increase sharply. The exoatmospheric environment offers many advantages for the application of all segments of the microwave spectrum as we have defined it. Already there have been sharp increases in the application of microwave devices to satellites for communications and surveillance purposes. This trend should continue. One example is the very recently announced five-year development leadership in satellite communications technology. The general objectives of the program are to increase the efficiency with which the RF spectrum is used by geostationary communication satellites, to lower space communication service costs and to stimulate the innovation of new services for improving the public good. The Defense Department will cooperate with and participate in this effort. But, by and large, what is put into space by the military will be paralleled by either base or earth-based systems. Understandably, the military remains concerned about the susceptibility of satellites to the actions of other nations.

An indication of just how crowded the space around the earth has become came from the recently concluded WARC. To accommodate the demand for additional geosynchronous communication satellite orbits, new standards were adopted for east-west station keeping and spacecraft antenna pointing. The former was reduced from ± 0.5° to ± -0.1° and the latter tightened from ± 0.5° to ± 0.3°.

The fourth major influence in the 80s on microwave technology is the Nation's program to develop directed energy beam weapons, pursuing dual efforts. One is exploring charged particle beams and the other, high energy lasers. One senior DoD official feels that the R&D funding for the charged particle beam weapon will increase steadily, perhaps exponentially, but that the R&D funding for laser weapons will continue to fluctuate.

The DoD has been investing heavily in R&D for high energy lasers for several years. Through FY 79, DoD had spent $1.27 billion on developing high energy laser technology. By 1985, it expects to spend about $1 billion more. In comparison, the charged particle beam effort is both more recent and more modest. It officially began in FY 79. DARPA's budgets for it include only $12.0 million in FY 79, and estimated of $24.0 million and $20.0 million, respectively, for FY 80 and 81. Additionally, in FY 80, the Services are budgeting a total of $5.3 million for their efforts.

DoD's high energy laser program will culminate in the early 80s in a series of weapon feasibility demonstrations. If they are successful, the responsible representative of the Office of the Secretary of Defense will decide to build one or more prototype weapon systems.

There are some second-order factors which could become dominating ones and have considerable influence on future microwave developments. These include:

- emphasis on the "ilities" (i.e. capability, useability and reliability)
- increasing priority for EW
- shift from mechanical to electronic antennas for radars
- increasing use of simulation
- DoD support of neglected research areas

Complaints from the field about electronic equipment, which is unreliable and neither maintainable nor operable by the personnel available, are finally beginning to have some effect on design. For a whole host of reasons, there is electronic equipment in the field which is inoperable. Some of this is caused by inadequate emphasis on reliability engineering and testing during development (funds were short so something has to be cut – reliability testing). Some of the problems result from assumptions made regarding the caliber of personnel and their state of training when the maintenance routines were planned. And still another part of the problem stems from a total lack of awareness on the part of designers of the difficulties of operating equipment in the field under combat conditions. In any event, a major attempt is underway within DoD to ensure that usability and reliability considerations go hand in hand with capability considerations throughout the design process.

For many reasons, including the ever increasing EW capabilities of the forces of the Soviet Union, improving the electronic warfare capabilities of US forces is assuming a higher and higher priority. A subdivision of this influential factor is the growing concern about the vulnerability of individual vehicles. Today every combat vehicle; aircraft, helicopter, tank, ship, etc., represents a major investment. Not only does each vehicle contain highly trained crewmen, whose training cost a great deal and took a long time, but the vehicle itself is expensive, up to a billion dollars in the extreme case of a modern aircraft carrier. Naturally one wants to protect that sort of investment. Accordingly, protective suits of EW eventually will come to be added to every major combat vehicle.

Another influential trend in EW is that expendable EW devices are becoming more attractive for several reasons. One of their most appealing features is that they can be located close to an enemy emitter; have maximum effect on it and minimal effect on our own. Also, they are versatile. They can be packaged in bombs and projectiles, as payloads for rockets, missiles, balloons and drones and can be used as repeater jammers, noise jammers, decoys or combinations thereof.

Desired, of course, are high volume, small, inexpensive devices which can generate power at microwave frequencies. Some will cost as much as $5000/unit. One such microwave source is now produced at $2000/unit. Sounds a bit like the sonobuoy business. The trick with sonobuoys as it will be with these EW expendables is low manufacturing costs with attendant high reliability standards.

In discussing processing, we noted that there will be a demand for more electronically sophisticated radars. Mechanical antennas, always will be with us; but in the not too distant future, however, electronically steerable antennas will continue to develop prominence. The 1970s saw PAVE PAWS (UHF), COBRA DANE (L-Band), AEGIS (S-Band) MLS and SAM-D (C-Band) and EAR (X-Band). Their characteristics, enabling antenna beams to be steered precisely and at inertialess speeds, have been proven by these land, sea, and air installations. Because of their special anti-jam characteristics, their abilities to discriminate against unwanted signals and to shift instantly from one target to another, we can expect still more elec-

Circle 59 on Reader Service Card

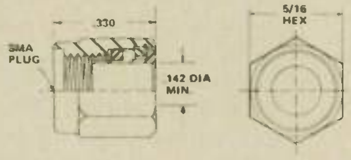
tronically steerable antennas in the 80s, across-the-board for surveillance, reconnaissance and fire-control purposes.

Because of the ever increasing costs of full-scale field testing and training, and the difficulty of creating a realistic combat signal environment, more and more use will be made of simulators and simulation. Furthermore, advances in integrated circuits, processing and, above all, computer-generated imagery, have made it easier and less costly to design and develop effective simulators. Accordingly, for use in both testing and training, the DoD will increase significantly the rate at which it acquires simulators.

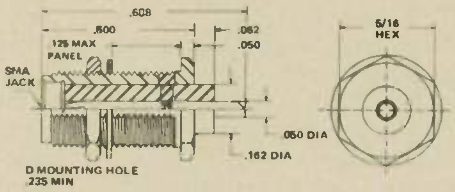
Finally, one other second order factor of influence needs to be mentioned. This concerns the DoD's willingness to help stimulate research in areas where it is being neglected. Most elements of the DoD are prepared to establish cooperative programs with universities and industry when DoD representatives can be convinced an area important to it is being neglected. The Air Force's AFTER (Air Force Thermionic Emission Research) Program is not only an example of this, but it might be serving as the model for restarting research in other areas that have been neglected or abandoned. The AFTER Program is set up with Stanford University and the microwave tube industry. AFTER is responsible for stimulating research in the area of high power vacuum tubes operating at microwave frequencies and increasing the number of engineers and scientists educated and trained up to the graduate level to work in this field.

Undoubtedly there will be other factors which will influence the direction of funding in microwave technology. There is a key consideration for industry. Each company must decide whether it wishes to live and compete in a high technology or a mature technology world. The former is characterized by very high unit cost. Every bolt, nut, screw, sensor, platform, etc., may be governed by a specification with unique performance and reliability requirements. Only a few models are to be made of such products. The less demanding, mature technology environment is characterized by a relatively pedestrian technology with the attendant manufacture of relatively large quantities. Each firm must decide for itself what its place within these extremes is. Some may be able to span this technological gamut, and by so doing, moderate the effects of the vicissitudes of the two businesses. Clearly, however, the cost and work environments of the high and pedestrian technologies are significantly different. Unless these differences are addressed through the use of appropriate controls and procedures, a company can get into financial difficulty quickly, even though it is pursuing the ever expanding Defense microwave market.

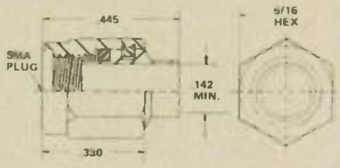
IMMEDIATE DELIVERY



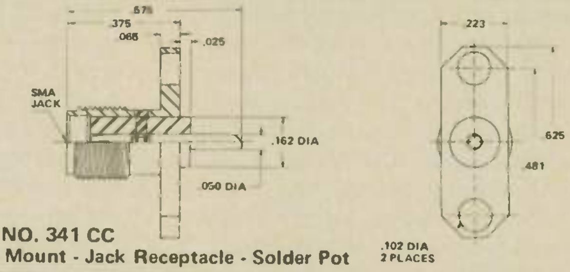
PART NO. 300-1
Straight Cable Plug - 141 Semi Rigid Cable



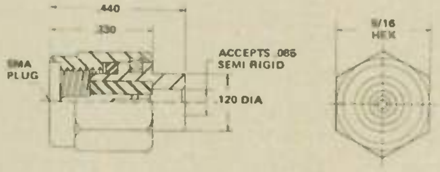
PART NO. 362 CC
Bulkhead Feedthrough - Jack Receptacle - Solder Pot



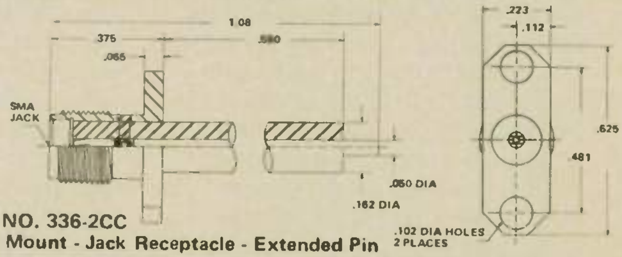
PART NO. 300
Straight Cable Plug - 141 Semi Rigid Cable



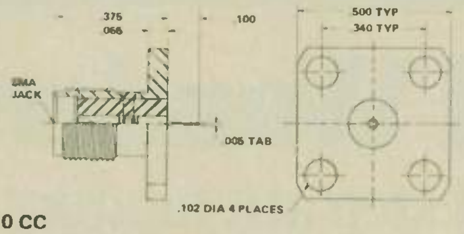
PART NO. 341 CC
Flange Mount - Jack Receptacle - Solder Pot



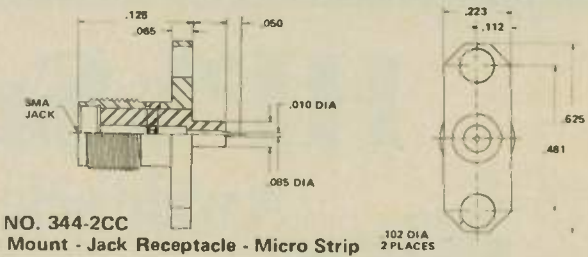
PART NO. 301-1
Straight Cable Plug - 085 Semi Rigid Cable



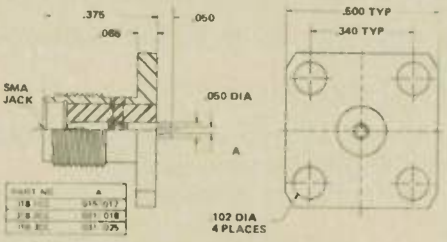
PART NO. 336-2CC
Flange Mount - Jack Receptacle - Extended Pin



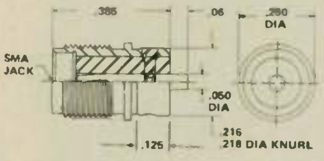
PART NO. 340 CC
Flange Mount - Jack Receptacle - Tab Contact



PART NO. 344-2CC
Flange Mount - Jack Receptacle - Micro Strip



PART NO.
318 CC
Flange Mount - Jack Receptacle - Slotted Contact



PART NO. 398 CC
Press Fit - Jack Receptacle

FEATURES:
- LOW VSWR
- HIGH QUALITY WORKMANSHIP
- MACHINE FINISHES — 32 OR BETTER
- AVAILABLE FROM STOCK

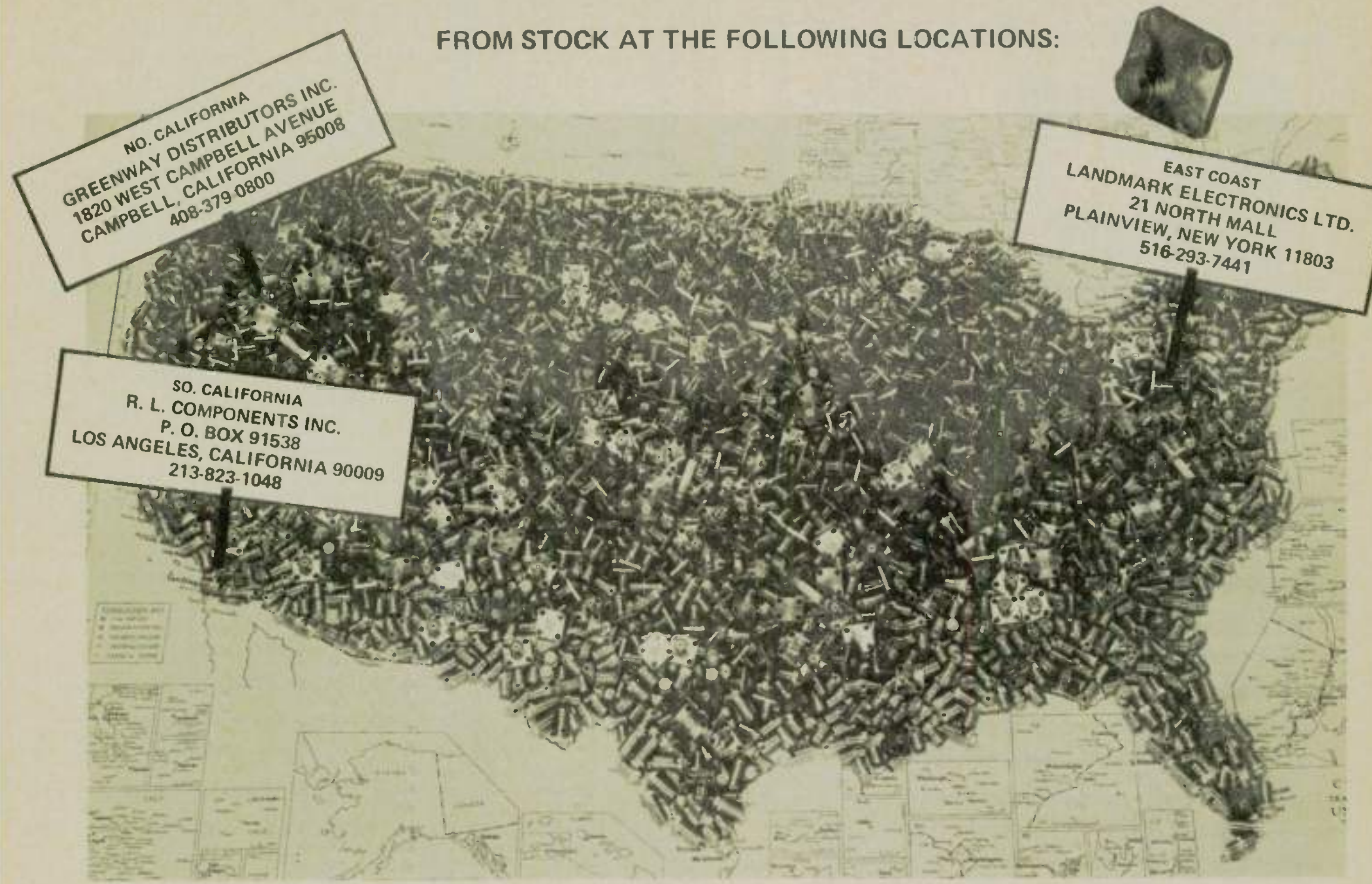
ALL CONNECTORS ARE AVAILABLE IN:
- STAINLESS STEEL WITH GOLD OR PASSIVATED FINISH FOR PASSIVATED STAINLESS USE SF FOR PREFIX.
- 4 HOLE AND 2 HOLE CONNECTORS ARE AVAILABLE IN BOTH CAPTIVATED OR NON CAPTIVE CONSTRUCTION.

UNITED MICROWAVE PRODUCTS, INC.

1815 West 205th Street · Suite 303
Torrance, California 90503
(213) 320-1244 · (213) 320-1246

IMMEDIATE DELIVERY

FROM STOCK AT THE FOLLOWING LOCATIONS:



NO. CALIFORNIA
GREENWAY DISTRIBUTORS INC.
1820 WEST CAMPBELL AVENUE
CAMPBELL, CALIFORNIA 95008
408-379-0800

SO. CALIFORNIA
R. L. COMPONENTS INC.
P. O. BOX 91538
LOS ANGELES, CALIFORNIA 90009
213-823-1048

EAST COAST
LANDMARK ELECTRONICS LTD.
21 NORTH MALL
PLAINVIEW, NEW YORK 11803
516-293-7441

MEETS OR EXCEEDS THE REQUIREMENTS OF MIL-C-39012

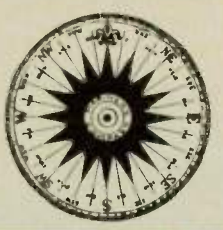
Requirement	MIL-C-39012 Paragraph	Specifications
MATERIAL	3.3	Stainless Steel QQ-S-764, Class 303
FINISH	3.3.1.	Contacts .0001 min. gold Per MIL G-45204
INSULATION RESISTANCE	3.11	5000 MEGOHMS min.
DWV	3.18	1000 VRMS
CONTACT RESISTANCE Milivolt Drop	3.17	Initial after Environment 3.0 4.0
CONNECTOR DURABILITY	3.16	Insertion withdrawal 500 cycles min. at 12 cyc/min. max.
VIBRATION	3.19	MIL STD. 202 Method 204 test cond. D
SHOCK	3.20	MIL. STD. 202 Method 213 test cond. 1
TEMP CYCLING	3.21	MIL. STD. 202 Method 102 test cond C
CORROSION	3.14	MIL. STD. 202 Method 101 test cond B
MOISTURE RESISTANCE	3.23	MIL-STD. 202 Method 106 IR shall be 200 MEGOHMS

UNITED MICROWAVE PRODUCTS, INC.

1815 West 205th Street · Suite 303
Torrance, California 90503
(213) 320-1244 · (213) 320-1246

Circle 21 on Reader Service Card

Around the Circuit



PERSONNEL

Microwave Associates Communications Co., one of M/A-Com, Inc.'s operating companies, named **Erik H. van der Kaay** as V.P. and General Manager – Broadcast Div. . .**Larry L. Moore** was appointed Corporate V.P., Marketing of Frequency Sources, Inc. . .**Philip Levine** was named as Product Manager for the RF Components Group of KDI Pyrofilm. . .EIP Microwave, Inc. appointed **Robert E. Loft** as Regional Sales Manager for the Central and Western US and **William F. Dentinger** as Regional Sales Manager for the Eastern US and Canada. . . .**William H. Anthony** joins K & L Microwave as V.P. of New Product Development. . .**Stephen N. Barthelmes** was promoted from Marketing Manager to General Manager of Thomson-CSF Electron Tube Div. . .**Francis W. Heintz** becomes V.P. and General Manager of Raytheon Co.'s Microwave and Power Tube Division. . .Alpha Industries, Inc. added **Alfred M. Bertocchi** to its Board of Directors. . .**James J. Connolly** joined the Anzac Div. of Adams-Russell as Corporate V.P. of the parent company and President of the division. . .Rogers Corp. named **Thomas H. Johnston, III** as Sales Engineer, for the Eastern New York State Region. . .At Narda Microwave Corporation, **Louis J. Nielsen** was promoted to Western Regional Sales Manager. . .LOCUS, INC., named **Joseph D. Sardonia** as V.P. of Washington operations. . .**Henry J. Breen** was appointed General Manager at JFD Electronic Components. . .LNR named **Howard C. Carlin** as Product Line Mgr. for Satellite Communications Products. . . At Parametric Industries, Inc., **George R. Sotiropoulos** was appointed V.P. of Manufacturing.

INDUSTRY NEWS

Aydin Corp. has purchased three buildings for $950K with total space of 50,000 sq. ft. in the Newtown Industrial Commons in Newtown, PA. . .Expansion plans at **Scientific-Atlanta, Inc.** call for 157,000 sq. ft. of new office, engineering and manufacturing facilities to be opened at Interstate Industrial Park, Beaver Ruin Rd., Gwinnett County, GA in March, 1980. The new building is adjacent to two other recently occupied facilities, which house the company's communications products group. . .**Omni Spectra, Inc.** received a merger proposal from **Frequency Sources, Inc.** The offer calls for Frequency Sources to exchange one share of its common stock for 2.1 shares of Omni Spectra's common stock. . . Purchase of a 105,000 sq. ft. building for manufacturing operations at 10707 Gateway West, El Paso, TX was announced by **GTE Lenkurt**. . .Officers of **Farinon Corp.** of San Mateo, CA signed a definitive agreement with **Harris Corp.** of Melbourne, FL to merge Farinon into Harris in a transaction valued at about $130M. . .**EPSCO** Microwave, a division of **EPSCO, INC.**, named **Daltron Ltd** as the firm's exclusive product line representative in the UK and the microwave company announced the addition of **Mark V Associates, Inc.** of Mountain View, CA to represent its products in Northern California. Mark V Associates will also act as the Northern Californian marketing representatives of **Micro-Tel Corp.** Representation in Southern California for Micro-Tel will be **Blair Associates**, Anaheim, CA.

CONTRACTS

Scientific-Atlanta, Inc. received an order in excess of $1M for five satellite earth stations and related electronics products from **American Satellite Corp.** . . This is the first order received under a recent memorandum of understanding which provides for SA to become a supplier of digital earth stations for the satellite data exchange (SDX) service offered by American Satellite to US business firms. . .**E-Systems ECI Div.** announced receipt of an order valued at more than $1M from the Spanish Navy for AN/WSC-3 UHF shipboard radio terminals. The ECI Div. of E-Systems also received a $10.1M contract from the US Navy for the production of AN/SYR-1 communication tracking systems for use with the SM-2ER missiles. . .**Northrop Corporation's Defense Systems Div.**, won a $2.8M contract from the Naval Air Systems Command to develop a compact radar jammer (ALQ-162) for Naval and Army aircraft. The new ECM system will be a small, internal jamming system intended for Navy aircraft now in service which will not receive the Airborne Self Protection Jammer (ASPJ) now under development for the US Navy and Air Force. . .Sperry Div. of **Sperry Corp.** received a $8M subcontract from **Boeing Aerospace Co.** to develop a target seeker for the USAF WASP anti-tank missile. Seeker will use mm-waves to acquire and track targets. . .**Cincinnati Electronics Corp.** was awarded a $2.9M contract by the USAF, Armament Div. at Eglin AFB, for a prototype Communications/Data Link Jammer (C/DLJ).

FINANCIAL NEWS

Vitramon, Inc. declared a 10¢ per share cash dividend and a special 5% stock dividend payable on Feb. 15, 1980 to its stockholders of record on Jan. 15, 1980. . .The Board of Directors of **Sanders Associates, Inc.**, voted a regular quarterly dividend of 12.5¢ per share payable Jan. 15, 1980 to its stockholders of record on Dec. 28, 1979. Directors of **Racal Electronics Ltd** announced pre-tax net profit for the half-year ended Sept. 30, 1979 of 25.2M pounds as compared with a net profit for the same period last year of 24.3M pounds. . .The Board of Directors of **Fairchild Industries, Inc.** declared a cash dividend of 30¢ per share payable Dec. 28, 1979 to stockholders of record on Dec. 17, 1979. . .**Loral Corp.** voted a 100% stock distribution on its outstanding common stock, and declared a 20% increase in the cash dividend on shares outstanding after the split. For the six months ended Dec. 31, 1979, **Narda Microwave Corp.** reported sales of $8.4M and $425K net income, or 56¢ per share. This compares with 1978 half-year sales of $7.6M and $219K net income, or 31¢ per share. . .For the third quarter ended Nov. 25, 1979, **General Instrument Corp.** announced revenue of $196.2M and earnings of $13.8M or $1.61 per common share. Last year's revenue was $140.4M and earnings $9.1M or $1.18 per share. . .For the nine months, ended Nov. 30, 1979, **AEL Industries, Inc.** reported sales of $43.3M and earnings of $469K or 25¢ per share; third quarter results showed a loss of 12¢ per share. During the comparable period last year, sales reached $43.4M and earnings totaled $1.4M or 77¢ per share. ■

In Class A solid state linear power amplifiers...

We're in a class by ourselves!

Series LWA and LAB; up to 200 watts power; frequencies from 1MHz to 8400MHz

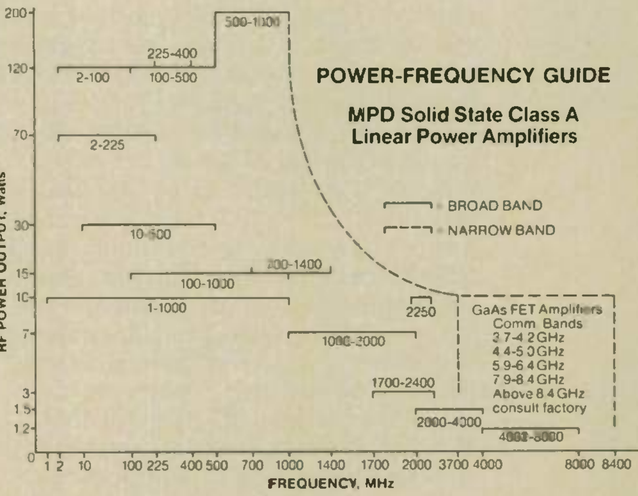
Higher powers, higher frequencies, more design and performance features, more models to fit your applications—that's the continuing story of MPD Class A solid state linear amplifiers. The result is a product line that nobody else in the industry—*repeat, nobody*—can even come close to matching!

You can now choose from 225 standard MPD models, available in module or rack-mounted cabinet configurations for systems applications, as well as self-contained instruments for laboratory use. Ultra-broadband frequency ranges from 1-1000MHz up to 7900-8400MHz, including our newest high power model with 200 watts saturated power rating at 500-1000MHz.

These Class A amplifiers are particularly recommended for applications requiring exceptional linearity and wide dynamic range. They combine low noise figure with high power output to yield low distortion amplification of both single and multi-carrier signals with any form of modulation. Other standard features of most models include: high efficiency; high gain; built-in protection against DC input reversal, thermal overload and infinite load VSWR; graceful degradation; drift-free output; field-replaceable modular construction.

In addition, MPD manufactures and markets the wideband linear transistor power amplifier product line acquired from the Hughes Electron Dynamics Division.

Complete technical details and specifications are yours for the asking—then get ready to move to the head of the class in solid state linear power amplifiers!



POWER-FREQUENCY GUIDE

MPD Solid State Class A Linear Power Amplifiers

MPD

MICROWAVE POWER DEVICES, INC.

330 Oser Avenue, Hauppauge, N.Y. 11787 • Tel. 516-231-1400 • TWX 510-227-6239

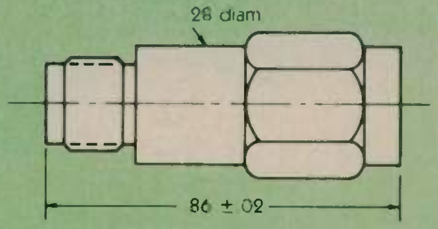
Circle 22 [illegible] Card

THE MINIPAD ATTENUATOR

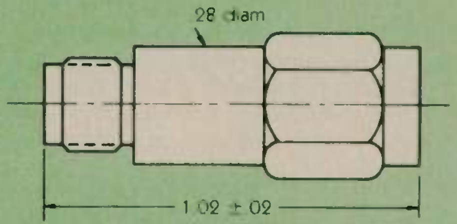
OUR SMALLEST, LIGHTEST, HIGH PERFORMANCE FIXED ATTENUATOR.

This miniature, high performance fixed attenuator has been designed to meet the needs of today's sophisticated microwave systems. The Minipad will operate within the stated specifications in most any hostile environment be it airborne, shipboard or land application. VSWR is typically less than 1.15 at 12.4 GHz and less than 1.25 at 18.0 GHz while the frequency sensitivity is normally less than 0.05 dB per GHz. The Minipad uses the Unique tube attenuator developed at Midwest Microwave. The tube attenuator is inherently a very reliable element because of its basic construction simplicity. The connectors for the Minipad attenuator are fabricated from stainless steel. The close tolerance machining plus the precise captivation techniques ensures an excellent match over the complete frequency range. All Minipads are production tested using the latest state-of-the-art swept frequency techniques. This complete testing assures that every attenuator will be within the published specifications.

- DC to 18.0 GHz
- 1 thru 30dB
- -65°C to+125°C
- 2 watts at +25°C
- MIL-E-5400 environment
- MIL-A-3933 requirements
- MIL-E-16400 environment
- 0.86 in. long × 0.28 in. diam.



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



13 through 30dB Weight: 6 grams (0.212 oz.)

DC to 18.0 GHz
HIGH PERFORMANCE

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

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

DC to 12.4 GHz
HIGH PERFORMANCE

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

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

DC to 8.0 GHz
HIGH PERFORMANCE

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

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

DC to 2.0 GHz
HIGH PERFORMANCE

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

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

DC to 18.0 GHz
INEXPENSIVE

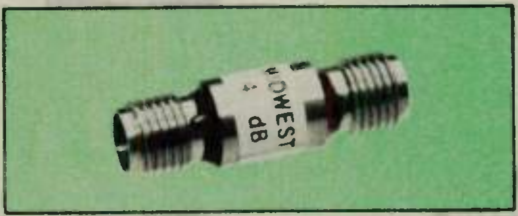
- Model 444, M444, F444
- Maximum VSWR: DC to 4.0 GHz 1.25 • 4.0 to 12.4 GHz 1.45 • 12.4 to 18.0 GHz 1.65
- Input Power: 2 watts average at +25°C derated linearly to 0.5 watts at +125°C
- Operating Temp. Range: -65°C to +125°C
- Connectors: Stainless Steel SMA per MIL-C-39012

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

Double Male Connectors
(M PREFIX TO MODEL NO.)

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

Double Female Connectors
(F PREFIX TO MODEL NO.)



dB VALUE	OVERALL LENGTH
1-12dB	.90"
13-30dB	1.03"

CALL TOLL FREE:1-800-521-4410

MIDWEST MICROWAVE

U.S.A.: 3800 Packard Rd., Ann Arbor, Michigan 48104
(313)971-1992 • TWX 810-223-6031

ENGLAND: Walmore Electronics Ltd.
01-836-1228

FRANCE: S.C.I.E.-D.I.M.E.S.
014-38-65

ISRAEL: Racom Electronics
443126-7-8

JAPAN: Toko Trading, Inc.
03-409-5831

W. GERMANY: Omecon Elektronik Gmbh • (08021) 1236

Circle 23 on Reader Service Card

In outer space,
around the world, and
in southern California,
high-technology electronics
means Hughes Support Systems

Come join our engineers working on state-of-the-art systems such as airborne and spaceborne radar avionics; tactical systems guided by lasers, TV, and infrared controls; automatic computer-based test systems; and computer-controlled trainers and simulators.

We supply integrated logistical support, including electronic testing, training, and maintenance. We need your know-how, and we'll reward you well if you can handle one of these responsible jobs:

- Design of automatic test systems
- Maintainability analysis
- Digital hardware development
- Electro-optical equipment design
- Real-time software
- Field system engineering
- RF circuit design

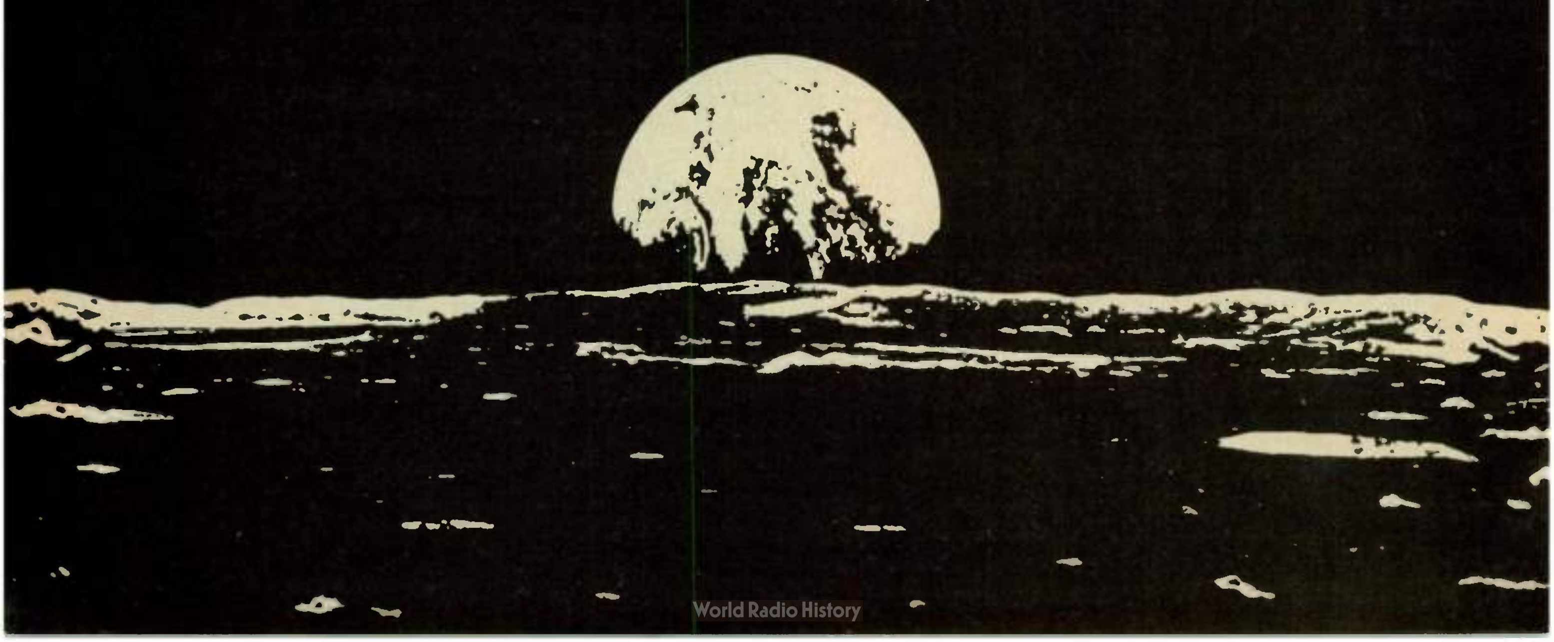
Hughes offers you a home base in the easy-living climate of southern California, near LA International Airport and beach communities; excellent salary and benefits; and this unique brand of stability:

Our company has a backlog of over $4 billion in contracts, comprising more than 1,500 different projects. When we complete one, there are a lot more challenges waiting, at Hughes.

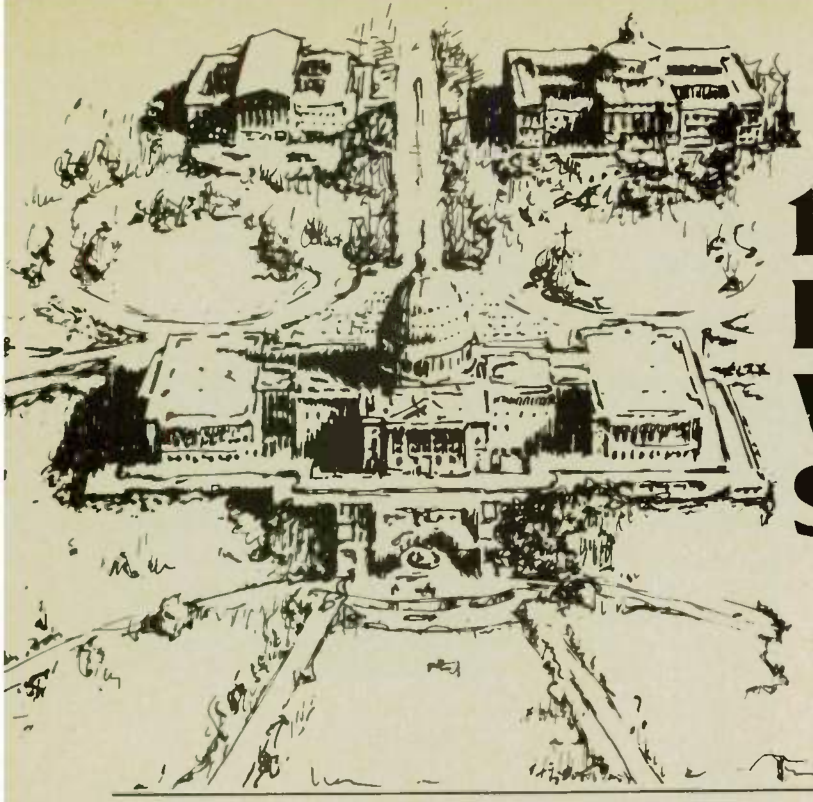
Let's talk about what you and Hughes can do for each other. Call collect to (213) 641-6691, or send your resume to: Professional Employment, Dept. 115, Hughes Support Systems, P.O. Box 90515, Los Angeles, CA 90009.

HUGHES
HUGHES AIRCRAFT COMPANY
SUPPORT SYSTEMS

U.S. CITIZENSHIP REQUIRED
Equal Opportunity M/F/HC Employer



World Radio History



1979 DoD/AOC Electronic Warfare Symposium

Electronic warfare is a military electronics arena of high interest to the microwave engineer. It represents a significant challenge because of the required ultra-broad bandwidth. In contradistinction to radar or communications applications where information bandwidths are just a few percent of the carrier frequency, the ECM engineer must contend with octave and multiple octave bandwidths. He must be prepared to counter in a single equipment the carrier frequencies and instantaneous bandwidths of many radar, communications, and navigation systems fielded by the enemy.

The annual Electronics Warfare Symposium, organized by the Association of Old Crows in conjunction with the Department of Defense, is an excellent source of information on the current status and future trends of the electronic warfare field. Because much of the material is classified, in a generally circulated journal it is impossible to provide complete detail on the field. However, the unclassified material presented is useful and the topics provide guidance to future trends in electronic countermeasures.

Compared to the technical symposia with which the microwave engineer is familiar (e.g. MTT Symposium, ISSCC, ED Conference, and APS Symposium), there is very little in specific mechanization details – only two or three of the 15 sessions discuss equipment specifics. The balance address operational and systems topics.

THREAT

A session titled "1980 Threats for the ECM Designer" provided an excellent summary of the radar and command, control, and communications (C^3) emissions which microwave engineers must counter. David A. Powell of the US Army Missile Intelligence Agency:

- described the Warsaw Pact surface-to-air missile (SAM) air-to-air missile (AAM), and anti-aircraft-artillery (AAA) fire control systems
- highlighted the ECCM capabilities employed throughout the total tactical air defense system, and
- forecast the most probable techniques which the Warsaw Pact members would use during the coming ten years.

In addition to specifics on enemy electronics systems it is useful to examine what the US radar designers are doing in the SAM and fire control arena, and in which areas we feel the Soviets are undertaking similar developments. Howard E. Wing of Raytheon considered this area with particular emphasis on:

- the impact of large scale integration (LSI) on radar and missile design
- the potential for low probability of intercept waveforms, and
- the active radar homing missile.

The fire control environment is not the only problem for the ECM designer – the design challenge arises from the sheer numbers of emitters in the field and the wide variety of possible operating modes. George R. Cotter of the National Security Agency detailed the expected numbers of electronic systems deployed in a battle area, and new concepts in use of the electro-magnetic spectrum including: 1) radio frequency diversity; 2) varying scan rates; 3) compound scan patterns; 4) shifting polarizations; 5) altering pulse rates; 6) changing pulse patterns, and; 7) modulating between and within pulses.

Peter M. Scop of the Defense Intelligence Agency presented an overview of the Counter C^3 targeting problem, citing Warsaw

Pact doctrine, netting, and Command Structure as well as disruption techniques.

The critical issues raised in the fire control and Counter C^3 area were summarized by David B. Newman of the Defense Intelligence Agency and placed in the context of a challenge for the ECM designer. George Nicholas of AFAL stressed the fact that with the new ECM technologies "situation determination" will become increasingly important, where the EW system rapidly assesses the dynamic situation and automatically initiates the proper ECM.

HARDWARE

The threats described in the preceeding paragraphs are addressed through the development of new hardware as well as through new applications of combinations of existing equipment. The specific threats considered are monopulse radar, coherent radar, and the use of active expendables to reduce vulnerability of aircraft.

The jamming of monopulse radar is a key requirement for survivability against modern enemy fire control radar. David W. Misek of AFAL described a flyable breadboard model now undergoing flight test. Two different ECM techniques have been combined – adaptive polarization ECM (APECM) and Cross Eye ECM, called Cross^2 ECM, – when combined in the same piece of hardware.

Multi-path propagation is utilized in terrain bounce jamming reported in a joint paper of Peter E. Redmill of the English Royal Aircraft Establishment and Paul J. Westcott of AFAL. They discussed the scattering theory, specular and diffuse reflection and the factors and properties affecting scattering loss, and summarized US and UK work to date.

Expendables were addressed in two papers – one by J. A. Montgomery of NRL on active decoys for deceiving AAM systems and SAM systems which have the most advanced technology. These decoys will be deployed from aircraft – "situation determination" assessing the dynamic situation and initiating the proper ECM will be important in this application.

Field army applications for expendable jammers for C/C^3 were described by Dave Garvey of US Army Signal Warfare Laboratory. The expendable jammer markets should be a key one in the next decade, utilizing monolithic microwave circuits and LSI.

German work on VHF and UHF automatic jammers was reported by D. Bienk of AEG-Telefunken. The jammers find the frequencies to be jammed and automatically do the jamming of enemy ground-to-air communication. The jammers are mounted in armored vehicles and can operate close to the FEBA.

The threat of coherent radar is addressed by an ultra-broadband countermeasures system which uses frequency division, digital signal manipulation, and frequency multiplication to counter frequency agile, Doppler, or coded waveforms. The system compresses the 125 MHz to 16 GHz range, in octave bands, into the 125 to 250 MHz band for digitation. The work has been done in Canada by W. D. Cornish of the Defense Research Establishment, and R. G. Harrison of Communications Development Limited.

SYSTEMS AND APPLICATIONS

The AF Precision Location Strike System (PLSS) is being developed to provide a tactical capability to locate a hostile emitter and then to direct an attack against it. (Major J. A. Koenig, USAF)

The Automated Ground Transportable Emitter Location and Identification System (AN/TSQ-109) (AGETLIS) detects signals within a defined instantaneous field of view and rejects signals outside the field of view. (G. P. Wood, US Army Signals Warfare Laboratory)

The Air Force has developed an Electronic Warfare Integrated Reprogramming (EWIR) concept. Key to the application of this concept is EW equipment using embedded digital processors – as a result the time needed to modify or reprogram EW equipment has been reduced from years to hours. (Maj. Gen. Gerald J. Carey, Jr. USAF, Tactical Air Warfare Center)

EW Flagging is a new AF initiative to assist intelligence collectors, processors, and reporters in identifying and supplying timely ELINT information to EW operational planning elements. Software models of EW systems are used in the near real-time ELINT processing streams in each theater to screen out specific ELINT intercepts which show potential for adverse impact upon EW system performance. (Wayne Noster, AFEW Center)

OPERATIONS

Several of the papers examined the operational use of EW systems from the point of view of a theater commander, defining requirements for peacetime and wartime environments.

A session on "The Integrated EW Mission" postulated a combined forces engagement with the Army, AF, and the Navy each contributing in their respective spheres of influence.

TESTING AND MAINTENANCE

Because of its complexity in terms of sheer numbers of emitters and modulations, testing requires the participation of many organizational units – during 1971 through 1979, 25 joint tests were conducted with total expenditures of $250 million. Analytical models and hybrid laboratory simulators are being evaluated in conjunction with field testing to define a methodology that could be accepted as standard.

Reliability, life-cycle costs, and built in test equipment were examined for missile, EW, and tactical Navy aircraft. The missile and EW systems historically have had goals of high reliability, but low reliability achievement. Missile systems are demonstrating a dramatic improvement in reliability which has not yet been reflected in electronic warfare systems. This is an objective of current and future work.

ELECTRO-OPTICAL AND INFRARED

There are five key threat areas in Warsaw Pact environments, according to Robert C. Frick, USAF Technology Division:

- E-O augmentation of ground-based or shipborne AAA and SAM fire control systems
- E-O seekers for SAM missiles
- E-O seekers for AAM missiles
- E-O guidance of ASM missiles, and
- airborne EW fire control and target designation systems

To meet the E-O/IR threat work in infrared warning receivers, solid state laser IR sources, and pyrophoric flares were described. Italian work in infrared warning receiver (IRWR) systems was presented by Carlo Corsi, Electronica S.p.A, Rome, Italy. A new IR focal plane array technology using a 32x32 array hybrid integrated for synthetic processing. Objectives ultimately are a 2π steradian field of view, greater than 95% detection probability and false alarm rate less than 10^{-4} $\sec^{-1}$, integrated with microwave ESM equipments.

Dr. L. Esterwitz, NRL, and Dr. Ron Paulsen, AFAL, are developing laser sources using resonance pumping for linear or nonlinear down conversion and multi-wavelength cascade laser action to provide near and mid-IR energy.

Flares for deceiving E-O threats are discussed by William J. Cannon and George Schivly of AFAL. The flares are produced by the use of metal alkyls, and flight test data under operational conditions were presented.

BUDGET

EW must provide a force multiplier on the battlefield in the face of numerically greater and more sophisticated enemy weaponry. EW expenditures are $1.6 billion annually for R&D and hardware procurement. Representative Ichord and Representative Dickinson, both members of the House Armed Services Committee, and their staff discussed the problem of budget priorities and direction in DoD programs.

Radar Systems Engineers

PAN AM

Long-term career opportunities with Pan Am are ideal for ambitious, experienced engineers who can provide engineering support to the COBRA JUDY project.

Requires 5-10 years of successful experience with tracking radars, including specific experience with phased array systems. Background in such programs as COBRA DAME, and PAVE PAWS especially desirable.

These permanent positions, based at Patrick AFB in Florida, will require extensive temporary travel to the Boston area. Duties will bring participation in sea trials of ship's systems as well as periodic sea assignments after project completion to test and support radar systems.

We offer excellent salary and benefits highlighted by reduced rate air travel for you and your immediate family. Another plus: no state or local income taxes.

Send resume and salary history to: D. K. Mosby, Ref 80.48, Pan American World Airways, Inc., Aerospace Services Bldg. 423, Box 4608, Patrick AFB, Florida 32925. An equal opportunity employer.

PAN AM *AEROSPACE SERVICES*

SPECIALIZE DIVERSIFY

The Microwave Option:

As an international leader in electronics products and services for communications transmission, reception and information processing, Microwave Associates boasts the broadest line of products in the industry. We're involved in every form of communications, from commercial electronics and broadcast applications to satellite telecommunications.

Microwave can offer you the broadest range of opportunities - and the option to specialize or diversify to maximize your talent.

We're the largest producer of microwave components in the country - and still rapidly growing...into such exciting new fields as solar cell research and cancer detection.

Design & Development Engineers

Take on project responsibility for the design and development of microwave devices. Your responsibilities will include the analysis, design and product development of state-of-the-art multipliers, amplifiers, oscillators and general RF circuitry. A BSEE or equivalent is required with a minimum of 3 years related experience. Some digital and/or systems exposure is desirable

Sales/Marketing Engineers - Entry Level

You will be marketing selected products such as waveguide components and microwave integrated assemblies. Your responsibilities will also include assisting our customers in defining their requirements and negotiating specifications and prices. A BSEE is required.

Quality Assurance Engineers

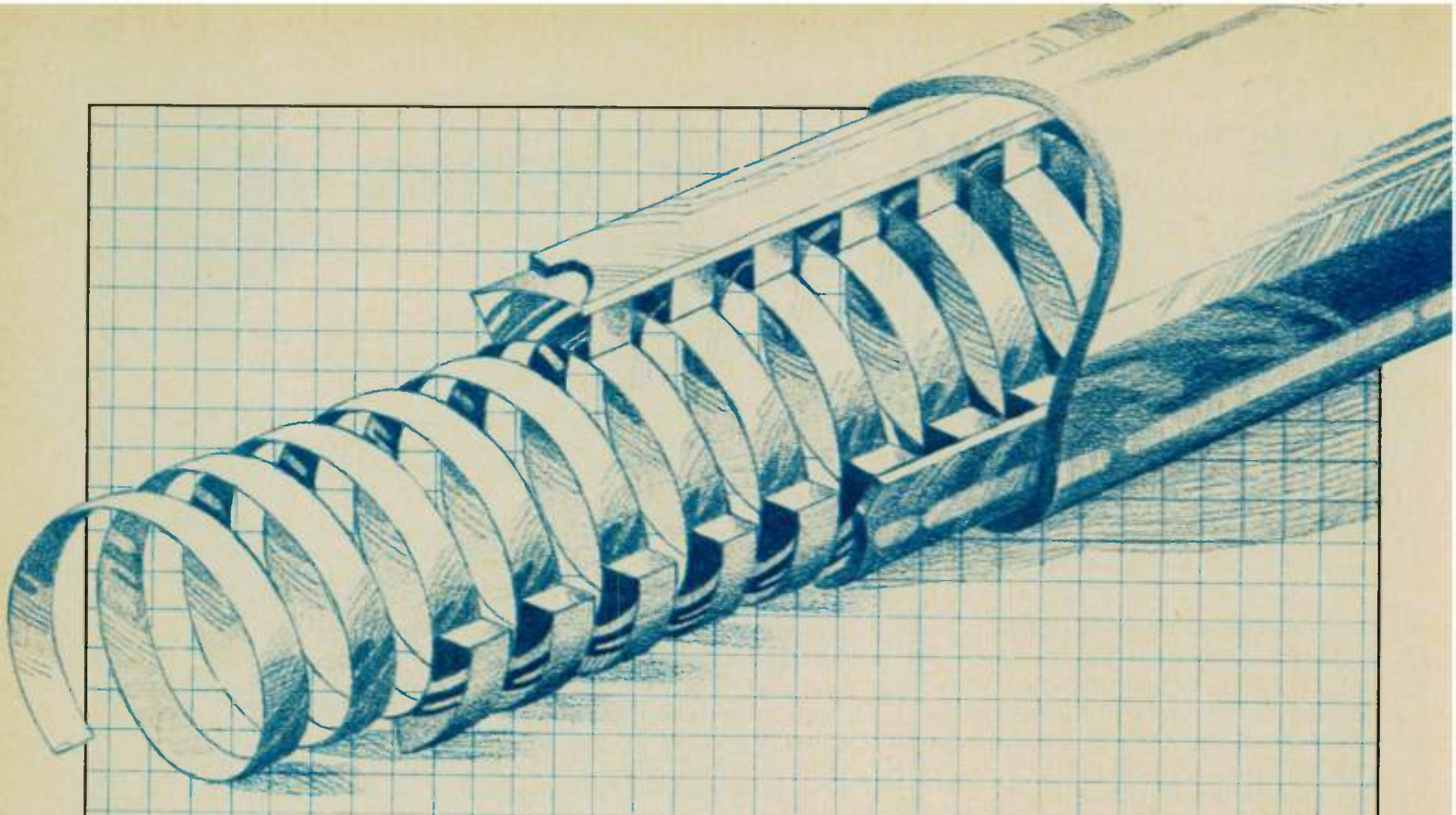
This requires your ability to prepare written procedures and plans to meet both internal and customer requirements. Your background should include a minimum of an ASEE or its equivalent with a working knowledge of semiconductor device/component technology and MIL-Q-9858A is highly desirable

For information regarding the aforementioned positions, please send your resume, including salary history, to: Carol Couture, Microwave Associates, Bldg. #2, Mailstop 213, South Avenue, Burlington, MA 01803.

An Equal Opportunity Employer M/F

Microwave Associates
A M/A-COM COMPANY

World Radio History



Power beyond the ordinary. Bandwidths beyond an octave.

Those are the advantages you get with Litton's high power CW TWT's.

Litton's patented Copper Brazed Wedge supported Helix circuit has beaten the heat dissipation problem in CW TWT's —and opened the way to new levels of performance, power and bandwidth.

It's no surprise these high power microwave tubes have earned immediate acceptance in current ECM applications.

Available now are C-Band tubes, 2000 watts CW; D/E-Band tubes, 1500 watts CW; E/F-Band tubes, 500 watts CW.

Check out these CW TWT's that give you extraordinary bandwidth coverage beyond an octave—at extraordinary power outputs.

Litton's patented Copper Brazed Wedge supported helix provides far more efficient heat dissipation permitting greater bandwidth at greater power.

Electron Tube Division, 960 Industrial Rd.,
San Carlos, Calif. 94070. (415) 591-8411.

Litton **ELECTRON TUBE DIVISION**

Electronics Technology and Devices

GEORGE C. UCHRIN
Technical Plans and Programs Office
Electronics Technology and Devices
Laboratory, ERADCOM
Ft. Monmouth, NJ

H. WARREN COOPER
Westinghouse Corp.
Baltimore, MD

INTRODUCTION

This paper is an excerpt of a more comprehensive paper covering the planned programs of the Electronics Technology and Devices Laboratory (ET&DL) and presented at the ERADCOM/TRADOC Advanced Planning Briefing, 8 November 1979, Adelphi, Maryland.* It must be realized that the funding given and programs identified are those which existed at the time the document was prepared (during the final quarter of FY 79). The planning and programming of the ET&DL is a continually changing process. This microwave excerpt is Part I of a two-part report. The second section on millimeter-wave developments will be published in a future issue of *Microwave Journal*. It is not intended as a detail update, however, some new high priority programs have been inserted and some lower priority programs eliminated. The total funding level is essentially the same. A number of new, high priority, classified programs are to be undertaken in the solid state and microwave tube area, however, these cannot be elaborated upon.

Planning Strategy

The planning strategy of the Electronics Technology and Devices Laboratory has changed from improving the technological base to one of concentrated thrusts to counter worldwide threats to the US Army.

Threats

The principal threats in a technological context, are:

- The effect of smoke, fog and obscurants on battlefield surveillance and target tracking.
- The extension of the Soviet radio electronic combat capability to higher frequencies.
- The impact of Soviet multimode tracking on the survivability of Army aircraft against terminal homing weapons.
- The projected increase in the number and sophistication of Soviet emitters in the 1980s battlefield.
- The number and mobility of Soviet forces versus our C^3 capability.
- The vanishing Soviet component technology gap.

Thrusts

The principal responding thrusts of the Electronics Technology and Devices Laboratory are development of:

- High speed signal processing devices to permit real time target identification and location of enemy emitters beyond 1982.
- Very wideband jamming devices and decoy components capable of operating from expendable and airborne platforms.

(continued on page 46)

---

* This paper summarizes information presented at US Army Electronics R&D Command Advanced Planning Briefing, 8 November 1979, Adelphi, Maryland, Volume 1. It represents the collaborative efforts of Messrs. H. Warren Cooper, Westinghouse Corp. and George C. Uchrin, ET&DL, ERADCOM.

50 to 1

50 to 1

50 to

broadband quadrature hybrids

the MOD QUAD

LOCUS, INC., has developed a family of modern broadband quadrature hybrids by utilizing the general properties of all-pass networks. This yields a constant amplitude response across the operating bandwidth, but with a variation in phase as a function of frequency. Due to constant resistance, composite phase shift curves can be constructed by cascading sections to obtain the desired over-all phase characteristic.

We call this family the MOD QUAD because the small size, low insertion loss, high isolation and flat frequency response permit system designs beyond the lineup of presently available bandwidths. The 50 to 1 bandwidth ratio makes these devices suitable for use in image reject mixers, amplifiers, frequency discriminators, phase comparators and other systems requiring precision response over a very wide frequency range. They are fast becoming NO. 1 on the MOST WANTED LIST.

So if your operation is being held up due to a lack of quality quadratures, don't give up. Send out an APB to LOCUS. We can deliver. It warrants your attention. Those who have used our quadratures will witness to their efficiency, but you can judge for yourself.

LOCUS can deliver standard models or tailor these designs to specifications for custom applications. For more detailed information concerning your specific requirements, contact LOCUS, INC., P.O. Box 740, State College, PA 16801. Telephone (814) 466-6275.

(ACTUAL SIZE)

LOCUS, INC.

Circle 28 on Reader Service Card

(from page 43)

- Low cost, practical millimeter-wave devices (35 to 600 GHz) and nanosecond pulsers for target location and identification systems capable of all weather operation through battlefield ECM.
- Devices for compact, non-jammable, secure, reliable C^3 voice and data links.
- Interactive, intelligent display devices to link the battlefield commander to the tactical situation.
- Low cost, small, reliable, modular assemblies.
- Lightweight, high efficiency, portable power sources for laser designators, night vision equipment and CE systems.
- Mobile, multi-megawatt pulse power sources for directed beam weapons.

These thrusts are currently augmented by two major initiatives.

- *Electronics technology* components and devices are being inserted into fielded systems and systems under development
- *VHSIC* (Very High Speed Integrated Circuits) is a silicon based sub-microwave DoD program

Resources

Total laboratory resources include Government in-house funding and contractual funds. Contractual funds, including VHSIC, are approximately 60% of the total. See Table I.

Of more interest to the microwave engineer is the apportionment of resources by frequency range and function as shown in Table II. The programs in microwave and millimeter range are identified in detail — it is interesting to note that more than half of the funding is in these areas, and some of the Low Cost Module Design/Techniques efforts apply also to the microwave area.

Table III further subdivides the microwave funding — it should be noted that some of the funding in the Jamming Devices

TABLE I

TOTAL FUNDING, ET&DL — BY BUDGET CATEGORY

	Funding (in thousands of $) FY 80	FY 81	FY 82
RDT&E 6.1 Electron Devices Research	2,400	2,200	2,300
RDT&E 6.2 Electronics & Electron Devices	13,700	16,433	19,895
RDT&E 6.2 Very High Speed Integrated Ckts	12,000[2]	12,000[3]	11,000[3]
RDT&E 6.3 Advanced Electron Devices	2,245	2,495	2,600
RDT&E 6.3 Adv. Tactical Power Sources	780	1,210	1,300
RDT&E 6.4 500 W Thermoelectric Power Source	0	560[2]	800[3]
RDT&E Total (Level 1)	19,125	22,898	26,095
PEMA Total	6,805	8,310	8,680

[2] — Level 2 Funding
[3] — Level 3 Funding

TABLE II

ET&DL OVERALL FUNDING IN THOUSANDS OF $ — BY TECHNOLOGY

	FY 1980		FY 1981		FY 1982	
	RDT&E	PEMA	RDT&E	PEMA	RDT&E	PEMA
Microwave	6,420	3,085	7,905	4,150	9,130	2,100
Mm wave	3,240	1,700	3,265	1,500	5,210	1,300
Frequency Control	1,000	0	880	1,810	1,660	1,300
Tactical Displays	820	800	900	1,050	1,035	630
Low Cost Module (Design/Techniques)	2,370	0	2,265	0	2,195	950
Batteries, Power Sources, Condit.	2,530	250	3,445	800	3,370	620
Total RDTE	16,380		18,660		22,600	
Total PEMA		5,835		9,310		6,900

TABLE III

ET&DL MICROWAVE FUNDING IN THOUSANDS OF $

	FY 1980		FY 1981		FY 1982	
	RDT&E	PEMA	RDT&E	PEMA	RDT&E	PEMA
Signal Processing Technology	2,535	1,600	2,660	0	2,730	0
Jamming Devices (Includes IR)	1,665	285	2,700	1,450	3,170	1,300
MW Signal Intelligence Receivers	1,400	1,000	1,365	2,700	1,690	800
Acoustic Signal Processing and Frequency Gen.	820	200	1,180	0	1,540	0
Total RDT&E	6,420		7,905		9,130	
Total PEMA		3,085		4,150		2,100

(continued on page 48)

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.)	Height	Size 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.)	Height	Size 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.)	Height	Size 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

Circle 29 on Reader Service Card

(from page 46)

area is for IR. The major effort is in signal processing technology, where the benefits of GaAs FET technology are emphasized. The article by V. Gelnovatch[1] in the December *Microwave Journal* provides further detail on current programs upon which future programs will build.

The following sections describe the general mission, applications, key information, and duration for each of the planned programs.

SIGNAL PROCESSING TECHNOLOGY

The Signal Processing Technology task provides the Army with the technology base: 1) to real time detect, locate, and identify signal emitting targets; 2) for secure anti-jam communications and data links; and 3) for nonvolatile memories for tactical computers. This task includes eleven programs, three of which are microwave logic related, and which will be described further,

---

[1] Gelnovatch, V.G., "Microwave Device and Circuit Contracts," *Microwave Journal*, December, 1979, p. 34

TABLE IV

SIGNAL PROCESSING TECHNOLOGY

FISCAL YEAR 80	81	82	83	84	85	PROGRAM TITLE AND KEY INFORMATION	APPLICATION
*	*	*				*SOS Circuit Development* GaAs IC feasibility, receiver-synthesizer circuits – 400 MHz operation and 1 GHz toggle rate. Modules for real time signal processing.	Data links, communication, real time signal processing
	*	*				*High Speed LSI* Objective 10 GHz operating speed using low temperature SOS, Josephson, Junction, or non SOS technologies. Project limits for speed, density, and minimum power consumption.	Broad
	*	***				*GaAs GHz Data Processing* Monolithic multi-GHz IC, single chip sub-system Analog-digital ICs, clocks and detection modules, to identify and reduce failures.	Ultra high speed processing of ISTA high density signals
*						*High Pressure Oxide IC Process* Low temperature oxidation through high pressure to increase yield and reliability.	VLSI systems fabrication also microwave capacitor needs

* FUNDED CORE PROGRAM

*** UNFUNDED INCREMENT 2

(See Table IV) six on charge coupled devices and memories, which are not microwave oriented, and two that are process oriented and thus would apply to microwave as well as non-microwave devices. The non-microwave programs will not be treated further.

JAMMING DEVICES

For Army airborne missions, weight and power consumption are driving forces. While solid state devices will ultimately move into the power generation role in jamming systems, high efficiency, broadband tubes and electron beam semiconductor (EBS) amplifiers will solve the near-term needs. The programs in jamming devices extend from basic work in cathodes to the improvement of packaged jamming systems.

MICROWAVE SIGNAL INTELLIGENCE RECEIVERS RPV DATA LINKS AMPLIFIERS

The battlefield commander requires microwave equipment to intercept enemy emissions which is compact, non-jammable, and has a low probability of intercept and a secure data transmission capability. GaAs FET technology can meet these needs:

- Low noise devices for sensitive, frequency agile receivers
- Power devices for secure data links
- Low cost GaAs MICs for miniaturized broadband power amplifiers for RPVs

To meet these needs thirteen programs are identified, of which three are MM&T, and some of which extend to fiscal year 1985.

ACOUSTIC SIGNAL PROCESSING AND FREQUENCY GENERATION DEVICES

SAW devices provide an order of magnitude reduction in size, weight, power consumption, and cost in communications data links, radar, and EW SIGINT.

Second and third generation SAW devices and processors provide correlation, interference, rejection, and fast frequency hopping capability.

H. Warren Cooper is currently Manager, Electromagnetic Technology at the Westinghouse Corp. Defense and Electronic Systems Center in Baltimore, MD, where he is responsible for advanced microwave and semiconductor technology for EW systems. He received his B.S.E.E. from New Mexico State University, and his M.S.E.E. from Stanford University. Mr. Cooper is a Fellow of IEEE, a past President of the Microwave Theory and Techniques Society and currently is a member of the Board of Governors of the Aerospace and Electronic Systems Society.

George C. Uchrin received his B.S. in E.E. from Rutgers University in 1949 and joined the US Army Signal R & D Laboratories the same year. In the 1950s, he pioneered the development of transistorized power converters and engaged in the Army's early major drone surveillance programs, AN/USD-4 and 5, and guided the Cornell Aeronautical Lab in its development of mathematical modeling of complete drone surveillance systems. In 1960, Mr. Uchrin joined the Electronics Technology and Devices Laboratory as a member of the Army's management group which guided high power klystron tube developments for the Nike Zeus discrimination and target track radars. In the 1970s, he served as ET&DL planning coordinator under QMDO (Qualitative Materiel Development Objective).

ISSCC 80

J. W. GEWARTOWSKI
Bell Telephone Labs, Inc.
Allentown, PA

The International Solid State Circuits Conference returns to San Francisco this year, February 13-15, at the San Francisco Hilton Hotel. There are two daytime sessions and two evening panel discussion sessions dedicated to the latest developments in microwave integrated circuits. Two topics are receiving heavy emphasis in this year's conference, GaAs FET circuits and monolithic microwave integrated circuits.

Rapid advances have continued to be made in GaAs FET devices. Circuit designers have exploited their unique characteristics to realize microwave amplifiers with solid state reliability and performance equal to or exceeding that of many traveling-wave tubes. One daytime session, chaired by Eliot Cohen, is devoted entirely to this topic. Two papers describe multi-octave bandwidth design, particularly useful for ECM applications. Two other papers describe TWT replacements for communications systems, having state-of-the-art power output and efficiency. Another paper explores the improvements in GaAs FET power output possible under pulsed operation.

The other daytime session, chaired by S. Y. Narayan, has several papers on monolithic GaAs integrated circuits. One of these papers shows the advantages of multi-level gates in achieving higher clock rates and lower gate counts in digital applications. Two other monolithic papers consider analog applications where complete subsystems are achieved on a single GaAs chip. One of these is particularly interesting in that it considers the problem of trim-tuning the circuit. Other papers in the session include a description of tunable GaAs FET oscillator with 19% efficiency and 100 mW output at 16 GHz and a pulsed IMPATT oscillator with 40 W output at 94 GHz.

The evening informal discussion sessions have always been some of the more interesting events at the conference, since they often include controversy and occasionally some verbal fireworks. The two microwave evening sessions will discuss two of the hottest topics surrounding today's technology.

The first evening session, moderated by Dick Eden, will discuss the competing technologies for gigabit logic. A select group of experts will compare GaAs and silicon integrated circuits and Josephson junctions. Topics for discussion will include performance, interfacing capabilities, cost, reliability, and the ease of manufacture.

The other evening session, moderated by Jim Gewartowski, will compare the monolithic to the hybrid approach for analog microwave integrated circuits. Eight experts will review the latest developments in monolithic technology and circuits. The advantages of the monolithic approach include small size and weight, greater reproducibility, and potentially lower cost for large scale production. Disadvantages include lower power output and unproven reliability. These issues will be discussed, and future trends will be noted and explored.

Except for the one mm-wave paper, IMPATT diodes are noticeably absent from this year's conference. This indicates a maturation of the IMPATT field. It may also be attributed to the fact that GaAs FETs are now able to outperform IMPATTS at all but the highest frequencies.

Based on the technical content alone, this conference is well worth the trip. With the added attractions of San Francisco, a record-breaking attendance is expected. Incidentally, the conference next year will be in New York City.

James W. Gewartowski was born in Chicago, Illinois on November 10, 1930. He received the B.S. degree in E.E. from Illinois Institute of Technology in 1952, the S.M. degree in E.E. from Massachusetts Institute of Technology in 1953, and the Ph.D. degree in E.E. from Stanford University in 1958. He was at Bell Telephone Laboratories, Murray Hill, New Jersey, from 1957 to 1971. His early work at Murray Hill included slow-wave structures and electron guns for high-power traveling-wave tubes and he was Supervisor of the Microwave Source Group from 1962 to 1971. Since 1971, he has been Supervisor of the Microwave Integrated Circuit and Amplifier Group at Bell Telephone Laboratories, Allentown, Pennsylvania.

Navy MW Component Contracts

ELIOT D. COHEN
Naval Research Laboratory
Washington, DC

NEW CONTRACT EFFORTS

Several new contract programs are expected to begin within the current fiscal year which ends on September 30, 1980. The first of these should lead to the development of S-band power GaAs FET devices which will produce a peak power output of at least 25 watts across the 3 to 3.5 GHz band when operated with 50 microsecond pulse widths and at a one percent duty factor. These devices may be an attractive alternative to silicon bipolar transistors because of their considerably simpler vertical structure. Also, GaAs FETs should lend themselves better to monolithic integration because they are fabricated on semi-insulating substrates. During the same program, multi-stage 45 watt, 25 dB gain, 3-3.5 GHz amplifiers will be developed and eventually a 200 watt amplifier/combiner. The work is expected to take three years to complete.

Another new program start will involve the development of low noise GaAs FET amplifiers for use in the 26.5 to 40 GHz range. A total of 40 dB gain and a maximum noise figure of 15 dB will be required from the multi-stage amplifiers. This program will continue the development of GaAs FET amplifiers for replacement of small signal, low noise TWTs in Navy systems. Previously, 7 to 18 GHz amplifiers with similar specifications were successfully completed by Avantek under contract N00014-75-C-1163 and at present Hughes Aircraft Company is developing 18 to 26.5 GHz GaAs FET amplifiers under contract N00173-78-C-0296. Demonstration of a three-stage 18 to 26.5 GHz amplifier with approximately 15 dB gain by Hughes is expected to occur in early January with completion of the entire program scheduled for September, 1980.

An additional new start will lead to the development of high burnout, Schottky barrier mixer diodes for use in 94 GHz systems. This work is expected to include development of metallization systems suitable for use at higher temperatures and employment of ion implantation to lower Schottky barrier height so that less local oscillator power is required for minimum noise figure operation. The program is an extension of work done at X-band under Navy contract programs N00173-77-C-0029 and N00173-78-C-0126, which successfully led to the development of silicon Schottky barrier mixer diodes having noise figures of 7.0 dB at 9.375 GHz with a 0.5 mW local oscillator level and an ability to withstand 1 microsecond pulses of up to 12 watts without degradation. Microwave Associates is currently engaged in a Manufacturing Technology program for the Navy (Contract No. N00173-79-C-0107) to establish production processes and technologies for these X-band devices so that reduced manufacturing costs can be achieved.

GaAs FET AMPLIFIERS

Excellent progress is continuing on the Texas Instruments program to develop 1 watt, 7 to 18 GHz GaAs FET amplifiers (Contract No. N00173-79-C-0047).[1] During the past few months, a four-stage amplifier has been produced which provides 200 milliwatts of output power with 20 dB gain from 6 to 16 GHz. The amplifier consists of three single-ended driver stages and a balanced output stage. Improvements in 3 dB hybrid coupler performance are expected to result in achievement of similar performance from 6 to 18 GHz in the near future. The three-stage driver amplifier yields approximately 125 milliwatts of power output with 16 dB gain over the 6 to 18 GHz range when operated separately. In addition to the above results, a single-stage, single-ended amplifier has been developed with a power output of 300 milliwatts from 6 to 18 GHz and 5 dB gain. All of the above amplifier stages use devices with 600 microns total gate width. Work currently in progress includes development of appropriate circuitry for use with devices having a 1200 micron total gate width so that the 1 watt power output goal can be achieved.

---

[1] The 1 watt, 7 to 18 GHz GaAs FET amplifier program is sponsored by Naval Air Systems Command. The other programs described are sponsored by Naval Electronics Systems Command.

Principles of Electronic Warfare: Radar and EW

WILLIAM A. DAVIS
Virginia Polytechnic Institute and State University
Blacksburg, VA

Electronic Warfare (EW) involves many of the disciplines of electrical engineering and other fields. However, radar is the most active area of pursuit. In this second of a series on EW,* we shall investigate the fundamentals of radar and associated counter and counter-countermeasure techniques. Closely related to this discussion is the transmission, interception, and interference of communication links.

Let us first ask what exactly is radar. The name is an acronym for *ra*dio *d*etection *a*nd *r*anging. In modern use, a radio signal is transmitted into space, reflected from a target, and received at the radar receiver. The angular location to a target is determined from the pattern information of the radar antenna. The distance to the target is usually obtained from a pulse modulation delay or similar delay caused by the finite travel speed of electromagnetic energy through space. The radial speed of the target may be obtained from the frequency modulation of the target, as is used by law enforcement organizations for detecting automobile speeders. The amplitude of the radar return or received signal is indicative of the size of the target and thus is associated with its identification. I will attempt to bring to light each of these features as we study the fundamentals of radar.

BASIC RADAR

From the acronym radar, we may conclude that the original intent of radar was to detect targets and the associated distances to the targets. With current technology, it is appropriate to ask not what the original intent was for radar, but rather what are the possible types of information that may be extracted from a radar signal, or more appropriately the radar return or reflection. In this context, there are four possible functions for which a radar might be used. The first is simply detection. The function of most early-warning radars is that of target detection within a given sector of space. After the target has been detected, more sophisticated radar techniques may then be employed to obtain further information.

Information such as the location may be separated into two parts, the direction and the distance to the target. The direction to the target is a function of the radar antenna pointing, and is the purpose for the discussion of the types of radar antenna scans which will follow. The distance to the target is obtained from the electronics in the radar by determining the delay of the radar modulation at the receiver as compared to the transmitted counterpart. This delay is proportional to the distance to the target and results from the finite speed of energy travel in space. This is 3×10^8 m/sec or very nearly 1 foot per nanosecond. A nautical mile is 6076.115 feet, requiring a travel time of 6 μsec, one way, or 12 μsec round trip, for a radar signal.

In many situations, it is desirable to know the velocity of a target. The angular velocity may be obtained from the rate of change of the direction to the target. In a similar manner, the radial velocity or velocity along the path between the target and the radar may be derived from the rate of change of the distance to the target. However, a more effective method of obtaining the radial velocity is to detect the Doppler frequency shift caused by a moving target. This shift in frequency is upward for incoming targets and downward for outgoing targets, and involves the same principle causing the rising shift in frequency of a train whistle as the train comes toward you and falling shift as it passes you. If only incoming targets are of interest, the radar return may be processed as an upper-side band signal, with the received modulation frequency proportional to the target velocity. This has the additional advantage of

---

* First article in March, 1979 issue.

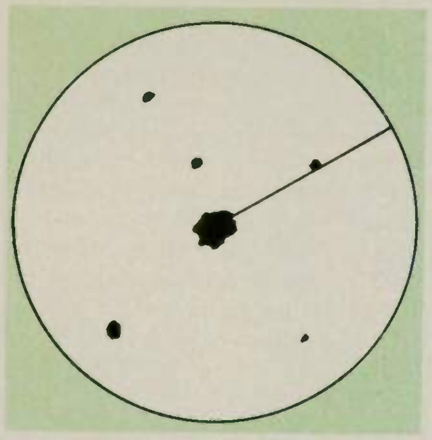


Fig. 1 Planned Position Indicator (PPI Scope).

eliminating unwanted clutter from outgoing targets for any radar display or processor that may be used.

The final function that may be desired of a radar is identification. Except for the size and speed-related signatures of targets used by experienced radar operators, there is essentially no radar technique in use for target identification. This is not to say that there have been no attempts to build identification systems, but that the philosophy of identification is a very ill-posed problem in radar and thus extremely prone to error with current technology. Several new techniques are under investigation, but none has yet been made operational. One of the primary means of identification in use is the IFF (identification friend or foe) query system.

Let us return to the detection-finding problem and the associated antenna scans. The most fundamental scan provides coverage over a sector of space using either a fixed broad beam antenna or a manually positioned beam. The primary purpose of such a system is for detection in an early-warning role. Once a target is detected, either the radar may switch to another scan mode or alert another radar to acquire the target. It is not uncommon to desire more information on target location without having an interest in tracking the target to within a few degrees' bearing or several meters' range. The circular scan, which is typical of airport surveillance radars, provides this type of information. The familiar output display for a circular scan radar is the PPI (planned position indicator). A drawing of such a display is shown in **Figure 1** with the existence of a target indicated by a light or intensity increase on the display, (represented as darkened spots in the figure) when the target is illuminated by the radar. The circular scan is obtained by rotating an antenna and its beam in a circular pattern in a plane parallel to the earth's surface. Since only azimuthal and not elevation information is obtained with a circular scan, the beam is designed to have a narrow width and a large height as shown in **Figure 2**.

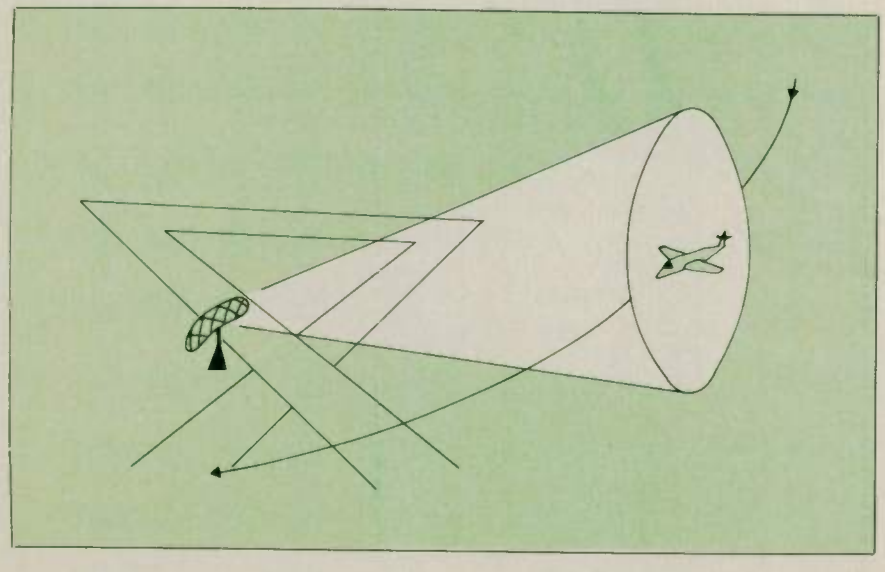


Fig. 2 Circular scan.

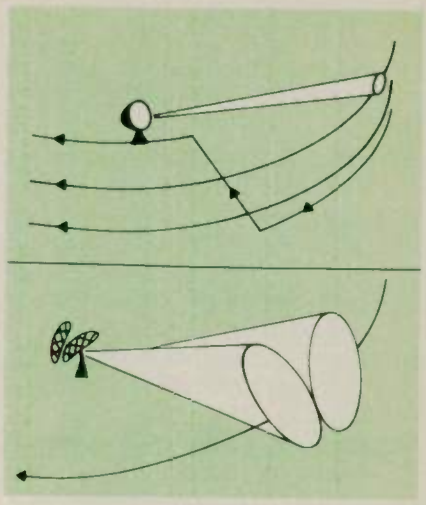


Fig. 3 (a) Helical scan and (b) V beam scan radar systems.

There are two popular modifications to the circular scan radar used for elevation determination. These modifications are shown in **Figure 3** and consist of a pencil beam scanned in a helical pattern so as to obtain elevation information, or a dual beam which detects two received pulses delayed in time with respect to each other and at an amount proportional to the elevation of the target. These radars all serve the surveillance role of monitoring the position of one or more targets in space.

ECM is not typically used against these radars since they are not directly associated with a threat. However, it may be required in some instances and takes very simple forms. The most obvious counter is evasion (as by flying low, below the beam) to avoid the early-warning or surveillance function of the radar. Once detected, a variety of other techniques may be employed. The most fundamental ECM technique is jamming. Jamming is often viewed in terms of a continuous tone, blocking a frequency to other signals; but actually it commonly takes the form of pulsed radio frequency energy, narrowband noise (spot jamming), wideband noise (barrage jamming), and frequency swept narrowband noise. The particular form of jamming depends on the available knowledge of the radar frequency and scan characteristics or the presence of multiple radars.

To locate the position or velocity of a target more closely, one must enter some type of tracking form of scanning. Before tracking may be accomplished, the target location must be determined with sufficient accuracy to be within the scanning area of the tracking radar. Rather than request this degree of accuracy of a surveillance radar, tracking radars usually begin operation in an acquisition mode. In this mode, the tracking radar scans a small sector of space, as may have been indicated by the surveillance radar, in a raster or spiral pattern as shown in **Figure 4**. Upon locating the target, the acquisition scan is automatically halted and the tracking procedure initiated if not already active.

Because of the threat of weapons usually associated with tracking radars, the primary thrust of EW has been in the area of tracking radars. There are three basic types of tracking radars with many possible alternatives available to obtain desired features. The most widely used tracking radar is the conical scan found not only in radars, but also in many satellite communications systems. This popularity is due in part to its simplicity of design, typically involving a dual reflector antenna such as the Cassegrain reflector. The signal is focused on an offset subreflector from an antenna mounted at the center of the main reflector. This subreflector redirects the energy to the main reflector and thus to the antenna main beam. By rotating the subreflector about the axis of the main reflector, the main beam is likewise rotated about the axis to form a conical scan as shown in **Figure 5**. The half-power point of the main beam is located on the axis or boresight of the main reflector. If a target is found on the boresight, the radar return is constant in amplitude and the antenna is considered to be on target. If the target is slightly off the boresight, then a sinusoidal signal will be imposed on the radar return, corresponding to the angular position of the target. This error signal may be detected as an amplitude modulation and used to correct for the pointing of the antenna system. A modification of this system is called lobe-switching. Instead of continuously scanning the mainbeam around the boresight, the lobe-switched scanning positions the mainbeam in discrete steps, typically using four steps to complete a scan. This technique is usually associated with discrete positioning of the conical scan beam using electronic scanning, rather than the mechanical scanning described.

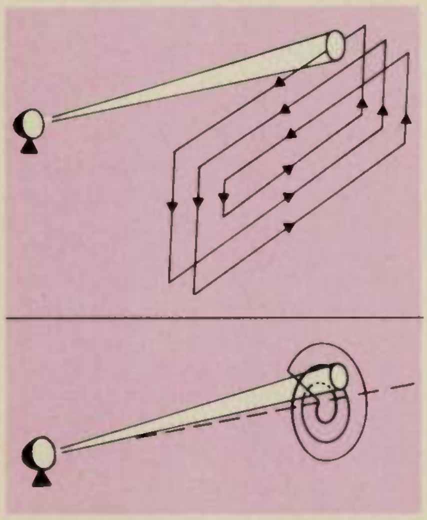


Fig. 4 Acquisition scans using (a) raster scan and (b) spiral scan.

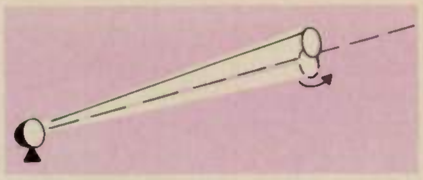


Fig. 5 Conical scan radar.

The second type of tracking radar is the monopulse scan. In this case the mainbeam is not actually scanned to determine the pointing error, but a comparison of the delay times occuring in arrival to different parts of the antenna are used to obtain the error. The antenna is divided into four sectors, obtained from the intersections of the upper and lower halves and the right and left halves. In actuality, the antenna consists of an array of four antennas located in the four quadrants, respectively. The same transmitted signal is radiated from all four antennas, forming a mainbeam on the axis or boresight of the antennas. If the target is on boresight, the time delay (usually termed phase delay for periods shorter than the RF cycle) and amplitude to each of the antennas is identical; thus, comparison of the received signals in each sector of the antenna gives no error signal. However, if the target raises slightly in elevation, the signal will be delayed momentarily in returning to the lower half of the antenna. Subtracting the signal in the lower section from the upper section, a non-zero error signal is now produced. A similar error signal would be produced between the right and left sides if there were an azimuthal tracking error. These error signals may be used directly for repointing the antenna until there is zero error. **Figure 6** shows the basic idea of the four sectors, though the implied amplitude variation is usually not the primary source of error signal. The delay required for the maximum error signal is 0.05 nanoseconds or 180°, at 10 gigahertz. This time delay corresponds to an angular tracking error of 1.72 degrees for a separation of 1/2 meter between the antenna sectors. Though this is comparable to the beamwidth of such antennas, this degree of error is not achieved practically; the target bearing being identified only within a region of relatively constant antenna pattern amplitude.

The last type of tracking scan to be considered is the track-while-scan format. This scan essentially comprises two sectorial circular scans oriented in the azimuthal and elevation orientations. As shown in **Figure 7**, one antenna scans a horizontal sector of space and the other antenna scans an overlapping vertical sec-

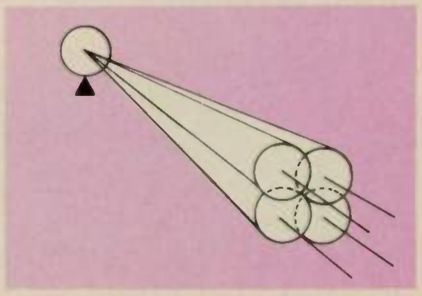


Fig. 6 Monopulse radar.

(continued on page 56)

System Components FROM ENGELMANN

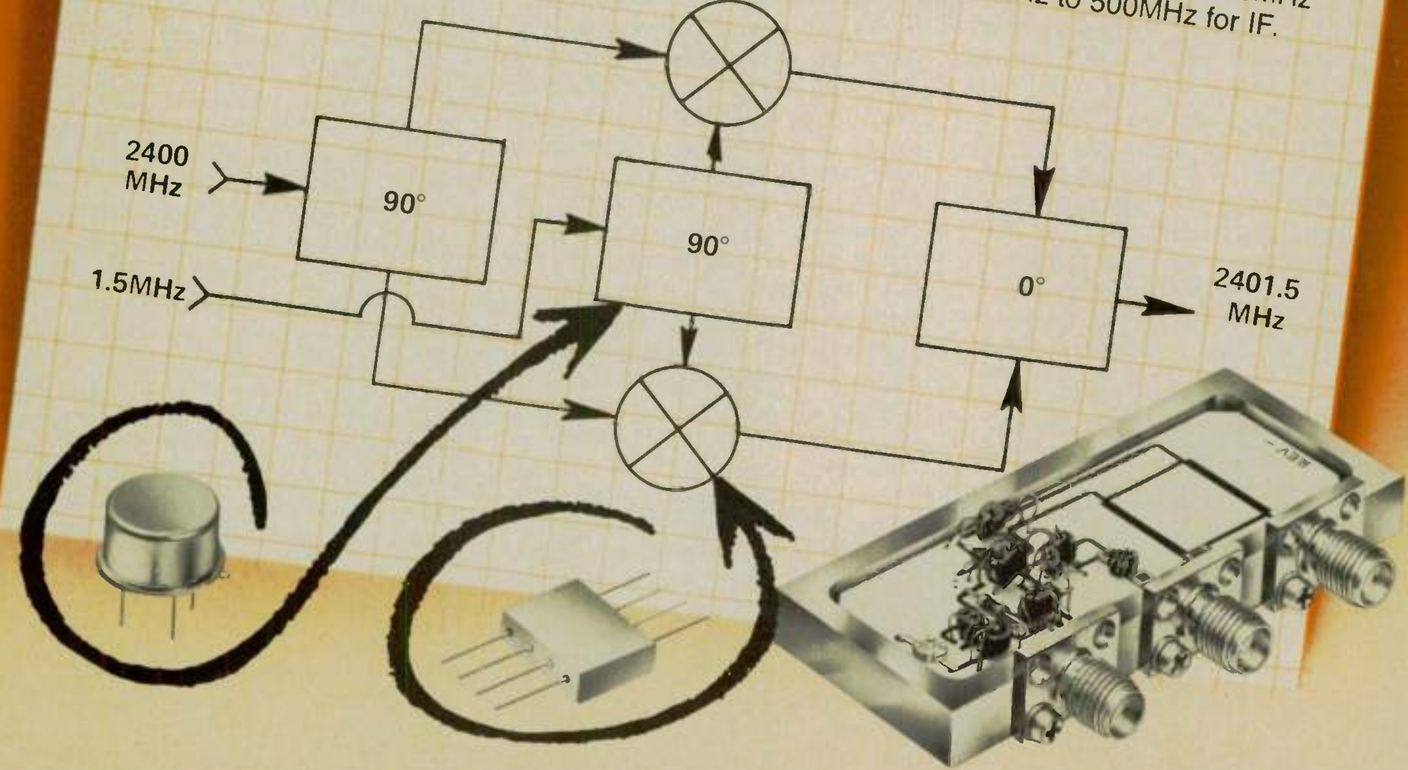
RF Subassembly used for SSB Modulator or Imageless Mixer

Integration of a microstrip quadrature hybrid @ 2.4GHz into a subassembly, with toroidal doubly balanced mixers and hybrids, provides a circuit that is useful for both modulator and imageless mixer applications.

This typical example is a modulator used in a transceiver. Engelmann has combined standard components to provide 1.5MHz SSB modulation @ 2400MHz with 30dB minimum rejection of undesirable sidebands. Additional specifications for this subassembly include 40dB input to RF output isolation, and 75dB min. isolation between modulation input and RF output. The overall net loss of the circuit is 10dB max. In this case, the RF level and modulation input levels are +10dbm and −5dbm respectively, and the RF output level is −15dbm nominal.

When used as an imageless mixer, the output port is used as the RF input, and the modulation and input ports are the IF and LO ports respectively.

The same basic circuit can be adapted to frequency ranges from 1MHz to 3000MHz for RF/LO, and 1MHz to 500MHz for IF.



We'll Supply the Components...or the Complete Integrated Sub-System!

MODEL PST-103
freq.: 1.3 - 1.7MHz
ins. loss: 0.2db
isolation: 25db
phase bal.: 1 deg.

MODEL MLF-101
LO/RF 0.25-2500MHz
IF = 0.25-600MHz
8.5 dB Conv. Loss Max.
30dB Typical Isolation

Available in SMA, Type N, Flat Pack, 8-Pin, TO-5 and TO-8

For all your components or sub-assemblies..from off-the-shelf to custom designs...contact

ENGELMANN

Engelmann Microwave Co. — Subsidiary of Pyrofilm Corporation
Skyline Drive, Montville, New Jersey 07045 • (201) 334-5700

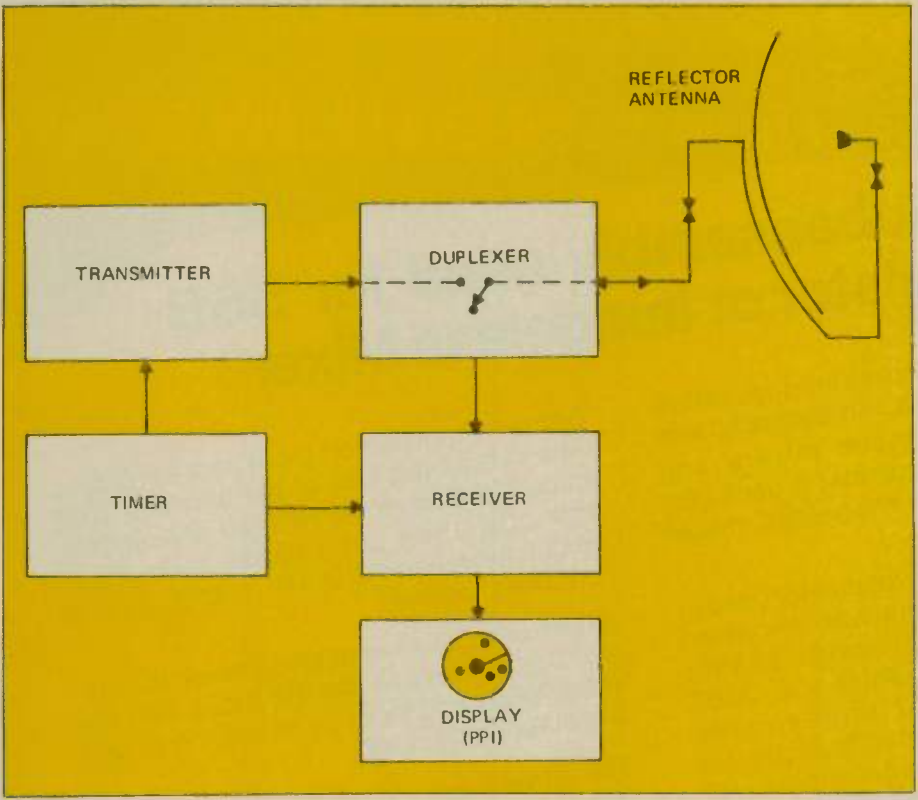


Fig. 8 Basic radar block diagram.

tor of space, referred to as a height-finder. By correlating the position of a target in the vertical and horizontal sectors, the direction to the target may be discerned. To avoid ambiguities that may arise in the location with the presence of more than one target, correlation may be obtained by comparing distances to targets, velocities of targets, and maintaining time histories of target location from initial observation.

The scanning methods so far discussed use either mechanical movement or electronic scanning by the adjustment of time delays. One additional method of scanning uses another electronic process. The previous electronic delays described were obtained by adjusting an electronic delay network. An alternate method of changing the delay is by shifting the frequency of the signal, since practical delay networks produce a delay which depends on the frequency. Hence, with no changes in the network, an antenna may be scanned by varying the frequency. In such a case, it is possible to obtain information at all angles of interest simultaneously by transmitting a frequency scanned pulse and then receiving with a multichannel receiver.

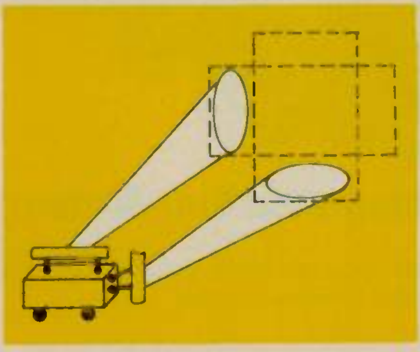


Fig. 7 Track-while-scan radar.

Let us now consider two methods of determining the distance to a target to complete the location information. The basic philosophy is to compare the time delay between the transmission of information and the reception of the same information at the receiver. The basic radar system used to detect the distance is shown in **Figure** 8. The most common information transmitted is a short burst of RF energy triggered by the timer in the radar. The timer also begins the sweep on the display or counter in the receiver, which will then display the distance to the target in terms of an elapsed time to the received pulse (12.35 μs delay per nautical mile to the target). A slightly different process sends out a continuous carrier with a slow variation in the frequency. This change in frequency is made linearly proportional to time so that the difference in frequency between the received signal and the transmitted signal is proportional to the elapsed time. The radars just described are referred to as pulse-CW and FM-CW, respectively.

The radial velocity of the target may be obtained either by observing the rate of change of the distance to the target or by Doppler shift. This Doppler shift may be detected with either a continuous carrier radar (CW) or a pulse radar which gives a time sampled Doppler output. For the pulsed radar case, the pulse delay information may be used for target distance while the pulses may be filtered in another channel to determine the residual Doppler shift. Though this sounds simple, an extremely important ambiguity problem arises when both functions are done simultaneously. To avoid false velocity identifications, the pulse repetition frequency (PRF) must be sufficiently high, often requiring new pulses to be sent before the return from previous pulses are received. This, however, causes range ambiguity; the target appears to be closer than its actual position by one or more pulse periods. This ambiguity may be eliminated by sophisticated processing, using staggered PRFs and correlating the shifts in position and the PRFs (no position change will occur if the target is within one pulse period).

Similarly, when the PRF is sufficiently slow for proper range information, then the velocity may be in error by the velocity corresponding to the sampling frequency or PRF. In the same way, this ambiguity may be eliminated by processing with staggered PRFs.

It is desirable to track targets in velocity and range, in addition

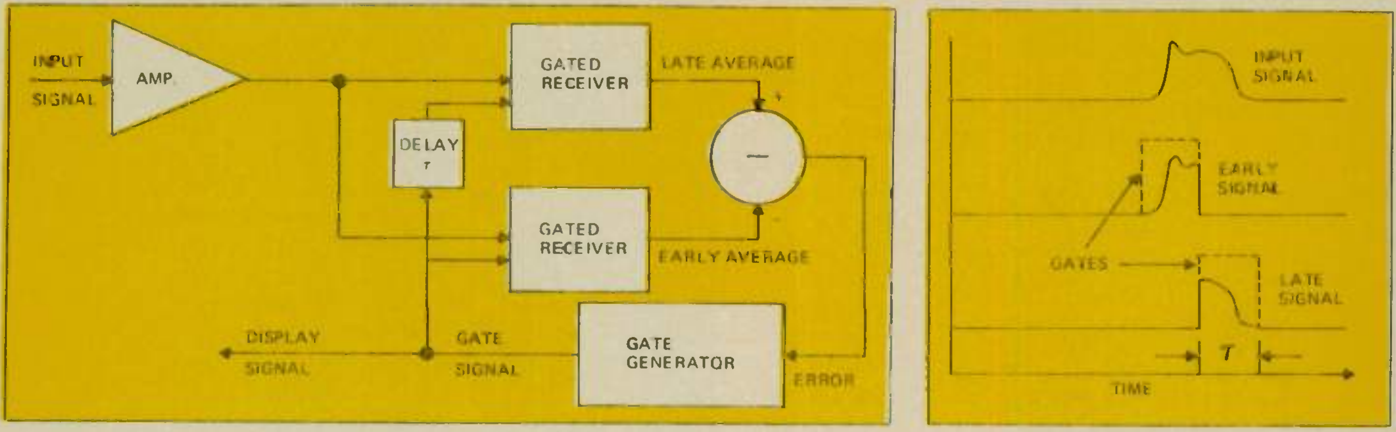


Fig. 9 (a) Range tracking system and (b) associated waveforms.

to angular position. Systems used for such tracking are called gates, and limit the range of operation of the receiver to a particular region in time, with a control circuit to maintain the desired region. A simple diagram of such a range gate is shown in Figure 9. The circuit turns on each of two channels of a receiver sequentially for the length of one pulse. The gate generator may be a voltage controlled pulse oscillator with the frequency determined by the difference in signal levels in the two channels. If no signal were present in either channel, the system would automatically enter a search mode. A velocity tracking method may be obtained in an analogous way. Replace each of the channels with adjacent frequency bandpass filters and use the gate generator as a local oscillator to convert the receiver frequency to that of the two filters. With a slight overlap of the filter frequency bands and the width of the received signal, the outputs of the filters are kept equal by adjusting the gate generator frequency, which indicates the target radial velocity. This technique may also be used for the angel track of the track-while-scan radar.

Let us briefly consider a variety of other ECCM techniques before considering the basic ECM techniques. A major problem in target detection is the elimination of background effects. For airborne targets, this means removing the interference of slowly moving targets such as clouds. The moving target indicator (MTI) simply adds and subtracts successive return pulses, which cancel for stationary targets but have a residual nonzero component for moving targets. This latter is used as the radar return for processing.

A choice of techniques is available for noise interference. For static burst type noise, one might use either a noise-blanker, which amplifies wideband pulses in a separate channel and uses the output to temporarily disable the signal channel, or use a Dicke Fixe. The latter amplifies the signal and noise in a wideband amplifier up to a clipping level just above the signal level, which clips the noise before entering a narrowband amplifier which rejects most of the now low level noise. Both of these techniques provide a protection for the automatic gain control (AGC) of the system from impulse override.

For the noise typical of jammers, other techniques are often useful. A simple technique is to average the return over several pulses. This is done with a range gate in operation or versus range using a memory persistence display or a digital processor. This latter process is called post detection-integration (PDI). Automatic gain control is used to increase the dynamic range of the receiver but is very susceptible to noise jamming. To improve the performance at the time of signal reception, a noise window, which obtains a detection or AGC threshold from the noise in adjacent range or velocity gates, is often used.

Additional noise immunity and also covertness can be obtained with the communication technique of spread spectrum. Though radar systems do not use the technique directly, several radars transmit pulse or frequency coded signals which require matched filters for reception. By proper design, these filters will have the noise cancelling properties of a PDI while receiving the signal at complete strength.

Repeater jammers often delay the signal one pulse period to overcome the delay problems in the repeater itself. A fixed PRF radar will not cancel such signals in the PDI. However, if the PRF has jitter (an advantage of cheap, noncrystal oscillators) then the PDI and other processors may easily defeat such a repeater.

The last technique of ECCM we shall discuss is obvious once it is considered. It was mentioned earlier that the monopulse scan had just a single beam on transmit and "scanned" on receive only. Some ECM techniques use the scan information to cause angle errors in the radar tracking. To prevent this, one simply transmits a broad beam over the full scan area and scans with a receive antenna only. This is an effective technique for conical scan and is referred to as scan-on-receive only.

ECM

We have discussed ECCM as part of the radar system design. ECM is the other side of the coin, by which we try to degrade the performance of a radar system (or communications system). Radar ECM falls into several categories, and can usually be classified as either deception or denial and active or passive. With deception, we provide false targets more desirable than ourselves. The confusion of too much information, to the point of noise, is called denial. Active and passive refer to powered or unpowered systems in the electronic sense. For example, a repeater is active while a reflector is passive.

In the previous section, we briefly discussed jammers. However, it is worth reviewing the pulse jammer in more detail. For the pulse jammer to be effective, the noise pulses must be correlated with the return pulse of the radar. In this sense, the noise pulse jammer is a repeater of sorts, through which the timing information of the radar signal is extracted and imposed on the jammer pulse. The primary advantages of this type of repeater over a standard repeater are in the design simplicity.

The suggestion of a repeater brings up the question of why one should aid a radar in its job. The answer is it should be aided only long enough to control it. Once one controls the radar with the repeater signal rather than the return, one can manipulate the repeater signal to cause the radar to lose track. For instance, one might slowly change the delay of the repeater to cause the radar to track in range to a distance other than that of the target. Once at another range, the repeater may be turned off leaving the radar bewildered. (Note: It is a good idea to turn off any electronics that radiate energy when not needed, this prevents hostile forces from homing in on these emissions.) This technique of range-gate-full-off is also applicable to velocity gates, with the exception that the frequency is shifted rather than having the pulse delayed.

Angle-gate-walk-off requires a slightly different technique than that used for the other two gates. One such technique is inverse gain, meaning the jamming signal has an amplitude inversely proportional to that of the radar. This widens the effective radar received angle. However, averaging at the radar can be used to improve range determination. By adding a slope or gradient to the inverse gain curve, the repeated signal will favor one side over the other while the antenna tracking system follows, deviating from the target angle. Obviously, this technique requires transmitted scan information from the radar, and may be defeated by a scan-on-receive-only system; thus the difficulty with ECM for monopulse. An alternate technique for scanning systems is to strobe the noise pulses at a multiple of the scan rate. These strobes can be provided with a slight variation in frequency to cause the same angle errors as with inverse gain.

Passive ECM takes three basic forms. First and most renown from World War II is "chaff", which took the form of lengths of foil (called rope) to defeat low frequency communications and radar. The "rope" was designed as dipole antennas, resonant at the desired frequency to enhance reflection. Today most chaff is short for the microwave frequencies and is designed to have not only good reflection properties, but good aerodynamic properties as well. Such ECM is used for decoys in small bundles or for a blanket to hide returns from an attacking force.

We may also enhance or reduce the *radar cross section*, or reflection properties, of a target to deceive or evade the opposing radar. The enhancement may be obtained by installing corner reflectors on a drone or remotely-piloted vehicle to make it appear to be a much larger aircraft. To be effective against sophisticated radars, the tactics of such vehicles must appropriately simulate a corresponding aircraft. The reduction of the aircraft radar cross section is desirable to minimize the probability of radar detection. This reduction is accomplished as an add-on to existent aircraft by the use of radar absorber material at selected positions. However, the additional weight of absorber is a disadvantage, and has led to increased efforts to design new aircraft with appropriately sloped surfaces to minimize reflection properties. Two simple techniques employed minimize vertical areas of large, nearly flat surfaces and corners that could enhance the reflection.

Several key terms are appropriate in summary. The first important term in EW is power management. This encompasses methods of using available techniques more effectively, and the power in a manner to obtain the maximum probability of mission success. Three basic words pertaining to jammer effectiveness are *jam-to-signal ratio, look-through,* and *burnthrough*. Jam-to-signal ratio is a figure of merit for jamming effectiveness. For a jammer to be effective, the jamming level at the radar must exceed the signal level in watts per megahertz by the stated ratio (J/S). The ability of a jammer to meet this level is a function of the square of the distance between radar and target, since the radar return is inversely proportional to the fourth power of the distance and the jammer signal is inversely proportional to the second power of the distance. Accordingly, there is a distance at which the J/S is just achieved, and this distance is called the burnthrough range. This is the distance within which the jammer is no longer effective. Look-through is simply the process of turning off the jammer to check its effectiveness. An inadequate jammer switches allegiance, being of use to the enemy, instead, for target homing.

SUMMARY

This installment of the fundamentals of electronic warfare, describes the basic forms of radar and discusses the various forms of electronic counter and counter-countermeasures. This paper can not be complete without mentioning that we have only touched on the more than one hundred ECM and ECCM techniques. In fact, with every system there appears a new technique. The goal here has been to portray the philosophy of electronic warfare and not to catalog the numerous specific techniques.

LINEARIZE VCOs by REACTANCE COMPENSATION

WILLIAM H. LOCKYEAR
Electron Dynamics Division
Hughes Aircraft Company
Torrance, CA

INTRODUCTION

This paper describes a technique which can be used to linearize a selected portion of the electronic tuning characteristic of a Gunn diode voltage controlled oscillator without using any external circuitry at the tuning port. The technique uses reactance compensation to change the reactance slope of the oscillator's basic resonance, thereby altering the normal exponential shape of the varactor-tuned oscillator. This technique has previously been applied to VCOs[1] but for the purpose of increasing tuning bandwidth rather than for linearization.

The linearization technique described below which involved reactance compensation of oscillator's basic resonance has several advantages over external electronic linearization schemes. They are as follows:

- No external linearizer is needed; this leads to size and cost improvement and reduced complexity and parts count. In addition, reliability is considerably better than the case where an active electronic linearizer is used.
- The noise characteristics and maximum slewing rate of the VCO are not fundamentally altered. (Active linearizers tend to add considerable amounts of FM noise to the VCO[2] and impose modulation bandwidth restrictions.)
- Tuning bandwidth is increased over the same VCO without reactance compensation.

REACTANCE COMPENSATION

The reactance compensation linearization technique can basically be described by considering the equivalent circuit shown in Figure 1. In this circuit the series resonance (L_s and C_s) represents the basic VCO including the Gunn and varactor diodes. A shunt resonance (L_p and C_p) has been introduced between the VCO and its load, R. The reactances of the series and shunt resonances vary with frequency as shown in Figure 2 by curves (a) and (b), respectively. Near the resonant frequency, ω_o, the reactance slope of the shunt circuit is negative which reduces the overall reactance slope of the circuit. By proper choice of L_p and C_p the overall reactance slope can be reduced to zero as shown by curve (c) of Figure 2. This was

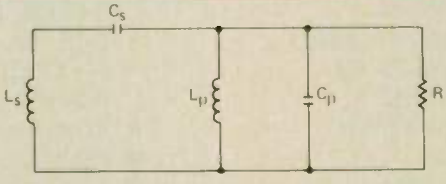


Fig. 1 Simplified equivalent circuit of reactance compensated voltage controlled oscillator.

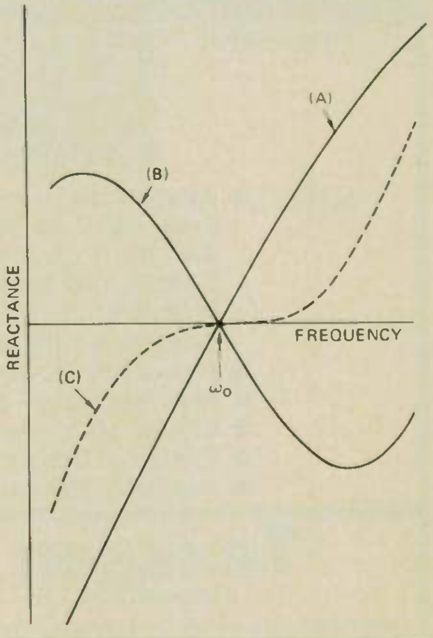


Fig. 2 Reactance variation with frequency of (a) series resonant oscillator, (b) shunt resonant compensation circuit and (c) the overall combination of (a) and (b).

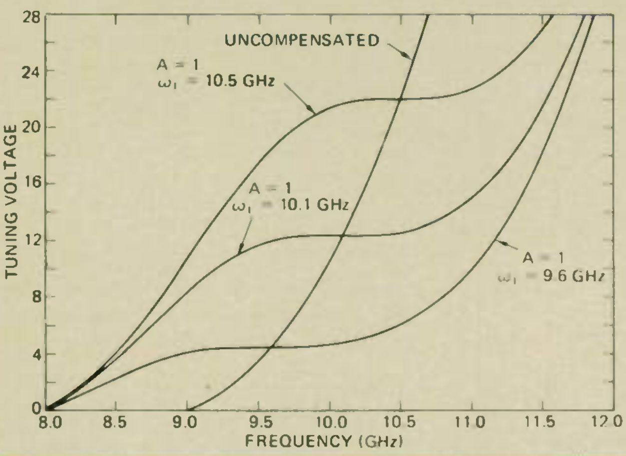


Fig. 3 Tuning curves of fully compensated VCO for various values of ω_1.

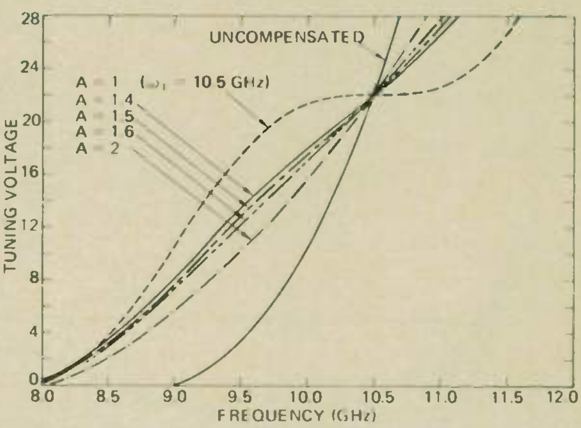


Fig. 4 Tuning curves of linearized VCO for various value of A.

originally introduced by Aitchison, et. al.[1] as a broadbanding technique since it lowers the circuit's overall rate of reactance change with frequency. However, it can also be used as a linearizing technique since it changes the reactance variation and therefore alters the usual exponential shape of the varactor-tuned Gunn oscillator.

The circuit of **Figure 1** was used to study the effect of reactance compensation upon the shape of the tuning curve of a VCO. We designate

$$C_p = L_s\ G^2/A \text{ and} \qquad (1)$$

$$L_p = A/\left(\omega_1^2\ L_s\ G^2\right)$$

where A is a constant, $G = 1/R$ and ω_1 is the resonant frequency of the shunt compensation circuit which is chosen to occur somewhere within the VCO's tuning range. As shown by Aitchison, A = 1 corresponds to the complete compensation case where the reactance slope is reduced to zero at ω_1 and the tuning bandwidth is maximized. The tuning characteristics for a simple varactor-tuned oscillator circuit like that of **Figure 1** have been calculated for three different values of ω_1 with A = 1 and are plotted in **Figure 3**. The uncompensated tuning curve is also shown for comparison. In all cases the tuning bandwidth has been considerably increased and the shape of the curve substantially altered.

By choosing the value of A to be larger than 1.0, a tuning curve is obtained which lies between the fully compensated and uncompensated curves as shown in **Figure 4**. For certain values of A, a reasonably high degree of linearity can be obtained over tuning ranges comparable to or larger than the overall tuning bandwidth of the uncompensated VCO. This is illustrated by the curves A = 1.4, 1.5 and 1.6 of **Figure 4**. The degree of linearity of these curves can be described in two ways; (1) by specifying the ratio between the maximum and minimum differential tuning sensitivities of the curve over a given tuning range or (2) by specifying the maximum frequency deviation of the curve from a straight line expressed as a percentage of the desired tuning range. In **Table I** both of these methods are used to describe the degrees of linearity of several of the curves shown in **Figure 4** (plus one unplotted curve, A = 1.55). For each level of compensation two choices of slope ratio were used to determine the range of linearity. First, a slope

TABLE I

LINEARITY CHARACTERISTICS OF REACTANCE COMPENSATED VCO FOR SEVERAL DEGREES OF COMPENSATION

A	Tuning Range (Volts)	Tuning Bandwidth (MHz)	Slope Ratio	Frequency Deviation (%)
1.4	2.7-27.6	2670	1.50	4.1
	2.7-26.5	2572	1.38	4.2
1.5	4.6-28.9	2446	1.50	3.8
	4.6-24.1	2037	1.14	1.8
1.55	6.0-29.2	2270	1.50	5.3
	6.0-27.5	1701	1.08	1.0
1.6	8.0-30.0	2067	1.50	8.4
	8.0-20.0	1221	1.03	0.3
∞ (Uncomp.)	0.0-30.0	1753	6.8	21.9
	14.7-30.0	553	1.50	5.3

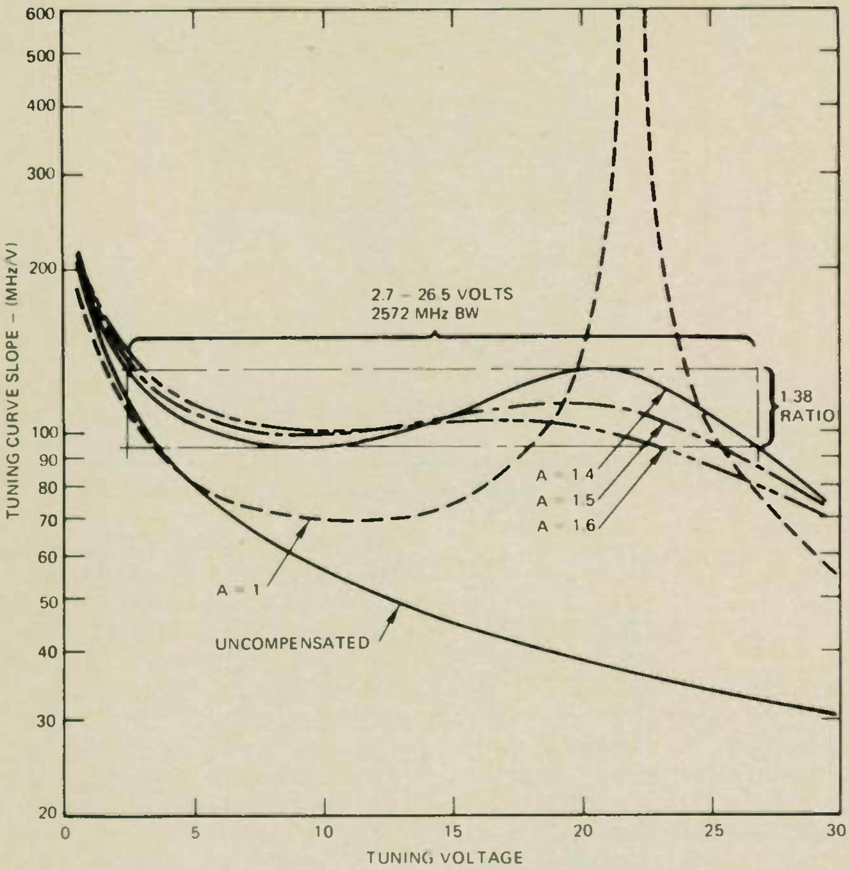


Fig. 5 Tuning curve slope plots for various levels of compensation.

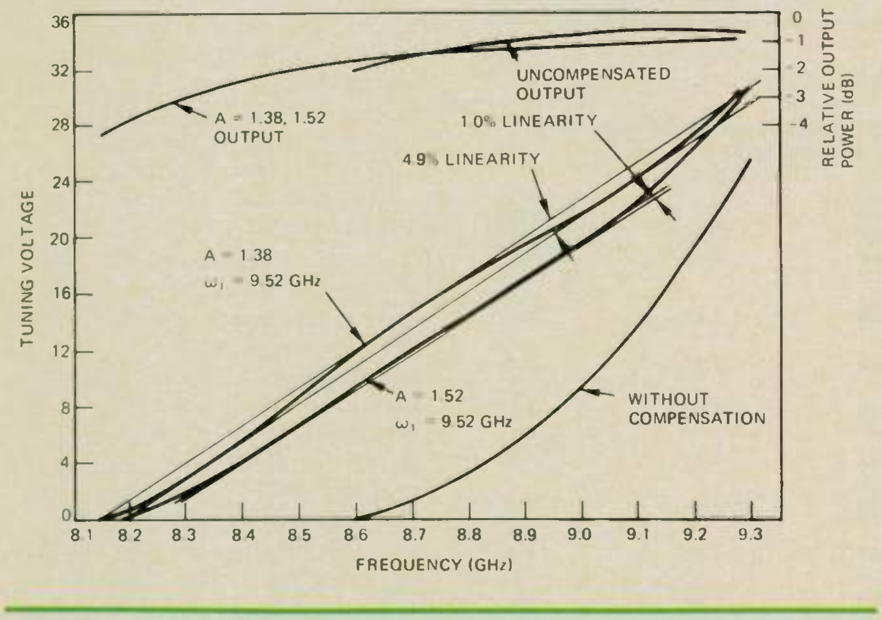


Fig. 7 Calculated performance curves of Gunn VCO model.

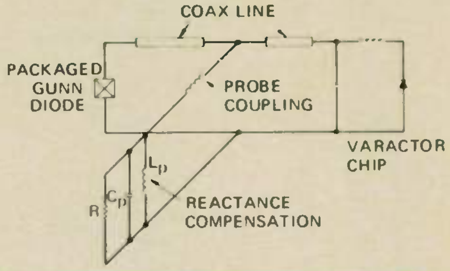


Fig. 6 Computer model of the coaxial cavity Gunn VCO design.

ratio of 1.50 was arbitrarily chosen and the maximum tuning range (between 0 and 30 volts) containing slopes within this ratio determined from the computed tuning curve data. Table I shows that for A = 1.4 to 1.6 all of the tuning bandwidths obtained by this definition are broader than the entire uncompensated tuning range. The frequency deviations obtained for these cases range from 3.8% (±1.9%) to 8.4% (±4.2%).

Secondly, the "equi-ripple" differential tuning sensitivity ratio was allowed to determine the range of linearity. By this we mean the ratio of the maximum to minimum slopes occurring in the region near ω_1 which is affected by the compensation resonance. Table I shows that increasingly high degrees of linearity are obtained over decreasing bandwidths as A varies from 1.4 to 1.6. This clearly shows a not-unexpected trade-off between the degree of linearity and bandwidth. The case A = 1.55 is of particular interest. It indicates a slope ratio of only 1.08 and a frequency deviation of 1.0% (±0.5%) is obtainable over a 1.7 GHz bandwidth which is nearly equal to the bandwidth of the uncompensated oscillator. Similarly, the A = 1.5 case shows a 1.14 slope ratio and 1.8% (±0.9%) frequency deviation over a 2.0 GHz bandwidth.

The effect of reactance compensation upon tuning sensitivity can be seen directly in Figure 5 where the tuning curve slopes are plotted against voltage. The Figure illustrates the determination of the "equi-ripple" linearity range for the A = 1.4 case. Multiple reactance compensation could be used to make further improvements in the degree of linearity and/or tuning bandwidth by using two or more resonators. The amount of improvement would be relatively small, however, at the expense of considerable increase in circuit complexity.

(continued on page 64)

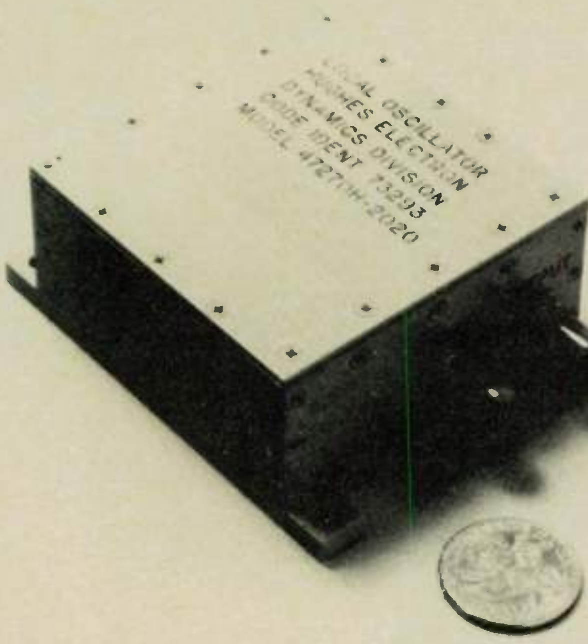


Fig. 8 Reactance linearized Gunn VCO.

TABLE II

LINEARITY CHARACTERISTICS OF GUNN VCO MODEL

A	Tuning Range (Volts)	Tuning Bandwidth (MHz)	Slope Ratio	Frequency Deviation (%)
1.38	1.9-26.4	912	1.48	4.9
1.52	4.3-19.0	576	1.11	1.0
Uncomp.	0.0-28.0	738	6.6	21.3

LINEARIZATION OF A VARACTOR-TUNED GUNN VCO

Reactance compensation has been used to linearize a coaxial cavity X-band Gunn VCO theoretically and experimentally. A simplified equivalent circuit for the oscillator is shown in Figure 6. Based on this model, computer aided design was used to study the VCO's performance. The circuit consists of a coaxial cavity with the Gunn and varactor diodes at opposite ends of the cavity, a probe coupled output and a shunt reactance compensation resonator at the output port. The Gunn diode model used is based on network analyzer impedance measurements of a packaged X-band 500 mW device. The computer program uses an iterative technique to determine the resonant frequency of the VCO at each given tuning voltage. It calculates the output impedance of the oscillator and from this data the reactance slope at the output port can be obtained. An equivalent total series inductance, L_s, can be defined by:

$$L_s = \frac{1}{2}\left.\frac{dX}{d\omega}\right|_{AVE} \qquad (2)$$

where $dX/d\omega_{AVE}$ is the average reactance slope in the desired frequency range of linearization. The compensation resonance, ω_1, is chosen to be in or near the uncompensated VCO's tuning bandwidth by computer optimization. Then, equation (1) is used to determine C_p and L_p for various levels of compensation, A.

Typical calculated performance curves are shown in Figure 7. The tuning curves for two different degrees of compensation (A = 1.38 and A = 1.52) are shown and their linearity characteristics are listed in Table II. The data predicts that slope ratios ranging from 1.11 to 1.48 can be achieved over bandwidths of 576 to 912 MHz. The corresponding frequency deviations vary from 1.0% (±0.5%) to 4.9% (±2.5%).

Figure 7 also shows the relative output power characteristics

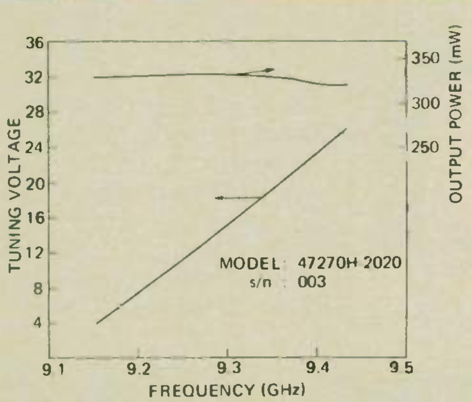


Fig. 9 Performance of reactance linearized Gunn VCO.

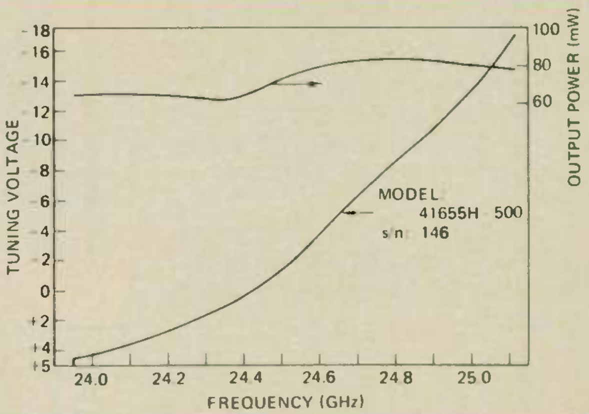


Fig. 10 Performance of reactance linearized K Band Gunn VCO.

(continued on page 68)

Now you can add famous Rust-Oleum® protection to aviation obstruction markings.

We're up to any job. Rust-Oleum offers a full line of tower coatings for marking aviation obstructions, such as microwave transmission towers, antennas and smokestacks. Our Aviation Surface White and Orange finish coats meet FAA specifications, including standards for luminosity and chromaticity. These durable coatings are available in high-gloss and flat finishes.

High quality, lasting protection. Backed by the right Rust-Oleum primer, our tough vinyl and water-base acrylic tower coatings give years of low-cost protection against weathering and corrosion without dulling or fading. No primer is usually needed on galvanized steel surfaces.

Easy on, easy clean-up. Rust-Oleum tower coatings can be applied with brush, roller, spray or paint mitten. And because they're water reducible, clean-up is fast and simple.

Get our free guide. Rust-Oleum offers a brochure explaining FAA regulations on tower coatings—including a guide to marking patterns. To get a free copy, contact your local Rust-Oleum distributor or applications specialist. Or write us at our home office.

RUST-OLEUM
CORPORATION
11 HAWTHORN PARKWAY
VERNON HILLS, ILLINOIS 60061
TELEPHONE (312) 367-7700
TELEX 72-4494

Rust-Oleum has the system.

Circle 36 on Reader Service Card

How a country's telephone system can take a bold leap into the future gradually.

In the next few years, country after country will be faced with critical timing questions in telecommunications.

How rapidly should they move into digital technology? Or should they stay a while longer with today's kind of telephone systems?

Not easy questions, certainly.

Technology is changing, and it's likely the world will be moving into a largely digital environment.

But it's difficult for any particular country to know how to respond—given its own needs, resources, growth plans.

To us at ITT, this all has a familiar ring.

For some years we've been working as partners with telephone administrations around the world, helping them adjust to new technologies.

Many technologies we introduced. (In digital, our involvement goes back to 1938—the year we invented Pulse Code Modulation.)

From experience, we know that some countries will want to continue for now with today's stored program control systems. And we can help; we've installed nearly 2 million SPC lines around the world.

But surely, global telecommunications will someday turn to an information delivery system like our conception, Network 2000.™

It will be a digital network, capable of handling voice and data at the same time.

And a network that will relieve central exchanges of a lot of their work—by distributing it to the subscriber's equipment.

This network, inevitable as tomorrow's needs, is some years off, however.

Meantime, no matter what a country's development scenario calls for, ITT has the equipment and experience to help you get there.

As quickly—or gradually—as seems right for you.

ITT

ITT NETWORK 2000

© 1980 International Telephone and Telegraph Corporation, 320 Park Avenue, New York, N.Y. 100 , U.S.A.

Circle 37 on Reader Service Card

World Radio History

of the compensated and uncompensated VCO's. These curves are normalized to the maximum power available from the Gunn device when used in a fixed tuned oscillator.

Several Gunn VCOs have been linearized by the reactance compensation technique. As an example, **Figure 8** shows an X band oscillator which includes the oscillator cavity, an isolator, a regulator and a temperature compensation circuit. It employs a coaxial cavity which is schematically similar to the model of **Figure 6**. Typical performance curves for this oscillator are shown in **Figure 9**. It displays a tuning slope ratio of less than 1.4 over a 260 MHz band. The tuning bandwidth of this oscillator appears to be considerably less than that of the computer model primarily because a resistor divider is used in the varactor tuning circuit. The divider is used to set the average tuning sensitivity to a specified value and to provide (in conjunction with a thermistor) temperature compensation. However, it narrows the apparent tuning bandwidth for a given voltage range. The linear tuning range of this oscillator basically extends over at least 800 MHz and has characteristics similar to the first line of **Table II**.

Differences between the experimental and theoretical results occur due to parasitics and biasing networks not included in the model and to errors in the diode models. The basic limitations on the degree of linearity achievable due to these second order effects has not yet been fully determined and further work is being done in this area.

Due to the nature of reactance compensation undesirable ripples could be introduced into the linearized curve by external reactances presented to the VCO by its load. Therefore, when using this technique, it will generally be necessary to use a good isolator in order to avoid these pulling effects.

Reactance compensation can also be applied to waveguide cavity VCOs by placing an appropriate resonance near the output iris. This was done to a K band Gunn VCO and the resulting performance curves are shown in **Figure 10**. This oscillator exhibits a linear tuning region between 24.5 and 25.0 GHz with a frequency deviation of 1.5%.

CONCLUSIONS

The technique of reactance compensation, previously used to broadband VCOs, has been shown to be useful for linearizing varactor tuned oscillators both theoretically and experimentally. The linear region of the modified tuning characteristic is comparable to or greater than the uncompensated bandwidth depending upon the degree of linearity desired. Although the technique is applied only to Gunn diode VCOs in this paper, it is very general and could be applied to other types of varactor tuned oscillators as well.

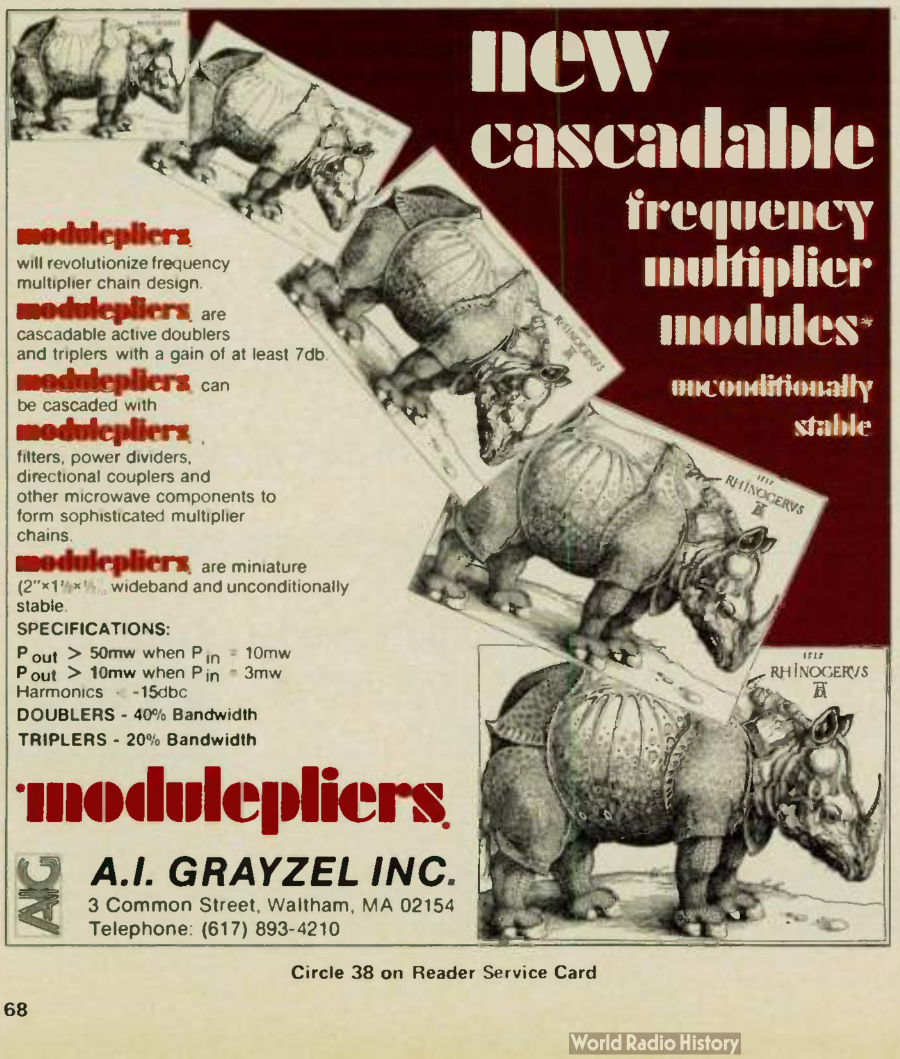
ACKNOWLEDGEMENT

The author wishes to express this gratitude to R. S. Tahim, J. A. Lovato and S. Back for making the experimental measurements and to D. S. Matthews for beginning the original reactance compensation work at Hughes, Electron Dynamics Div.

REFERENCES

1. Aitchison, C. S., and R. V. Gelsthorpe, "A Circuit Technique for Broadbanding the Electronic Tuning Range of Gunn Oscillators," *IEEE Journal of Solid State Circuits*, Vol. SC 12, No. 1, Feb. 1977, pp. 21-28.
2. Buswell, R. N., "Behind the Design of VCO Linearizers," *Microwaves*, Sept. 1976, pp. 36-40.

W. H. Lockyear received a B.S. (Engineering) from the University of California, Los Angeles in 1965. He graduated from UCLA with a M.S. (Electrical Engineering) in 1967. He joined Hughes Aircraft Co. in 1965 on the Hughes M.S. Fellowship program. From 1965 to 1967, he designed electron guns for travelling-wave tubes and in the evaluation of TWT electron optics. From 1967 to 1970, he engaged in development of varactor and step recovery frequency multiplier chains. In 1970, he became involved in the design of injection locked IMPATT diode oscillators and IMPATT diode reflection and transmission amplifiers. Since 1975, Mr. Lockyear has directed an advanced development group responsible for various types of microwave/millimeter wave power generation devices. He is currently the Head, Microwave Sources of Hughes Aircraft's Electron Dynamics Div.



FEBRUARY 1980 • MICROWAVE JOURNAL • USE BEFORE MAY 1980

PLEASE PRINT OR TYPE

NAME ____________________ TITLE ____________________

DEPT OR MAIL STOP __________ PHONE ____________________

COMPANY ____

STREET ____

CITY ____________________ STATE ______ ZIP ______

COUNTRY ____

Are you a subscriber to MICROWAVE JOURNAL? ☐ YES ☐ NO

Please send details on how I can receive MICROWAVE JOURNAL *free* each month. ☐

Enter company name and page number for ads without R.S. numbers.

____

For more information circle appropriate number below

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255
256	257	258	259	260	261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280	281	282	283	284	285
286	287	288	289	290	291	292	293	294	295	296	297	298	299	300

FEBRUARY 1980 • MICROWAVE JOURNAL • USE BEFORE MAY 1980

PLEASE PRINT OR TYPE

NAME ____________________ TITLE ____________________

DEPT OR MAIL STOP __________ PHONE ____________________

COMPANY ____

STREET ____

CITY ____________________ STATE ______ ZIP ______

COUNTRY ____

Are you a subscriber to MICROWAVE JOURNAL? ☐ YES ☐ NO

Please send details on how I can receive MICROWAVE JOURNAL *free* each month. ☐

Enter company name and page number for ads without R.S. numbers.

____

For more information circle appropriate number below

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255
256	257	258	259	260	261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280	281	282	283	284	285
286	287	288	289	290	291	292	293	294	295	296	297	298	299	300

FEBRUARY 1980 • MICROWAVE JOURNAL • USE BEFORE MAY 1980

PLEASE PRINT OR TYPE

NAME ____________________ TITLE ____________________

DEPT OR MAIL STOP __________ PHONE ____________________

COMPANY ____

STREET ____

CITY ____________________ STATE ______ ZIP ______

COUNTRY ____

Are you a subscriber to MICROWAVE JOURNAL? ☐ YES ☐ NO

Please send details on how I can receive MICROWAVE JOURNAL *free* each month. ☐

Enter company name and page number for ads without R.S. numbers.

____

For more information circle appropriate number below

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255
256	257	258	259	260	261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280	281	282	283	284	285
286	287	288	289	290	291	292	293	294	295	296	297	298	299	300

NAME ____________________
COMPANY ____________________
STREET ____________________
CITY ____________ STATE ____ ZIP ______
COUNTRY ____________________

PLACE
STAMP
HERE

MICROWAVE
JOURNAL
COMPUTER CENTER
610 WASHINGTON STREET
DEDHAM, MASSACHUSETTS 02026

NAME ____________________
COMPANY ____________________
STREET ____________________
CITY ____________ STATE ____ ZIP ______
COUNTRY ____________________

PLACE
STAMP
HERE

MICROWAVE
JOURNAL
COMPUTER CENTER
610 WASHINGTON STREET
DEDHAM, MASSACHUSETTS 02026

NAME ____________________
COMPANY ____________________
STREET ____________________
CITY ____________ STATE ____ ZIP ______
COUNTRY ____________________

PLACE
STAMP
HERE

MICROWAVE
JOURNAL
COMPUTER CENTER
610 WASHINGTON STREET
DEDHAM, MASSACHUSETTS 02026

The Systems Engineer's Primer on IFM Receivers

DEAN HEATON
Aertech Industries
Sunnyvale, CA

The Digital Instantaneous Frequency Measurement Receiver (DIFM) is a recognized product which in a few cases is now deployed in the field. Yet it should be considered a very recent technology breakthrough. Its predecessor, the single channel, coarse frequency resolution, analog frequency discriminator has been around for many years, although it has never been widely publicized. The inner workings of the DIFM receiver have had even less discussion. This article will review the general principles of operation of the DIFM and will discuss some potential performance trade offs which can minimize the escalation of costs associated with extensive custom design changes.

BRIEF THEORY OF OPERATION

The simplified block diagram shown in **Figure 1** is typical of each receiver, regardless of the frequency band. A bandpass filter is provided at the receiver input to attenuate signals outside the desired frequency range. A limiting RF amplifier is included to amplify signal levels to within the dynamic range of the discriminator assembly. The gain and limiting characteristics of the RF amplifier are chosen to assure a constant amplitude as the input signal frequency is varied and as the input signal amplitude is varied within the dynamic range. The limiting amplifier is followed by a second bandpass filter, which reduces out-of-band spurious sig-

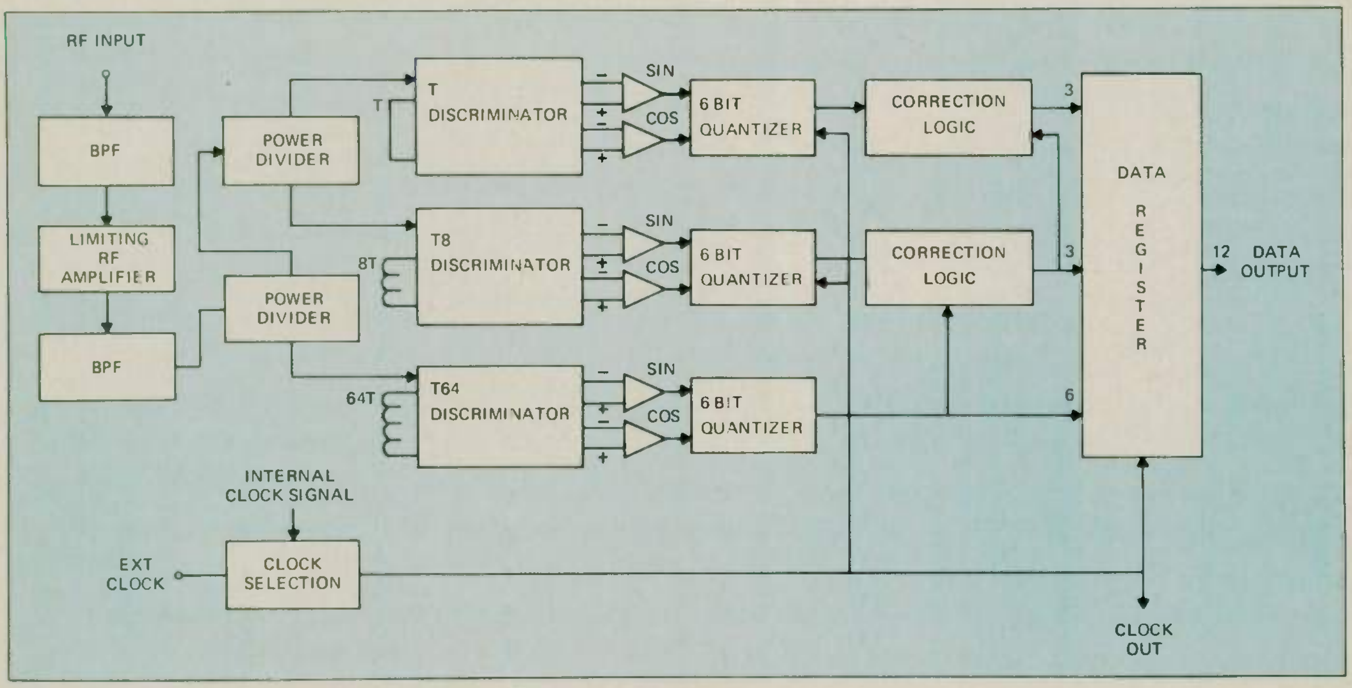


Fig. 1 DIFM Receiver block diagram.

nals generated by the limiting amplifier and limits the noise power produced by the RF amplifier.

The integrated RF assembly or frequency discriminator consists of a complex stripline circuit containing power dividers, hybrids, delay lines and detectors which convert the incoming RF signals to the appropriate sine/cosine relationship video signals. Two differential input video amplifiers per channel convert the four discriminator outputs to a form required by the digitizing circuits. These outputs are then processed in a high speed quantizer.

The quantizer consists of a bank of 32 comparators which produce a measure of the incoming phase angle. Each comparator in the bank has a distinct voltage threshold, corresponding to a discrete angular increment, such that when the net input voltages exceeds that point, the comparator output changes its binary state. The thresholds for the comparator are developed by a matrix of high precision resistive voltage dividers. The 32 comparators in the bank quantize the phase angle from each discriminator channel to within 6 bits of resolution. In order to cast the output into the proper digital format, the comparator outputs are fed to an array of exclusive OR gates, which produce a single indication corresponding to the comparator in the comparator bank, where the output changes from one digital state to another. The ex-OR array feeds this indication to a Gray-to-binary ROM, which completes the formal quantization process and yields a binary representation of the input phase angle. Through a like quantization in the other discriminator channels, the unambiguous bandwidth is divided into n bits, depending on the number of channels. The signal then circulates through a series of data buffers, correction circuits and latches which synchronize the binary word for storage in the output buffer. The output interface is typically TTL; however, a variety of customer specified interfaces may be used. There is a parallel line for each bit of resolution plus the required control line or lines, such as external triggering and the data ready pulse.

INTEGRATED RF ASSEMBLY

The Integrated RF Assembly can contain a single discriminator or n discriminators (the discriminators are often called correlators.) The number of discriminators is determined by required resolution or absolute accuracy or both. The techniques required to integrate multiple discriminators into one stripline assembly are not within the scope of this article. The overwhelming majority of DIFM receivers have either 3 or 4 discriminators, depending on the delay line ratios used. The most common delay line ratios used by IFM manufacturers are 4:1 or 8:1 or some combination of those ratios. There are advantages and disadvantages to both ratios. With the 4:1 ratio, four discriminators are required to achieve 12 bits of resolution. This can be an important consideration when an extremely small package size is required. Twelve bits of resolution can be achieved with three discriminators when 8:1 delay line ratios are used. This ratio requires some special RF design techniques and more care in adjusting delay line slopes. In addition, some extra temperature compensation may be required for large changes in expected operating temperature.

The system engineer who is engaged in specifying a future IFM receiver should not attempt to assign delay ratios Furthermore, system engineers should make an effort to determine what DIFM receiver manufacturers have built, are now building or plan to develop on IR & D programs. The non-recurring costs to develop a new multichannel discriminator is significant. Most standard DIFM receiver product lines are designed to cover basically octave bandwidths or standard EW bands such as 2-4 GHz, 4-8 GHz, 8-12 GHz, 12-18 GHz. Before finalizing that specification, check to see what trade-offs can be made when using standard products.

SENSITIVITY AND DYNAMIC RANGE

The discriminators or correlators have a fairly limited sensitivity and dynamic range. A single, off-the-shelf discriminator can have tangential sensitivities from −40 dBm to −50 dBm. However, when multiple discriminators are packaged into full receivers with digitizing circuits, the sensitivity and dynamic range is somewhat reduced. This characteristic is dealt with by adding a limiting RF amplifier. The limiting amplifier provides a constant amplitude to the discriminator and small signal suppression which improves the signal-to-noise ratio of the stronger signal. There are several excellent articles which deal with the subject in considerable detail. The limiting amplifier is the single most expensive module in the IFM receiver.

Most IFM requirements to date can be grouped into two basic sensitivity specifications. Low sensitivity, in the −25 dBm to −35 dBm range, and high sensitivity, in the −60 dBm or better range. If one were to put a price tag on receiver sensitivity, it would likely be in the following ball park: L, S, and C band, $70/ per dB; X band, $100/ per dB; and K_u band, $190/ per dB. The increases in sensitivity do not, in real life, occur in 1 dB increments; however, these dollar values which include integration and the peripheral costs, are very close to actual.

SIMULTANEOUS SIGNALS

It is possible in the real world environment to have a condition where two or more signals, with similar amplitudes, occur simultaneously. These signals may be pulse on pulse, CW on CW, or CW on pulse. If the amplitudes are within a window of less than 3 to 5 dB, depending on the IFM manufacturer, the probability of a gross error can become intolerable. There are a number of ways of coping with this condition within the receiver. The systems engineer should know that specifying special treatment of simultaneous signals can be expensive. Most DIFM manufacturers have

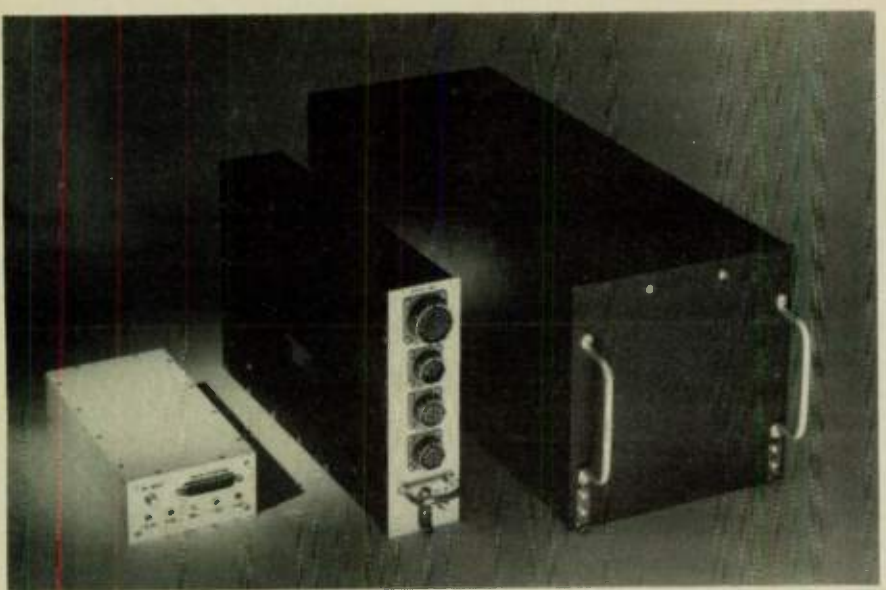


Fig. 2 Aertech Industries progression of DIFM miniaturization (largest 1125 cu in, smallest 64 cu in.)

an option which will set a flag for a simultaneous signal condition.

WHY THE MINI BOX?

During 1979, a great deal of emphasis has been placed on package size and the latest buzz word is "Mini Receiver". A mini receiver is a complete digital IFM receiver (including RF amplifier and bandpass filters) which is packaged in a volume of 100 cubic inches or less. Aertech entered the DIFM market in 1978 with a complete receiver in a 1/4 ATR package size (220 cubic inches). See **Figure 1**. This size was projected to be adequate to meet tactical and strategic EW market needs, at least through the early part of the 1980s. Subsequent to this investigation, it was found that more recent EW update programs could not accommodate a package occupying that much volume. Because of this, Aertech and its parent company TRW made a decision to invest major IR & D funds, in 1979 and 1980, toward a size reduction program that would lead to two different types of advanced development miniature receivers in early 1980. One model will be packaged in approximately 64 cubic inches, the other in 84 cubic inches. See **Figure 2** and **3**.

WHAT CAN BE MINIATURIZED?

The theoretical answer to that question is easy – *everything*! However, in practice, the number of techniques that can be implemented are very limited. Any IFM advanced development program will be faced with all sorts of restrictions, the most severe of which will be money and development time, in that order of priority.

Fig. 4 230 × 200 mil VLSI chip.

Liberal use of hybrid circuits is currently being employed by all IFM manufacturers, but that can be considered an interim solution at best. There are cost disadvantages to the use of hybrids in small quantities, as well as some potential unfavorable technical penalties which have not been fully evaluated. The discriminator circuits are certainly a candidate for significant reduction in overall volume. However, the market is too unsettled to determine what specific bandwidths and frequency ranges can be considered ***common*** to many future production programs. This is an area which will be least likely to be supported on company IR & D programs. Some reduction is possible in the limiting amplifiers, but this seems to be low priority with all of the current suppliers. The final and most likely candidate for volume reduction are the video and digital processing circuits. The current IFM suppliers are using either full hybridization or partial hybridization, with the exception of Aertech, who will soon be delivering a mini box which will include the latest VLSI technology. The A/D conversion and digital processing portion associated with each discriminator channel will be integrated on a single chip. This chip is being developed by TRW on an internally funded program. Potential manufacturers of mini IFMs will have to strongly consider the use of VLSI technology.

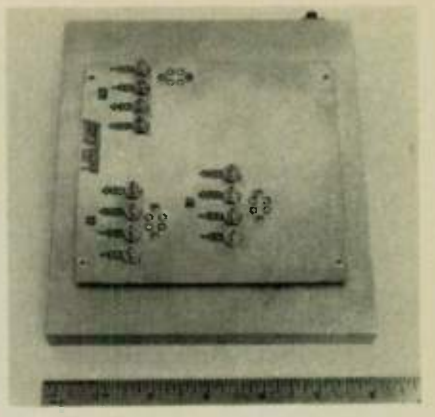
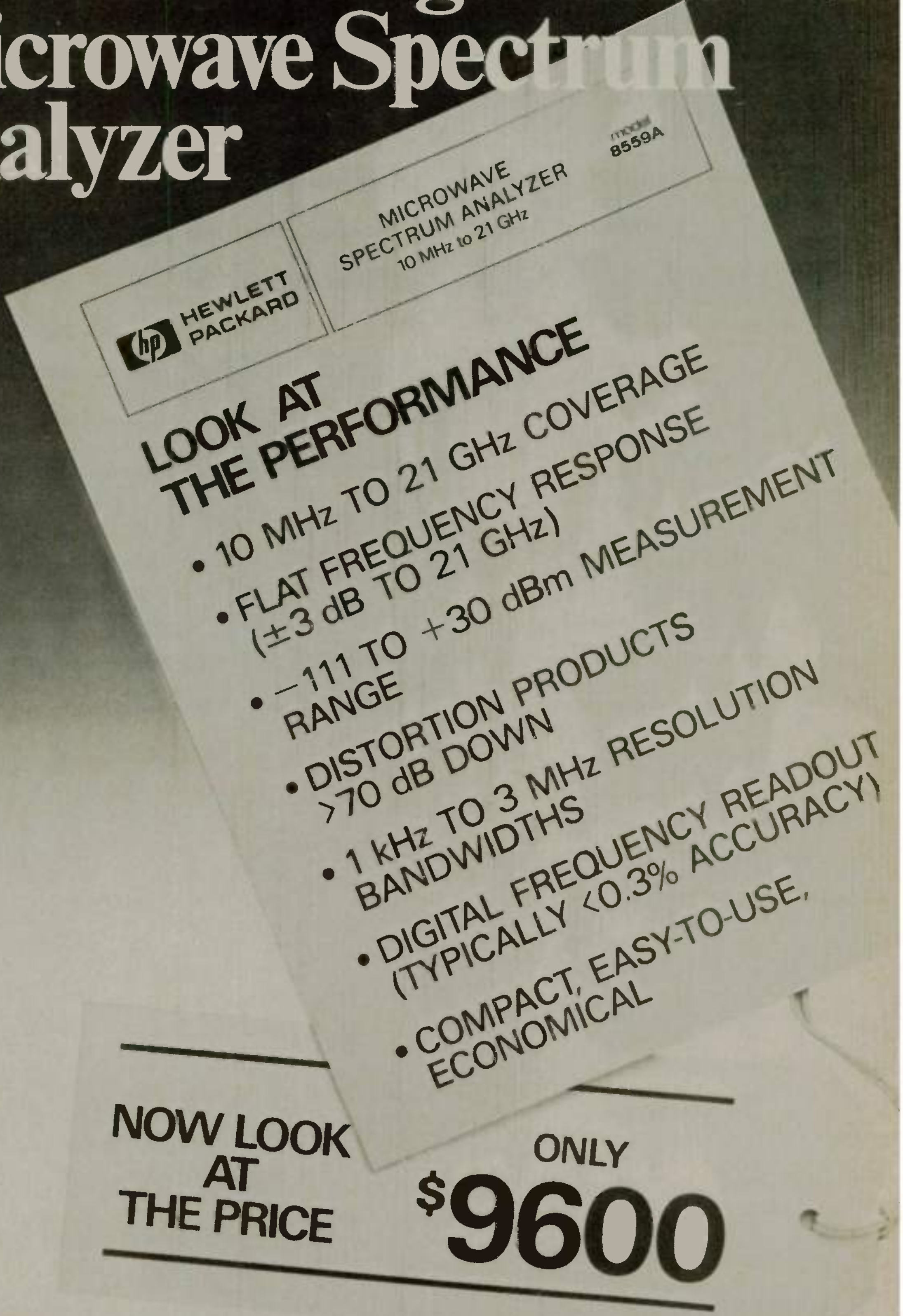


Fig. 3 Three channel Discriminator for 84 cu in IFM receiver

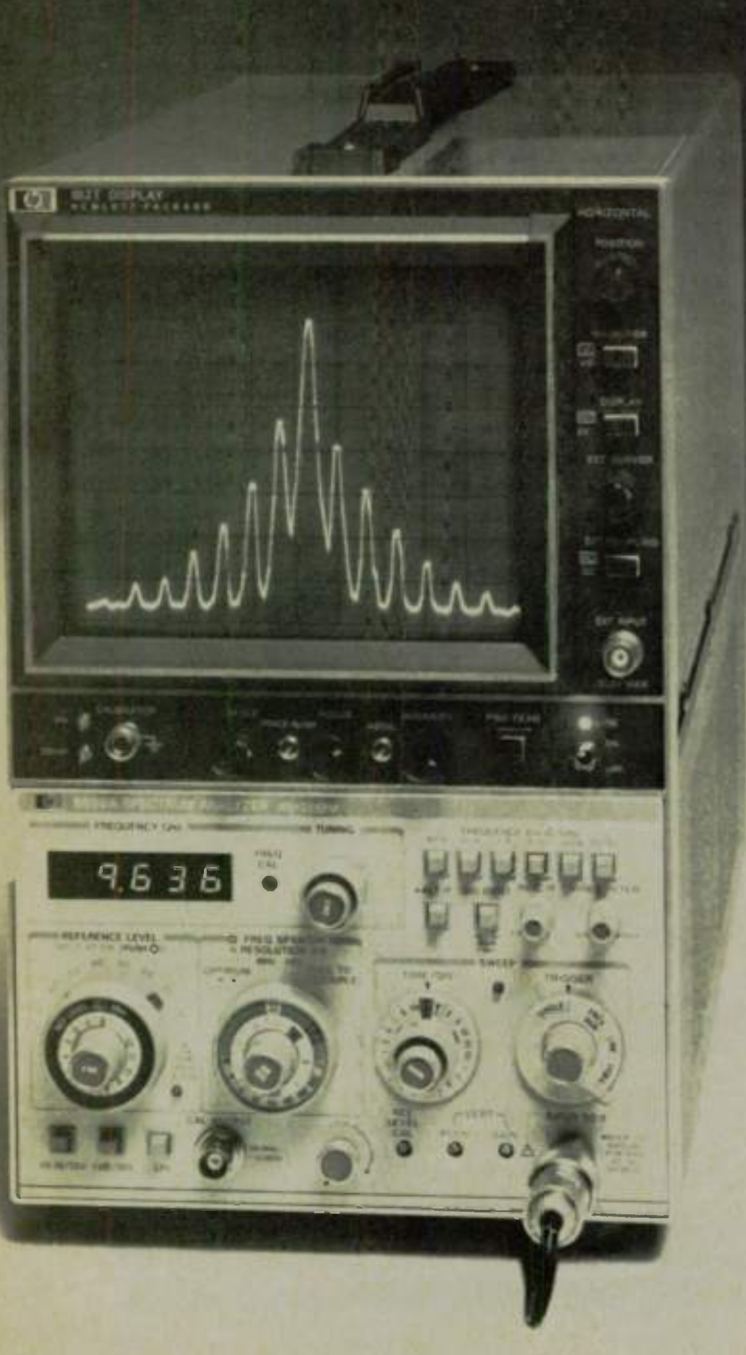
ABOUT THE VLSI CHIP

The chip contains over 6,000 transistor functions which perform at least the processing functions; A/D conversion in a 6 bit angle quantizer, ambiguity resolution, error correction, clocking, latching, buffer, and gating circuits. The chip is 230 × 200 mils (not including the carrier) and has 64 pins. See **Figure 4**. Each channel in the DIFM receiver utilizes one VLSI chip. Discrete components are used only in the

(continued on page 85)



The new HP 8559A delivers precision and convenience for a wide range of applications.



HP's new 8559A Spectrum Analyzer plug-in with the HP 182T display is easy-to-use, economical, and portable. The combination weighs less than 40 pounds and its rugged design makes it excellent for field use. Most measurements can be made using only 3 controls. You simply tune to the signal, set frequency span (resolution and sweep time are automatically optimized), and then set the reference level and read signal amplitude.

The 8559A is a high-performance instrument at a truly affordable price. For more information on this budget-minded instrument call your nearby HP sales office, or write Hewlett-Packard, 1507 Page Mill Rd., Palo Alto, CA 94304.

Domestic U.S. price only.

HEWLETT PACKARD

Circle 39 on Reader Service Card

Intelligent Instruments
Automate Network Analysis

ROHDE & SCHWARZ
Munich, Germany

A combination of two intelligent, bus-compatible instruments and a controlling calculator offers a low-cost system for complex measurements in production-testing and quality-assurance departments.

The measuring brains of the system are represented by the Vector Analyzer ZPV. Essentially a vector voltmeter with exchangeable input sampling stages covering 0.1 to 1000 MHz and 0.3 to 2000 MHz, the ZPV adds the computational power of an internal microprocessor to its measuring capabilities. For applications up to 1 GHz, the synthesized Signal Generator SMS is the ideal partner for the Vector Analyzer. Both instruments are fully compatible with the IEEE 488 instrument bus and bring the best results when used with a controlling computer in automatic configurations. Even in manual test setups, with the pushbutton entry of all settings, digital readout of set parameters and test results and the microprocessor's capability for interpreting and transforming the measured data into the required final parameters, the system has distinct advantages.

It's as a computerized test assembly, however, that the combination is most effective. The concentration of computing power directly in the Vector Analyzer brings a number of signifi-

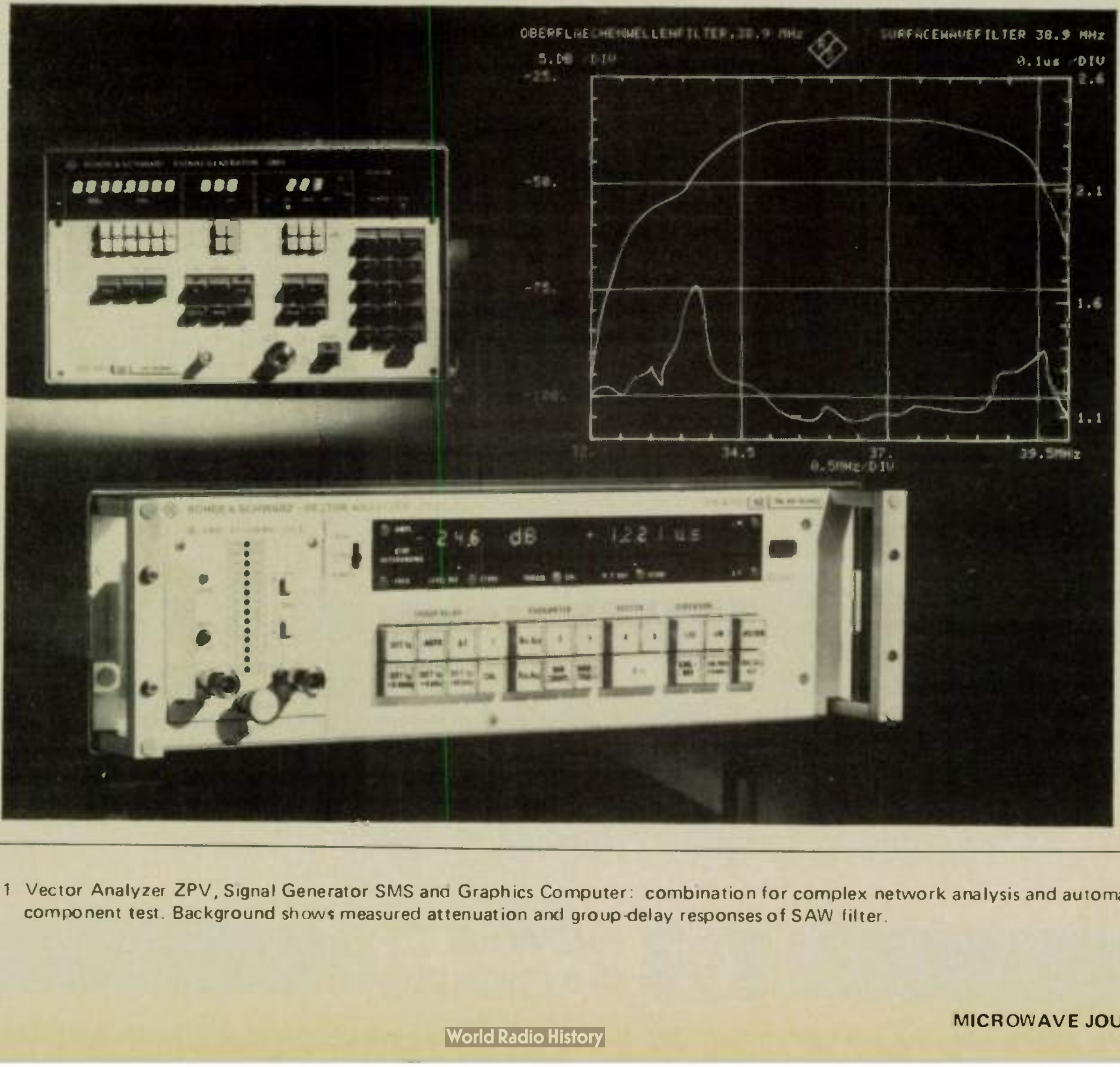


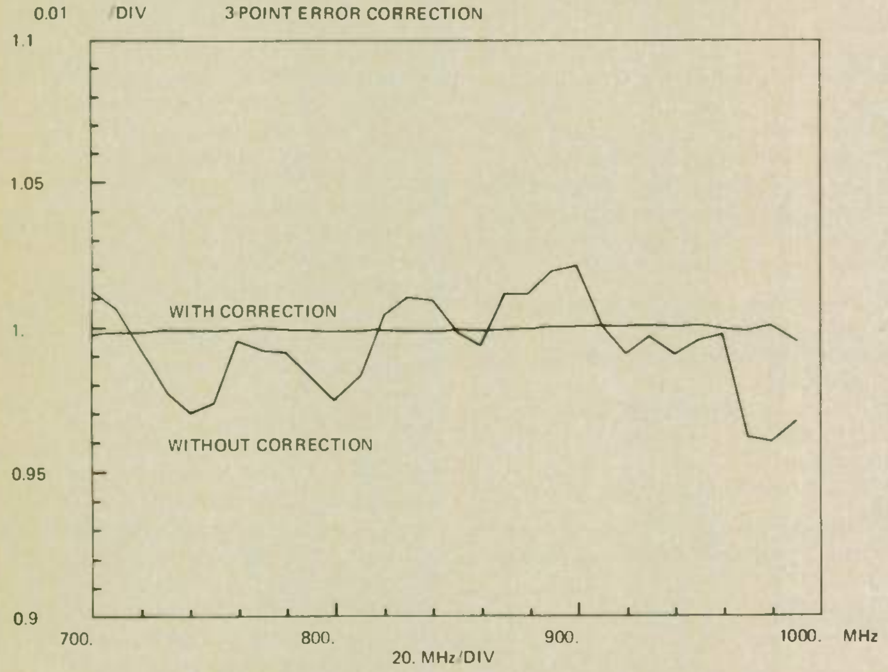
Fig. 1 Vector Analyzer ZPV, Signal Generator SMS and Graphics Computer: combination for complex network analysis and automated component test. Background shows measured attenuation and group-delay responses of SAW filter.

cant advantages. First point, the controlling computer can be kept cheap and simple and the programming effort minimized by using the test and measurement routines supplied by the instrument manufacturer as a basic software package. Relieving the external computer of this processing load also speeds up the entire measurement cycle, a big consideration when large numbers of parts are to be tested. Second point is that the capacity of the controlling computer is freed for other interesting tasks such as graphic display of the results and accuracy-enhancement programs, both of which are also available from the test-equipment maker.

The application area served by such a system is naturally a function of both the quality of the signal source and the versatility of the analyzer.

Thus the synthesizer SMS offers a basic frequency stability of better than 1 part in 10^8/month and a resolution of 100 Hz (200 Hz from 520 to 1040 MHz). Of special importance in many measurement situations are the residual FM of only 3 Hz via a CCITT filter and the overall output-level accuracy of +1.5 dB over a dynamic range of 150 dB (-137 dBm to +13 dBm). The SMS is a synthesizer instrument with AM, FM and φM modulation facilities. The design uses keyboard entry and separate digital display for all set parameters. For manual use, features such as the provision of variation keys permit digital sweeping or channel stepping in frequency steps of any size. Up to three full settings can be stored and recalled as required. For automatic operation, the setting time of 40 ms and the full GPIB compatibility are critical.

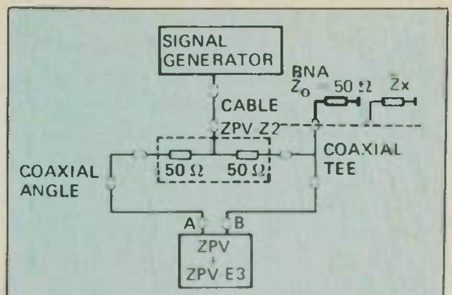
For its part, the Vector Analyzer offers a high degree of measurement sophistication. This vector voltmeter has a dynamic range of 110 dB and sensitivity of 3 μV (5 μV for 2 GHz



FREQUENCY (MHz)	|r|	<r	FREQUENCY (MHz)	|r|	<r
700.0000	0.9934	−91.0066	850.0000	0.9965	173.5522
710.0000	0.9956	−97.2942	860.0000	0.9974	167.0837
720.0000	0.9959	−103.5903	870.0000	0.9970	160.5765
730.0000	0.9968	−109.8903	880.0000	0.9981	154.1822
740.0000	0.9965	−116.1878	890.0000	0.9973	147.6854
750.0000	0.9963	−122.5132	900.0000	0.9985	141.2015
760.0000	0.9967	−128.8499	910.0000	0.9987	134.6395
770.0000	0.9964	−135.1799	920.0000	0.9974	128.0688
780.0000	0.9963	−141.6089	930.0000	0.9979	121.4991
790.0000	0.9965	−147.9974	940.0000	0.9973	114.9146
800.0000	0.9972	−154.3816	950.0000	0.9977	108.2798
810.0000	0.9962	−160.7765	960.0000	0.9972	101.5989
820.0000	0.9963	−167.1590	970.0000	0.9968	94.9332
830.0000	0.9957	−173.5942	980.0000	0.9976	88.3213
840.0000	0.9960	179.9590	990.0000	0.9930	81.6578

Fig. 2 Effect of 3-point correction program on reflection measurement on a shorted cable.

(continued on page 78)



Simple setup using neither bridges nor directional couplers for measurement of input reflection factor $\bar{S}_{11}$ up to 2 GHz. The formula:

$$\bar{S}_{11} = \bar{r} = \frac{3\,\frac{B}{A}\cos\varphi - 2 + j\,3\,\frac{B}{A}\sin\varphi}{2 - \frac{B}{A}\cos\varphi + j\,\frac{B}{A}\sin\varphi}$$

is evaluated by the microprocessor in the Vector Analyzer ZPV and the result displayed directly in polar or rectangular coordinates.

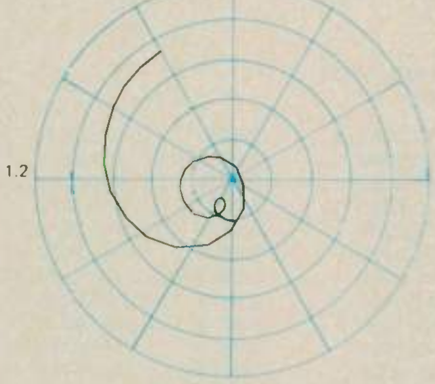
Fig. 3

input section). It complements its measurement capability with a wide repertoire of computing functions, by means of which the raw measured values are transformed and converted to obtain the full assortment of complex circuit parameters. Among the quantities which can be directly presented on the two digital displays are:

- voltage and voltage ratio (gain, attenuation),
- complex impedance and admittance;
- reflection coefficient, SWR and return loss;
- s parameters;
- group delay and delay variation.

The display can be switched for polar (r, φ) or rectangular (x, y) coordinates

LOWPASS FILTER REFLECTION 6 to 8 GHz



PHASE 30 GRAD/DIV
AMPLITUDE 0.24/DIV

Fig. 4 Polar plot of reflection coefficient at input of lowpass filter between 6 and 8 GHz.

and for linear (mV) or logarithmic (dBm) scales. Store functions also permit measurements relative to any desired reference value and fixing of the reference plane. The complicated formula conversions always associated with the use of directional couplers, SWR bridges and the like in complex measurements are completely taken over by the internal microprocessor. Using this computing power, new and simplified test setups requiring neither couplers nor bridges have also been introduced.

Both instruments are fully compatible with the IEEE 488 (GPIB) interface bus and can be supplied with a basic software package which condenses all the essential setting and measurement procedures to the call of a subroutine. The same software includes routines for the graphic display of the results on the screen of a suitable controlling computer such as the 4051 or 4052 from Tektronix. The capacity of the computer can be further employed for the execution of accuracy-improvement routines, available in an alternative software package. By means of stored calibration measurements at each test frequency, this software can raise the system accuracy to about 0.2% at low SWRs or about 1% with total mismatch, even when using directional couplers of bridges with only 40 dB directivity.

Many production-line or QA situations require an alternative to the screen display. One possibility is documentation of the displayed curve with a hard-copy unit, but simple comparison routines can also be used so that the computer issues a PASS/FAIL answer. For low-cost computers with no graphics capability, a plotter may be used to obtain hard-copy diagrams. Using the D/A conversion and memory capabilities of the Vector Analyzer, it becomes feasible to trace the results on a conventional XY-recorder.

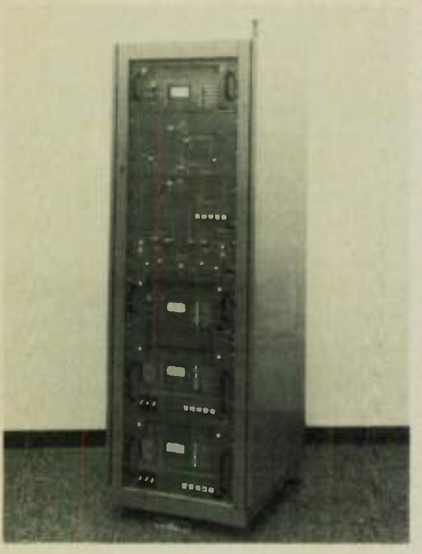
The network analysis system is aimed at test departments in production and quality assurance, and will best be used for components and subassemblies which allow no trimming, so that a fully automatic test can be run. Typical candidates are the surface acoustic wave filters being produced in vast quantities for TV set manufacturers, the crystal filters used in many IF circuits and a vast range of hybrid amplifier modules and semiconductor devices. Antenna manufacturers, for whom the phase accuracy is of paramount importance, should find the system suitable for production-line alignment of multi-element arrays.

Circle 115 on Reader Service Card

Microwave Products

Devices

NPN POWER TRANSISTORS SPAN 806-866 MHz BAND



Series of 806 to 866 MHz NPN power transistors are designed for land mobile communications equipment. Power outputs of 1, 5, 15, 30 and 45 watts are offered. RF performance is 100% tested and guaranteed in a wideband fixed, tuned test fixture. Devices operate at $V_{CC} = 12.5$ V. Units feature thin film Nichrome emitter ballasting for improved current distribution and load SWR tolerance. Low thermal-resistance packages and eutectic die attachment permit low junction temperatures and contribute to maximal MTTF. **Acrian, Cupertino, CA.** (408) 996-8522. Circle 119.

Systems

HIGH POWER AMPLIFIER FOR SATELLITE UPLINK

Model 9740H02 is a high power amplifier subsystem which performs either redundantly or in a power-combining role in the uplink service of a satellite earth terminal. The subsystem provides 330 W of output power in its redundancy mode and 650 W when used as a power combiner. It operates at of 6 GHz ± 500 MHz with a width of 500 MHz, min. Model is designed for automatic, manual or remote control operation. It contains a metal-ceramic TWT and uses integral forced air cooling. **Hughes Aircraft Co., Electron Dynamics Div., Torrance, CA.** (213) 534-2121. Circle 121.

Materials

FERRITE ABSORBER SERIES FOR 50 MHz - 15 GHz BAND

A series of thin absorbing materials, ECCOSORB® NZ, is designed for use in the 50 MHz to 15 GHz frequency range. ECCOSORB NZ-2 is a broadband material while ECCOSORB NZ-31, NZ-41, and NZ-51 are relatively narrowband materials suited to the lower portion of this frequency spectrum. Materials are sintered ferrites suitable for use in high temperature, high power and space environments. ECCOSORB NZ is available as square tiles that can be bonded to flat or moderately curved surfaces. It has a typical thermal conductivity of 45 (BTU) (in)/(hr) (ft^2) (°F) or 0.0155 (cal) (cm)/(sec) (cm^2) (°C) and typical specific heat of 0.2 BTU/ (lb) (°F) or 0.2 cal/ (g) (°C). **Emerson & Cuming, Canton, MA. Jeanne B. O'Brien,** (617) 828-3300. Circle 120.

Instrumentation

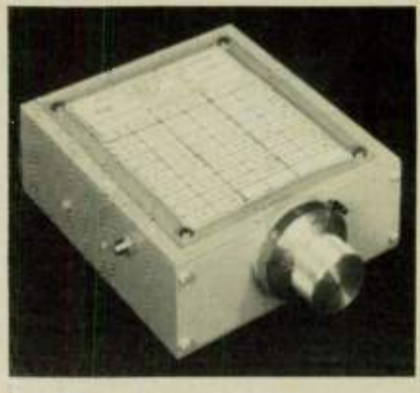
NOISE GENERATOR

Model NOD 102-1A is a noise generator which covers the .005-500 MHz band. The generator provides an output of 0 dBm ± 1.5 dB into 50 ohms at a 24 V., 125 mA drive. An SMA (F) RF termination and a bias solder lug are provided. Case is 2" x 6" x 1" (excluding terminations). Price: For 1-9 qty., $1250. Del: 6 wks, ARO. **Micronetics, Inc., Norwood, NJ.** (201) 767-1320. Circle 125.

AIR-LINE AIDS SWR MEASUREMENT

Models 19S50 and 19SF50 are precision 25 cm. long air lines which have a maximum SWR of 1.006 from 2-18 GHz. They are available with WSMA (SMA compatible) male or female connectors. Return losses from 0 to 45 dB may be measured up to 34 GHz on APC-3.5 and SMA connected devices. Impedance of the lines is held to 50 ± 0.1 ohms, a 60 dB return loss. Price: both models, $450. Del: 90 days. **Wiltron Co., Mountain View, CA. Walt Baxter,** (415) 969-6500. Circle 126.

FREQUENCY SYNTHESIZER CONVERTS YIG OSCILLATORS



Model FS-1000 is a frequency synthesizer which converts YIG oscillators to synthesized, digitally-controllable operation. It is also designed to control most microwave sweep generators. Frequency is controlled to an accuracy of 3 x 10^{-9} per day and residual FM is reduced to less than 100 Hz. Frequency can be controlled in 100 Hz steps remotely through IEEE-488 bus, parallel BCD, or manually from the front panel. Unit has a .01-18 GHz frequency range and resolution can be selected to 1 kHz (with 100 Hz option). Price: standard model — $17,000. Del: 45-60 days. **Micro-Tel Corporation, Baltimore, MD.** (301) 823-6227. Circle 124.

RF THRESHOLD DETECTOR

Line of RF threshold detectors with built-in test feature covers the 50 MHz to 12 GHz band. Units offer local or remote command selection of threshold level, and TTL compatible logic output. Test circuit reports detector ready condition and senses all failure modes. A typical model, P/N OMC-2003, operates from 2-18 GHz with a SWR of 3.5:1 max., a 0 to - 20 dBm threshold range and a temperature stability range of -55°C to +85°C. **Omni-Wave Electronics Corp., Gloucester, MA. J. A. Ward,** (617) 281-2800. Circle 122.

FM AND AM MODULATION METER

Model 82AD is an AM and FM modulation meter which offers a digital display; automatic tuning and leveling and an optional IEE-488 bus interface. Carrier frequency range is 10 MHz - 1.2 GHz. Front pushbuttons control response and post-detection bandwidth. FM deviation accuracy is 2% with ranges of 10, 100 and 300 kHz at rates from 30 Hz to 100 kHz. AM accuracy is also 2% of reading from 10% to 90% AM. Sensitivity is 10 mV into 50 ohms up to 520 MHz, 30 mV to 1.2 GHz. Size: 12.5" W x 5.25" H x 14.5" D. **Boonton Electronics Corp., Parsippany, NJ.** (201) 887-5110. Circle 123.

Components

FIBER OPTIC EMITTER & DETECTOR

Model IRE-170, fiber optic emitter, is a visible LED coupled to 30 cm of DuPont type step index plastic fiber and terminated in an F/O connector. Unit yields 5 μW into the fiber at 100 ma dc drive; peak wavelength of emission is 670 nm. Typical rise and fall times is 70 ns and operating and storage temperature range is 0° to 70°C. The detector, DIR-170 is a high speed silicon PIN detector coupled to DuPont fiber and terminated with a connector. It has a responsivity of 0.2 amps/watt at 670 nm but offers sensitivity over the 350 to 1150 nm range. Rise and fall times for the unit are 3 ns typ. at a bias of 100 V and dark current is less than 3 na with an NEP of 2×10^{-13} W/Hz$^{1/2}$. Devices are intended for communication requirements to 100 m operating at data rates to 7 Mbs. Price: in qty. of 100, IRE-170, $30.50 each and DIR-170, $40.00 each. Del: stock to 2 wks. **Laser Diode Laboratories, Inc., New Brunswick, NJ. (201) 249-7000.** Circle 130.

LOW NOISE SYNTHESIZER FOR SATCOM USE

Synthesizer for satellite earth station communications systems provides a signal in the 4.5-5.0 GHz band that is tunable in 1 MHz steps. Long-term stability is that of the external 5 MHz reference source. Typical spurious output is −100 dBc/Hz. Phase noise at frequencies close to the carrier is typically −84 dBc/Hz at 300 Hz from the carrier. Output power is 50 mW and input power requirements are +20 V at .5 amp and −5.2 V at 1 amp. Size: 2.75" x 4.5" x 4.2". **West Div. of Frequency Sources, Inc., Santa Clara, CA. (408) 249-2850.** Circle 132.

100 W, CONDUCTION COOLED POWER ATTENUATOR

Model PAA-100 is a 100 W conduction cooled flange-mounted power attenuator. Unit is designed to dissipate 100 W at a heat sink temperature of 100°C. Attenuation values of 1.0 thru 20 dB ± 0.5 dB are offered. Frequency range is dc to 750 MHz with a maximum SWR of 1.25. Attenuator has resistor substrate of beryllium oxide ceramic, a 96% alumina ceramic cover and tabs of beryllium copper. Price: $30 each in qty. of 100 pieces. Del: Stock to 8 wks. **KDI Pyrofilm Corp., Whippany, NJ. Al Arfin, (201) 887-8100.** Circle 133.

SERIES OF ENCAPSULATED RF & MW AMPLIFIER MODULES

CERMODS is a series of epoxy encapsulated RF and microwave amplifier modules. Model CM-151 covers the 5-15 MHz band, CM-501 spans 5-500 MHz and CM-1001 covers 5-1000 MHz frequency band. Units have a typ. gain of 12 to 15 dB with output power of +5 dBm which can be obtained using a +15 V power supply. Maximum flatness is ± 1.0 to ± 1.5 dB; NF is 7.5 to 8.0 dB, max. and SWR max. at 50 Ω is from 2.0:1 to 2.5:1. Size: .6" L x .6" W x .15" H. Del: small qty., 60 days; 1000 pieces, 90-120 days. **Optimax Div. of Alpha Industries, Inc., Colmar, PA. (215) 822-1311.** Circle 135.

GaAs FET AMPLIFIER LINE

Omnipac line of 2.0-8.0 GHz GaAs FET amplifiers offer power outputs of +10 dBm or +17 dBm at gains of 15 to 45 dB. Gain flatness is ± 1.0 dB to ± 2.0 dB and noise figure is 7.0 dB. Third order intermod products are typically +20 to +27 dBm. **Omni Spectra, Inc., Microwave Subsystems Div., Tempe, AZ. (602) 966-1471.**
Circle 146.

SOLID STATE SWITCH SERIES

C-001 to C-004 series of solid state, single pole/single throw switches offer low loss (0.8 dB-2.7 dB max. range) or (0.5 dB-1.7 dB max. range) and/or high isolation (35 dB-60 dB min. range) or (35 dB-70 dB min. range). Available in both octave and broadband versions over the 0.5-18 GHz range, these hermetic SPST modules provide speeds of less than 5 ns (min) or power handling of 100 W (pk). Drive levels range from 10 to 30 mA and 0 to −10 V. SWR at 0 V ranges from 1.7:1 to 2.0:1, maximum, or from 1.5:1 to 2.0:1, max. Del: 4 wks. ARO, with or without internal biasing circuitry. **Microwave Semiconductor Corp./Diode Operation, North Billerica, MA. (617) 667-7700.**
Circle 137.

ATTENUATOR/SWITCH DRIVER FOR MW SYSTEMS

Model 11713A is an attenuator/switch driver which combines a relay actuator with a power supply in a single package. Unit interfaces with the HP-IB (IEEE-488) and can be used to actuate one or two step attenuators plus one or two electromechanical switches. Manual attenuator control is available from two sets of four front panel pushbuttons; two additional pushbuttons control the switches. These ten front panel pushbuttons each control a transistor switch, they can also be used to control up to 10 external 24 V relays. Price: $1,200. Del: from stock. **Hewlett-Packard Co., Palo Alto, CA. (415) 856-1501.**
Circle 129.

MULTI-OCTAVE BANDPASS FILTERS WITH MECHANICAL TUNING

The B-Series of mechanically tunable filters operate over the 0.4 to 18 GHz frequency range. Instantaneous bandwidth characteristics (up to 10%) are maintained over a tuning range ratio up to 4:1 at any frequency range in the 0.4-18 GHz band. Typical insertion loss is 1.5 dB, SWR is 1.5:1. 2-6 section designs with either direct or indirect readout are available. **Frequency Engineering Laboratories, Farmingdale, NJ. (201) 938-9000.**
Circle 131.

LOW COST MIXER COVERS 1-1000 MHz RANGE

MLP-109 is a mixer which offers LO-RF frequency range of 1-1000 MHz and a dc to 1000 MHz IF range. Worst case conversion loss for the unit is 8 dB with mid-band performance typ. 2 dB better, specified with a LO input of +7 dBm. Minimum LO-RF isolation is 25 dB, LO to IF is 15 dB worst case; typ. mid-band isolation is 10-15 dB greater. Package is standard 8-pin relay header. Price: $8.50, single piece; $6.97, 100 pieces. **Engelmann Microwave Company, Montville, NJ. Carl Schraufnagl, (201) 334-5700.**
Circle 128.

(continued on page 82)

(from page 81) NEW PRODUCTS

SMA CONNECTOR WITH FLOAT MOUNTING

The PMA™ product line is designed for applications where exact alignment is not possible and push-on mating is desired. Connectors consist of a body assembly floating inside a coil steel spring, which itself is contained within a flanged shell. This design provides a spring compression loading which maintains the mated condition when plug and jack are clamped into position in the system. Line includes plugs and jacks for .085 semi-rigid and RG-188 type cables. SWR is 1.3 to 18 GHz for a mated pair. Price: $20 for pair in 1,000 piece qty. Del: 12-14 wks. **Automatic Connector, Inc., (ASU Industries, Inc. subsidiary), Commack, NY. (516)**

Circle 138.

PARABOLIC AMPLITUDE EQUALIZERS FOR SATCOM

Model No. 11783-12 is an amplitude equalizer designed for leveling gain variations encountered in satellite and terrestrial microwave communications systems. Electrical response can be optimized over specific bandwidths (1% to 5%) and gain envelopes. Model operates from 0°C to 50°C, in 2.5-4.5 GHz band – other models cover 1.0-2.5, 4.5-8.5 and 10.95-14.50 GHz ranges. Max. insertion less is 2.5 dB; SWR max. is 1.15, RF power handling is 1 W CW; and residual delay is < 1.0 ns. Maximum unequalized envelope is .7 dB while tolerance for equalized amplitude is ± .15 dB. **Com Dev Ltd., Cambridge, Ontario, CANADA. (519) 622-2300.** Circle 139.

TUNABLE 1 W OSCILLATOR

Model SO 8006-1 is a cavity stabilized oscillator covering the 1.03-2.35 GHz frequency range with RF output power of 1 W CW. Precision ball bearing tuning with non-contacting tuning mechanism allows noise-free tuning with minimal backlash (less than 200 kHz). Harmonic content is -20 dBc max. and non-harmonic spurious content is -80 dBc max. Temperature stability is ± 100 PPM/°C over the operating temperature range of 0 to +60°C. Optional voltage input tuning is available for AFC purposes with a ± .15% tuning range and operating voltage is -25 Vdc at 200 ma. Size: 8.1″ x 1.75″ x 1.75″ excluding projections. Price: $825 each. Del: in 8 wks, from 1-9 qty. **RFD Inc., Tampa, FL. Carla Bailey, (813) 872-1505.** Circle 142.

AUTOMATIC TRACKING FILTER

An automatic tracking filter, Model ATF-1800, combines YIG technology with microprocessor systems to control harmonic and spurious signals. It can reduce sweeper harmonics and spurious signals by 30 dB. Control unit, RF head and single-stage YIG filter make up the model. The RF head has a 1-18 GHz frequency range and typ. insertion loss of 2.5 dB. Size: Control unit – 8½″ x 5¼″ x 12¾″; RF unit – 4″ x 4″ x 7.5″. Price: $3950 for all parts of unit. Del: 8-12 wks. **Integra Microwave, Santa Clara, CA. Werner Schuerch, (408) 247-9601.** Circle 143.

COAXIAL AND WAVEGUIDE TERMINATION LINE OFFERS LOW SWR, WIDE RANGE

Additions to a coaxial and waveguide termination product line are Model 4380, a .5 W SMA termination and two series of medium power SMA terminations. Model 4380 covers dc to 26.5 GHz, the medium power models are useful up to 18 GHz. Maximum power ratings for series range up to 40 W. Narda Microwave Corporation, Plainview, NY. Robert E. Sowden, (516) 349-9600.

Circle 141.

HIGH-SPEED ANALOG ATTENUATOR

A high-speed analog attenuator, Model TG-1056, can be switched from any level of attenuation to any other level in less than 100 ns. Unit has a frequency range of 7-18 GHz; RF power handling capability of 250 mW max. CW; an SWR of 2.0 max., an insertion loss of 4.0 dB max. and isolation of 45 dB min. Attenuator offers a ± 2.5 dB frequency flatness; ± 2 dB linearity and its voltage requirements are ± 15 V at ± 25 mA (dc), control voltage is 0-10 V. Price: $3,600 in small qty. Triangle Microwave, East Hanover, NJ. Bernard J. Scorza, (201) 884-1423.

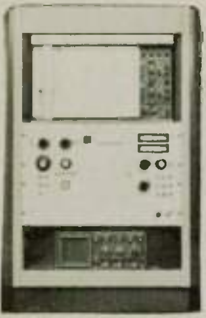
Circle 144.

LOW PASS FILTER

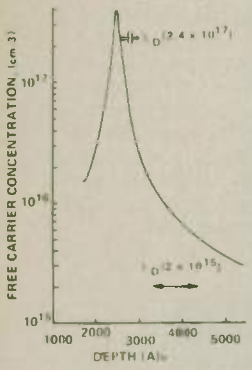
A low pass filter, Model FF2573, combines 10 kW peak power capability with freedom from spurious responses to above 10 GHz. Filter features SWR of less than 1.2:1 and an insertion loss of $<$ 0.3 dB over the 962-1213 MHz frequency band. Minimum rejection is 30 dB at 1600 MHz and 45 dB through the eighth harmonic. Price: $250 each. Del: within 45 days. Sage Laboratories, Inc., Natick, MA. Tony Cieri, (617) 653-0844. Circle 140.

LEI Miller Feedback Profile Plotter:

For Ion Implant, Epitaxy & Diffusion Profiles



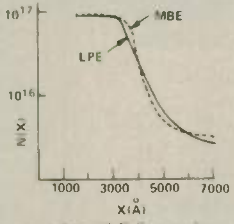
LO-HI-LO IMPATT Profile



Model CL-2000 Profiler Console

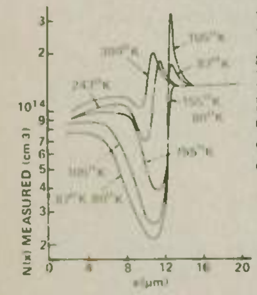
Use the Miller in trap studies for an improved (constant volume) form of transient capacitance measurement. Evaluate various kinds of epitaxy.

Accurately determine epi thickness. Multiple measurements enable impurity concentration mapping over wafer surface. Can be used with any semiconductor. Evaluate post-implant annealing procedures by their effect upon dopant distribution.



LPE & MBE Comparison

LEI Contactless Conductivity/Resistivity Probes are also available for laboratory, medium production or high volume wafer handling. Microprocessor controlled modular construction.

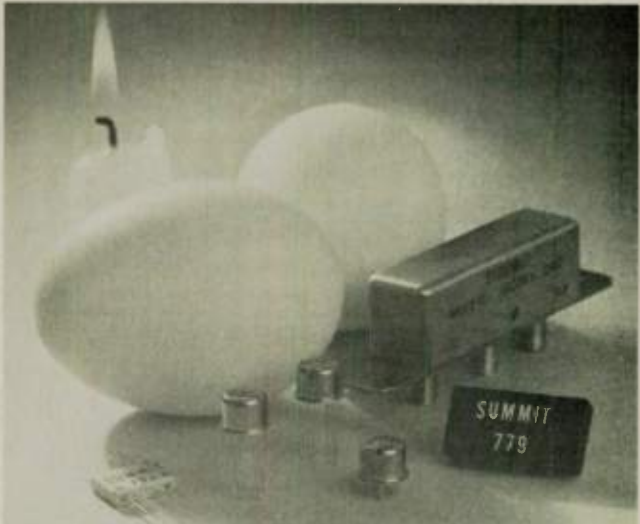


Proton damage profiles in N-type Silicon at various temperatures

Ask about our "Profiling Handbook."

LEHIGHTON
Electronics, Inc.
P O BOX 328
LEHIGHTON, PA 18235
PHONE (215) 377 5990

Circle 47 on Reader Service Card



INSPECTED GRADED and DELIVERED

QUALITY—BACKED BY A 2-YEAR WARRANTY!!!

Our hot carrier diodes are tightly computer matched over their entire operating range to give Summit switches and mixers dependable high performance . . . performance that we back by a straightforward 2 year guarantee

740 SERIES MIXERS

Mixers in a TO 5 package Single and double balanced in 3 different LO drive levels +3dbm, +7dbm and +17dbm RFI shielded and hermetically sealed Available in frequencies up to 3000mhz

750 SERIES BALANCED MIXERS

A plastic 7 lead mixer designed for commercial applications Frequency range from 2khz to 500mhz

760 SERIES MIXERS

Metal package, 8 lead, RFI shielded and hermetically sealed Frequencies from 2khz to 1250mhz and drive levels from +3dbm to +27dbm

770 SERIES MIXERS

A 6 lead mixer for the replacement market Frequencies from 2khz to 500mhz Drive levels +7dbm to +17dbm

780 SERIES MIXERS

Single balanced mixers in a 4 lead plastic package 100khz to 1200mhz

1300 SERIES COAXIAL MIXERS

Coaxial mixers with a choice of SMA, BNC, or TNC connectors Available in frequencies from 200khz to 3000mhz Also available in LO drive levels from +7dbm to +27dbm

MATCHED DIODES AND ASSEMBLIES

Computer matched hot carrier diodes in bridge and ring configurations or available as 4 matched diodes (loose)

FREQUENCY DOUBLER

A TO 5 packaged doubler with an output to 1000mhz

RF SWITCHES

Hi speed solid state RF switches in SPST and SPDT configurations Four packages connector type, 8 lead metal, 6 lead plastic, and 6 lead metal Switching speeds to 2 nanoseconds and on off ratios up to 100db

TRANSFORMERS AND HYBRIDS

Single ended and balanced transformers of various impedance ratios in TO 5 and 5 lead plastic packages Transformers available in frequency ranges to 1000mhz

Reactive hybrids are also available in the TO 5 and 5 lead plastic package Impedances are 25 and 50 ohms, output phases are 0°, 90° and 180° with frequency ranges to 500mhz

Thirty day delivery, up to 200 pieces Custom products or configurations are a Summit specialty Ask for details

SUMMIT RF COMPONENTS

SUMMIT ENGINEERING

P.O. Box 1906 Bozeman, MT 59715
Phone (406) 587 4511 TWX (910) 975-1950

Circle 48 on Reader Service Card

World Radio History

New Literature

GRID ANTENNA SYSTEMS BULLETIN

Bulletin 1196A presents system design and product information on a line of grid antennas, HELIAX coaxial cables, and accessories. Brochure includes detailed line drawings and photographs of products, performance specifications, electrical characteristics, reference dimensions and shipping information. Advantages and performance parameters are described. Both pressurized and unpressurized systems are treated. **Andrew Corp., Orland Park, IL. (312) 349-3300.** Circle 102.

SMA CONNECTOR CATALOG

A 28-page catalog on SMA microwave connectors describes a line of standard and high performance and MIC-C-39012 qualified connectors for use with flexible cable, semi-rigid cable and for stripline applications. A line of in-series, between-series, and "tee" type adapters is also shown. **B & W Associates, Inc., Newton, MA. Robert W. Gray, (617) 272-4420.** Circle 103.

TRANSISTOR PRODUCT GUIDE SERIES

A series of "Quick Reference Guides" to a line of transistor products is organized by applications. One-page guides are available on: military wideband balanced transistors, microwave transistors, military transistors, linear transistors, land mobile transistors, TACAN/DME/IFF transistors. **Communications Transistor Corporation, Varian subsidiary, San Carlos, CA., (415) 592-9390.** Circle 104.

ATTENUATOR AND TERMINATION CATALOG

A 32-page catalog, No. 781, lists a complete line of coaxial attenuators and terminations in addition to minimum loss pads, multicouplers and double balanced mixers. Booklet describes product line which operates in the dc to 4 GHz range and uses BNC, N, TNC and SMA type connectors. **Elcom Systems, Inc., Boca Raton, FL. (305) 994-1774.** Circle 105.

MILLIMETER COMPONENTS CATALOG

A 20-page catalog features technical and descriptive information for fixed tuned, tunable and adjustable bandwidth bandpass and bandstop filters. Other components covered include wavemeters, mixers, and noise sources for the 26.5-110 GHz range. **Frequency Engineering Laboratories, Farmingdale, NJ. A. E. Steinhauer, (201) 938-9000.** Circle 108.

NPN POWER TRANSISTORS PRODUCT SHEET

A line of 1030/1090 MHz NPN power transistors for transponder/interrogator avionics applications, is described in a two-page product sheet. The two-color literature provides details on power transistor design and process technologies used in the production of the devices, lists performance parameters and benefits, illustrates typical amplifier lineups and includes package diagrams specifying product dimensions and physical characteristics. **Acrian, Inc., Cupertino, CA. (408) 996-8522.** Circle 101.

FOLDER ON ONE-PART EPOXY SYSTEMS

A four-page illustrated folder on "ECCOPRIME" provides information on resins, adhesives and coatings available in one-part formulations which can be used directly from the container. These one-part epoxy systems are presented in a format designed for convenient selection of the desired "mix" of properties from up to sixteen different systems. **Emerson & Cuming, Canton, MA. Jeanne B. O'Brien, (617) 828-3300.** Circle 106.

PROFESSIONAL 1980/81 ELECTRON TUBE CATALOGUE

The latest edition of the EEV/M-OV Abridged Data Book for 1980/81 describes in short form a range of professional electron tubes and devices. It also contains a comprehensive Equivalents Index listing over 3,000 types of internationally used electron tubes. The publication contains 85 pages of listed products with a 24-page Equivalent Index. **English Electric Valve Co., Chelmsford, Essex CM1 2QU, ENGLAND.** Circle 107.

BROCHURE ON LOW PASS FILTER CABLE

An eight-page illustrated brochure, No. 774A, describes low pass filter cable and cable assemblies. Literature provides technical data, including tables which show product characteristics in various configurations from 7 to 21 sections. Also included are product features, applications and performance graphs of line of implanted low pass filter elements. **MicroDelay Div., Uniform Tubes, Inc., Collegeville, PA. (215) 539-0700.** Circle 110.

FREQUENCY CONTROL PRODUCT CATALOGUE

A complete line of products designed for microwave frequency control is described in catalogue 579. These include crystal controlled sources, cavity stabilized oscillators, high stability crystal oscillators, LC and voltage controlled oscillators, discrete multipliers, phase locked multipliers and audio components. This 21-page booklet includes capabilities of product line and ordering information. Specifications, characteristics, applications and photographs are included. **Tecktrol, New Cumberland, PA. Perry C. Bates, (717) 774-2746.** Circle 118.

CATALOG OF SATELLITE EARTH STATION COMPONENTS

Catalog TD-1 features satellite earth station components for the TVRO and Data Communications market. The 12-page brochure describes down converters with RF input of 3.7-4.2 GHz and IF output of 880 MHz and a double conversion model with 70 MHz IF output. Other products included are biphase modulators, quadraphase modulators, single and double balanced mixers, power dividers/combiners, terminations, fixed pads and isolators. **Merrimac Industries, Inc., West Caldwell, NJ. (201) 575-1300.** **Circle 109.**

GaAs FET GUIDE BOOK

A 16-page guide book provides technical information for low noise, 2-18 GHz GaAs FET amplifiers for radar, telecommunications, telemetry and EW applications. The publication gives product specifications and outline drawings from the entire amplifier line. **The Narda Microwave Corp., Plainview, NY. Robert E. Sowden, (516) 349-9600.** **Circle 111.**

COATING SYSTEMS BULLETIN

An eight-page bulletin, No. 7810, describes engineered coating systems for obstruction markings. These systems provide color marking and long-term protection on a variety of structures. The booklet contains specific FAA requirements for proper color marking of obstructions along with complete information for selection of acrylic emulsion or alkyd coating systems that follow FAA standards. **Rust-Oleum Corp., Vernon Hills, IL. John J. Fell, (312) 367-7700.** **Circle 112.**

WAVEGUIDE WALL CHART

A wall chart provides rigid waveguide mechanical and electrical data. It details design and procurement information for some 50 popular waveguide sizes from 1.0 GHz to 300 GHz. Chart contains cross referenced military and industrial nomenclature as well as electrical and mechanical parameters for each guide size. **Waveline, Inc., West Caldwell, NJ. (201) 226-9100.** **Circle 113.**

MIC DATA SHEETS

A line of microwave integrated circuits is described in data sheets and a four-page capability brochure. Product line information is provided on voltage variable attenuators, DB mixers/mixer-preamplifiers, RF thin film amplifier and drop-in mixers. **Western Microwave, Sunnyvale, CA. (408) 734-1631.** **Circle 114.**

RF AND POWER TRANSISTOR CATALOGUE

Catalog provides descriptions of complete line of RF and microwave power transistors for communications, radar and avionics applications. Devices cover 2.0 MHz to 2.0 GHz for most FM, AM, pulse, sideband and linear applications. Also describes gold metallized broadband internally matched structures. **Solid State Microwave, Montgomeryville, PA. Jeff Holmquest, (215) 362-8500.** **Circle 116.** ◼

(from page 73) PRIMER

final output interface. The VLSI chip is created with a triple diffusion bipolar process, better known as 3D and uses nominally 2 μm devices. Five masks delineate the collector, base, emitter, contacts, and interconnect metal. A sixth mask etches the surface protecting oxide away from the pad sites for wire bonding to the package leads. The area of the resulting NPN transistor is 1.41 mils.[2] Resistors are self-isolating in this technology and formed from "collector" impurity regions diffused into the P type substrate. Metal interconnect runs are on 9 μm centers and are 4.5 μm wide.

THE IFM COST DRIVERS

The DIFM receiver is not an inexpensive device although it is competitive when compared to other techniques which perform the same function. We have discussed some important receiver functions which are not easily adaptable to either modularity or commonality from receiver to receiver. Therefore, the systems designer should take some time to become familiar with what IFM manufacturers have built, or have on the drawing board. The acquisition cost of the first article system can be ***significantly*** reduced if available performance parameters are utilized wherever possible. To summarize, the IFM specifications which have significant cost impact upon standard pricing:

- Sensitivity/Dynamic Range
- Resolution/Accuracy
- Simultaneous Signal Detector
- Non Standard Bandwidth

The engineer and program manager will find all IFM receiver producers most willing to supply applications engineering support, technical briefings and demonstrations to aid in this familiarization process. ◼

REFERENCES

1. Emery, F. E., "Solid-State Limiting Amplifiers," *Watkins-Johnson Tech-Notes*, Volume 5, Number 5.
2. King, D., and Dean Heaton, "Digital IFM Receiver Planned for the '80s," *Defense Electronics*, August 79, Volume II, Number 8.

Advertising Index

Company	Page
California Eastern Laboratories	COVER 3
EIP, Inc.	11
Electromagnetic Sciences, Inc.	17
Emerson & Cuming, Inc.	19, 20
Engelmann Microwave Corp.	55
EPSCO Microwave	80
Goodyear Aerospace Corp.	78
A. I. Grayzel, Inc.	68
Hewlett Packard Co.	14, 15, 31, 74, 75
Hughes Aircraft Co.	38, COVER 4
IEEE	30
International Telecommunications Satellite Organization	78
ITT Telecommunications	66, 67
K&L Microwave, Inc.	3
Lehighton Electronics, Inc.	83
Litton Industries, Inc.	42
Locus, Inc.	44, 45
Maury Microwave Corp.	51
Microlab/FXR	86
Microwave Associates, Inc.	41
Microwave Power Devices, Inc.	35
Microwave Semiconductor Corp.	10
Midwest Microwave, Inc.	36, 37
Mini Circuits Laboratory	4, 5, 7
3M Company	18
Oak Materials Group, Inc.	63
Omni Spectra, Inc.	84, 85
Pan American World Airways, Inc.	41
Polarad Electronics	COVER 2
Q Bit Corp.	58
Rogers Corp.	77
Rustoleum Corp.	65
Solid State Microwave	25
Solitron/Microwave	21
Summit Engineering	83
Systron Donner Advanced Components Division	8, 9
Teledyne Microwave	47
Texscan Corp.	58, 59, 82
Trak Microwave Corp.	28
Transco Products, Inc.	81
United Microwave	32, 33
Watkins Johnson Co.	13
Weinschel Engineering Co.	48, 49
Western Microwave	26, 27
Wiltron Co.	22, 23

Sales Representatives

William Bazzy — President
Howard Ellowitz — Publisher
Bernard Bossard — Vice President, Marketing
Sandra Pasqualucci — Mgr. Sales/Marketing Administration

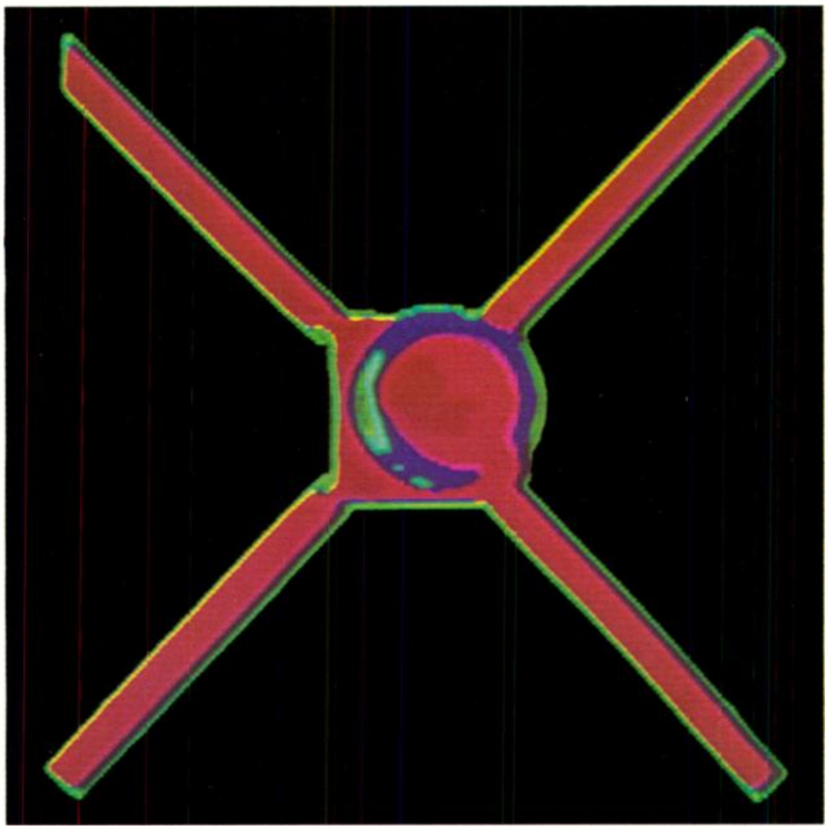
NEW ENGLAND,
NEW YORK STATE,
MID-ATLANTIC, NORTHEAST,
SOUTHEAST, AND MIDWEST
John Hartnett
610 Washington Street
Dedham, MA 02026
Tel: (617) 326-8220

PACIFIC & MOUNTAIN
TIME ZONES
John Cotsworth
1000 Elwell Court
Suite 234
Palo Alto, CA 94303
Tel: (415) 969-3886

EUROPE
Derek Hopkins
25 Victoria Street
London SW1H OEX, England
Tel: 44-(1)-222-0466
TLX: 851-885744

JAPAN
Tokyo Representative Corporation
Aizawa Bldg. 3F.
2-14-6, Misaki-Cho,
Chiyoda-ku, Tokyo 101 Japan
Tel: 230-4117, 4118
Cable: REPRETIV Tokyo
TLX: J26860

Micro-X



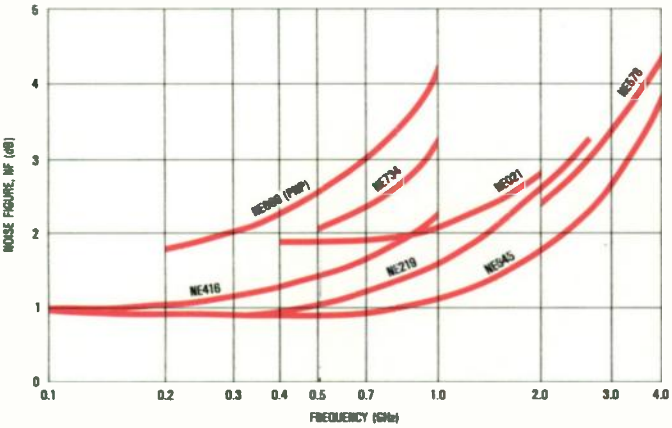
The Best Package Deal Available—In Performance, Reliability and Price

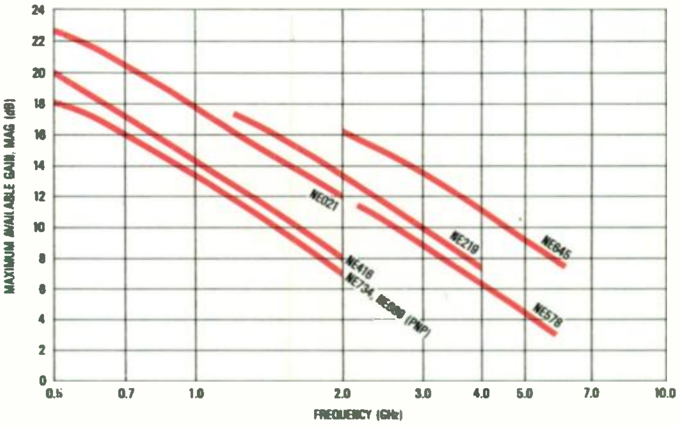
The key to NEC's newly-developed MICRO-X series of hermetically sealed transistors is in manufacturing these high-performance microwave components, with a proprietary ceramic package, using high-speed automated assembly and testing equipment.

The result is a series of state-of-the-art transistors economically priced for large volume OEM's where performance and reliability are primary design considerations.

Ideal for industrial and military applications such as low noise front ends, IF amplifiers and oscillators where plastic transistors cannot be used.

Many devices are priced below $5.00 at 1K. All components available from stock, and Grade C (TXV) screening is available for military applications. Contact your local Cal Eastern representative for a free application note, specification sheet and samples.





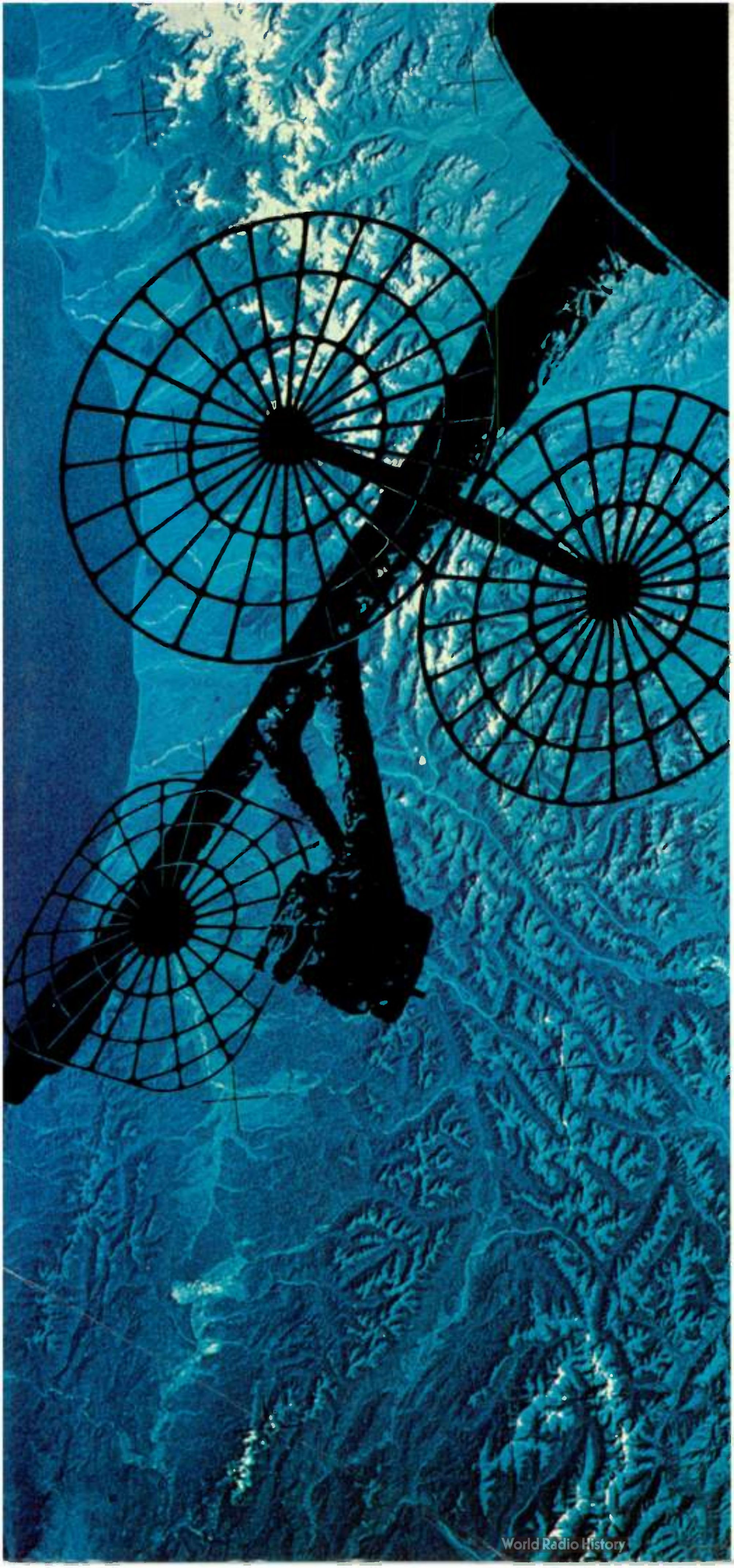
NEC microwave semiconductors

California Eastern Laboratories, Inc.

Exclusive sales agent for **Nippon Electric Co., Ltd.** Microwave Semiconductor Products. U.S.A. ☐ Canada ☐ Europe

U.S. Headquarters and Warehouse—California Eastern Laboratories, Inc., 3005 Democracy Way, Santa Clara, CA 95050, (408) 988-3500 • **Eastern Office**—California Eastern Laboratories, Inc., 3 New England Executive Park, Burlington, MA 01803, (617) 272-2300 • **Southwest Office**—California Eastern Laboratories, Inc., 4236 North Brown Ave., Scottsdale, AZ 85251, (602) 945-1381 • **European Headquarters and Warehouse**—California Eastern Laboratories, International, B.V., Havenstraat 8a-Postbus 1258, Zaandam, Nederland, 075-158944 • **Southern California Offices**—California Eastern Laboratories, Inc., 2182 Dupont Drive—Suite #24, Irvine, CA 92715, (714) 752-1665; California Eastern Laboratories, Inc., 2659 Townsgate Road, Suite 101-6, Westlake Village, CA 91361, (213) 991-4436.

Circle 2 on Reader Service Card



Introducing the latest– but not last– Hughes Uplink HPAs

We've just added 14.5 GHz to our growing family of reliable satcom subsystems.

Awhile back, we introduced a 6 GHz uplink high-power amplifier. Now we've expanded the family to include a new series of 14.5 GHz, 250-watt HPAs for the newest generation of communication satellites. Special features provide automatic redundancy with complete remote monitoring and control functions. Which means that every function can be monitored to provide diagnostic status and functional control to the operator at a remote or distant site. This in turn provides easy interface with satellite earth station systems. The entire subsystem consists of two assemblies, an RF drawer and power conditioner drawer.

Soon to come, still another HPA, a 600-watt Ku Band amplifier. And you may be sure it will have the same Hughes reliability, flexibility and efficiency of the rest of Hughes HPAs. In a word, "outstanding."

For more information on any of many Hughes HPAs and subsystems for satellite communications, write Hughes Electron Dynamics Division, 3100 W. Lomita Blvd., Torrance, CA 90509. Or call (213) 534-2121, ext. 2114.

International offices:
France: 161, de Tolbiac, 75013, Paris, Tel. 580-9527.
West Germany: Oskar-v-Miller Ring 29, 8 Munich 2, Tel. 089/28 0600.
England: 12-18 Queens Road, Weybridge, Surrey KT13 9XD, Tel. (0932) 53180.

Where innovations in TWT technology are a tradition.

HUGHES

HUGHES AIRCRAFT COMPANY
ELECTRON DYNAMICS DIVISION

Circle 3 on Reader Service Card