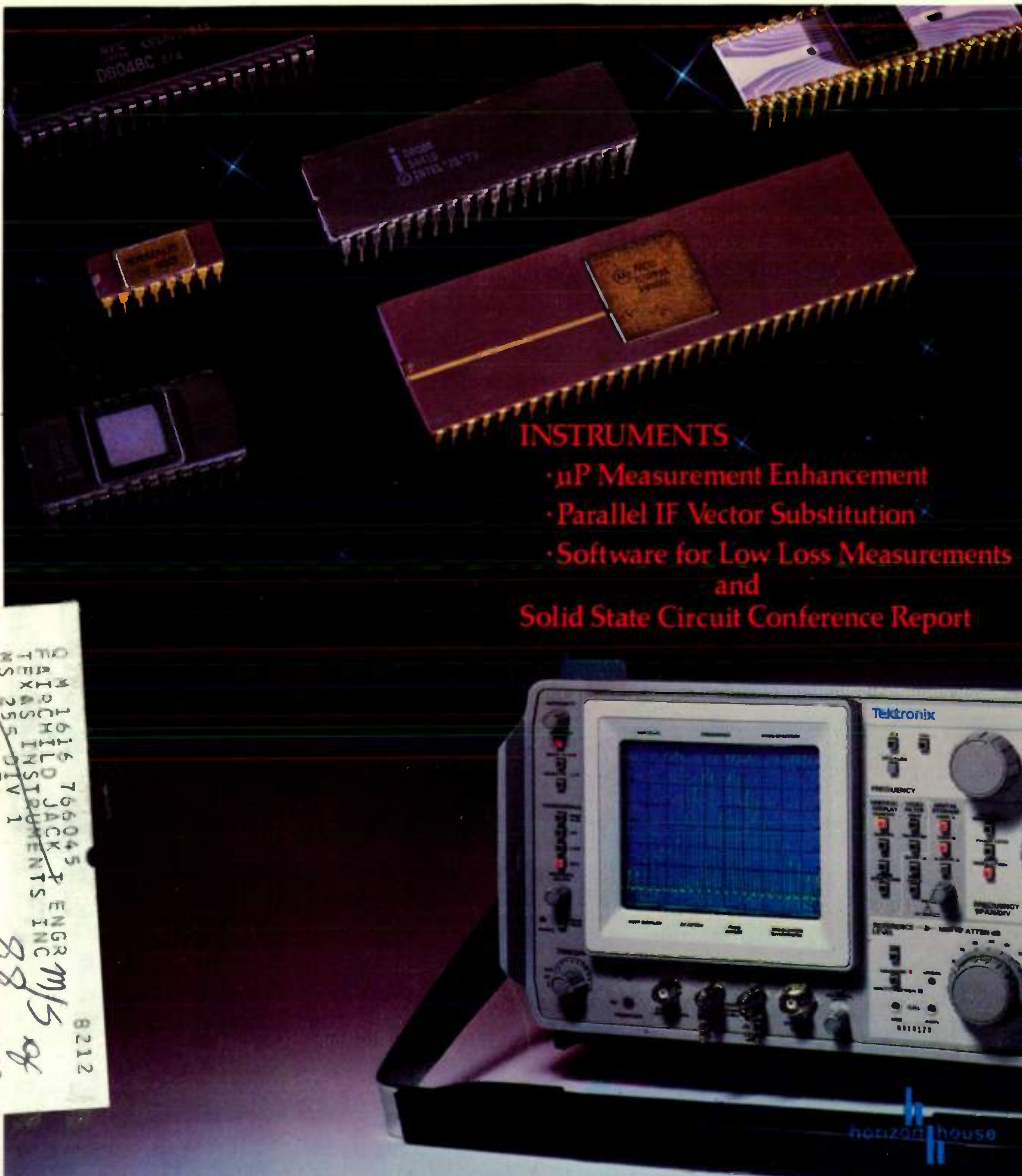
microwave JOURNAL

INTERNATIONAL EDITION □ VOL. 24, NO. 4 □ APRIL 1981



INSTRUMENTS

- µP Measurement Enhancement
- Parallel IF Vector Substitution
- Software for Low Loss Measurements

and

Solid State Circuit Conference Report

NEW SPECTRUM ANALYZERS

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

100 kHz to 40 GHz

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

- 80 dB on-scale range for 10 dB/div. log scale.
- Improved accuracy for 2 dB/div. and linear scales.
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NEW ACCESSORIES for the Internal Digital Memory and Programmable Data Processing Interface:

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Model	Freq. Range	U.S.A. Prices (Jan. 81) Without Memory	Including Memory
632B-1	100 kHz to 2 GHz	N/A	$10,175
630B	3 MHz to 40 GHz	$12,460	$14,285
640B	3 MHz to 40 GHz with internal preselector	$16,170	$17,995

Call or write for complete specifications or to request a demonstration.

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

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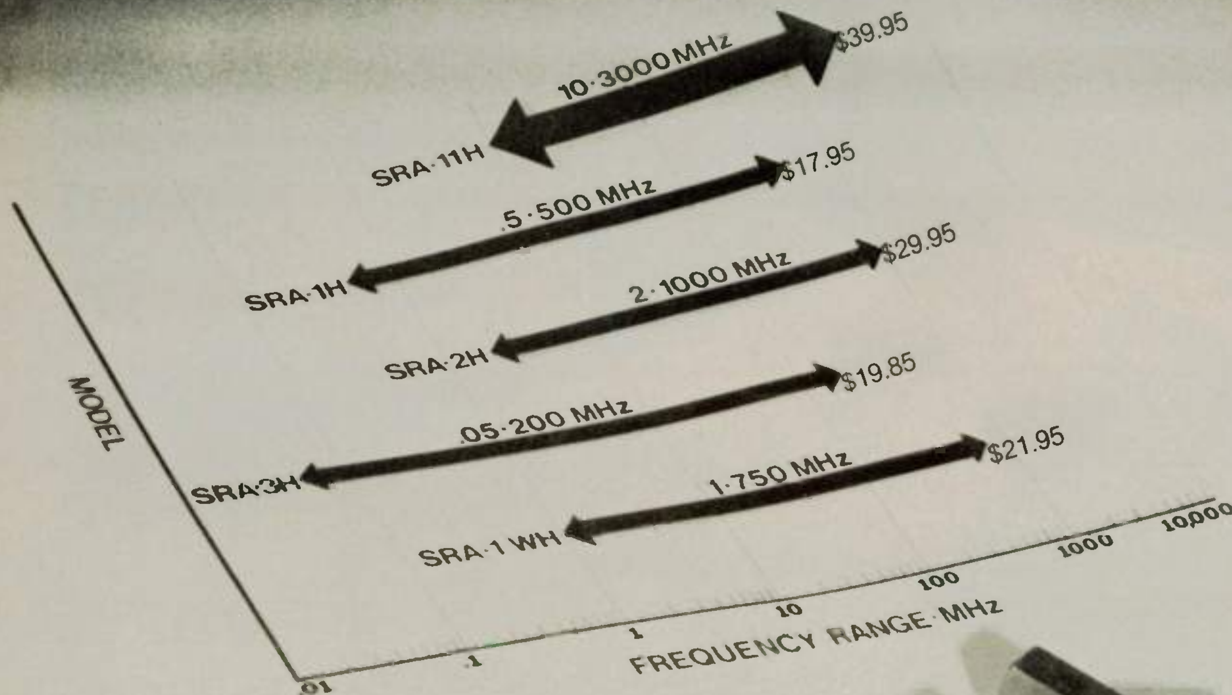
CIRCLE 4 ON READER SERVICE CARD

.05 MHz to 3 GHz (+17dBm LO)

HIGH-LEVEL Double Balanced Mixers



Model	Frequency Range (MHz)	Conversion loss (dB) Total Range	Isolation, dB: Lower band edge to one decade higher		Isolation, dB: Mid range		Isolation, dB: Upper band edge to one octave lower		Price Quant.
			LO-RF	LO-IF	LO-RF	LO-IF	LO-RF	LO-IF	
SRA-11H	RF, LO-10-3000 IF - 10-1000	9.5 typ. 12 max.	27 typ. 20 min.	27 typ. 20 min.	25 typ. 18 min.	25 typ. 18 min.	23 typ. 16 min.	23 typ. 16 min.	$39.95 (1-24)
SRA-1H	RF, LO-.5-500 IF - DC-500	6.5 typ. 8.5 max.	55 typ. 45 min.	45 typ. 35 min.	45 typ. 30 min.	40 typ. 30 min.	35 typ. 25 min.	30 typ. 20 min.	$17.95 (5-24)
SRA-2H	RF, LO-2-1000 IF - DC-1000	7.5 typ. 9.5 max.	50 typ. 40 min.	45 typ. 35 min.	45 typ. 25 min.	40 typ. 25 min.	35 typ. 25 min.	25 typ. 20 min.	$29.95 (4-24)
SRA-3H	RF, LO-.05-200 IF - DC-200	5.5 typ. 7.5 max.	55 typ. 45 min.	45 typ. 35 min.	45 typ. 30 min.	40 typ. 30 min.	35 typ. 25 min.	30 typ. 20 min.	$19.85 (5-24)
SRA-1WH	RF, LO-1-750 IF - DC-750	5.5 typ. 7.5 max.	50 typ. 40 min.	45 typ 35 min.	45 typ. 25 min.	40 typ 25 min.	35 typ. 25 min.	30 typ. 20 min.	$21.95 (5-24)

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MINI-CIRCUITS LABORATORY
A Division of Scientific Components Corp

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15 Rev. F

CIRCLE 5 ON READER SERVICE CARD

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 1/3 to 1/2 the price of competitive units, with immediate off-the-shelf delivery. . . from Mini-Circuits, of course.

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

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

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A Division of Scientific Components Corp.

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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

Look what we're up to...

Microwave Mixers. New from Anzac. Eleven new hermetically sealed models cover the 0.5 to 18 GHz range in octave, multi-octave, and special interest bands. Termination-Insensitive versions as well as regular double-balanced units. Each available in either drop-in flatpack or connectorized versions. All are built for military environments.

And like all Anzac standard products, these Microwave Mixers are available from stock. Our million-dollar-plus inventory allows us to ship any standard order within 48 hours. Send for the special 20-page Microwave Mixer catalog supplement. Complete with specifications and performance curves.

Microwave Mixers. Complementing our standard mixer line from 20 kHz to

...18 GHz!

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ANZAC DIVISION

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CIRCLE 7 ON READER SERVICE CARD

52 REV. ORIG.

microwave JOURNAL

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USPS 396-250
APRIL 1981

BUSINESS/SPECIAL REPORTS

TECHNICAL/APPLICATIONS SECTION

DEPARTMENTS

* Euro-Global Edition Only

ON THE COVER: The impact of the microprocessor on the newest generation of microwave instrumentation is depicted in the design by Tektronix's Andrea Fowler. Artwork courtesy of Tektronix, Inc.

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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, $36 per year, two-year subscriptions $65, foreign $48 per year, two-year subscriptions $85, back issues (if available) and single copies $5.00.

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- Single screw tunable over standard communications, radar, and telemetry bands
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- AFC modulation options
- Excellent klystron replacement

Phase Locked Sources
- Field tunable
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- Low residual AM/FM noise
- ±0.0005% stability with internal crystal

Automatic Locking Sources
- INTELSAT and SCPC compatible
- Output frequency constant multiple of reference input
- Automatic loop bandwidth switching for acquisition under shock, vibration, or transient

DRO (dielectric resonator oscillator)
- Low cost
- Small size
- Low FM noise
- High frequency stability

Microwave Synthesizers

Mechanically Tunable
- Excellent spectral purity
- Low residual AM/FM noise
- Frequency stability options from $\pm 50 \times 10^{-6}$ to $\pm 1 \times 10^{-8}$
- 10 mW, 50 mW output power or higher
- Optional thumbwheel programming switches readout receive or transmit frequencies directly

Directly Modulated Transmitter Source
- Direct baseband to RF message channel modulation eliminates 70 MHz FMT and upconverters in remodulating radios and FM terminal equipment
- Up to 960 voice channels CCIR, plus orderwire from 300 Hz
- Insert baseband modulation, 300 Hz to 12 MHz at heterodyne repeaters
- Wide peak deviation capability ±5 Mhz
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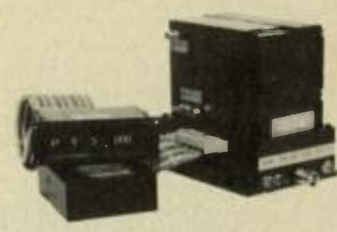
- Crystal stability to ±0.005%



Automatic Locking Satellite Communications Synthesizer
- Fully automatic with 50 kHz steps
- Frequency stability options from $\pm 5 \times 10^{-8}$ to $\pm 10^{-8}$
- 10 mW, 50 mW or higher output power
- FM noise −70 dBm at 12 kHz
- Optional thumbwheel programming switches readout receive or transmit frequencies directly

More than 50 standard bands available from 0.5 to 18 Ghz with up to 250 mW output power.

It takes a special kind of local oscillator for digital radio!

In digital radio, solid state local oscillators with high phase stability are a must for low bit error rates. Performance characteristics such as low microphonics, low noise and high spurious rejection are ultra-critical, too.

Many have *tried* to build sources in quantity to meet the tough requirements of digital service. Frequency Sources West Division has *succeeded!*

These are not special products either. We have produced thousands of sources and are now delivering units to many leading digital radio manufacturers in volume.

If you're not now using Frequency Sources West Division digital sources, it will pay you to write or call today for complete details.

Here are some of the standard units available.

Model Number	Frequency Range (GHz)	Output Power (mW)	Model Number	Frequency Range (GHz)	Output Power (mW)
MS-54XOL	5.9-6.4	10	MS-74XOL	10.63-11.23	10
MS-540XOL		100	MS-740XOL		100
MS-62XOL	7.5-8.0	10	MS-76XOL	10.63-11.63	10
MS-620XOL		100	MS-760XOL		100
MS-64XOL	7.98-8.5	10	MS-800XEL	12.5-12.9	20
MS-640XOL		100			

Higher output power available, all models.

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Better Products For Communications

CIRCLE 10 ON READER SERVICE CARD

Coming Events

16TH ANNUAL MICROWAVE POWER SYMPOSIUM JUNE 9-12, 1981

Sponsor: International Microwave Power Institute. Place: Royal York Hotel, Toronto, Canada. Theme: Interdisciplinary gathering devoted to examining an integration of various microwave applications with a view into the future. Contact: Susan Menuez, IMPI, 211 East 43rd St., New York, NY 10017. Tel: (212) 867-4659.

INTERNATIONAL CONFERENCE ON COMMUNICATIONS JUNE 14-17, 1981

Sponsors: Denver Section and Communications Society of IEEE. Place: Denver Hilton Hotel, Denver, CO. Theme: "Communications: The Expanding Resource, includes tutorial courses and exhibit of recent equipment. Contact: Bob Shuffler, ICC '81, P.O. Box 2191, Denver, CO 80221. Tel: (303) 667-5000, ext. 2360.

1981 IEEE/MTT-S INT'L MICROWAVE SYMPOSIUM JUNE 15-17, 1981

Sponsor: IEEE MTT-S (held jointly with IEEE AP-S on June 17-19, 1981). Place: Bonaventure Hotel, Los Angeles, CA. Theme: "Around the World with Microwaves," includes such topics as CAD and measurement techniques, microwave and mm-wave solid-state devices, IC's, low noise techniques, mw passive components and networks, microwave ferrite devices, satellite communication, submillimeter-wave techniques and devices, microwave bioeffects, etc. Contact: Al Clavin, Hughes Aircraft Company, Bldg. 268/A-55, Canoga Park, CA 91304. Tel: (213) 702-1778.

27TH ANNUAL TRI-SERVICE RADAR SYMPOSIUM JUNE 23-25, 1981

Sponsors: US Navy and DoD agencies. Place: The Naval Postgraduate School Monterey, CA. Theme: Development and operation of military radar systems. DoD security clearance through SECRET and a need-to-know endorsement will be required for attendance at the Symposium. Contact: Radar Symposium Coordinator, Environmental Research Institute of Michigan, P.O. Box 8616, Ann Arbor, MI 48107. Tel: (313) 994-1200, ext. 324.

WASHINGTON NEWS

Beginning with this issue, a 2-page Washington News column will appear in each issue. The column will be edited by Gerald Green who also serves as Washington Editor for *Journal of Electronic Defense*. Gerry brings extensive experience in the Washington area to this assignment. Many segments of the new administration's program appear likely to effect significant growth in our industry and Gerry's material will concentrate on keeping us up-to-date as specific moves are made.

Sum Up

SOLID STATE CIRCUITS STATE CONFERENCE REPORT

The annual Solid State Circuits Conference covers a broad spectrum of solid state device topics and always devotes a number of sessions to microwave devices. The report on the 1981 Conference by Consulting Editor Joe White covers the microwave sessions in detail. It also describes two sessions devoted to VLSI. In those sessions the rather startling developments during the past year in this field were reported to audiences which, in each case, exceeded 1,500. VLSI was the focus of the Conference and the technology discussed has important implications in the microwave area.

MICROPROCESSOR MICROWAVE MEASUREMENT ENHANCEMENT

The 1970s witnessed a complete revolution in the approach to and the precision of the results available from microwave test systems. The latest phase of this revolution, which is still underway, involves the widespread use of microprocessors for instrument set-up, data analysis and hardcopy data formating. The review article in this issue touches on each aspect of microwave measurement to which the microprocessor contributes and provides an excellent perspective of the range of its capabilities.

PRECISION IF SUBSTITUTION VECTOR RATIO METER

A dual channel complex vector ratio meter for microwave measurements employing a parallel IF vector substitution principle is discussed. Covering a dynamic range of 140 dB and a frequency range of 10 MHz to 18 GHz, the instrument's theoretical basis and its capabilities relative to other system approaches are discussed. A full discussion of error sources together with a description of the major system components are included. The particular virtues of the instrument for very low level signal situations is highlighted.

SOFTWARE FOR LOW LOSS ANA MEASUREMENTS

A new software program suitable for the HP8409A semiautomatic network analyzer which enhances the ability of that system to measure electrically long, low-loss 2-port networks over broad bandwidths is described. Recognizing that nonsystematic errors contribute disproportionately to low loss network measurements, the approach seeks to eliminate the potential for error from these sources and is based upon the use of short circuits, only, as calibration standards. Test results derived from the use of software are illustrated.

Howard Ellowitz

Workshops & Courses

GEORGE WASHINGTON U. COURSES

Sponsor: George Washington U. Continuing Engineering Ed.
Site: GWU, Washington, DC
Subject and Dates: Fundamentals of Communication Satellite Systems (No. 503) – June 8-12, 1981
Principles, theories, and design and analysis of operational satellite systems.
Fee: $715
Contact: Director, Continuing Eng. Ed., GWU
Washington, DC 20052
Tel: (202) 676-6106

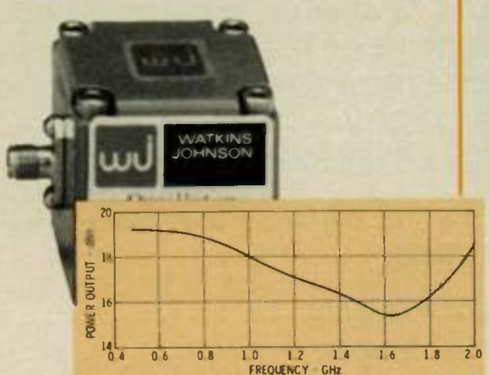
1981 ENGINEERING SUMMER CONFERENCES

Sponsor: The University of Michigan College of Engineering
Site: U. of Michigan, Ann Arbor, MI
Date: July 6-10, 1981
Fee: $625
Subject: Synthetic Aperture Radar Technology and Applications (#8112)
Design, operation and application of synthetic aperture radar (SAR).
Contact: Continuing Engineering Education, U. of Michigan, 300 Chrysler Center, North Campus, Ann Arbor, MI 48109
Tel: (313) 764-8490

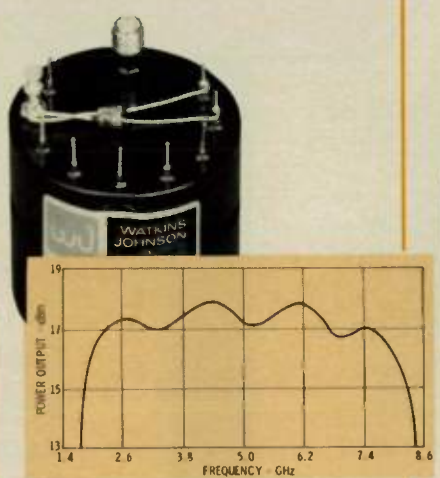
GEORGIA INSTITUTE OF TECHNOLOGY SHORT COURSES

Sponsor: Georgia Institute of Technology
Site: GIT, Atlanta, GA
Subject: Millimeter and Microwave Ferrite Materials
Fee: $350
Date: July 20-22, 1981
Study of the structure and properties of ferrite materials and the application of these materials in microwave signal processing and control functions.
Contact: Dept. of Continuing Ed., GIT, Atlanta, GA 30332
Tel: (404) 894-2400

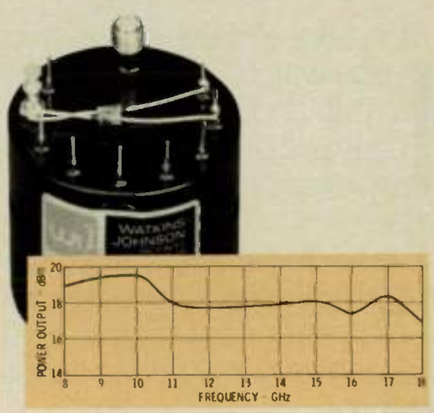
Watkins-Johnson Yig-tuned Oscillators— 0.5-18 GHz in Three Easy Steps.



1. 0.5–2 GHz



2. 2–8 GHz



3. 8–18 GHz

Now, cover 0.5 to 18 GHz with three multiband oscillators. These oscillators feature a unique low-surge-current hybrid YIG heater. Internal buffer amplifiers provide high output power and excellent load isolation. These units are available for commercial applications and for the full military environment, including −54° to +85°C, at competitive prices.

These broadband units continue to feature the same precise tuning linearity, temperature stability and high reliability that you have come to expect from Watkins-Johnson.

To find out how a Watkins-Johnson YIG-tuned oscillator can enhance your system's design, contact the W-J Field Sales Office in your area or phone Ferrimagnetic Applications Engineering in Palo Alto, California at (415) 493-4141, extension 2252.

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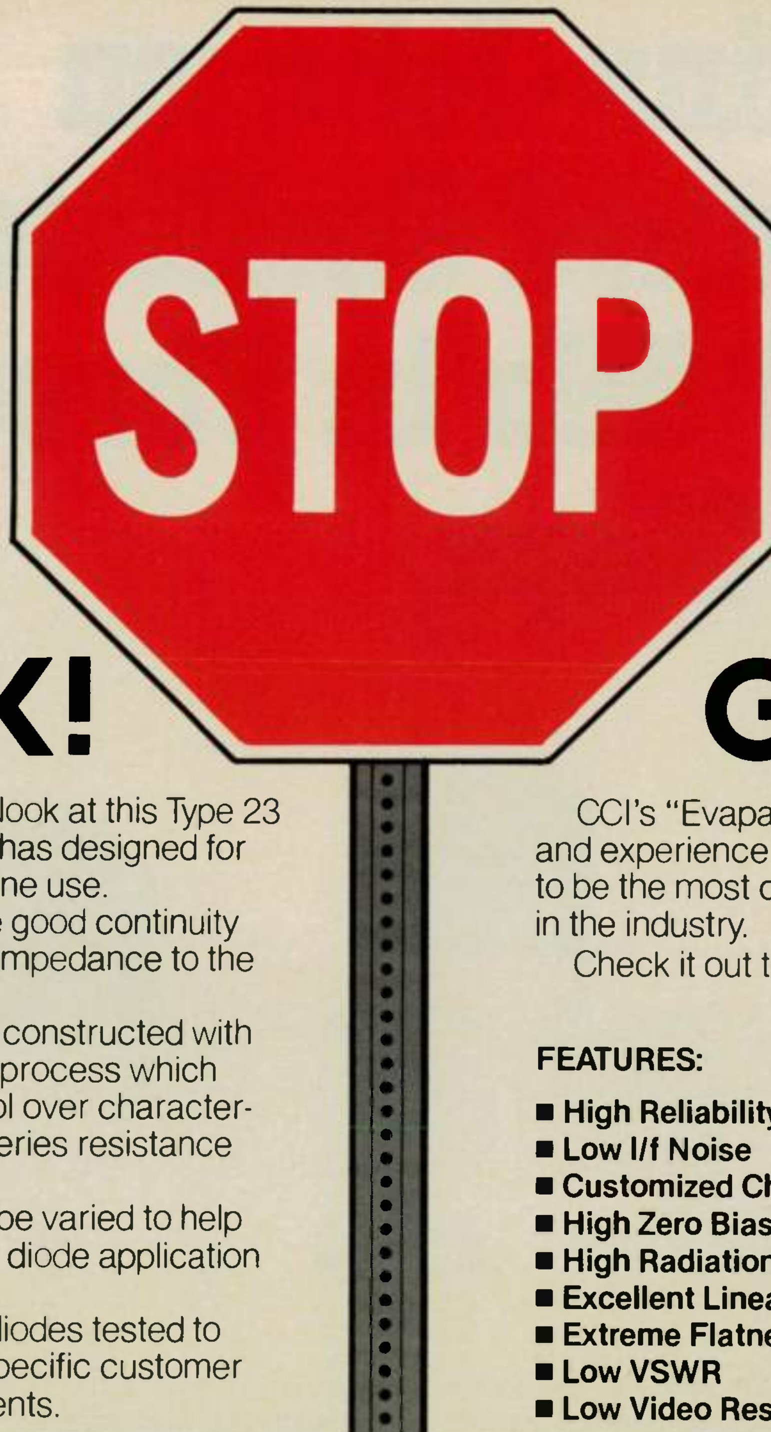
CIRCLE 14 ON READER SERVICE CARD



LOOK!

Yes, take a close look at this Type 23 Package which CCI has designed for microstrip and stripline use.

The leads provide good continuity of transmission line impedance to the diode.

These diodes are constructed with the CCI "Evapalloy" process which insures better control over characteristics and very low series resistance junctions.

Parameters may be varied to help solve your particular diode application problem.

CCI can provide diodes tested to MIL-STD-19500 or specific customer screening requirements.

GO!

CCI's "Evapalloy" process control and experience has proven CCI diodes to be the most consistent and reliable in the industry.

Check it out today. GO with CCI!

FEATURES:

- **High Reliability**
- **Low I/f Noise**
- **Customized Characteristics**
- **High Zero Bias Sensitivity**
- **High Radiation Resistance**
- **Excellent Linearity**
- **Extreme Flatness with Temperature**
- **Low VSWR**
- **Low Video Resistance**

Stripline Back Diode

For Video Detector Applications

CCI

CUSTOM COMPONENTS, INC.

ELECTRICAL CHARACTERISTICS

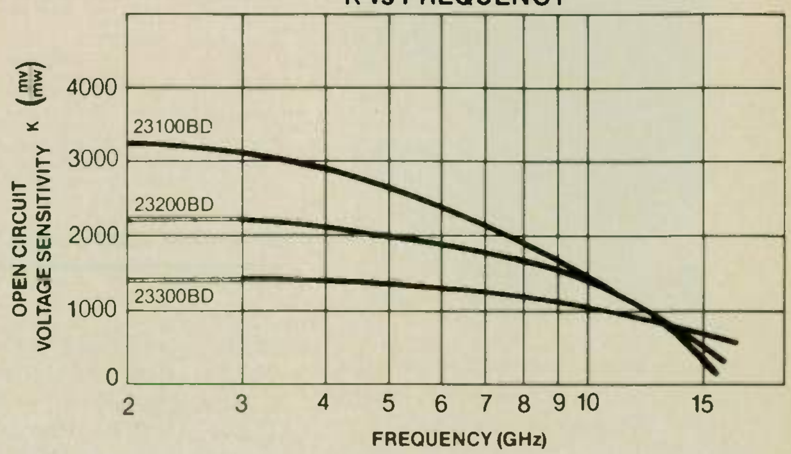
Part Number	Ip (μa)	Vr (Mv) Typ.	Vf (Mv) Typ.	Rs (Ω) Max.	Ct (pf) Max.
23100BD	50-150	540	120	12	.7
23150BD	50-150	540	100	9	1.0
23200BD	150-250	550	110	11	.7
23250BD	150-250	550	100	8	1.0
23300BD	250-350	540	110	11	.7
23350BD	250-350	540	100	8	1.0
23400BD	400-500	530	100	10	.7
23450BD	400-500	530	80	8	1.0

Typical Performance

Type	Rv (Ω)	Tss (−dbm)	M $\left(\frac{K}{\sqrt{Rv}}\right)$	K $\left(\frac{mv}{mw}\right)$
23100BD	400	−52	80	1600
23200BD	180	−51	90	1200
23300BD	80	−50	100	900

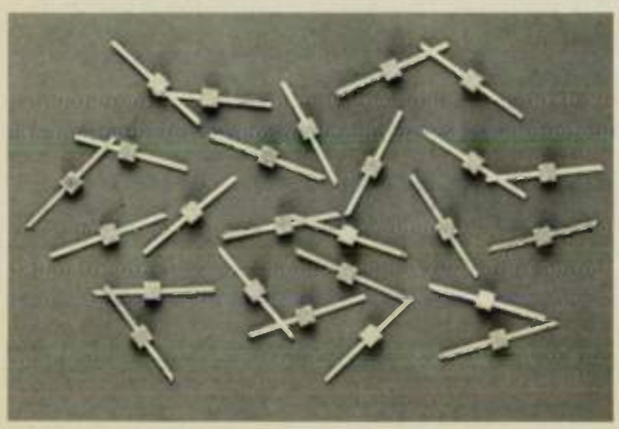
NOTES: 1. 2MHz Band Width **2.** Input Power −20 dbm **3.** Fo 10GHz

K vs FREQUENCY



ENVIRONMENTAL RATINGS

Storage Temp.—65°C to +100°C
Operating Temp.—65°C to +100°C
Temperature Cycle—MIL-STD-202, Method 107, T.C. A
Shock—MIL-STD-750, Method 2016
Vibration—MIL-STD-750, Method 2056
Acceleration—MIL-STD-750, Method 2056
Fine Leak—MIL-STD-750, Method 1071, T.C. G
Gross Leak—MIL-STD-750, Method 1071, T.C. C



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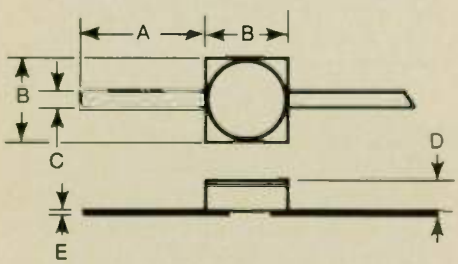
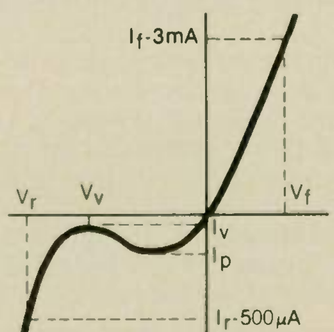


DIM	A	B	C	D	E
MIN	13	.064	.018	.026	.003
MAX	17	.076	.022	.034	.006

BACK DIODE STATIC V-I CHARACTERISTIC



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New Implications for Microwaves at the '81 Solid State Circuits Conference

JOSEPH F. WHITE *Consulting Editor*

This year's International Solid State Circuits Conference, held in New York City in the Grand Hyatt Hotel, Feb. 18 - 20, 1981 was attended by over 2,000 delegates. Through the years the Solid State Conference has supported the microwave field with special sessions dedicated to it; this year's coverage is reviewed in the following paragraphs. However, what is possibly of even more significance to the microwave field is the impact of very large scale integration (VLSI) on systems in general, and on microwave components and systems in particular, a topic covered in the second part of this report.

Two microwave sessions were held along with an informal evening Discussion on Power GaAs FET Amplifiers. The first session chaired by Eliot Cohen, Naval Electronic Systems Command, Washington, DC, and entitled "Microwave Amplifiers," stressed new device technologies and circuit techniques. A 0.15 to 16 GHz FET amplifier with 15 dB of gain ± 2 dB was described by Thomson CSF, France. RCA Laboratories, Princeton, NJ, described a dual-gate MESFET amplifier with automatically variable gain covering a 45 dB dynamic range and operating from 4 to 8

". . .attended by over 2,000 delegates. . ."

GHz. This amplifier used dual-gate GaAs FET's to achieve the automatic gain control and raised the input signal (between -10 dBm to -45 dBm) to a constant output level of +3 dBm over the octave bandwidth. Following this paper, a state-of-the-art data point for power FET's was presented by Texas Instruments whose single packaged, two-chip device yielded 675 milliwatts at 20.5 GHz with 5.8 dB gain.

A General Electric Company, Syracuse, NY paper, "Silicon on Sapphire Monolithic Microwave IC's," described a three-state low noise amplifier with 20 dB gain operating from 1050 to 1300 MHz with 3.8 dB noise figure. The circuit used silicon FET's (for low cost) with 0.5 micron to 1.0 microns source to gate lengths. In a Raytheon, Waltham, MA, paper, a two-stage monolithic X-band power amplifier

"Two microwave sessions were held along with an informal evening discussion. . ."

was described which provides 565 milliwatts of output power, 8 dB gain, with 1 dB rolloff from 8.2 to 10.5 GHz, all realized on a 2.5 by 3.5 millimeter GaAs chip. In the final paper of the amplifier session presented by Hughes Aircraft, Torrance, CA, a chip level power combinatorial method was described which sums the output of six FET chips operating at 15 GHz to yield a net power out of 2 watts CW at a power added efficiency of 28%,

"A 0.15 to 16 GHz FET amplifier. . ."

another state of the art frontier advancement. Moding within combiners was minimized by making the miniature microstrip Wilkinson combiner with thin film isolation resistors. High efficiency and low loss, greater than 90% combining efficiency, was attributed to printing the circuit on a sapphire substrate. Overall amplifier gain was 3.9 dB with power added efficiency of 27.5%.

In a second session entitled "Microwave Circuits, chaired by John Kuno of Hughes Aircraft, six additional microwave papers

"Silicon on Sapphire Monolithic Microwave IC's. . ."

were presented. The first described application of new techniques to an old art, harmonic generators. For devices with up to 25 microseconds output pulse lengths, peak powers of up to 40 watts were described for X-band output. Up to 100 peak watts are available using combinatorial techniques and efficiencies of about 1/N where N is the multiplication ratio. The paper following, from the Institute for High

". . .VCO performance from 7.3 to 15.6 GHz using a 0 to 16 volt varactor. . ."

Frequency in Munich, Germany discussed noise minimization using coherent AM to PM noise processing in multipliers. Another paper entitled "Octave Band Varactor Tuned GaAs FET Oscillators" from Texas Instruments, Dallas, Texas, gave VCO perform-

(continued on page 24)

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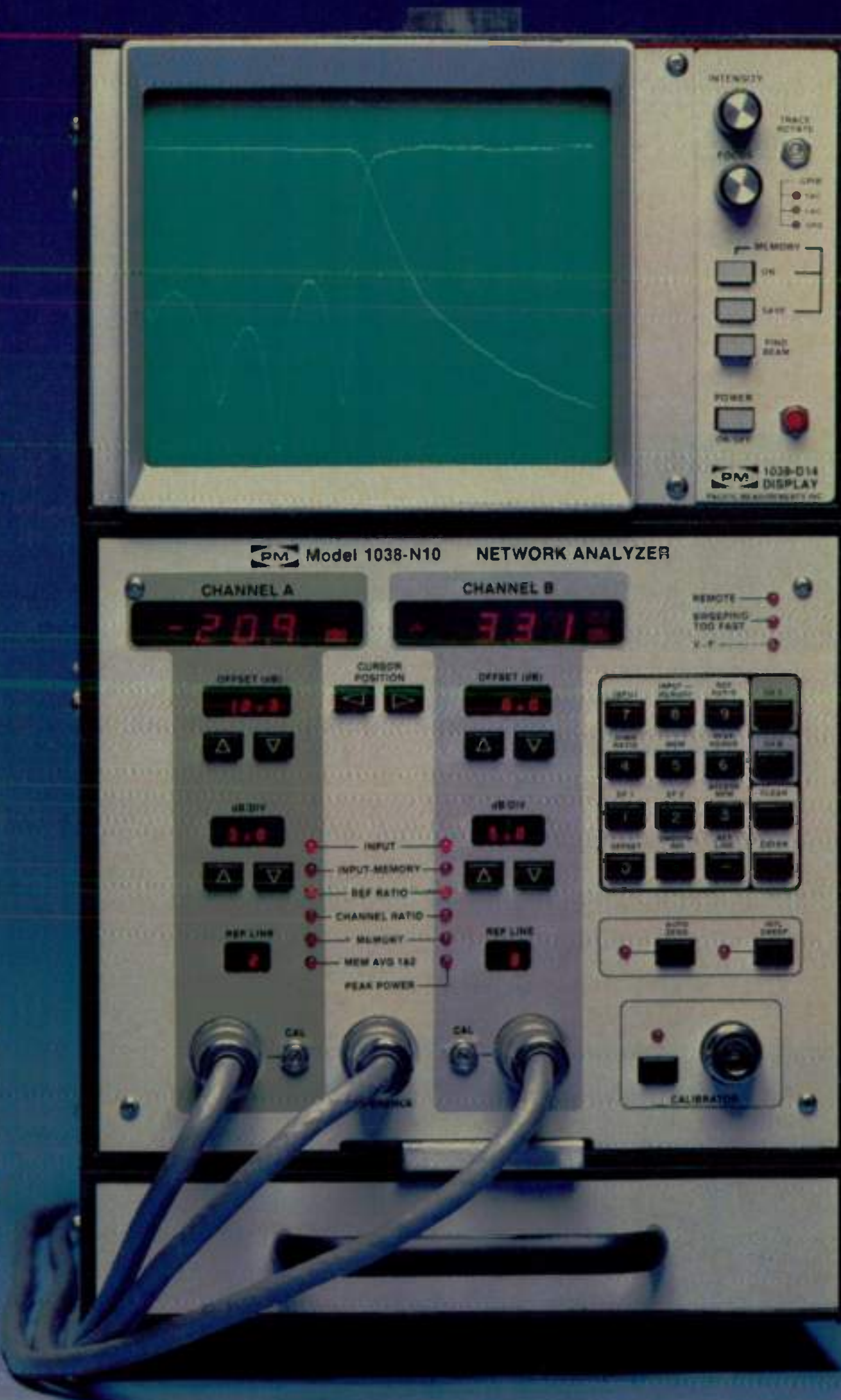

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ance from 7.3 to 15.6 GHz using a 0 to 16 volt varactor tuned oscillator with 4 milliwatts power output and only 4 volts, 80 milliamperes of power supply to the single 0.5 micron by 300 micron gate GaAs FET. The extended tuning range was achieved using a hyperabrupt GaAs varactor diode chip having a zero voltage capacitance of 1.2 picofarads and a capacitance at −16 volts of approximately 0.08 microfarads. The two papers which followed this described research in the use of dual gate FET's to provide phase shift control for array antennas as well as for phase modulator applications. The first paper by Laboratories D'Eléctronique à de Physique Appliquée, France, desribed work with a single dual-gate FET operated with an output frequency of 12 GHz and 10 dB of gain. Simultaneous with this performance, it yielded 90° of continuous phase variation with an output power variation of ± 1.8 dB and noise figure of about 8.5 dB. In the second paper from Plessey Research, Northants, England, a dual gate FET circuit was operated at S band in which bias voltages were programmed for gates 1 and 2 so that not only was a 90° phase shift obtained but constant output power as well. These experiments were conducted around a 0 dB gain operating point. The final paper of the session from MIT, Lincoln Laboratory, Lexington, MA described GaAs monolithic circuitry for millimeter wave receivers and included a complete heterodyne receiver chip operating at 21 GHz with 12 dB noise figure and 2 - 4 dB gain using IF frequencies between 2.0 and 2.6 GHz.

VLSI, FOCUS OF THE CONFERENCE

Those of you who have attended evening panel discussions at conferences know how hard it is to return after dinner to the meeting for a two-hour evening session. Not infrequently whole panel discussions wind up being held around the bar because of the paucity of attendees. No such problem befell the "CMOS versus NMOS for VLSI" informal discussion held at 8 PM Wednesday and organized by Harry Boll of Bell Laboratories, Murray Hill, New Jersey. Three ballroom areas were connected together in anticipation of the broad attendance for this debate topic, but even their combined seating capacity of 1200 was inadequate on this occasion. The room was absolutely filled, with standees extending outside and into the corridors, for a total of over 1500 engineers and physicists gathered to hear 10 panelists present their views on these competing technologies used in very large scale integration (VLSI).

Remarkably, all ten speakers presented their views so concisely, many using vugraphs prepared for the occasion, that the discussion was open to audience participation by 9 PM. The competing technologies would hardly be viewed as distinct approaches by most microwave engineers. In fact, NMOS is a subset of CMOS and consists of only one polarity of silicon FET on a chip as opposed to the two polarity (NPN

(continued on page 26)

(from page 24) **'81 CIRCUITS**

and PNP) CMOS (Complementary Metal Oxide Semiconductor) topology. The difference between these two lies in the method by which they realize an element across which to drop the voltage of the supply when creating a low state or "zero" logic level.

". . .over 1500 engineers and physicists gathered to hear. . .competing technologies used in VLSI."

With CMOS complimentary transistors are always wired in series, one in the high impedance and the other in low impedance state, thus each represents a high impedance load to the other, inhibiting the consumption of large amounts of current (and thereby power) from the 5 volt supply. With NMOS only one polarity, the NPN FET switch, is used and the high impedance is realized by the use of a very high resistance polycrystalline resistor. This minor difference in the realization of the element has profound impact on the cost of the large scale integrated circuits, in particular the density with which memory cells can be created, as well their susceptibility to being inadvertently triggered by alpha particles (a condition called "latchup"), and therein lies the controversy. Without probing more deeply into the nuances of integrated circuits realization, the matter of greatest interest to microwave engineers should be the inherent capacity of such small silicon chips.

The same three ballrooms, once again filled to standing room, and accommodating an audience of over 1500 people heard a presentation by Hewlett Packard the following morning at 9 o'clock describing a breakthrough in VLSI, a 32 bit central processor chip containing *450 thousand individual transistors in an area only 1/4 inch square* and operating at up to 18 MHz frequency. So small were the interconnect lines that they repeated one another on a 2.5 micron (that's 1/10,000 of an inch) grid. The metal conductors themselves were only 1.5 microns wide and spaced by 1 micron. To show them in a slide requires such a large magnification that if the entire chip had been shown at that magnification, 300 thousand separate photographs would have been needed. Eight masking steps involving depositions of phosphorous and boron using E beams, nitride and oxide growth, and dry etching (using inert zenon gas), were needed to make this supremely complex chip. The memory alone occupying less than one half of the chip's area, contains a storage capacity of 9000 "words" each consisting of 38 bits, representing a 342 kilobit ROM (Read Only Memory), a memory so large it can store enough code to permit the microprocessor chip to accept program instructions in a high level language. Although not discussed, the implications of so much in a single chip certainly bode well for "smart" microwave components and subsystems of the future.

". . .a 32 bit central processor chip containing 450 thousand individual transistors in an area only 1/4 inch square. . ."

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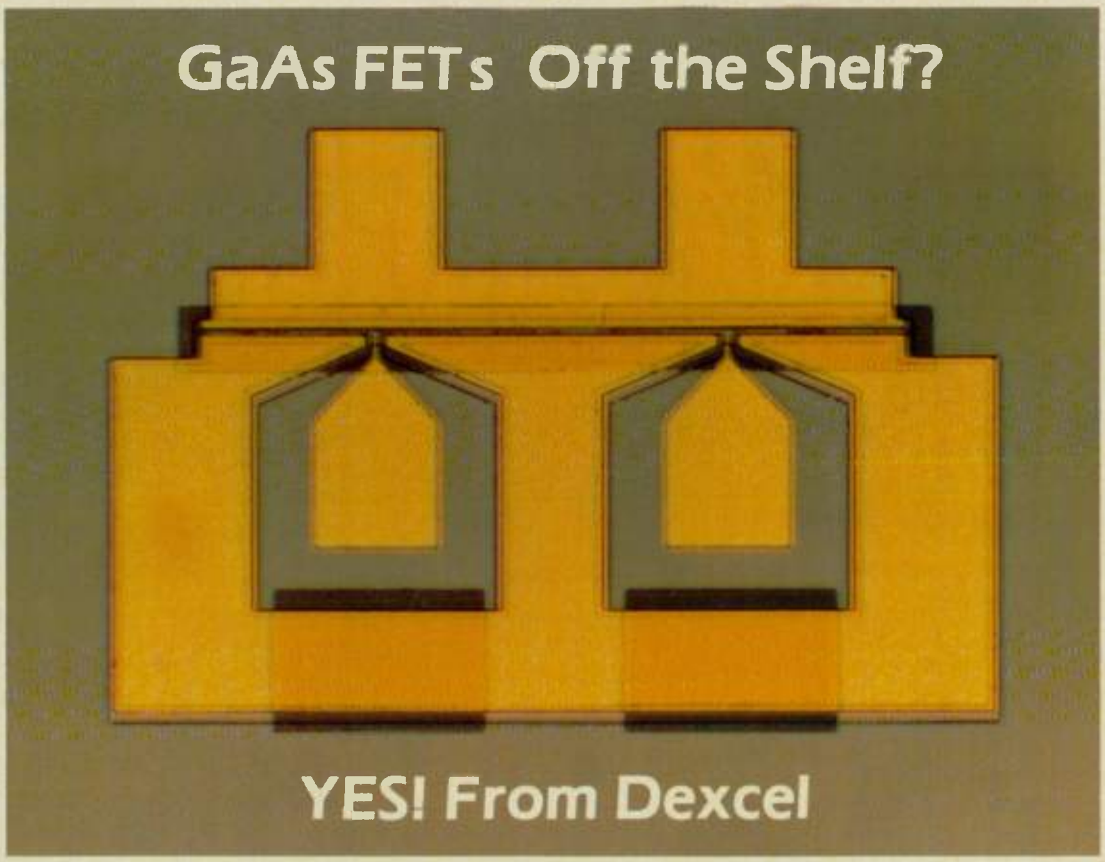

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	NF (dB)	G_A (dB)	G_{MAX} (dB)	NF (dB)	G_A (dB)	G_{MAX} (dB)	NF (dB)	G_A (dB)	G_{MAX} (dB)	NF (dB)	G_A (dB)	G_{MAX} (dB)
DXL-2501A	1.8	10.5	13.5	2.7	8.5	10	4.0	5.5	7.0			
DXL-2502A	2.0	8.5	13.0	2.4	8.5	10	3.5	6.0	8.0			
DXL-2503A				2.3	9.0	13	3.2	7.0	9.0	5.5	6.0	7.0
DXL-2503B -P70	0.9	13.0	16.5									

Medium and High Power

Performance Device	4 GHz		8 GHz		12 GHz		18 GHz	
	P_{1dBc} (dBm)	G_{1dBc} (dB)	P_{1dBc} (dBm)	G_{1dBc} (dB)	P_{1dBc} (dBm)	G_{1dBc} (dB)	P_{1dBc} (dBm)	G_{1dBc} (dB)
DXL-3501A	20	13	20	10	17	6.5		
DXL-3504A	20	13	20	11	19	7.0	17	5
DXL-3615A	25	10	24	6				
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Microwave Measurement Accuracy Enhancement

via Distributed Microprocessing

ROBERT H. BATHIANY and PETER LACY
Mountain View, CA —Wiltron

INTRODUCTION

The 1970s encompassed a revolution in microwave measurement capabilities. Three ingredients fueled this forward thrust[1]:

- The Automatic Network Analyzer (ANA)
- The General Purpose Interface Bus (GPIB)
- The Microprocessor (μP)

The ANA initiated face-to-face interaction of the vendor and user body of practicing microwave engineers. The ANA-ATE User's Organization was first gathered in 1972 and has now become the Automatic RF Techniques Group that is affiliated with the MTT Society of IEEE.

The first Automatic Measuring Systems adapted instruments to digital control and output with analog/digital plus electromechanical converters. Thereafter, all commands and the resulting data were handled by a minicomputer. The assembled automatic test systems allowed much progress in programming strategies that can be carried into future measurement automation.

The present focus is now on the use of microprocessors to refine performance in each thrust of the measurement process. Non reproducible functions; such as tuning curves, amplitude control, detection and amplifier response, step attenuators etc. are individually shaped to an idealized or normalized shape by stored corrections of a PROM prepared for each individual unit. The "microprocessor" label is widely applied and frequently is used where the roles are routine, gate-keeper, functions. However, at this time, some microprocessor instruments have achieved order-of-magnitude improvements in the generation and sensing of microwave parameters. These instruments have powerful front panel operator control to achieve new levels of real-time high accuracy microwave measurements plus GPIB control.

Some new steps in microwave measurements will be referenced and then a specific example will be described in detail.

REFERENCE EXAMPLES

For several decades, high echelon microwave attenuation cali-

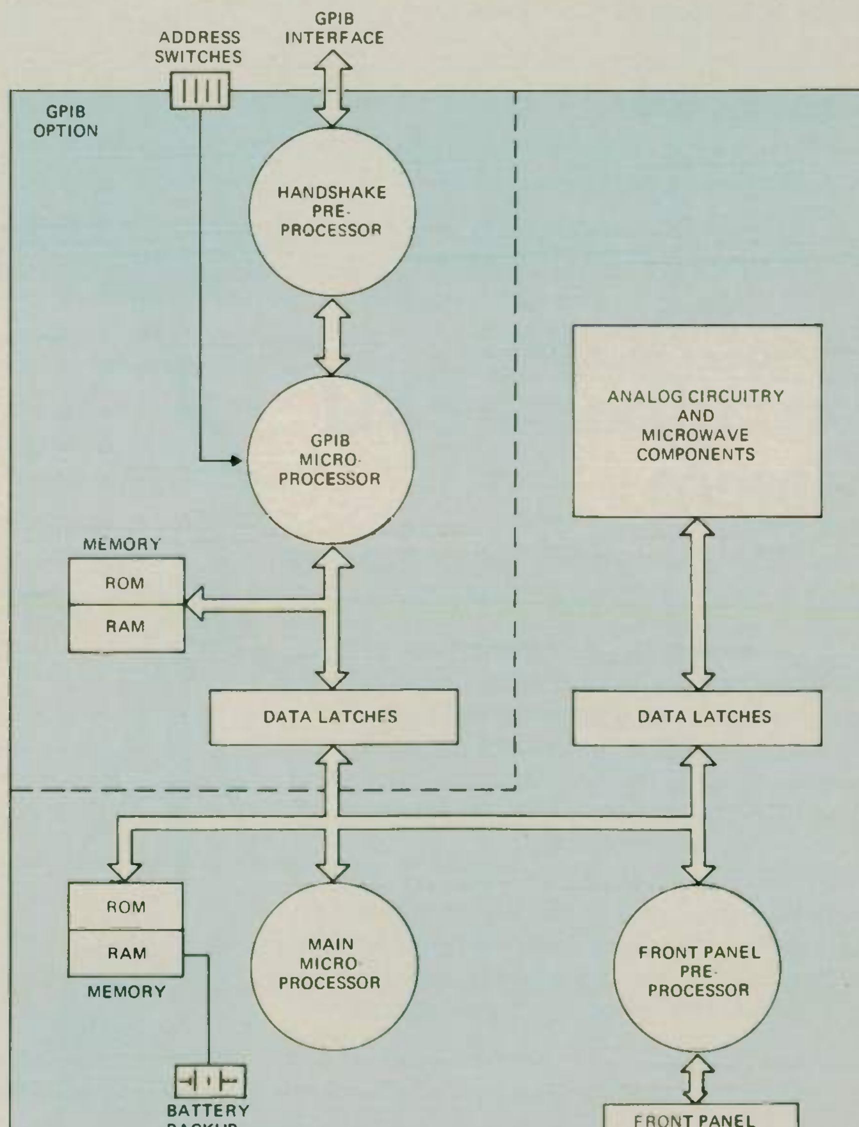

Fig. 1 Simplified microprocessor block diagram of microprocessor-equipped sweep generator (Wiltron 6600 Series).

(continued on page 30)

(from page 29) ENHANCEMENT

bration has used waveguide below cutoff IF attenuators in substitution measurement configurations. In Reference 1, it was proposed to calibrate wide dynamic range IF step attenuators by reference to an IF cutoff attenuator with a laser interferometer read-out. Rigid control of long term stability for the step film attenuator sections and their switching is required. The step attenuator errors are stored for data correction on a PROM for processor execution.

The other ingredient of microwave measurement capability maturing in the 1970s was the Interface Bus (GPIB: IEEE488, IEC625) for control and communication to and between instruments. In 1978, several specialized microprocessors were introduced to efficiently conduct this function. A specific application will be described here later.

Microprocessor-based programmable spectrum analyzers (HP 8666A and TEK492P) have made great strides in all performance characteristics for both panel and GPIB control. The low spurious response and narrow spectral resolution of the HP 8666A spectrum analyzer up to 22 GHz with a tracked YIG preselector and harmonic mixing of the swept YIG tuned LO is achieved through multiple corrections applied through microprocessor control.

LSI has now made possible low cost desk computer/controllers of high capability with integral display and print-out capability. The Automated Scalar Network Analyzer to be described has the basic desk controller capabilities enhanced by plug-in modules to extend memory, I/O access, GPIB control and to execute program functions.

In summary, examining the front panels of new microwave instrumentation it's obvious that ease of use and measurement versatility are at a level never before achieved. However, this is just the tip of the "measurement iceberg." The microprocessor technology resident in modern instrumentation does much more than improve user interface; it also enhances microwave performance, programmability, and serviceability. In addition, when this technology is applied throughout the measurement system, data can be enhanced, corrected, and presented in a way which requires little interpretation from the user. Let's explore how the microprocessor accomplishes all this, first from the individual instrument standpoint and then from the overall measurement system view.

THE MICROPROCESSOR BASED SWEEP GENERATOR

In a new microwave instrument, the main microprocessor has a variety of tasks to perform. Many of these tasks must be accomplished within the same time frame, so efficient instrument design usually requires the use of multiple processors and preprocessors. Figure 1 shows a simplified block diagram of a microprocessor-based sweep generator (Wiltron 6600 Series) which is representative of the most recent microprocessor instrumentation. The central microprocessor has three main tasks to perform: it must interface with the user through the front panel, control the internal circuitry and components of the instrument, and be prepared to communicate with other instruments through the GPIB (IEEE 488). This is all controlled through the main instrument program that is stored in ROM (read-only memory) within the instrument.

Design of the front panel interface is of critical concern, as this is the key microprocessor/user link. The operator expects constant update of parameters on the front panel, and desires the instrument to respond the moment a front panel key is depressed. Efficient instrument design dictates the use of a preprocessor to handle communications between the front panel and main microprocessor. The preprocessor not only optimizes response time, but also organizes the information into a format which is most easily used by the operator.

All setup information entered by the user from the front panel

(continued on page 32)

(from page 31) **ENHANCEMENT**

is stored in RAM (random-access-memory), which is volatile (i.e., if line power is lost, this information is gone forever). Battery backup is a virtual necessity because the user expects the new instrumentation to return to the same state in the morning to which it was set the night before. Older instrumentation with pots and rotary or slide switches always did, so why shouldn't modern microprocessor instrumentation?

Since the microprocessor has the opportunity to improve microwave performance, we should investigate some of the weaknesses of older designs to understand the nature of this improvement. Designers of previous sweep oscillators constantly battled noise and drift from analog circuits, two factors which relate directly to the frequency accuracy, stability, and quality (residual FM) of the microwave output. The enormity of this problem can be fully understood when one considers that 10 kHz of noise on a 10 GHz signal is equivalent to 1 part-per-million (ppm), or 10 microvolts of variation on a 10-volt signal. These problems were further compounded by the use of RF section plug-ins and the fact that the majority of the instrument power dissipation was within the plug-in. To make matters worse, additional analog circuitry was required within both mainframe and plug-in so that all mainframes and all plug-ins could be adapted to a standardized interface.

The solution, therefore, is to use digital circuitry as much as possible, to minimize and carefully design the analog parts of the instrument, and to eliminate the costly and inefficient mainframe plug-in interface. In addition, the intelligence of the microprocessor can be used to make basic operating mode decisions to enhance the performance of the instrument. As an example, the microprocessor enables the swept residual FM of a sweep generator during narrow sweeps (50 MHz) to be held to the value applicable to CW conditions. To do this, it sets the main tuning coil of the YIG

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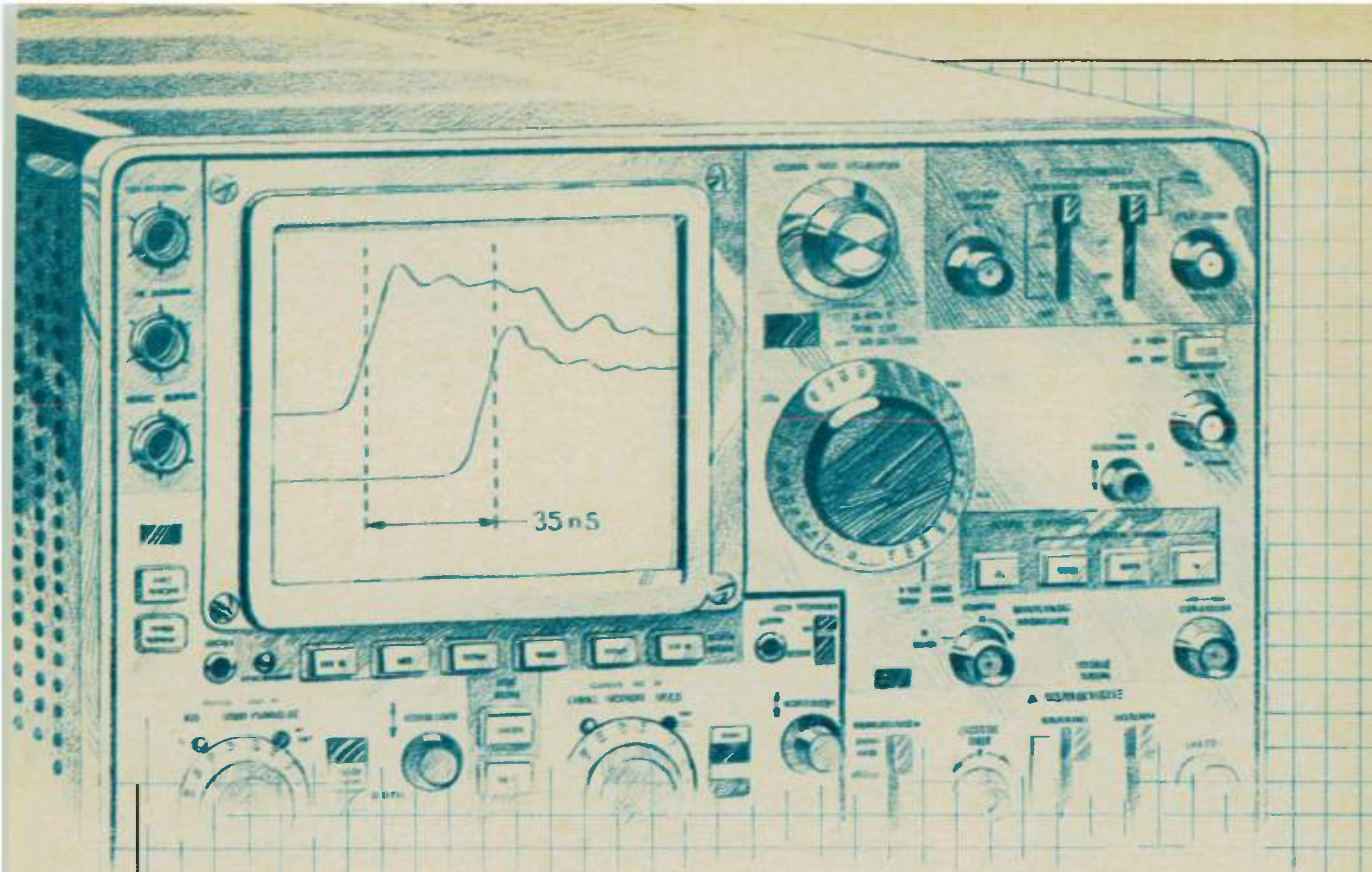
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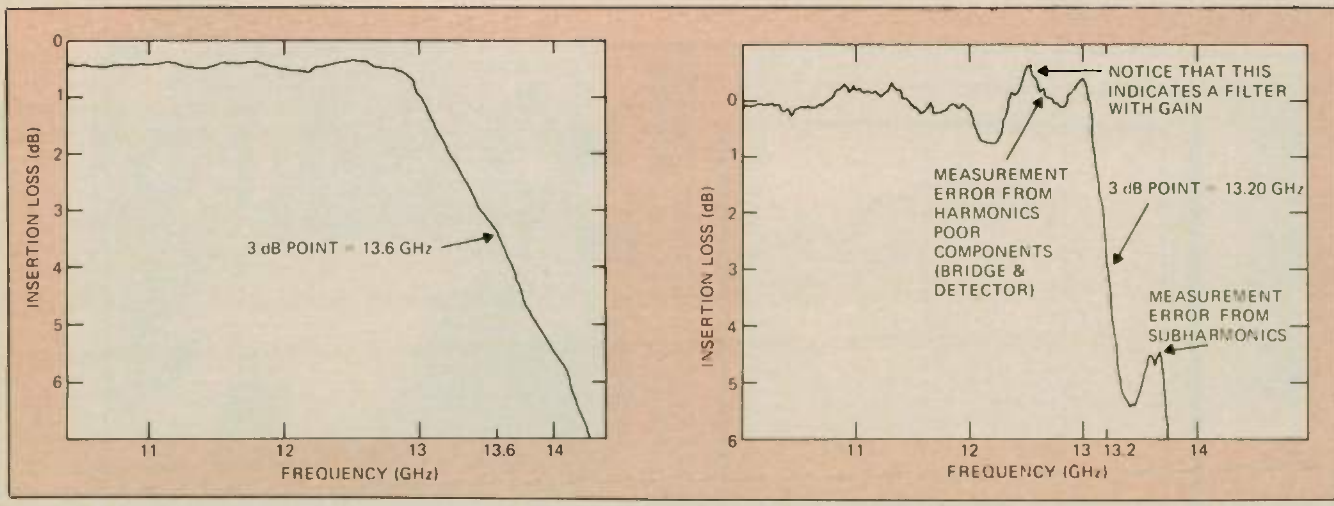

Fig. 2 Measurements on the same low-pass filter using different measurement systems. 2a is the result with a sweeper offering harmonics of 40 dBc and spurious of 60 dBc. 2b is the result with a signal having higher harmonic and/or spurious levels.

oscillator at the center of the sweep reducing the tuning bandwidth, thereby reducing noise (residual FM). The oscillator is then swept using the small FM "tickler coil" which is located in the air gap near the YIG sphere. The low tuning sensitivity of this coil reduces the swept residual FM to that of the residual FM present in the CW mode.

It must be remembered, however, that microprocessor-based instrumentation does not replace the need for high-performance microwave components within the instrument. Certain faults do not lend themselves to microprocessor correction and basic considerations such as harmonic and spurious outputs must be given proper attention. The measurement results obtained as a result of improved microwave components can clearly be seen in Figure 2, which compares measurements of the same filter under different harmonic and spurious conditions.

THE GPIB SYSTEM IMPLEMENTATION

Microprocessors also play a key role in the programmability of modern instrumentation. The overwhelming acceptance of the GPIB (IEEE 488) interface in automated system design has designers using a resident microprocessor to achieve optimum performance in interface bus implementation. The automated system user can expect total programmability and the implementation of specialized bus techniques such as group-execute-trigger (GET) and service request (SRQ). Group-execute-trigger allows the user to simultaneously trigger two or more instruments on the bus. In addition, some instruments can be instructed as to what its task will be when the trigger command is received.

The service request capability allows the instrument to get the attention of the controller when it has finished an assigned task, or when it encounters difficulties such as an error mode. The controller must then identify which instrument requires service through a method called polling. In serial polling, the controller contacts each instrument one by one until it identifies the source of the service request. Parallel polling, a method by which the controller can check the status of a number of instruments simultaneously, therefore greatly reducing the polling time, is also used. This implementation is especially of concern to designers and users of large systems such as ATE.

The addition of a controller, another microprocessor-based in-

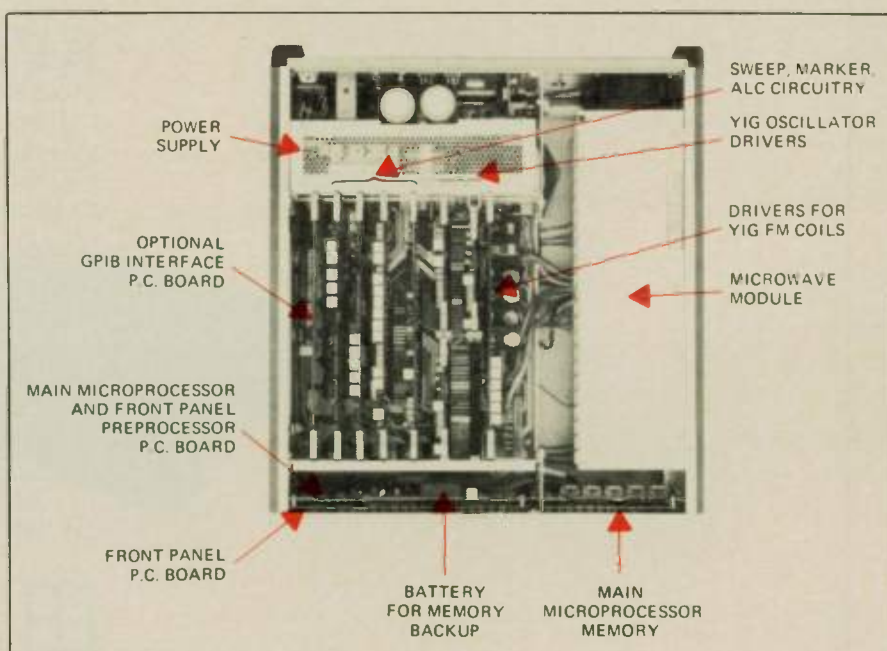

Fig. 3 Internal view of microprocessor-equipped sweeper shows accessibility and modularity possible with microprocessor-based instrumentation (Wiltron 6600 Series).

strument, to a test system employing a microprocessor-based microwave instrument enhances the overall flexibility of that system. Any test routine, data display format or user interface within the basic capability of the microwave instrument may be generated by programming the controller in a high-level language. Most microwave instruments with GPIB interface capabilities are offered with some software for use with a controller.

A recent new GPIB implementation includes a helpful command called "Instrument Identify." Upon receiving this command, a sweeper sends to the controller its model number, frequency range, maximum leveled power, minimum power and even the software revision level. This allows programs within the controller to be written in such a manner as to work with any sweeper, without requiring the user to enter the parameter limits of the sweeper every time the system is operated.

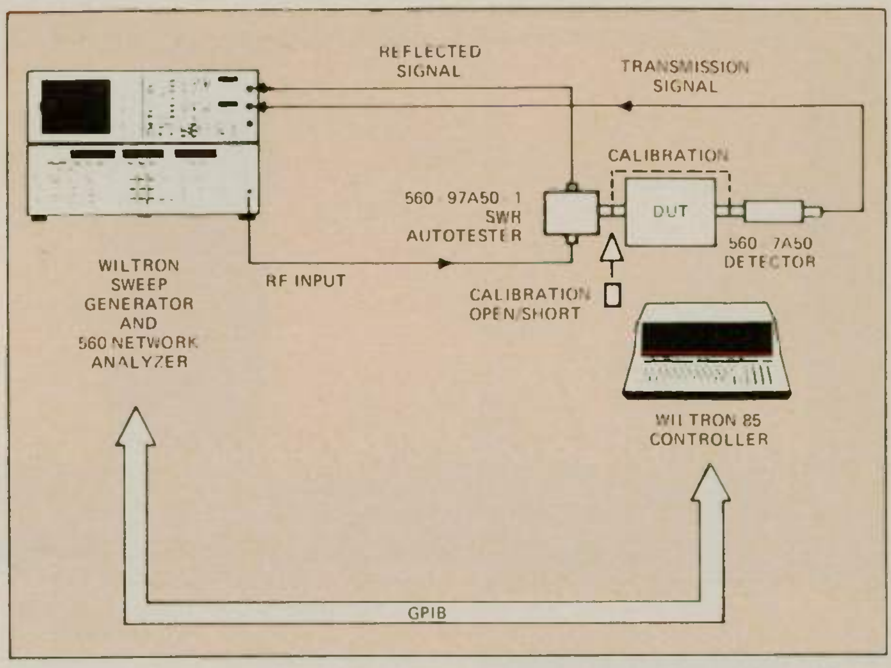

Fig. 4 Automatic scalar network analyzer system block diagram (Wiltron 5600 Series).

NEW INSTRUMENT DIAGNOSTICS

Microprocessor implementation within an instrument also reaps benefits from the standpoint of serviceability. Most microprocessor instruments contain a self-test mode which allows the instrument to go through a series of basic diagnostics to confirm that it is operating correctly. If an error is found, the microprocessor will output an error code indicating the module or circuit block which is malfunctioning. Since communication within the instrument is along the microprocessor data bus, a well-designed product will be very modular, accessible, and easy to troubleshoot to a replaceable module level. Figure 3 shows the internal layout and modular configuration of a microprocessor-based sweeper.

If problems are encountered with the microprocessor or directly-related circuitry, this can be troubleshot with a method known as signature analysis. Normally the manufacturer will supply a removable plug or series of switches on each board containing a microprocessor. These allow disconnecting the microprocessor from the data bus and forcing it into a known cyclical state. Signature analysis is then used to analyze the digital pattern or "signature" at each point in the circuit. This pattern is represented by a series of numbers and letters on the display of the signature analyzer and compared with the proper signatures, which are identified on the schematic. In addition, instruments may have a signature analysis test stimulus program which tests RAM, ROM, LSI (large scale integration) chips, and I/O ports.

To locate a problem in the analog circuitry of the instrument, another troubleshooting scheme is to command the microprocessor to send specific digital commands and data to the digital control ports driving various analog circuits. The response of the analog circuitry can then be analyzed and diagnosed.

SYSTEM ASPECTS

To illustrate system operation, a block diagram of an automated

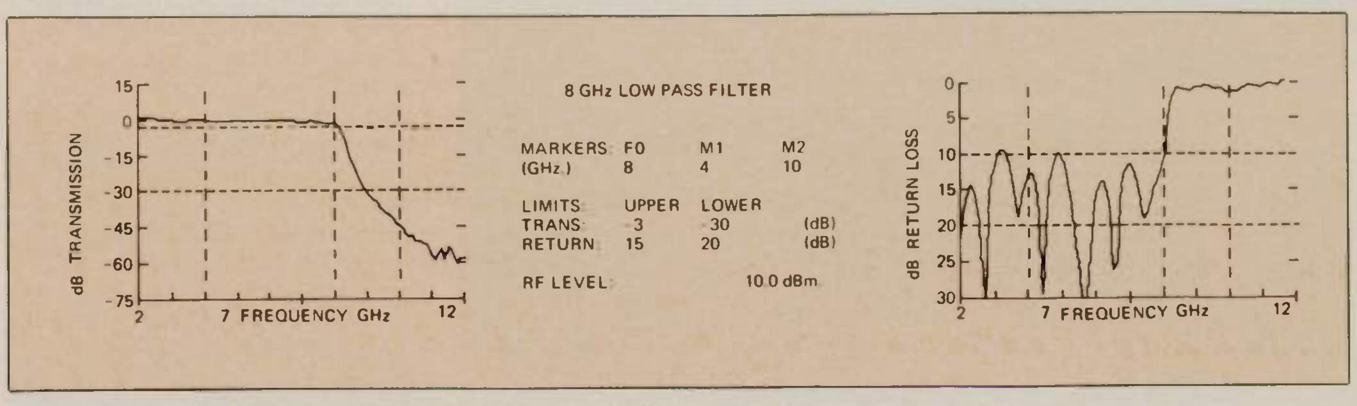

Fig. 5 Low-pass filter data from a microprocessor-enhanced measurement system.

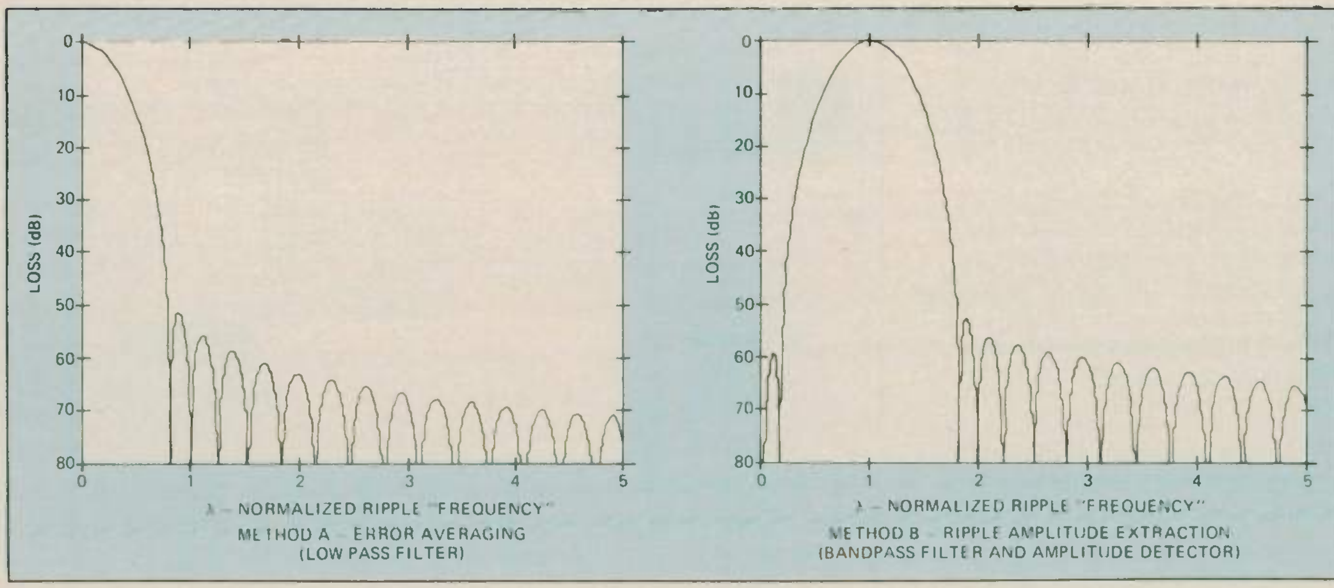

Fig. 6 Digital signal-processing methods.

scalar network analyzer covering 10 MHz to 40 GHz (Wiltron 5600 series) is shown in **Figure 4**. Return loss and transmission data is digitized by the scalar network analyzer and sent over the GPIB to the controller. If manual adjustments must be made on a test device before automatic data-taking, the user is free to change the display sensitivity or offset without affecting the data that will be automatically sent to the controller.

APC-7 TO TYPE N MALE ADAPTER

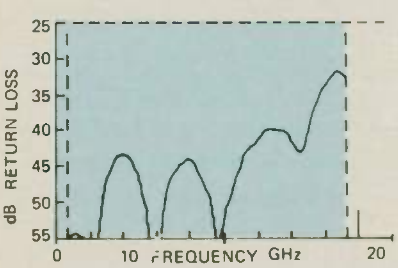

Fig. 7 Adapter measurement using an accuracy enhancement program with a network analyzer.

The microprocessor analyzes the data and automatically scales the transmission and return loss axis for optimum data presentation. If desired, the user can enter a fixed dB per division and fixed offset level, so that all plots will be similar and easy to compare. Marker frequencies and specification limits can be plotted, to make go, no-go analysis straightforward for the operator. **Figure 5** illustrates the kind of data presentation available from such a system.

Once the frequency measurement range, step size, and data presentation information have been entered into the controller, the particular test setup can be stored on a magnetic tape cartridge for future recall and use. With these aids, such systems can easily be operated by relatively unskilled personnel.

SIGNAL PROCESSING

In addition to the benefits of its test routine control functions, the signal processing capabilities of the microprocessor add another important dimension to overall instrument performance.

Enhanced accuracy techniques, which separate desired measurement reflections from test system mismatch and/or directivity imperfections,[3,5] may be employed with manual data reduction at great expense in time and with limited accuracy. With microprocessor processing of the information, the technique may be applied conveniently and effectively. **Figure 6** shows response characteristics produced by digital signal-processing algorithms from the raw swept data illustrated in References 3, 5 and 6. **Figure 7** shows measurements derived from a program using a windowed discreet Fourier transform algorithm to spatially focus on a GPC-7 to Type N male adapter with air lines preceding and following the unit. **Figure 8** shows insertion loss measurements of the 40 dB sections of two programmable attenuators. Air lines are used ahead of and behind the units and error-averaging acts as a low-pass digital filter to virtually eliminate mismatch uncertainties.

(continued on page 38)

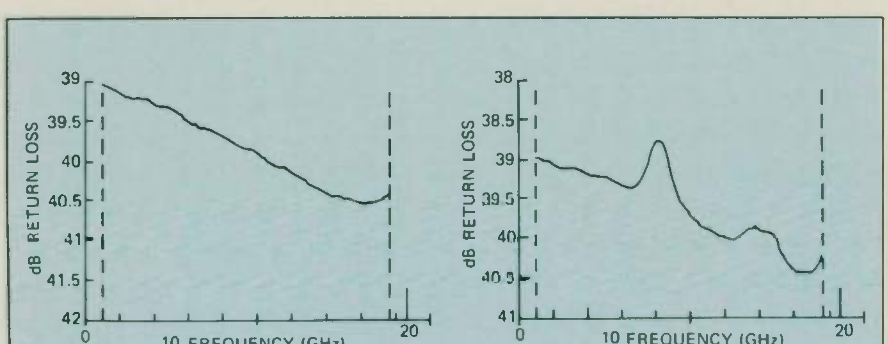

Fig. 8 Comparison of 40 dB sections measured on two programmable step attenuators. Plot on right shows variations due to radiated-mode coupling across the TEM attenuator structure.

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- Accuracy: to ± 0.05 dB
- Resolution: 0.01 dB

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- Automatic Zero Set
- Automatic Factor Compensator
- Auxiliary Tuning Meter
- Automatic Scale Indication
- Power Head Overload Indicator

Options:
- IEEE GPIB Bus interface allows communications with controllers or other instruments
- BCD Output provides a standard 1-2-4-8 parallel output
- Programmable Zero provides a remote zeroing capability

Model 476
Analog Power Meter

Key Specs
- 0.01 to 40 GHz frequency range
- Dynamic Range: 30 nW to 3W
- Accuracy: ± 1% of full scale

Features:
- Internal Calibrator
- Automatic Zero Set
- Automatic Factor Compensator
- Automatic Scale Indication

Option:
- Rechargeable Battery Pack allows for field and other portable applications.

Both models operate with GMC Series 4200 coaxial and waveguide power heads ranging in frequency to 40 GHz, and power measuring capability to 3 watts. All power heads feature field-replaceable sensing elements. Another unique feature is that the power meter-power head assembly calibration can be checked at the power meter front panel using a built-in power standard without disconnecting the power head from the RF system.

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Tel: 516-694-3600

(from page 36) ENHANCEMENT

The second attenuator data shows cyclic variations due to radiated-mode coupling across the TEM attenuator structure.

CONCLUSION

Precise and convenient broadband microwave measurements still require high quality components, such as swept sources, switches, directional coupler, reflection bridges, detectors, etc. Thence, from a firm basis of quality hardware, the microprocessor can control and normalize many components functions and process the RF data to reduce residual errors and format data rapidly for the microwave engineer.

REFERENCES

1. Lacy, P., "Intelligent & Social Instruments for Microwave Tasks," *Microwave Journal*, May 1979.
2. Weinert, F. K., and B. O. Weinschel, "A 1-18 GHz Attenuator," *IEEE Trans. IM*, Dec., 1976.
3. Lacy, P., and W. Oldfield, "A Precision Swept Reflectometer," *Microwave J.*, Apr. 1973.
4. Hollway, D. L., and P. I. Somlo, "Origin of High-Resolution, Swept-Frequency Reflectometry," *Microwave J.*, Aug. 1973.
5. Dunwoodie, D., and P. Lacy, "Why Tolerate Unnecessary Measurement Errors," WILTRON Technical Review No. 5, June 1979.
6. Lacy, P., and W. Oldfield, "Calculable Physical Impedance References in Automated Precision Reflection Measurement," *IEEE Trans. IM*, Dec. 1980.

Robert H. Bathiany joined Wiltron Company in 1972 as Engineering Manager for RF and Microwave Instrumentation, including network analyzers and sweeper design and the development of microwave link testing upconversion techniques. He received his BSEE and MSEE from the University of Washington in Seattle, and consulted on electronic processing methods associated with gas chromatographic chemical analysis. He served on the Steering Committee for the 1975 Microwave Symposium, and is a member of the committee organizing the 1984 Symposium.

Dr. Peter Lacy was a founder in 1960 of Wiltron Company, a manufacturer of electronic measurement systems and components for microwave, RF, and telecommunications applications, and now serves as Chairman of the Board. He received a BSEE from the University of Florida. In the Navy, he coordinated projects in ECM on power sources and radar targets in Washington, DC, later serving on the Pacific Fleet Headquarters staff and the Naval Technical Commission to Japan. He received MS and PhD degrees from Stanford, and studied microwave noise in electron beams. At Hewlett Packard for ten years, he led R&D on microwave tubes and developed related instrumentation. Dr. Lacy served as chairman of the MTT chapter, IEEE section, and 1966 Microwave Symposium. He has served on several national committees and is a IEEE Fellow.

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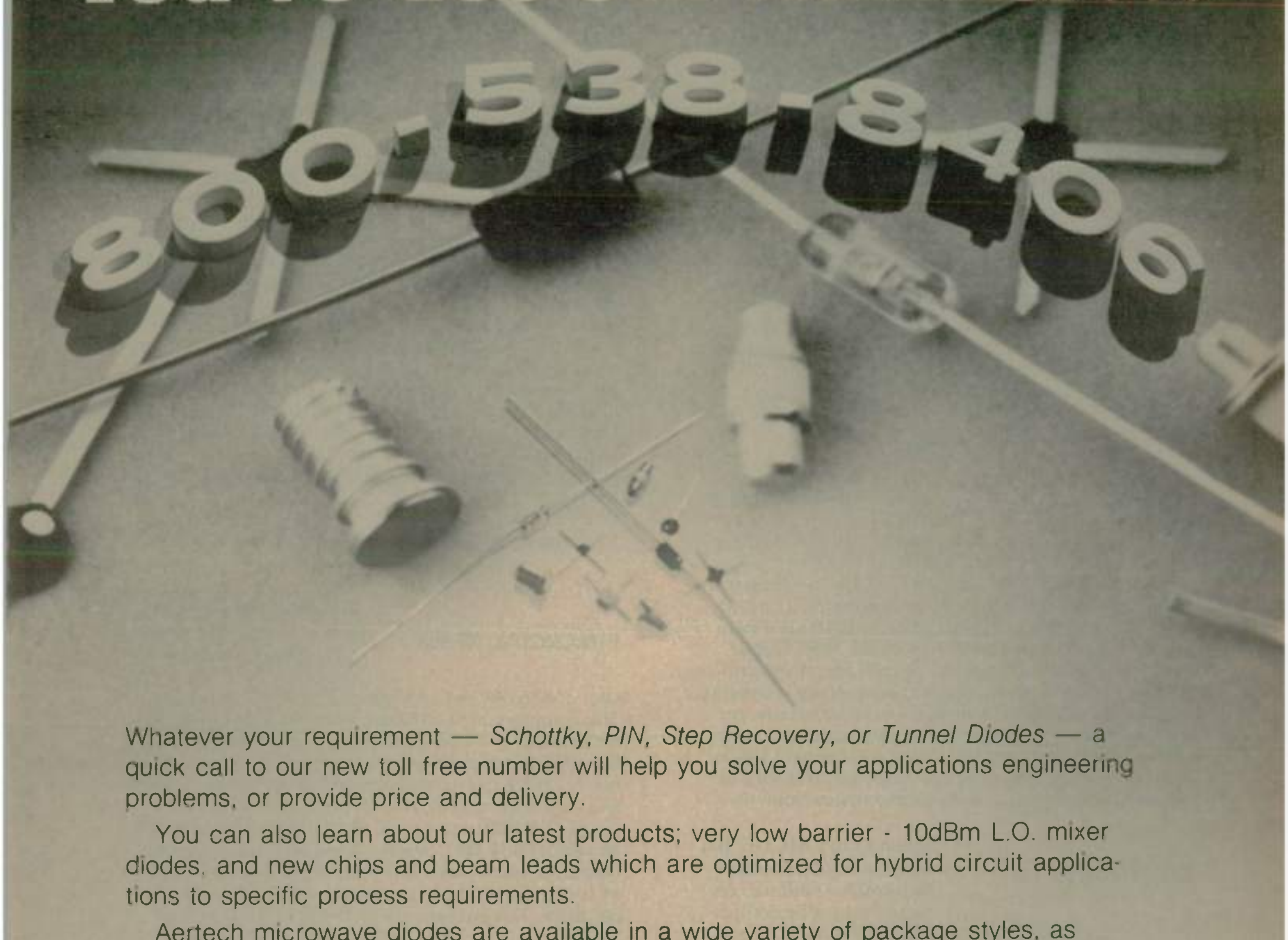

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CIRCLE 28 ON READER SERVICE CARD

Around the Circuit

PERSONNEL

John R. Martin was appointed Western Regional Sales Manager for Keene Corporation's Chase-Foster Laminates Division. . .**Richard Fritz** was appointed Operations Manager, Daico Industries, Inc. . .General Microwave Corp. announced the promotion of **Bernard Grand** to V.P.-Engineering. . .**Robert W. Van Ness** joined Adams-Russell Co. Inc. as Corporate Director of Human Resources. . .Under a corporate reorganization plan at Omni Spectra, Inc.'s Eastern Operations, the Microwave Connector and Components Divisions are consolidated into one sales and marketing group under the direction of **John C. Callahan**, Dir. of Marketing, and **Ernest J. DeVita**, V.P. of Sales. . .Scientific-Atlanta, Inc. named **Delwin Bothof** as its Vice President-Marketing. . .**Gordon E. Eubanks** was promoted to V.P., Marketing at Whittaker Corp.'s Electronic Resources Division. . .**Dr. L. A. Cambey**, Senior V.P. of Materials Research Corp. has been promoted to Executive V.P.

1981 IEEE FELLOWS IN MICROWAVE ENGINEERING

Recipients of the award include: **James W. Duncan**, TRW, Inc, for development of communications satellite antennas; **Nabil H. Farhat**, U. of Penn., for work in microwave holography and E.E. education; **Robert V. Garver**, Harry Diamond Labs, for development and understanding of the limitations of broadband solid state microwave switches; **Yoshihiro Konishi**, NHK (Japan Broadcasting Corp.), Technical Rsch. Labs., for contributions to microwave component technology in satellite broadcasting; **Nobuaki Kumagai**, Osaka University, for contributions to the study of wave propagation in electromagnetics, optics and acoustics; and **Leonard Lewin**, University of Colorado, for contributions to theory of waveguides, antennas and microstrip transmission lines.

CONTRACTS

Eaton Corp's AIL Div. has been awarded a contract to provide a national, system of air traffic control to the Federal Civil Aviation Administration of Yugoslavia. . .Contracts from **Loral Electronic Systems** for the F-15 ECM system, **Applied Technology Div. of Itek** for Compass Tie and from **Westinghouse** for AN/ALQ-131 represent $2M in solid-state control device orders for **Alpha Industries, Inc. Alpha** also received a contract from **California Microwave, Inc.** valued at $260K for GaAs FET low noise amplifiers for use in a Mexican telecommunications network. . .**California Microwave, Inc.** announced the signing of a long-term purchase contract valued at $18.6M with **AT&T** for CA42 transmitting amplifier systems. . .**Northrop Corp.** was awarded contracts totaling $63.3M by the USAF for continued production of ECM equipment for F-15 fighter aircraft. . .**Loral Corp.** received a contract valued at $78M to furnish its Rapport III Self-Protection System to a friendly foreign nation.

INDUSTRY NEWS

M/A-COM, Inc. and **Microwave Power Devices, Inc.** announced completion of the transaction whereby MPD becomes a M/A-COM company. In another action, **Microwave Associates, Inc.**, announced that its new $6M, 22,000 sq. ft. Silicon Materials Division's epitaxy facility will begin operations in April 1981. . .**Omni Spectra, Inc.** is currently expanding operations in the Merrimack, NH plant from 42,000 sq. ft. to 87,600 sq. ft. to be completed in May, 1981. . .Also expanding plant size is **Epsilon Lambda Electronics Corp.**, which is adding a new building with 3,000 sq. ft. for engineering and administration and 10,000 sq. ft. for manufacturing millimeter components. . .**Materials Research Corp.** is also expanding its plant with 65,000 sq. ft. of production floor space for its ceramic substrate operation. Concurrent with the plant growth, the company has placed in operation a CO_2 laser system for high precision machining. . . Also growing is **Tecknit, Inc.**, of Santa Barbara, CA, which has nearly doubled its plant's production facilities to 30,000 sq. ft. . .COMSAT and **Radiation Systems, Inc.** (RSI) announced that they have entered into an agreement which authorizes RSI to manufacture and sell a variety of COMSAT designed Multiple Beam Torus Antennas. . .**General Instrument Corp.** has reached an agreement in principle with **SED Systems, Inc.** of Canada which licenses General Instrument to manufacture and market television receive only (TVRO) and direct broadcast satellite to home earth station (DBS) equipment using patents and technology developed by SED Systems. . . .**Keene Corporation's Chase-Foster Laminates Division** has started a new production line for its Di-Clad line PC board materials believed to be the largest dedicated to microwave PC board material production.

FINANCIAL NEWS

Scientific-Atlanta, Inc. reported second quarter results for the period ended December 31, 1980 of net sales of $65.0M, net earnings of $4.2M or 40¢ per share. This compares with 1979 quarterly net sales of $46.5M, net earnings of $2.95M or 32¢ per share. . .**M/A-COM, Inc.** reported that during the first quarter ended December 27, 1980, net income was $6.95M or 20¢ per share and sales totaled $102.7M. This compares with first quarter FY1980 net income of $3.6M, or 12¢ per share on sales of $64.5M. . .**Varian Associates, Inc.**, reported results for fiscal year 1980 ended September 30, 1980 of sales of $620.9M, net earnings of $22.1M or $2.77 per share. This compares with 1979 results of sales of $493M, net earnings of $8.6M, or $1.15 per share. . . **Electromagnetic Sciences, Inc.** reported year-end net earnings of $403K, earnings per share of 43¢ and sales of $6.3M for the period ended February 20, 1981. This compares with 1979 net earnings of $262K, earnings per share of 30¢ and sales of $5.1M. . .For the second quarter ended January 23, 1981, **Sanders Associates, Inc.** reported 1981 results of net sales of $81.2M, net income of $5.6M or 71¢ per share. This compares with 1980 quarterly net sales of $71.9M, net income of $4.4M or 70¢ per share. . .**Adams-Russell, Inc.** reported first quarter results for the period ended January 4, 1981 of net sales of $10.7M, net income of $814K or 25¢ per share. This compares with 1980 first quarter net sales of $8.0M, net income of $529K or 19¢ per share.

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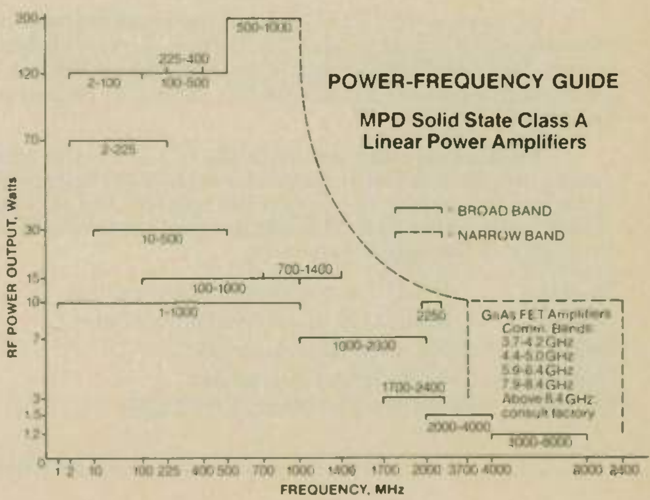
Higher powers, higher frequencies, more design and performance features, more models to fit your applications—that's the continuing story of MPD Class A solid state linear amplifiers. The result is a product line that nobody else in the industry—*repeat, nobody*—can even come close to matching!

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!



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CIRCLE 23 ON READER SERVICE CARD

A Unique Multi-octave Signal Generator...

Dear Signal Generator User:

Several manufacturers supply .01 to 40 GHz signal sources, but there are five distinct reasons — differences — why you should consider the Micro-Tel SG-811 Swept Signal Generator.

1 - It is truly a signal generator with RFI shielding, low harmonic output, and -120 dB output power control.

2 - The internal pulse generator is variable from .05 to 100 microseconds, 100 to 10,000 pps and has a pulse On-Off ratio of 70 dB.

3 - It has been specially ruggedized for field use. The reliability performance of several hundred units attests to its construction and basic quality design.

4 - The RF Unit is independently shielded and mounts inside the generator. However, it may be removed and located up to 200 feet from the main frame — an ideal feature for system test purposes.

5 - An accessory FS-1000 Frequency Synthesizer can be added to give frequency control in 100 Hz steps with commensurable accuracy and stability.

6 - Another accessory, the FE-811, extends frequency coverage from 18 to 40 GHz while retaining all features including fast pulse generation and synthesized operation.

If any of these six features are important, you should consider the SG-811, since they are not provided in other multi-octave signal generators or sweepers.

Of course, the SG-811 has all the usual features of modern sweep signal generators: Delta F, F_1-F_2, full band sweep, five presettable frequencies, FM-AM, as well as pulse modulation, and IEEE-488 bus control of frequency and power output.

Another valuable feature of the SG-811 is the wide variety of options permitting the user to tailor the instrument to his specific needs. The option list follows, and is worth some careful study since it illustrates the fundamental versatility of this signal generator.

SG-811A	- 2-18 GHz - 8 mw leveled power output
G-811B	- 2-18 GHz - 12 mw leveled power output
Option 1	- Adds .01-2 GHz coverage
Option 2	- 110 dB Output Attenuator
Option 3	- 60 dB Tracked Filter, 1.9-18 GHz
Option 3A	- 60 dB Tracked Filter, .40-18 GHz
Option 4	- RF Sample
Option 5	- Pulse Generator 70 dB On-Off
Option 6	- Digital Frequency Control
Option 6A	- Digital Control - IEEE-488
Option 7	- 12 VDC Input
Option 8	- Protective Cover
Option 9	- Offset Power Level
Option 10	- Provision for 18-40 GHz Coverage
RCC-811	- Cable for Remote RF Assembly
C-811	- Fitted Fiberglass Carrying Case

The power outputs noted above are without options. Output is reduced in varying amounts by the attenuator, filter, and pulse options, but is always in excess of 0 dBm with the SG-811B.

The internal pulse generator is one of the most useful options for EW and ECM system checkout. In addition to the 70 dB On-Off ratio, the rise time is guaranteed to 20 nanoseconds maximum, and is typically less than 10 nanoseconds.

The Removable-Remotable RF Unit is very useful for ramp testing of EW and ECM systems. For example, the RF Unit may be located in the vicinity of an EW antenna. Cable loss is eliminated and one man can perform system measurements with the SG-811 located at the EW console.

The FS-1000 Frequency Synthesizer allows the operator to "tune it digital — or tune it analog." Digital tuning is by means of a conventional keyboard and microprocessor. In the analog tuning mode, a continuously variable encoder control knob gives the "feel" of conventional tuning in selected steps from 100 Hz to 1 MHz. This feature combines the convenience of both analog and digitally synthesized frequency control. The FS-1000 is IEEE-488 bus-controlled or operable from its own micro-processor. The Synthesizer can be switched out at any time to restore normal sweep or CW operation — very useful in some applications.

The FE-811 Frequency Extender is a convenient means of extending frequency coverage from 18 to 26 and 26 to 40 GHz. All control is from the panel of the SG-811; however, the most important feature is the retention of the fast pulse modulation capability to 40 GHz — ideal for EW/ECM measurements — and the capability for synthesized frequency generation to 40 GHz when used with the FS-1000 Frequency Synthesizer.

The SG-811 is in widespread use commercially, as well as in the U.S. Military, NATO, and the armed forces of numerous other countries. Why not investigate whether it will fit your application.

Detailed data sheets are available upon request, we can demonstrate at your convenience and location, or a no-charge purchase order will bring you an SG-811 for a one-week, no-obligation evaluation.

We'll be looking for your call or letter.

Sincerely,

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CIRCLE 31 ON READER SERVICE CARD

News from ★ Washington

GERALD GREEN, Washington Editor

LAMPS Mk III Program Costs Go Over-the-Horizon

With total program costs up to $7 billion, representing a cost growth of nearly 100 percent in 16 months, and with results of a recent General Accounting Office (GAO) investigation raising questions about the ability of LAMPS (Light Airborne Multipurpose System) Mk III to carry out its missions, the scrutinizing eyes of Congress, Department of Defense, and the Office of Management and Budget will certainly give the program critical review.

LAMPS Mk III is a computer-integrated ship and helicopter system designed principally for antisubmarine warfare (ASW) with secondary mission capabilities of antiship surveillance and targeting (ASST), search and rescue, medical evacuation, and logistics support. The program is currently in full-scale development and is scheduled for deployment aboard cruisers, destroyers, and frigates.

GAO investigators, based on their investigation, report concern about the reduced number of helicopters the Navy is planning to procure (because of skyrocketing program costs), potential for reliability and maintainability problems, and the potential for continuing cost increases in the LAMPS Mk III program.

Advanced Technology Program Initiated for Small Business

An Advanced Technology Program has been established for small business firms by the Department of Defense in order to increase the participation of such firms in DoD's research and development initiatives and to capitalize on the creative potential of small high technology firms.

Approximately 20 research and development project areas of particular interest to the Army, Navy, Air Force and Defense Advanced Research Projects Agency (DARPA), will be identified for exploration under a three-phase program.

Phase I awards of up to $50,000 each are contemplated for preliminary research and development to demonstrate the feasibility of those proposals deemed most likely to yield solutions to R&D problems identified by the Military Departments and DARPA.

Contracts under Phase I will last for six months. Based on the results of Phase I efforts, DoD plans to award advanced development contracts ranging from $100,000 to $500,000 each in Phase II for a period of up to two years for the projects judged most promising. Phase III will include follow-on DoD production awards, where appropriate, and/or commercial application of the research and development. Commercial application would be funded with private venture capital.

A key figure of the program is its streamlined procedure for reducing the small firm's initial investment in proposal writing. Phase I proposals are limited to 20 pages.

The Defense Small Business Advanced Technology Program is not intended to be a substitute for current unsolicited proposal mechanisms. According to DoD, it is designed to augment existing acquisition processes and to better inform DoD research offices of the technological potential of the small business community.

The Defense Small Business Advanced Technology Program Brochure is scheduled for distribution in April 1981, with proposals to be submitted to the respective Services and DARPA by August 31, 1981. Awards are expected to be made in December 1981.

Program information may be obtained by writing to:

Director for Small Business & Economic Utilization Policy
Office of the Under Secretary of Defense
Research and Engineering (Acquisition Policy)
Room 2A340, The Pentagon, Washington, D.C. 20301

Balloon-Borne Radars — Back to Basics

The first incident of aerial surveillance was reported to occur in the United States during the Civil War when Union troops raised a balloon in Virginia, near Washington, DC to spy on Confederate troop movements.

Despite the trend to surveillance from satellite platforms in space, it now appears that the Air Force, followed by Treasury's Customs Service, is going back to basics and again using balloon platforms for surveillance.

The Air Force is already using a balloon-borne radar, part of the SEEK SKYHOOK program, to keep an eye on air and sea approaches to the southeastern United States, as part of the North American Air Defense Command's radar early warning system.

News from ★ Washington

Now the Customs Service also has a program to utilize a balloon type platform (they call it an aerostat) to carry a surveillance radar.

According to John Schoolmeester, head of Custom's Engineering Service Branch, Customs plans to float their tethered aerostat, which resembles a miniature SEEK SKYHOOK, at a 3,000 foot altitude to give their radar an effective position to look for smuggling boats and aircraft.

Richard D. Delauer Confirmed Under Secdef for Research & Engrg.

Dr. Richard D. DeLauer has finally been confirmed as the new Under Secretary of Defense for Research and Engineering, perhaps the most powerful research and engineering position in the world. Dr. DeLauer was officially confirmed after actually working on the job for about a month.

He comes to DoD from TRW Inc., where he was an Executive Vice President with responsibility for the Company's Industrial Operations, Systems and Systems Application Center groups. Those operating units employ more than 14,000 people and provide a wide variety of products and services for aerospace, electronic, industrial and commercial markets.

Dr. DeLauer is considered an expert in nuclear propulsion and is the co-author of two books on that subject, "Nuclear Rocket Propulsion" and Fundamentals of Nuclear Flight.

He replaces Dr. William J. Perry who served as Under Secretary for Research and Engineering in the Carter administration.

USAF's Electronic Systems Div. Awards "Leader-Follower" Contract

The Electronic Systems Division of Air Force Systems Command recently awarded its first "leader-follower" contract which will qualify two companies for later production awards and hopefully result in delivery of a better product.

"Leader-follower" contracts are awarded to one company with the stipulation that the firm share all contract responsibilities – such as designing, manufacturing and testing a product – with a second company. Either or both firms will be considered for follow-on production contracts.

"This is one of several 'tools' the Department of Defense encourages us to use to promote competition for systems that have high production order potential," said Maurice Fowler, Electronic Systems Division's Assistant Deputy for Contracting.

He explained, "Since first introduced, some 10 DoD systems contracts have included 'leader-follower' requirements in their final phase. The contract we recently awarded was for full scale, engineering development of the Joint Tactical Information Distribution System's (JTIDS) Class 2 terminal. JTIDS is a communication system that will make tactical battle information immediately available to Air Force pilots, Army personnel, and ground stations that control combat activities. A significant contract feature called for the 'leader' – Singer Company's Kearfott Division – to develop a 'follower' – Collins Government Avionics Division of Rockwell International – as a second production source. Besides, by promoting competition in the system's full scale engineering development stage, we also hope to get a better product."

According to Mr. Fowler, if the recently awarded contract proves successful, the Electronic Systems Divison may incorporate the "leader-follower" clause in other future contracts with high production potential.

Flight-Deck Communications System Secure Against Hostile and Friendly Interference

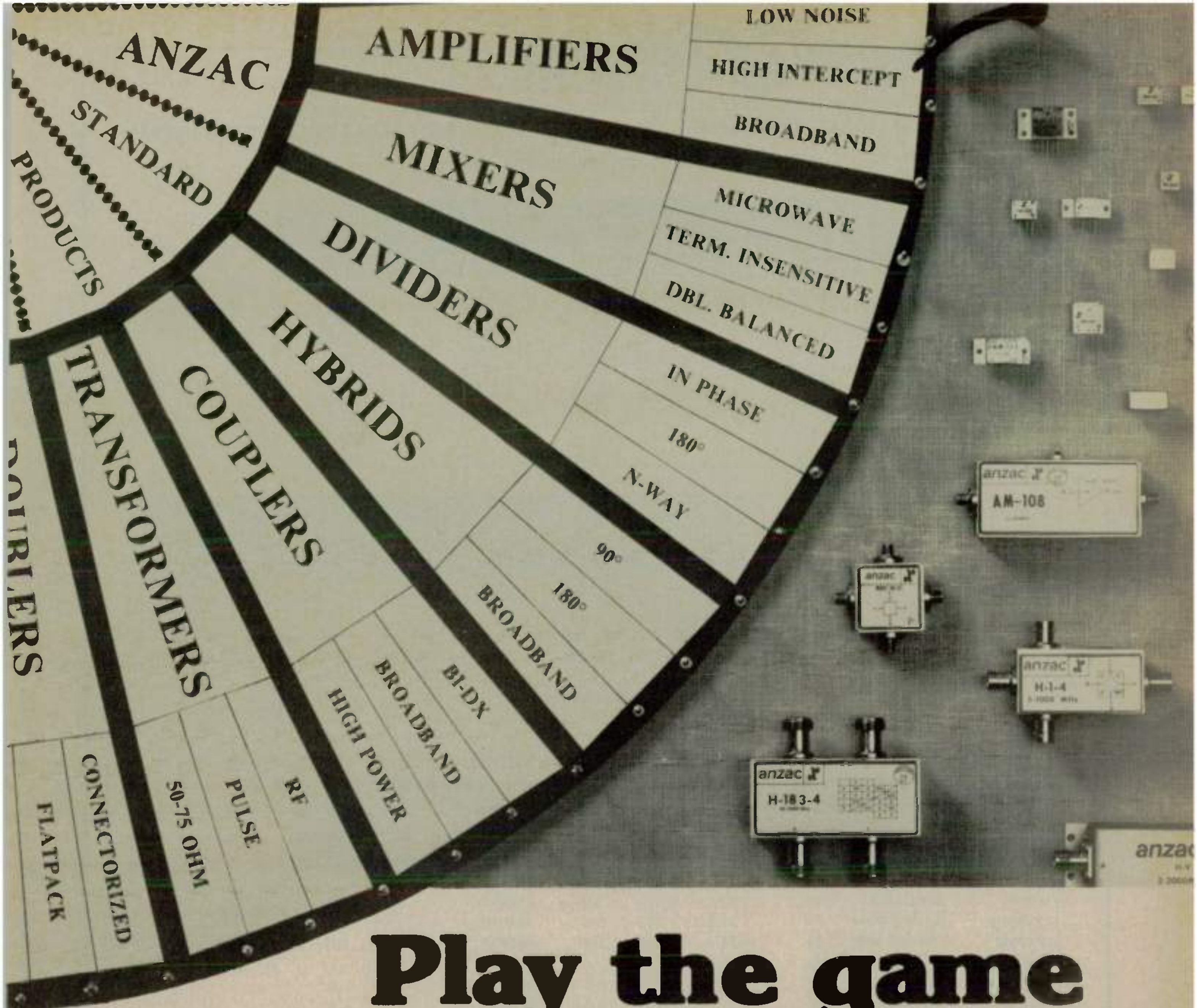
A radio system that permits flight deck crews of aircraft carriers to communicate effectively and is secured against hostile listeners was described at the Navy League Sea-Air-Space Exposition in Washington, DC recently.

The system effectively overcomes the noise of aircraft engines and radio frequency interference from other electronic communications equipment, said Andris Bikis, Product Manager at GTE's Communication Systems Division in Needham, MA, the developer of the system.

The short-range, intra-ship voice system includes a hand-held radio, protective communications helmet, vehicular transmitters and receivers, and fixed base-station equipment.

"Key features designed in response to operational needs which are not met with current equipment are secure voice, availability of 500 channels, and effective operation in an environment of very high noise levels," Mr. Bikis said.

He said the system underwent successful design verification trials aboard the *U.S.S. Independence* last fall and is scheduled for fabrication of service test models and formal test and evaluation.



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CIRCLE 32 ON READER SERVICE CARD

Amplifiers

• Ultra Low Noise • Wide Dynamic Range • Custom Design

Ultra Low Noise Amplifiers

Model Number	Frequency (MHz)	Min. Gain (dB)	Flatness (dB)	Noise Figure (dB) typ.	Noise Figure (dB) max.	Pwr. Out @ 1 dB Compression Pt. (dBm)	Case/ Connectors*
W50ETD	0.01-50	50	± .5	1.3	1.5	0	C/SMA
W50ETC	0.01-50	20	± .5	4.0	4.5	+ 23	C/SMA
W250G	5-250	43	± .5	1.3	1.5	+ 25	B/SMA
W500E	5-500	30	± .5	1.3	1.4	0	C/SMA
L60E-2	50-70	60	± .5	0.9	1.0	+ 10	C/SMA
L450E	400-500	27	± .5	1.2	1.4	+ 5	C/SMA
WIG2H	5-1000	30	± .5	1.3	1.5	+ 5	C/SMA
W2GHH2	1-2 GHz	30	± .5	2.3	2.5	+ 5	AB/SMA

Special Purpose Amplifiers

Model Number	Frequency (GHz)	Gain (dB)	Noise Figure (dB)	Pwr. Out @ 1 dB Compression Pt. (dBm)	Case/ Connectors
L13GE	1.25-1.35	25	2.2	+ 5	C/SMA
W89DGA	0.47-0.89	25	2.0	+ 5	C/SMA
L215GA	2.15-2.165	11	3.2	−3	C/N
L215GC	2.15-2.165	29	2.9	+ 7	C/N
W2GH	0.5-2.0	25	3.0	+ 10	B/SMA
P150P	0.08-150 MHz	60	1.5	+ 30	H/BNC
W15GB1	0.05-1.5	20	1.8	−3	C/SMA
W23GA	0.1-2.3	8	9.0	+ 20	C/SMA

Wide Dynamic Range Amplifiers

Model Number	Frequency (GHz)	Min. Gain (dB)	Pwr. Out @ 1 dB Compression Pt. (dBm) typ.	Pwr. Out @ 1 dB Compression Pt. (dBm) min.	Noise Figure (dB)	Case/ Connectors	Typical Intercept Pt. (dBm)
P60F	30-90 MHz	30	+ 32	+ 31	5.5	H/BNC	+ 43
P150H2	0.1-150 MHz	27	+ 31.5	+ 30	6.5	H/BNC	+ 44
P175M	150-200 MHz	23	+ 34	+ 33	8.0	H/BNC	+ 45
P400C	10-400 MHz	20	+ 31	+ 30	7.0	H/BNC	+ 42
P500N	2-500 MHz	17	+ 31	+ 30	8.0	H/BNC	+ 42
P10GL	0.5-1.0	30	+ 31	+ 30	5.0	H/SMA	+ 42
P2GS-7	0.5-2.0 GHz	30	+ 30	+ 29	10.0	FS/SMA	+ 42
P24GB	1.4-2.4	16	+ 20	+ 19	8.0	A/SMA	+ 32

CASE DIMENSIONS:
(Others Available)

	L (in.)	W (in.)	H (in.)
C	1.875	1.875	0.465
A	3.375	1.875	0.465
H	3.75	2.60	1.95
AB	3.00	1.875	0.465
B	2.625	1.875	0.465
FS	4.5	2.8	1.1

*Standard this model; others may be specified.
VSWR all models:
2:1 max, 1.5:1 typ.

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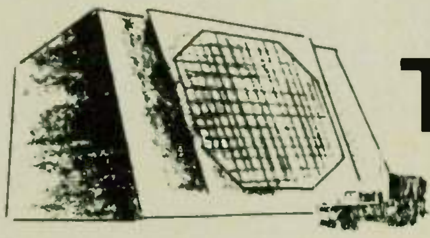

Antenna Technology

JOHN McILVENNA
Electromagnetic Sciences Division
Rome Air Development Center
Hanscom AFB, MA

Unattended or minimally attended radars require low power, lost cost, high reliability antenna technology. Under Contract F19628-78-C-0166, Sperry-Rand Corp. performed an overall antenna system configuration study for such an L-band radar system with a large phased array. A basic building block for such phased arrays is a dual beam elevation column network whose driving parameters are cost, loss, antenna pattern performance and reliability. A study of competitive fabrication techniques resulted in an exploratory model that was built using computer-aided design. A 12-foot experimental, printed circuit, dual beam stripline column weighed about 7 lbs. Insertion loss was approximately 1 dB, although resonances over the operating band raised the loss to about 2 dB. Further analysis showed that an alternative technique using a pressed laminate assembly meets all the mechanical and electrical performance specifications without the resonances, and can be built for about 300 dollars. With its associated support structure, it would weigh about 39 lbs.

Circular arrays are also candidates for unattended radars. They offer 360° scan and unlike multi-faced planar phased arrays, can provide a beam that remains undistorted as scan angle changes. Mechanically rotated antennas (such as reflector type antennas) can provide the azimuthal coverage but usually cannot provide the required data rate. Existing all-electronic circular arrays have some disadvantages. In a practical configuration, they require many active subassemblies with large loss, and they also require frequent maintenance. In addition, variations in subassembly characteristics due to component differences can cause variations in the beam characteristics with azimuth scan angle, as well as high sidelobes. Low power consumption and high reliability can be obtained in a mechanically scanned circular array by using a low inertia mechanically rotated commutator feed. Such feeds typically use capacitive coupling to transfer power from a rotating to a stationary transmission line that connects to the circular array elements. However, the capacitive coupling causes unacceptable loss and flutter or fluctuations in the radiated beam as it rotates. Under Contract F19628-79-C-0034, ITT Gilfillan has developed large-scale parallel-plate combiner/dividers that make use of a magnetic loop coupler. This device derives its properties from both a waveguide loop coupler and a 3 dB quarter-wave directional coupler. In the waveguide version, matched coupling to the dominant mode is obtained by proper quarter-wave transformation of the waveguide impedance to that of the coaxial input. Wide bandwidth is insured by coupling to the fields in a manner that minimizes impedance change thereby reducing the Q of the network. The use of magnetic loop couplers in a commutating feed provides low RF loss and inertia while limiting flutter to the narrow range of angles where the rotor loops pass over small gaps between adjacent stator loops.

Low sidelobe phased array antenna technology is represented by Contract F19628-78-C-0151 with Westinghouse Corp. The critical subunit in an S-band, polarization diverse, low sidelobe array, is a line source. One of these has been fabricated and tested, showing that S-band, low sidelobe performance over a wide bandwidth (200 MHz) is entirely within the capability of present design and fabrication technology. The line source required the development of wideband, high isolation couplers, a corporate-fed power divider in air dielectric stripline, and computer controlled punching, milling and drilling techniques. The test line source was a 14-foot long row of 64 crossed dipole elements. Seventy-two such line sources would comprise a 14-foot square L-band aperture capable of −35 dB first azimuth sidelobes and −38 dB, −41 dB and −50 dB for the second, third and remote sidelobes, respectively. The line source is 1.3 inches thick and weighs 33.4 lbs. Insertion loss is 1.1 dB. Error tolerances of 0.3 dB and 2.5° rms included both design and manufacturing errors.

Contract F19628-79-C-0157 with Raytheon, Wayland is a study of feed techniques for the space based radar program. Future spaced based radars will require antennas with low sidelobes, wide instantaneous bandwidth, beam agility and configurations that are lightweight, deployable and reliable. The contract provides a design study of overlapped subarray feed structures, the development and testing of a model, and delivery of a computer program that calculates the feed aperture fields for any given excitation. The system requirements include L-band operation, scan angle of ± 22.5°, a 3 dB beamwidth of 0.2°, near in sidelobes of −40 dB and remote sidelobes of −60 dB rms. The contract has explored the use of a two-dimensional transform feed to provide overlapped subarray illumination in an optically fed, active, lens phased array. The lens contains transmit/receive modules and/or phase shifters, and front and rear radiating elements. The feed includes time delay units, phase shifters and circulators. One trade-off examined was the selection of the Fourier transform network from among candidates that include the Rotman lens, the parallel plate lens, and the Butler or Blass matrices. Both the Butler and Blass matrices are microwave networks that create a set of phase steered beams through a matrix of transmission lines, couplers and phase shifters. Since the beams are generated by phase shifters, they will squint with frequency and distort the main beam illumination. The Rotman lens however, is a true time delay device that creates a set of beams which remain fixed as frequency changes; it was selected for this investigation. A key parameter in the design of a transform feed is the number of subarray beams. Computer studies have shown that for 40 dB sidelobes about 37 subarrays will be required. The design of the transform feed will be verified in an experiment that is a one dimension embodiment of the proposed device.

Contact: Dr. Robert Mailloux, RADC/EEEA, Antennas & RF Components Branch, 617-861-3710.

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Data
Data

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signal showers

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

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High Performance Microwave Ratio Meter

employs parallel IF complex vector substitution

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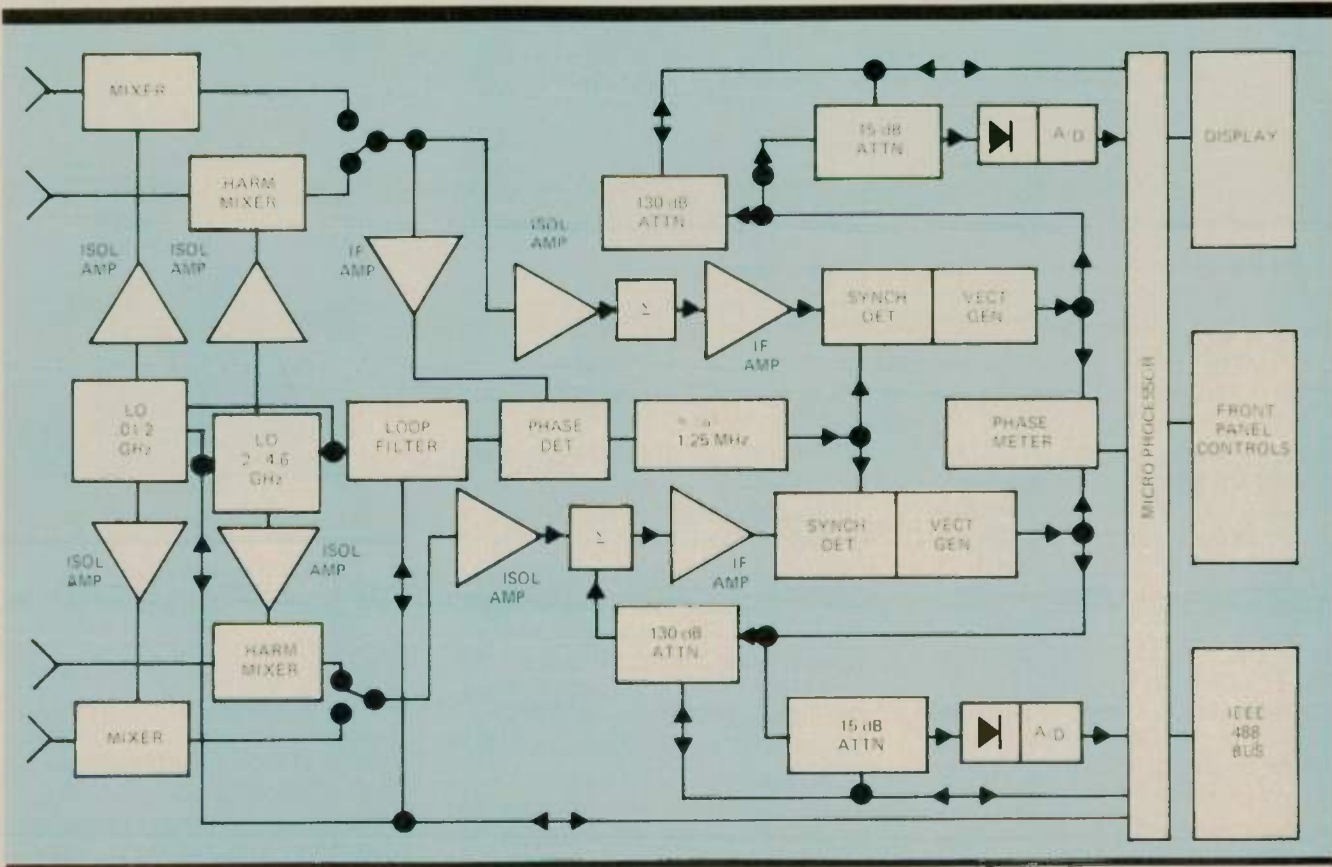

Fig. 1 Simplified block diagram of precision microwave vector ratio meter.

INTRODUCTION

A dual channel complex vector ratio meter has a greatly improved dynamic range and higher accuracy than presently available attenuator calibrators[1] or network analyzers.[5] Application of a new parallel IF vector substitution principle produces measurements in digital form over a 140 dB single step dynamic and display range with 0.001 dB and 0.01° resolutions for a 10 MHz - 18 GHz frequency range.

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It is operated manually or under internal or external program control in stepped or swept frequency modes, without the need for equalized cables. It performs S-parameter and insertion loss measurements. When under external computer or programmable calculator control, it makes use of self-calibration procedures to eliminate source and load mismatch errors[2] and reduces connector inaccuracies by applying frequency domain reflectometer routines.[3]

Signal-to-noise ratios are enhanced adaptively by control of the closed loop bandwidth of the vector substitution balancing loop. Adaptive digital averaging provides shortest measurement times consistent with the selected resolutions. Digital data processing, local oscillator tuning and tracking, internal programming and self-test functions are provided by two internal microprocessors. A simplified block diagram of the instrument is shown in Figure 1.

PARALLEL IF VECTOR SUBSTITUTION

The parallel IF vector substitution described in this paper is a high level complex vector of

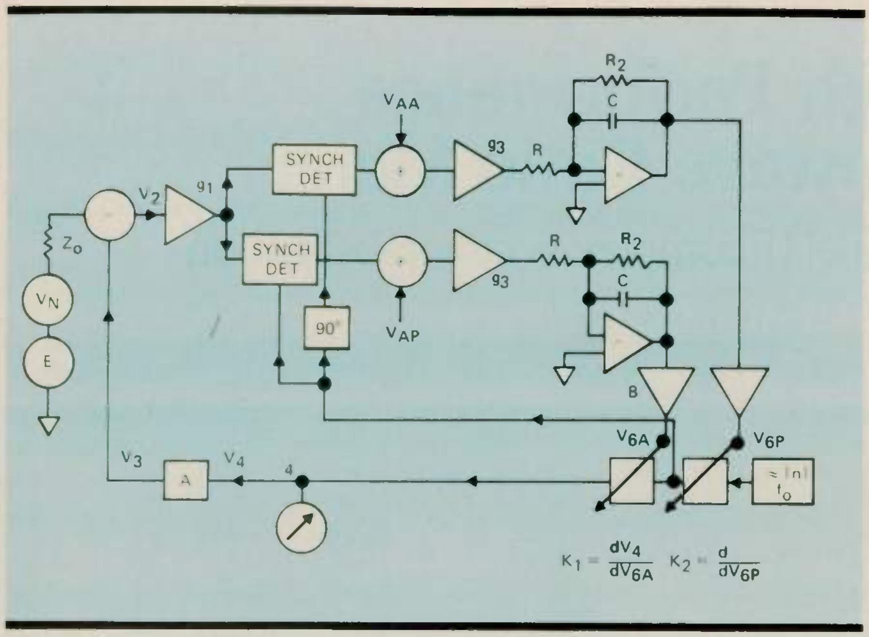

Fig. 2 Automatic IF vector substitution circuit block diagram.

$V_N = \sqrt{nkT_oZ_oB_W}$, n = system noise factor, $nkT_o = 4 \cdot 10^{-21}$ Watts/Hz.

B_W = system random noise bandwidth, $g_o = R_2/R_1$ = dc integrator gain

$f_o = 1/(2\pi RC)$ = unity gain frequency, $A = V_4/V_3$ = attenuator voltage division

known amplitude and phase generated by a high gain negative feedback balancing circuit and attenuated by a precision step attenuator of 130 dB in 10 dB steps.[4] This accurately known substitution vector is summed with the IF signal from the mixer. The feedback control loops keep the sum voltage at zero and therefore the substituted vector equal in amplitude and of opposite phase to the IF vector.

A simplified block diagram is shown in **Figure 2**. The IF vector substitution balancing circuit contains two high gain feedback loops, one for the control of the amplitude and the other for the control of the phase of the substitution vector. Their closed loop bandwidths are functions of the loop gains and are controlled adaptively in response to the measured signal level. At high levels the bandwidths are at their greatest values of about 500 Hz. For signal levels below -60 dBm they are gradually decreased to about 0.2 Hz. The output signal-to-noise ratio is enhanced in this way and is better than 40 dB for signal levels above -90 dBm and better than 20 dB for levels down to -140 dBm.

No signal modulation is required. The measurement of signals buried in noise is more accurate and/or faster than it is possible to do with measurement receivers using non-coherent envellope detectors. The latter suffers from the effect of signal compression by noise, leading to an effective square-law detection characteristic. In contrast, the described IF vector substitution principle has a linear detector transfer function which accounts for the greater dynamic range of the principle.

Figure 3 shows the vector diagram at the input of the balancing circuit. The IF vector V_2 coming from the mixer is added with the substitution vector V_3. The resulting sum vector V_3 is amplified by the IF amplifier and separately synchronously rectified in quadrature. This amounts to dc outputs one proportional to V_{2a} the other to V_{2p}, which are used to control the amplitude and the phase respectively of the 1.25 MHz crystal controlled reference signal in the direction of reducing V_2.

The control is achieved through high gain integrators. V_{2a} and V_{2p} are zero when perfect balancing is obtained, i.e. when V_2 equals V_3 and the known value of V_3 is substituted for V_2. Also the phase error is zero, i.e., V_3 and V_2 are of opposite phase. The dc integrator output voltages are fixed when V_{2a} and V_{2p} are zero.

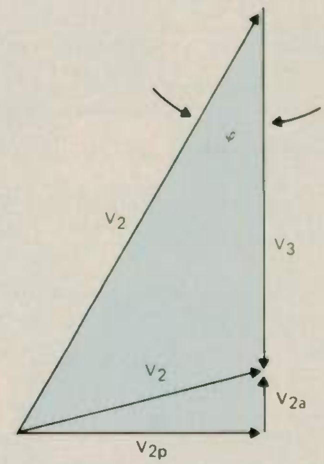

Fig. 3 Vector diagram.

The operation of the amplitude and the phase control loops become independent of each other in the vicinity of balance but their outputs are coupled when in a condition far off balance. The latter condition generally produces a controlled limiting operation with the output control voltages slewing.

The slew rates are optimized by design in order to keep the time of non-linear operation short. The closed loop transfer functions for the non-linear operation are complicated and their evaluation is cumbersome because of the wide variety of the possible initial conditions (any phase, ±140 dB ratio). They will not be discussed here, mainly for that reason that they do not contribute to the development of design parameters.

The near-balance closed loop transfer characteristics between the input IF vector V_2 and the vector $V_4 = V_3 \cdot A$ determine the performance of the system in equilibrium. They will be used to compare the parallel IF Vector substitution against other well established state-of-the-art methods.

The transfer functions become with the definitions in **Figure 2**.

$$V_4 = \frac{\dfrac{A(V_o + V_N + V_{AA}/g_1)}{1 + \dfrac{A}{g_o g_1 g_3 Bk_1}}}{1 + j\dfrac{f}{f_o}\dfrac{1}{\dfrac{1}{g_o} + \dfrac{g_1 g_3 Bk_1}{A}}} \approx \frac{A(V_o + V_N + V_{AA}/g_1)}{1 + j\dfrac{f}{f_o}\dfrac{A}{g_1 g_3 Bk_1}} \quad (1)$$

for the amplitude loop and

$$\varphi_4 = \frac{\dfrac{\alpha + (V_N + V_{AP}/g_1)/V_o}{1 + \dfrac{1}{g_o g_1 g_3 Bk_2 V_o}}}{1 + j\dfrac{f}{f_o}\dfrac{1}{\dfrac{1}{g_o} + g_1 g_3 Bk_2 V_o}} \approx \frac{\alpha + (V_N + V_{AP}/g_1)/V_o}{1 + j\dfrac{f}{f_o}\dfrac{1}{g_1 g_3 Bk_2 V_o}} \quad (2)$$

The steady state readout signals V_4 and φ_4 are composed as shown in Equations 1 and 2 of the true signal voltage $V_4 \cdot A \exp \alpha$, an amplitude offset voltage $V_{AA} \cdot A/g_1$ an offset phase $V_{Ap}/(V_o \cdot g_1)$, an amplitude noise voltage $V_n \cdot A$ and a phase noise V_N/V_o.

The dynamic responses of the closed loops are those of single pole filters and can be characterized by their time constants.

$$T_A = \frac{1}{2\pi f_o \cdot \left(\dfrac{1}{g_o} + \dfrac{g_1 g_3 Bk_1}{A}\right)} \approx \frac{A}{2\pi f_o g_1 g_3 Bk_1} \quad (3)$$

and

$$T_P = \frac{1}{2\pi f_o \cdot \left(\dfrac{1}{g_o} + g_1 g_3 Bk_2 V_o\right)} \approx \frac{A}{2\pi f_o g_1 g_3 Bk_2 V_4} \quad (4)$$

B_{WNA} and B_{WNP} are the random noise bandwidths of the closed amplitude and phase loops respectively and are,

$$B_{WNA} = \frac{1}{4T_A} = \frac{\pi f_o g_1 g_3 Bk_1}{2A} \quad (5)$$

$$B_{WNP} = \frac{1}{4T_P} = \frac{\pi f_o g_1 g_3 Bk_2 V_4}{2A} \quad (6)$$

The amplitude loop output signal to noise ratios are considering the synchronous detection sideband folding from Equation 1.

$$\left(\frac{V_s}{V_N}\right)_A = \frac{V_o}{\sqrt{nkT_o Z_o 2B_{WNA}}} \quad (7)$$

For a random noise error defined as three times the standard deviation for any set of measurement observations (99.73% probability that each observation will fall within the specified random error limit) we obtain for the amplitude loop the three sigma noise error in dB as.

$$NE_{A3\sigma} = 20 \log \left(1 + 3\left(\frac{V_N}{V_s}\right)_A\right) \quad [\text{dB}] \quad (8)$$

and from it

$$\left(\frac{V_s}{V_N}\right)_A = \frac{3}{10^{NE_{A3\sigma}/20} - 1} \quad (9)$$

and inserting Eq. (9) in Eq. (7) we obtain for the closed amplitude loop bandwidth required to obtain the 3 noise error at the output

$$T_A = \frac{1}{2B_{WNA}} = \frac{9nkT_o Z_o}{2V_o^2 (10^{NE_{A3\sigma}/20} - 1)^2} \quad (10)$$

Where P_o is the nominal input signal power. When expressed as input level S_o in dBm and with $N = 10 \log n$ = noise figure in dB we get

$$T_A = \frac{4.5 \cdot 10^{(S_o + 174 - N)/10}}{(10^{NE_{A3\sigma}/20} - 1)^2} \quad (11)$$

= closed amplitude control loop constant

In the same way we obtain the signal to noise ratio for the phase loop as

$$\alpha_N = \frac{V_N}{V_o} = \frac{\sqrt{nkT_o Z_o 2B_{WNP}}}{V_o} \quad (12)$$

and the 3σ noise error as

$$NE_{P3\sigma} = 3\alpha_N \quad [\text{rad}] \quad (13)$$

and substituted in Equation 12

$$T_P = \frac{1}{2B_{WNP}} = \frac{9nkT_o Z_o}{2V_o^2 \; NE_{P3\sigma}^2} = \frac{4.5 \cdot 10^{(S_o + 174 - N)/10}}{NE_{P3\sigma}^2} \quad (14)$$

where T_P is the closed loop time constant of the phase control loop required to obtain the 3 phase noise error NE_{P3}.

One of the practical aspects of an accurate measurement instrument which can operate under computer control is the desirability of performing the individual measurement observations in as short a time as possible. The total time for one measurement can be divided in the setting time and the processing time. The settling time is required for the signal to achieve its final value at the point where the actual measurement takes place. The processing time is the time required to convert the signal to a numerical value to be delivered to the outside as the measurement result. The time required in the linear single pole closed amplitude system for settling to an error ϵ from a step of a [dB] is.

$$t_{AS} = T_A \ln \frac{1 - 10^{a/20}}{1 - 10^{\epsilon/20}} \quad (15)$$

and for the linear closed loop phase control system for settling to a phase error δ from a phase step Δ is:

$$t_{PS} = T_P \ln \frac{\Delta}{\delta} \quad (16)$$

If the instrument would be implemented strictly by analog means, then the closed loop systems time constants for the required noise errors are given by Equations 11 and 14 and the required settling times become with Equations 15 and 16.

(continued on page 56)

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Peak Power — **10 kW**
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Model 41

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- dc — 18.0 GHz
- Power Rating: 10 W Avg., 1 kW Peak
- Standard Values — 3, 6, 10 and 20 dB
- Calibrated at Five Frequencies thru 18 GHz
- Stainless Steel WPM Connectors — Mate with SMA per MIL-C-39012

Circle Reader Service 102

High Power Fixed Coaxial Attenuators
Models 33, 34 & 35

25 WATTS

- dc — 8.0 GHz — Model 33
- dc — 4.0 GHz — Model 34
- dc — 1.5 GHz — Model 35
- High Power — 25 W Avg., 5 kW Peak
- Standard Values — 3, 6, 10, 20 and 30 dB
- Stainless Steel Type N Connectors — Mate with N per MIL-C-39012

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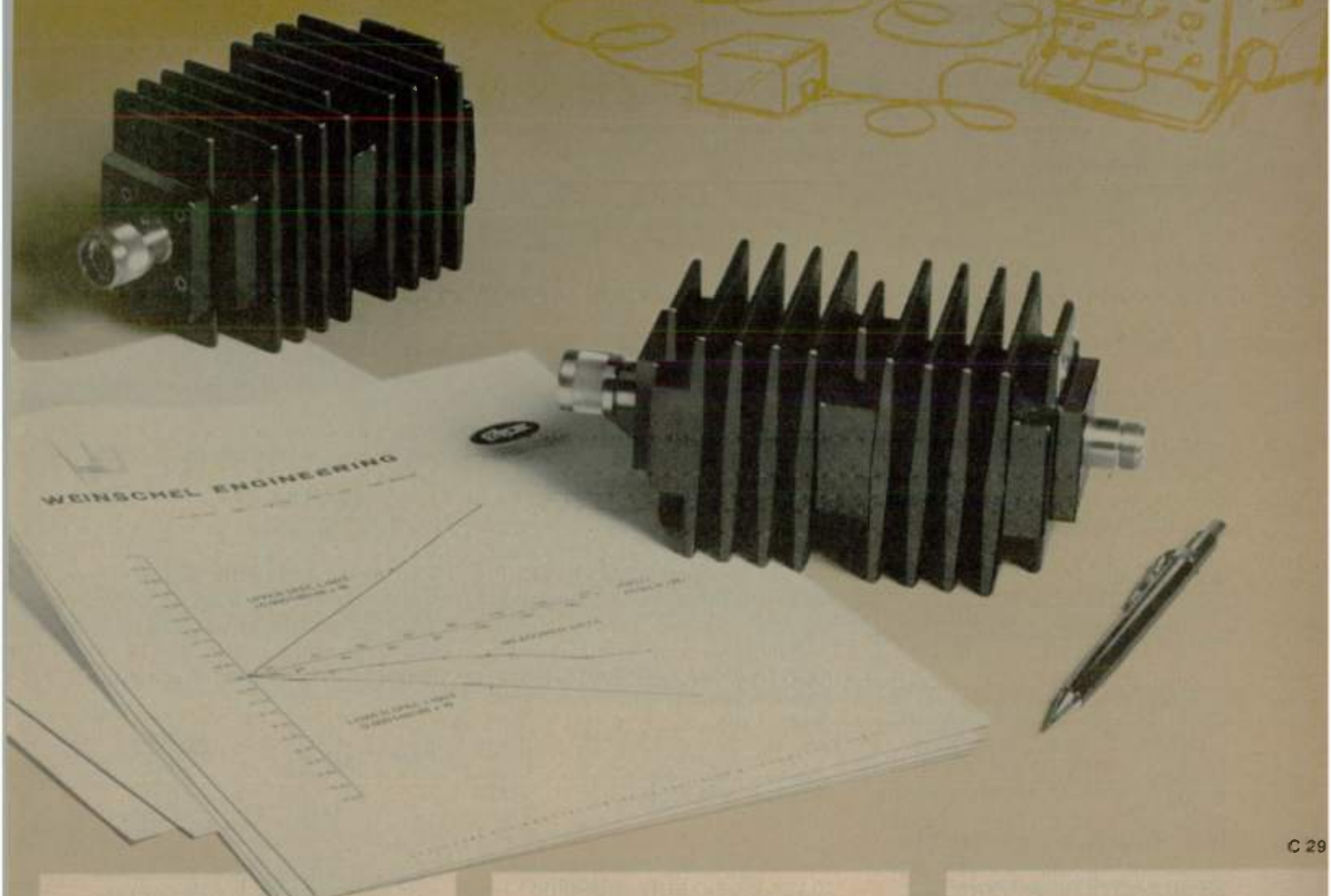
Terminations... Others are



C 29

High Power Coaxial Fixed Attenuators
Models 24, 25 & 26

50 WATTS
- dc — 8.0 GHz — Model 24
- dc — 4.0 GHz — Model 25
- dc — 1.5 GHz — Model 26
- High Power — 50 W Avg., 5 kW Peak
- Standard Values — 3, 6, 10, 20 and 30 dB
- Stainless Steel Type N Connectors — Mate with N per MIL-C-39012

Circle Reader Service 104

High Power Coaxial Terminations
Models 1426 & 1427

50 WATTS
- dc — 8 GHz
- High Power — 50 W Avg., 5 kW Peak — Model 1426 25 W Avg., 5 kW Peak — Model 1427
- Low VSWR — 1.30:1 Maximum
- Calibration Data — dc Resistance and VSWR Supplied
- Stainless Steel Type N Connectors — Mate with N per MIL-C-39012

Circle Reader Service 105

Miniature Medium Power Termination
Model 1419

10 WATTS
- dc — 18.0 GHz
- Power Rating — 10 W, 1 kW Peak
- Low VSWR — 1.35:1 Maximum
- Stainless Steel WPM Connectors — Mate with SMA per MIL-C-39012

Circle Reader Service 106

$$t_{AS} = \frac{4.5 \cdot 10^{-(S_o + 174 - N)/10}}{(10^{NE_{A3\sigma}/20} - 1)^2} \quad (17)$$

$$\times \ln \frac{1 - 10^{a/20}}{1 - 10^{\epsilon/20}}$$

for the amplitude control loop and

$$t_{PS} = \frac{4.5\ 10^{-(S_o + 174 - N)/10}}{NE_{P3\sigma}^{\ 2}} \ln \frac{\Delta}{\delta} \quad (18)$$

When this is compared with the settling time obtained for a system using a parallel IF substitution method with non-coherent detection[1] for which is:

$$t_{os} = 4.5 \ln \frac{1 - 10^{a/20}}{1 - 10^{\epsilon/20}} \Big/ B_{WIF} (10^{NE_{3\sigma}} - 1)^2 \left(\sqrt{1 + \frac{10^{(S_o + 174 - N)/10}}{B_{WIF}}} - 1\right)^2 \quad (19)$$

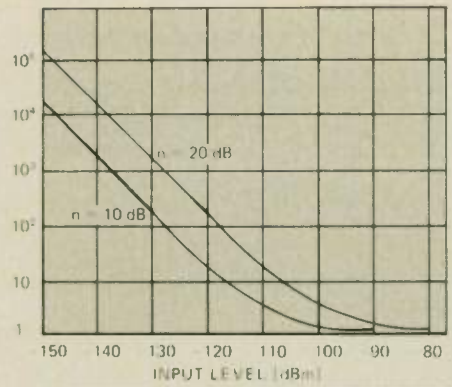


Fig. 4 Settling time improvement of IF vector substitution system over non-coherent detection meter.

Then the ratio of the amplitude settling times of the noncoherent detection system over the coherent vector substitution system or the settling time improvement by the latter becomes:

$$\frac{t_{OS}}{t_{AS}} = \frac{10^{(S_o + 174 - N)/10}}{B_{WIF} \left(\sqrt{1 + \frac{10^{(S_o + 174 - N)/10}}{B_{WIF}}} - 1\right)^2} \quad (20)$$

Equation 20 is plotted in **Figure 4** for a typical IF bandwidth of 100 kHz and systems noise figures of 10 dB and 20 dB. It shows that the IF vector substitution method provides an improvement in measurement time of a factor $1.6 \cdot 10^4$ at −140 dBm and 20 dB system noise figure.

The actual settling times are for a −10 dB step, and a settling error = 0.01 dB, N = 10 dB, and a 3σ noise error of 0.1 dB from Equation 17 and t_{as} = 1008 sec = 16.8 minutes (coherent IF vector substitution). $t_{os} = 1.6 \cdot 10^6$ sec = 446 hrs. = 18.6 days (noncoherent substitution). The improvement the parallel IF vector substitution principle offers is evident from these results, it is the difference between a feasible and an impossible measurement.

Digital data averaging has been used to advantage to shorten the total measurement time. The closed loop bandwidths have been made much wider than required for the random noise error of Equations 10 and 14. (The upper limit is given by practical considerations of avoidance of non-linear operations during the highest amplitude excursions.) This way, a short signal settling time is achieved with degraded signal to noise ratio. Digital averaging is used to improve the signal to noise ratio then to the required value.

Averaging is achieved by summing of m measurement samples and dividing the sum by m. This gives:

$$\left(\frac{V_s}{V_N}\right)_a = \sqrt{m} \left(\frac{V_s}{V_N}\right)_b \quad (21)$$

where $(V_S/V_N)_a$ = voltage signal to noise ratio after averaging $(V_S/V_N)_b$ = voltage signal to noise ratio before averaging, m = number of samples.

Equation 21 is only valid for statistically independent samples. When samples are taken from a band limited signal then the samples are statistically independent only when the sampling frequency is much less than the signal bandwidth. Implementing, this principle is inconvenient since it requires the determination of the analog bandwidth, the sampling rate (depending on the degree of independence required for the improvement sought) and the number of samples. A better way of operating the average is employed and described below.

The sampling frequency is made greater than the analog filter bandwidth. The frequency domain response of this system is that of a comb line filter with pass bands at multiples of the sampling frequency. No noise exists at these pass bands because of the analog filtering and therefore no extra noise is introduced. Neighboring samples are not statistically independent of each other. The transfer function for such an average is:

$$S_a = \frac{1}{t_i} \int_0^{t_i} f(t)\, dt \quad (22)$$

where S_a = output of signal averager at time ti for an input signal y = f(t).

For an input signal y = c · cos ωt Equation 22 becomes:

$$S_a = \frac{1}{t_i} \int_0^{t_i} c \cos(2\pi f t)\, dt \quad (23)$$

$$= c \frac{\sin(2\pi f t_i)}{2\pi f t_i}$$

The noise bandwidth for the fixed time t_i is obtained by integrating the squared transfer function amplitude divided by the maximum amplitude (c) squared

$$B_{WN} = \frac{1}{2\pi t} \frac{c^2}{c^2} \int_0^{\infty} \left(\frac{\sin(2\pi f t)}{2\pi f t}\right)^2 \quad (24)$$

$$\times\ d(2\pi f t') = \frac{1}{2\pi} \frac{\pi}{2} = \frac{1}{4 t_i}$$

Measurements samples are taken and digitized at 5 millisecond intervals and averaged over a period t_i.

By substituting Equation 24 into Equation 7 and 12 one obtains for the processing time (averaging time) for the amplitude control loop:

$$t_{AP} = \frac{4.5 \cdot 10^{-(S_o + 174 - N)/10}}{(10^{NE_{A3\sigma}} - 1)^2} \quad (25)$$

and for the phase control loop.

$$t_{PP} = \frac{4.5 \cdot 10^{-(S_o + 174 - N)/10}}{NE_{P3\sigma}^{\ 2}} \quad (26)$$

The total measurement time then is for the amplitude loop.

$$t_{TA} = t_{AP} + t_{AS} \qquad (27)$$
$$= 4.5\cdot 10^{-(S_o + 174 - N)/10}$$
$$\times \left(\frac{\ln \dfrac{1-10^{-a/20}}{1-10^{c/20}}}{(10^{ne_A} - 1)^2} + \frac{1}{(10^{NE_{A3\sigma}} - 1)^2} \right)$$

and for the phase control loop:

$$t_{TP} = t_{PP} + t_{PS} \qquad (28)$$
$$= 4.5\cdot 10^{-(S_o + 174 - N)/10}$$
$$\times \left(\frac{\ln \dfrac{\Delta}{\delta}}{ne_P{}^2} + \frac{1}{NE_{P3\sigma}{}^2} \right)$$

ne_a = 3σ noise error after analog filtering by the amplitude control loop in [dB]

ne_p = 3σ noise error after analog filtering by the phase control loop in (degrees)

For practical reasons the measurement times for the amplitude and the phase of Equation 27 and 28 have been made equal. Since the settling time contribution is small compared to the processing times, it follows for the 3 phase error (in degrees).

$$\frac{180}{\pi} 10^{NE_{A3\sigma}} - 1 = NE_{P3\sigma} \text{ [degrees]} \qquad (29)$$

which gives for the selectable amplitude resolutions

$NE_{A3\sigma}$	$NE_{P3\sigma}$
0.001 dB	0.0066 deg
0.01 dB	0.066 deg
0.1 dB	0.66 deg

COMPARISON OF PERFORMANCE

Table 1 give a performance comparison between the parallel IF-vector substitution principle and the non-coherent IF substitution method[1] for insertion loss measurements of a device under test with SWR's of 1.1. The theoretical achievable results together with the required measurement times are shown. Not included are times required for mismatch error correction processing. Levels are shown for the fundamental and second harmonic mixing modes (0.1 - 9.2 GHz). For fourth harmonic mode (8 - 18 GHz) the levels have to be 8 dB higher.

The mismatch error correcting routines are usable only with an attenuator pad in front of the test channel mixer for a dual channel system. Table 1 shows that the parallel IF vector substitution extends the measurement range to about 20 dB lower levels at same noise errors and equal or reduced mismatch uncertainty errors. Mismatch uncertainty errors below 0.06 dB and phase measurements can only be performed by the parallel IF vector substitution principle.

OTHER ERROR SOURCES

Transfer functions of closed loop negative feedback systems can be made independent of the open loop transfer function if the gain reduction by feedback is very large. This is achieved in the amplitude and the phase control feedback loops by the high dc gain of the active integrators employed, therefore, removing this as an error source. It should be noted that this is also the time for the phase shift of the IF amplifier which can have a tolerance of ± 60° without affecting the 0.01° accuracy of the system.

The accuracy of the precision attenuators is directly responsible for the accuracy of the system. Their accuracy and stability are consistent with the .001 dB systems resolution as described previously.[1] The attenuators are calibrated by the Weinschel Model PA-3 Laser Piston Attenuator below cutoff which employs temperature and air pressure corrections for thermal expansions of the waveguide and changes in laser-light wavelength and has a 0.0001 dB resolution. The incremental attenuation step errors are stored in a PROM and are automatically corrected for in real time.

Inspection of Equations 1 and 2 reveals dc offset signals at the integrator inputs as error sources. These offsets are generated by the operational amplifiers em-

(continued on page 60)

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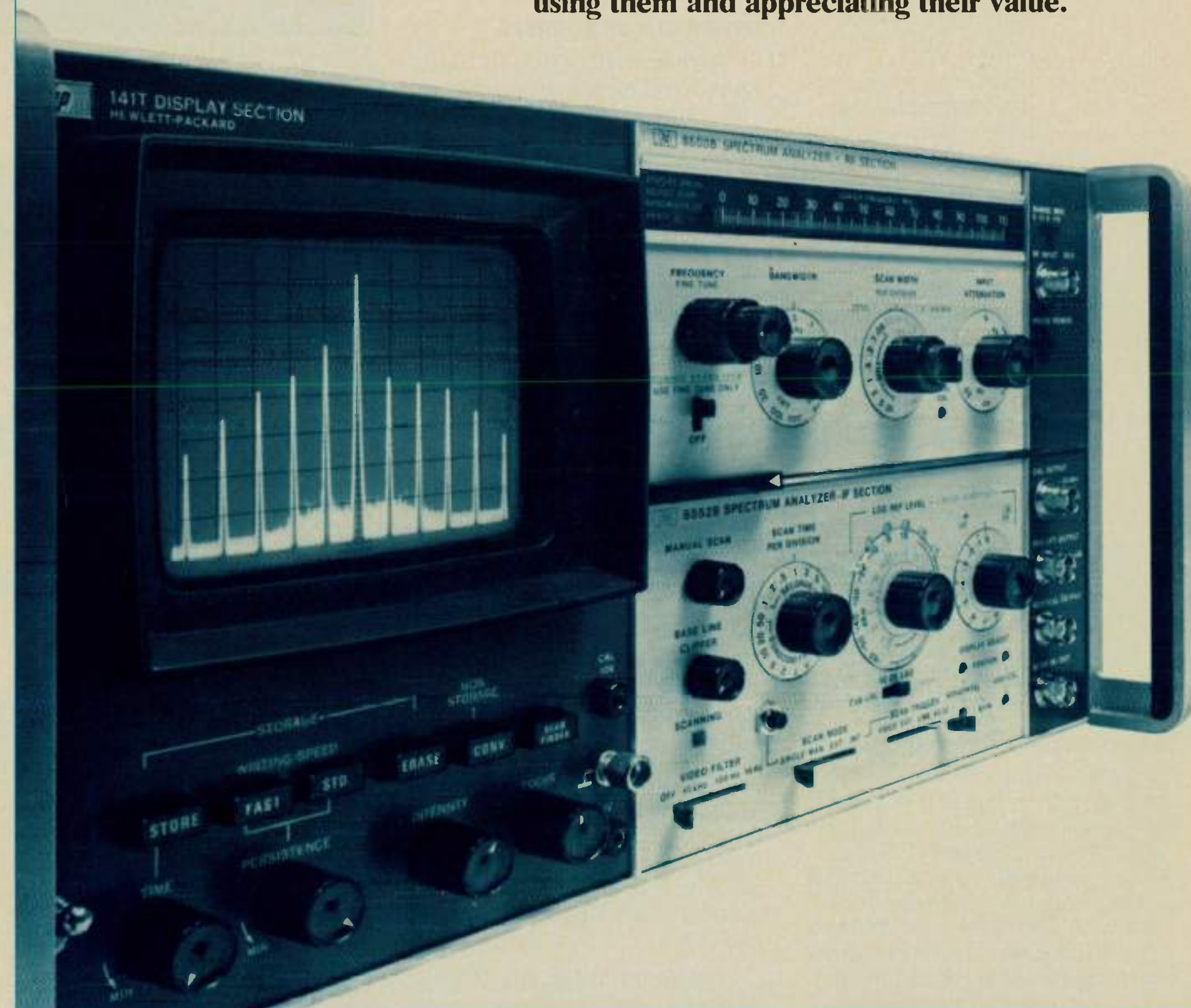

TABLE 1

TOTAL MEASUREMENT TIMES AND PERFORMANCE COMPARISON

NOISE FIG.	10 dB							
IF BW	–	100kHz	–	100kHz	–	100kHz	–	100kHz
DIGITAL AVG.	Yes	No	Yes	No	Yes	No	Yes	No
SETTL. ERROR AFTER –10 dB STEP	.0001dB	0.1dB	.0001dB	0.01dB	.0001dB	.001dB	.0001dB	.0001dB
MIXER PAD	0dB		10dB 1.1 SWR		20dB 1.1 SWR		20dB 1.1 SWR	
3σ NOISE ERROR	1dB 6.7°		0.1dB 0.67°		0.01dB 0.067°		0.001dB 0.0067°	
MIS-MATCH ERROR	0.5dB 3.6°	0.5dB	0.05dB 0.36°	0.105dB	0.002dB 0.013°	0.06dB	0.02dB 0.013°	0.06dB
LEVEL dBm	DUAL. CH. IF VECTOR SUB.	SGL. CH. NON-COHER. SUB.	DUAL. CH. IF VECTOR SUB.	SGL. CH. NON-COHER. SUB.	DUAL. CH. IF VECTOR SUB.	SGL. CH. NON-COHER. SUB.	DUAL. CH. IF VECTOR SUB.	SGL. CH. NON-COHER. SUB.
–150	14s	11da	3.8hr	508yr	158da	>1000yr	43yr	>1000yr
–140	1.4s	2.7hr	23min	51yr	16da		4.3yr	
–130	.14s	102s	137s	19da	1.6da	671yr	158da	
–120	14ms	1.1s	14s	4.5hr	3.8hr	6.7yr	16da	830yr
–110	1.4ms	21ms	1.4s	180s	23min	25da	1.6da	8.4yr
–100	.14ms	1ms	.14s	3.3s	137s	6.6hr	3.8hr	34da
– 90			14ms	.15s	14s	7.3min	23min	15hr
– 80			1.4ms	11ms	1.4s	20s	137s	41min
– 70			.14ms	1ms	.14s	1.5s	14s	186s
– 60					14ms	1.4s	1.4s	17s
– 50					1.4ms	13ms	1.4ms	1.6s
– 40					.14ms	1.3ms	1.4ms	.16s
– 30							.14ms	16ms
– 20	<.1ms	<.1ms	<.1ms	<.1ms	<.1ms	<.1ms	14μs	1.6ms

ployed in the integrators and by limited isolation in the synchronous detectors. A wide dynamic range is required for these circuits, i.e. the offset voltage should be small while the maximum voltage at the integrator should be as high as possible in order to achieve fast slew speeds. The ratio of both of these numbers gives a figure of merit for the circuit. For the devices employed, this number is 10 V/50V $= 2 \cdot 10^5$ and the errors obtained are a function of input level (because the open loop gain is controlled by it) and are worse at low levels. They are about 0.6 dB and 4 degrees at mixer input levels of -148 dBm, and are below 0.001 dB and 0.006 degrees for input levels above -90 dBm.

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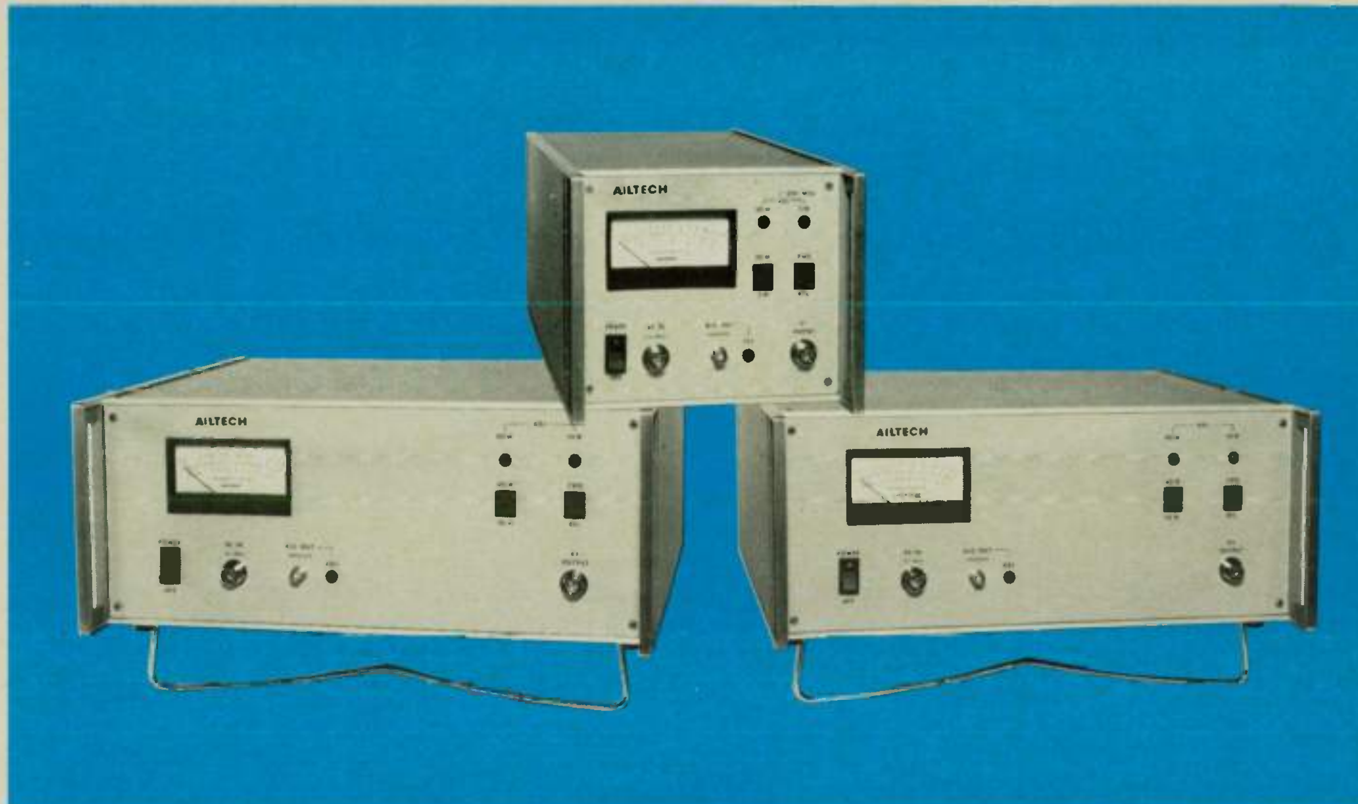
Two YIG-tuned local oscillators (LO) are employed for the conversion of the RF signal to the IF frequency. Phase coherence is obtained by phase locking the LO's to channel 1 at the IF. High spectral purity is obtained by tuning in coarse digital steps of about 10 MHz of a very low noise digital to analog converter and by analog fine tuning by means of the phase locked loop. Tuning, searching, sideband determination, locking and signal tracking are under control of a micro-processor. Search width is nominal 2% of center frequency and is selectable from 1 to 20%.

The IF frequency of 1.25 MHz was chosen in order to obtain a spurious free locking range down to 10 MHz. LO frequencies below 500 MHz are generated by digital frequency divider circuits. This gives superior performance over heterodyne LO's because of improved carrier to noise ratio and better tuning accuracy.

Fundamental mixing is employed in the frequency range 10 MHz - 2 GHz where double balanced broadband mixers are used. Balanced harmonic mixers are used in the 2-18 GHz range. Fundamental mixing is employed from 2-4.6 GHz, second harmonic mixing from 4-9.2 GHz without increase of conversion loss due to a antiparallel diode pair construction of the mixer.[6] Fourth harmonic mixing is used from 8-18 GHz with an increase

(continued on page 85)



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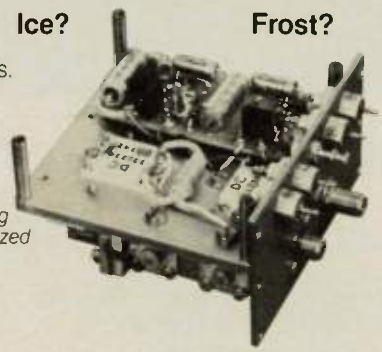

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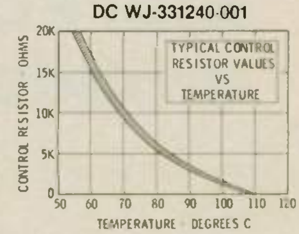

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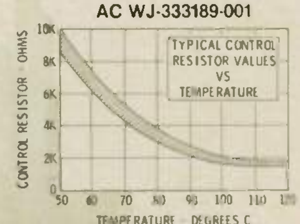

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New Software for Low Loss Two-Port Measurements

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A new software "accuracy enhancement program,"† suitable for the HP8409A Semi-Automatic Network Analyzer has been developed specifically for the characterization of low loss microwave components.

In particular, the measurement of electrically long (10 - 100 wavelengths) and low loss (< 1.0 dB) 2-port networks over broad frequency bandwidths, to date, has been notoriously difficult to achieve with any degree of accuracy or repeatability. Semi-rigid and flexible coaxial cables, flexible and rigid waveguide transmission lines are classic examples of such 2-ports. The technique developed demonstrates a useful improvement on the currently available accuracy of systems using enhancement software for low loss measurements.

INTRODUCTION

In recent times, the growth of automated measurement throughout the electronics/telecommunications industry has been very rapid and in this respect microwave measurements and testing techniques are no exception. The available schemes for microwaves range from real time data loggers and normalization processes (which can manipulate measured data in the scalar sense) to complex correction methods using computer controlled network analyzer equipments. It is to the latter approach that this article refers and attempts to show that there is still work to be done in learning about the practical applications of such systems to continual production problems.

The introduction of economic versions of automatic network analyzers has contributed a great deal to the reduction of systematic measuring errors in the conventional reflectometer arrangement. However, non-systematic errors, due to interconnections, RF switching, analog to digital quantization and instrumentation can still remain relatively high when low losses are being evaluated. To put this in perspective one manufacturer has quoted[1,2] that a "*short* term repeatability as *high* as 0.1 dB and 1° is achievable" with a production oriented software enhanced network analyzer system. These figures are, in fact, RSS (Root-Sum-Squared)* values and as such do not represent the worst case condition. Additionally, this same manufacturer provides, as standard, an accuracy enhancement program which does not provide full correction for its measuring system.[5] To quote from the literature "The accuracy enhancement software removes frequency response errors from transmission magnitude and phase measurements; it removes directivity, source match and frequency response errors from reflection magnitude and phase measurements." This software makes use of a substitution measurement for S_{21}. Here, no attempt has been made to correct for the system termination port reflection coefficient (a necessary requisite for the correct measurement of 2-port transmission parameters) which can cause significant errors particularly in low loss devices.

The reasons for not doing the full corrections will become apparent later in this discussion. In essence, it involves increase computer activity absorbing more storage space, increased calibration time and conversely, greater inaccuracy for low loss transmission measurements using non-selected equipment.

THEORY

Most complex error correction techniques make use of the "S" matrix representation of an "n" port device. The elements of the matrix are complex quantities and are indicative of power flow in the system. Hence, the generalized 2-port device would be modeled by a box representation as in Figure 1.

The elements of the matrix can be defined by imposing ideal conditions on the ports available. In the 2-port case then, they are:

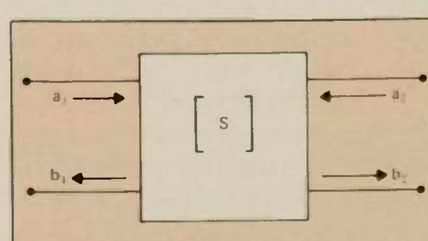


Fig. 1 "S" Matrix representation of 2-port.

* The RSS values generally lie about half way between the RMS and peak values.

† It is not Marconi's policy to market this as a proprietary product item, however, depending on interest, the Company may make the source program available, at a small charge, on a direct contact basis. In such a case, contact Mr. W. Wride, Chief Engineer, Marconic Space Defense Systems Ltd, Broad Oak Works, The Airport, Portsmouth P03 5PH, England.

$$S_{11} = \frac{b_1}{a_1} \Big| \; a_2 = 0 \; ; \qquad S_{21} = \frac{b_2}{a_1} \Big| \; a_2 = 0$$

$$S_{22} = \frac{b_2}{a_2} \Big| \; a_1 = 0 \; ; \qquad S_{12} = \frac{b_1}{a_2} \Big| \; a_1 = 0$$

Hence the matrix can be written:

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

It now this 2-port is terminated at its output with a load possessing a reflection coefficient ρ_L, Appendix 1 shows that the transformed reflection coefficient ρ_T, at the input port is:

$$\rho_T = \frac{b_1}{a_1} = S_{11} + \frac{S_{12}S_{21}\rho_L}{1 - S_{22}\rho_L} \qquad 1$$

This is a fairly significant result as it shows by rearrangement that if the elements of the "S" matrix (which may represent an error network) are known, an unknown reflection ρ_L can be evaluated just by processing the measured result ρ_T. Now, this error network can represent a model of the actual inaccuracies in the measuring instrument which is set-up to resolve the unknown reflection ρ_L.

It turns out, in fact, that this error model is quite a good approximation of the major sources of systematic uncertainty in reflectometer test set-ups. The elements of the "S" matrix account for errors more commonly known as:

S_{11} = Effective directivity (includes coupler directivity and terminal adaptor reflections etc.)
S_{21} = Transmission gain tracking (includes source flatness etc.)
S_{12} = Reflection gain tracking (includes source flatness test coupler flatness etc.)
S_{22} = Source match (includes source SWR, internal mainline connections and adaptor reflections).

To use this concept of our error model to represent measuring system inaccuracies, it is necessary to be able to quantify the elements of the scattering matrix. Because there are four unknowns it should be necessary to connect four known values of ρ_L to the system to create four simultaneous equations.

However, life can be made a little easier by stating that in a general passive 2-port $S_{21} = S_{12}$ and the product $S_{21}S_{12}$ can be evaluated as one element. Therefore, only three known values of ρ_L are required to form three equations with three unknowns.

$$\rho_1 = S_{11} + \frac{S_{12}S_{21}\Gamma_1}{1 - S_{22}\Gamma_1}$$

$$\rho_2 = S_{11} + \frac{S_{12}S_{21}\Gamma_2}{1 - S_{22}\Gamma_2}$$

$$\rho_3 = S_{11} + \frac{S_{12}S_{21}\Gamma_3}{1 - S_{22}\Gamma_3}$$

Many of the software controlled systems available to solve these equations are due to Hackborn[3] who proposed using firstly a perfect load (i.e. $\Gamma_1 = 0$) and thus make the first measure $\rho_1 = S_{11}$. A perfect load does not exist, but a good approximation to this can be made by using a sliding load.

A sliding load consists of a field absorbent element which has a finite reflection and which can be mechanically moved along a high precision coaxial airline. The finite reflection coefficient of the load element is transformed around the accurate impedance of the airline so that when moved through 180° electrical length, the reflection coefficient at the terminals of the device prescribe a perfect circle in the complex impedance plane.

The radius of this circle is directly proportional to the load element reflection and the center of this circle is the absolute value of the airline impedance Figure 2.

In reputable sliding loads the airline section is manufactured to minimize dimensional variations over a useful length of typically 10 cm. As such, the center of the complex impedance plane circle

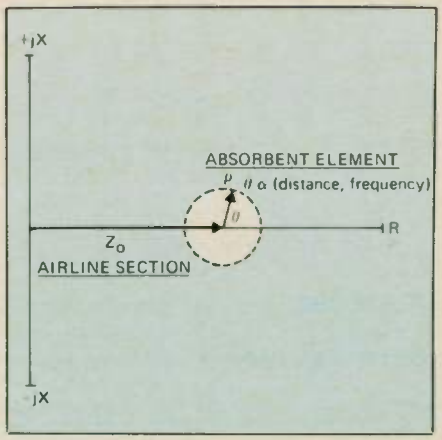


Fig. 2 Terminal plane impedance of sliding termination.

prescribed by the moving load element is equivalent to a load whose reflection coefficient is close to zero. In a computer controlled system it is necessary for the software component to calculate this circle center given a sufficient number of points. Theoretically, only three points are required to find this center, but in practice as many as six are needed to reduce ambiguity over broad frequency bands.

Using the sliding load reduces the problem to the solution of two equations with two unknowns to evaluate the remaining elements of the matrix. Theoretically, any two different but known calibration pieces could be used to evaluate these elements. However, to limit the difficulties in characterization of standards, terminations are generally restricted to a short-circuit and an open-circuit. In practice, this technique provides a useful measure of accuracy enhancement removing systematic errors to a relatively low level.

From experience, the actual value of residual left in the result is somewhat dependent on environmental conditions. For controlled environment of ± 1°C, for example, measured residuals can be as low as −60 dB whereas relaxing control to ± 2°C can result in residuals rising to −50 dB. It should be noted, however, that there are still a number of nonsystematic errors left which add a range of uncertainty to the value of measurements made with such a system. Briefly, some of these can be stated as:

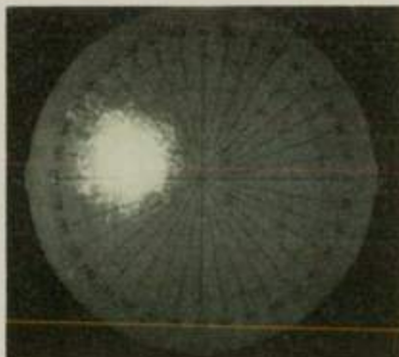


Fig. 3 Signal/noise ratio of ≈ 8 dB on a polar display unit.

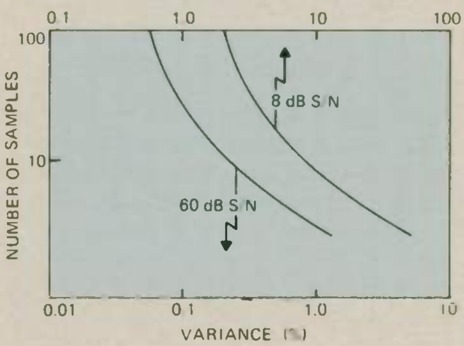


Fig. 4 Polar display of 8 dB signal/noise ratio signal.

- Absolute accuracy of the sliding load coaxial section
- Connector interface uncertainty and repeatability
- Instrumentation linearity in absolute terms
- Change in linearity with environmental condition
- Noise in the measurement data

Some of these affect the absolute accuracy of the desired result and some create a time-dependent probability of acquiring correct data to produce the desired result. One of the major sources of error in the latter category is the electrical noise associated with the measurement of the sliding load values.

Over the frequency range of a reputable sliding load, the element reflection coefficient in terms of system signal/noise ratio can vary from 20 dB to as low as 3 dB and the use of software averaging becomes essential to define a reasonably invariant result. Figure 3 shows a signal of approximately 8 dB signal/noise ratio displayed on a polar display unit typical of that used in network analyzers.

Some measurements have been carried out to evaluate the variance of the sampled value using an IEEE 488 protocol bus and a recommended A-D converter connected to the polar display. The results are shown in Figure 4 and reveal that for 8 dB signal/noise ratio the number of samples required for less than 5% variance is in the region of 15 or 16. This may seem a reasonably small value of variance for such low signal/noise ratios and should produce an acceptable error in the system residuals at least with regard to the SWR result. However, it can have a rather more serious affect on the insertion loss measurement. By inspection of the solutions, of the "S" matrix elements, it can be seen that the non systematic component of S_{11} appears in all the other elements. Thus noise in this result will be transformed onto the other desired results. In terms of the transmission product $S_{21} S_{12}$, this can represent ± 0.1 dB variation which tends to be a random fluctuation.

On top of this noise contribution, however, lies an accuracy problem associated with the absolute value of S_{11} which contains a linearity error. This contribution can be in the region of 0.3 - 0.5 dB for measured losses of less than 3 dB. For both these reasons it is more accurate, when using non-selected apparatus, to

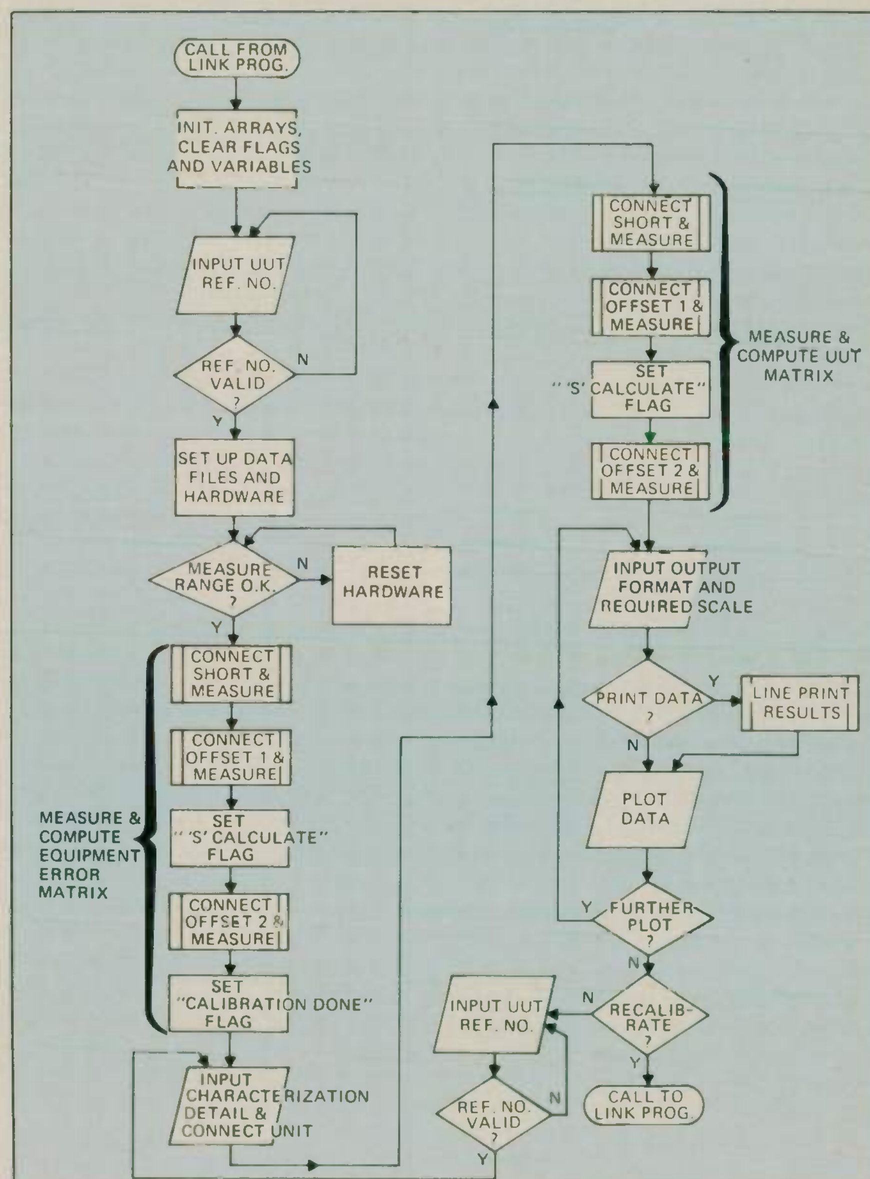


Fig. 5a Process flow diagram.

measure low losses by a substitution method as in the standard software rather than fully correct for load reflection.

Of course, the invariance noted can be improved by averaging larger numbers of measurements to yield much cleaner results but this takes a greater time and for a large number of frequencies can be a serious limitation in practical application.

ALTERNATIVE SOLUTION

In 1973, Da Silva and McPhun[4] reported that the elements of the "S" parameter error network matrix may be evaluated using only short-circuits as calibration standards. These standards are a reference plane short and two offset shorts with differing phase length. They also provided practical evidence of the technique applied to the measurement of a one-port device (a high quality termination) of low reflection coefficient. The explicit solution of the matrix elements are shown in **Appendix 2**. It is suggested that this technique provides an optimum solution in terms of measurement uncertainties for low loss two-ports for three main reasons.

First, all the signals measured are of a high value which implies good signal/noise ratio and low variance. Second, for low losses the dynamic range of the measure is limited to the product $S_{21} S_{12}$ and hence reduces non-linearity by many orders. Third, better phase resolution results because all the measures are close to the periphery of the complex impedance plane. Typically, for low losses the measures may have a 60 dB signal/noise ratio and the curve for this is also shown in the graph of **Figure 4**.

This curve is plotted from measured results in the same way as the curve of the lower signal/noise ratio and it can be seen that for the same number of samples the variance drops from 5% to about 0.1% – a significant improvement.

This technique has been subjected to a practical application of characterization of external two-port devices producing much smaller uncertainties. The process involves connecting the calibration standards to the test system, storing the results and computing the scattering parameters which are representative of the measuring system errors. This is done for every frequency that the device under test is going to be characterized. Next, the device under test is connected to the test system and the same short-circuit standards are connected to the remote end. The following equation (which is an inversion of Equation 1).

$$\rho_L = \frac{\rho_T - S_{11}}{S_{21}S_{12} - S_{11}S_{22} + S_{22}\rho_T}$$

is used to compute, using the previously stored "S" parameter values, the true reflection coefficient of the standards and device under test combination. In this situation, the reflection standards

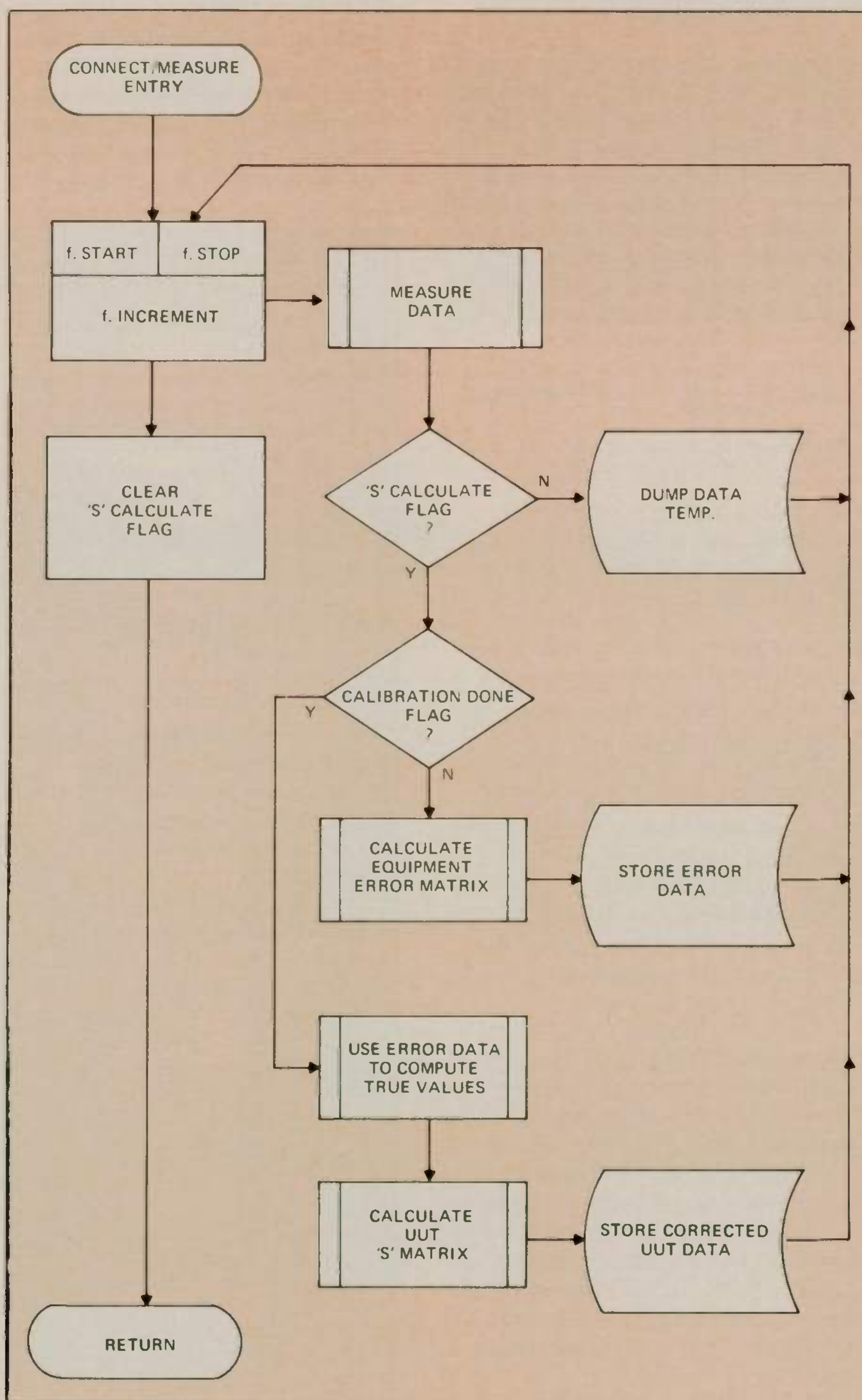


Fig. 5b Connect and measure routine.

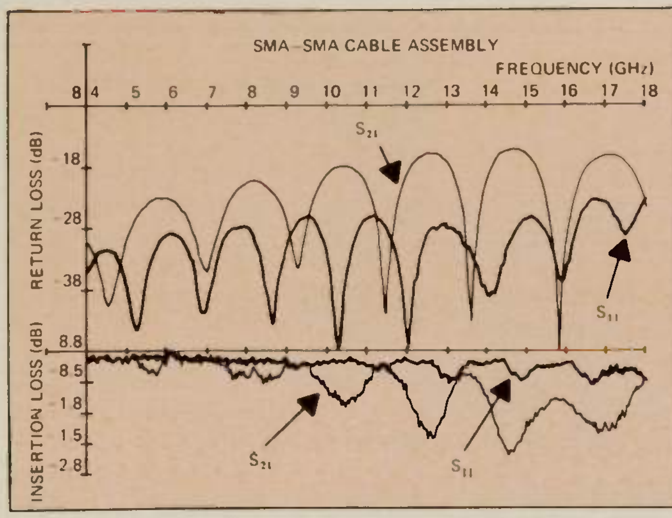


Fig. 6 Test results with standard procedure.

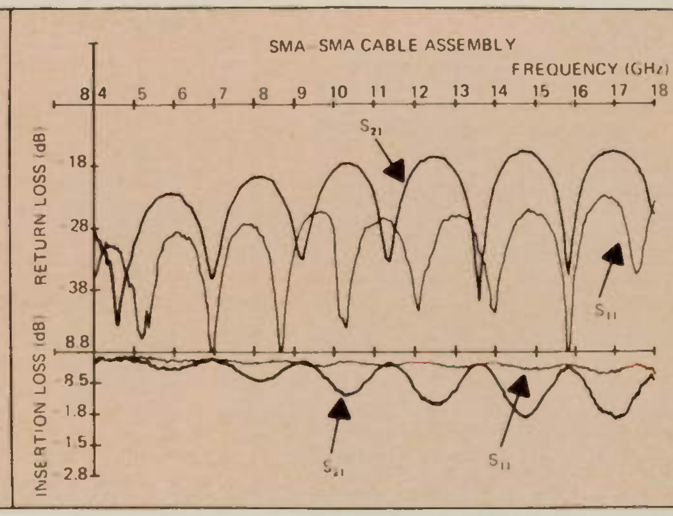


Fig. 7 Test results with new procedure.

are transformed by the equivalent "S" matrix representation of the device under test to the now known, and accurately measured, terminal plane reflection coefficient. Therefore, if this new matrix of coefficients is now evaluated in the same way as before, the elements represent those of the device under test.

A typical flow chart of the computational and control processes involved is shown in **Figure 5a** and **5b**. This is a particular application of this technique to a range of transmission line products which are subject to 100% characterization.

From the systematic error involved in the measurement of low loss two-ports using this method, some of the advantages have been discussed but there are others. Briefly they concern a smaller number of connections to the test interface, there is no need to reverse the device under test to evaluate S_{22}, there are no RF switch operations necessary and there is no through port connection. The through port connection usually means a flexible or semi-flexible line to the transmission test port of the test system and infers variability problems in the transmission parameters. This flexibility is often necessary due to the varying geometry of items to be tested.

TEST RESULTS

The standard software was altered to take account of the transmission test port reflection coefficient and a fully corrected result was output in graphic form. Two short examples of semi-rigid coaxial cables were then tested for S_{11} and S_{21}. The results are shown in **Figure 6**. The predicted random noise, due to the measurement of low level residual signals during calibration, is present on the insertion loss result.

Also, there can be seen an inconsistency in the loss function with frequency which is due to linearity errors in the measurements system and stored in the calibration data.

Using the new procedure described, the same two samples were tested using the same output format. These results are shown in **Figure 7**. The noise phenomena is much reduced in the insertion loss characteristic and the dissipation/ripple values are more consistent with the known transmission line length and measured return loss characteristics.

CONCLUSIONS

Using the procedure described, a device under test is fully characterized in terms of the equivalent "S" parameter matrix. The final results can be operated upon to produce output data in a form which is acceptable to the user. The process takes about 40% of the time taken by other software systems, using more conventional methods, for the same degree of characterization. The practical results of accuracy have been demonstrated from both the systematic and non-systematic errors.

Typical residuals for a hardware system consisting of a Hewlett Packard 8410A Analyzer and a 9825B desk top computer with 23K bytes of memory and the software procedure described are consistently held at better than −45 dB with environmental control of ± 3°C. For insertion or transmission losses of less than 1 dB, total uncertainty experienced, including noise contribution, is better than 0.04 dB.

Superior uncertainties are experienced for two-port insertion losses up to 15 dB. The system shown was designed to operate over a frequency band of 4.0 to 18.0 GHz with suitable sample increments up to a maximum of 600 points. Beyond this number of intervals it is recommended that phase-lock techniques be used on sources.

ACKNOWLEDGEMENTS

Grateful thanks are due to the Secretary of the Marconi Company Limited for permission to publish this paper and to Mr. B. Whiteley of Marconi Space Defense Systems Ltd, Portsmouth, who carried out a great deal of the system evaluation work.

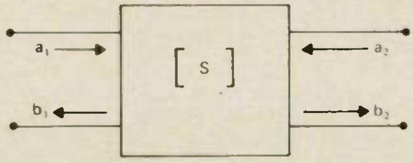
REFERENCES

1. Fitzpatrick, J., "Accuracy Enhancement in Vector Measurement Systems," a Hewlett Packard Symposia Note,
2. "The 8409A Semi-automatic Network Analyzer manual," March 1978.
3. Hackborn, R. A., "An Automatic Network Analyzer System," *Microwave Journal*, May 1968, pp. 45-72.
4. Da Silva, E., and M. McPhun, "Calibration of Microwave Network Analyzer for Computer Corrected S-Parameter Measurements," *Electronic Letters*, Vol. 9, No. 6, March 1973, pp. 126-128.
5. Hewlett Packard Application Note No. 221, October 1977, pp. 7, Par. 4.

Gary R. Cobb was born in Bournmouth England on 7th September, 1947. He received an M.I.E.E.E. and thereafter served an apprenticeship with G.E.C./Marconi, where he specialized in problems of microwave measurements. He joined the staff of Sealectro, UK in 1973 to study design of microwave passive networks and miniature connectors. In 1975 he worked at Southern Microwave and acted as consultant engineer to Admiralty Surface Weapons Establishment, handling antenna and passive network design. Since rejoining Marconi Space Defense Systems, Ltd in 1979 he has been studying problems associated with network analysis. He is a member of I.E.E.E.

APPENDIX 1

A general 2 port



Hence the matrix representation is defined as

$$S_{11} = \frac{b_1}{a_1}\bigg|_{a_2 = 0}\ ; \quad S_{21} = \frac{b_2}{a_1}\bigg|_{a_2 = 0}$$

$$S_{22} = \frac{b_2}{a_2}\bigg|_{a_1 = 0}\ ; \quad S_{12} = \frac{b_1}{a_2}\bigg|_{a_1 = 0}$$

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

which expanded yields the simultaneous equation

$$b_1 = a_1 S_{11} + a_2 S_{12} \qquad (1)$$

$$b_2 = a_1 S_{21} + a_2 S_{22} \qquad (2)$$

Now, if a termination ρ_L is connected to the output port, then the coefficient

$a_2 = b_2 \rho_L$

therefore

$$b_2 = \frac{a_2}{\rho_L} \qquad (3)$$

From 2 and 3

$$\frac{a_2}{\rho_L} = a_1 S_{21} + a_2 S_{22}$$

$$\text{therefore } a_2 = a_1 \left(\frac{S_{21}\rho_L}{1 - S_{22}\rho_L} \right)$$

Substitution in 1 for a_2 gives:

$$b_1 = a_1 S_{11} + \frac{a_1 S_{12} S_{21} \rho_L}{1 - S_{22}\rho_L}$$

$$\text{therefore } \frac{b_1}{a_1} = S_{11} + \left(\frac{S_{12} S_{21} \rho_L}{1 - S_{22}\rho_L} \right) = \rho_T$$

APPENDIX 2

$$\rho_1 = S_{11} + \frac{S_{12} S_{21} \Gamma_1}{1 - S_{22}\Gamma_1} \qquad (1)$$

$$\rho_2 = S_{11} + \frac{S_{12} S_{21} \Gamma_2}{1 - S_{22}\Gamma_2} \qquad (2)$$

$$\rho_3 = S_{11} + \frac{S_{12} S_{21} \Gamma_3}{1 - S_{22}\Gamma_3} \qquad (3)$$

Subtracting Equation 2 from 1 gives:

$$S_{12} S_{21} = \frac{(\rho_1 - \rho_2)(1 - S_{22}\Gamma_1)(1 - S_{22}\Gamma_2)}{\Gamma_1 - \Gamma_2} \qquad (4)$$

Adding Equation 2 and 1 gives also

$$S_{12} S_{21} = \frac{(\rho_1 + \rho_2 + 2S_{11})(1 - S_{22}\Gamma_1)(1 - S_{22}\Gamma_2)}{\Gamma_1 + \Gamma_2 - 2S_{22}\Gamma_1\Gamma_2} \qquad (5)$$

and Equating 4 and 5 produces

$$S_{22}\Gamma_2 = \frac{S_{11}(\Gamma_2 - \Gamma_1) - \rho_1\Gamma_2 + \rho_2\Gamma_1}{\Gamma_1(\rho_2 - \rho_1)} \qquad (6)$$

A similar process can take place operating on Equations 2 and 3 to yield the equation:

$$S_{22}\Gamma_2 = \frac{S_{11}(\Gamma_2 - \Gamma_3) - \rho_3\Gamma_2 + \rho_2\Gamma_3}{\Gamma_3(\rho_2 - \rho_3)} \qquad (7)$$

Now, Equating 6 and 7 yield a general expression for S_{11}:

$$S_{11} = \frac{\Gamma_1\Gamma_2\rho_3(\rho_1 - \rho_2) + \Gamma_2\Gamma_3\rho_1(\rho_2 - \rho_3) + \Gamma_3\Gamma_1\rho_2(\rho_3 - \rho_1)}{\Gamma_1\Gamma_2(\rho_1 - \rho_2) + \Gamma_2\Gamma_3(\rho_2 - \rho_3) + \Gamma_3\Gamma_1(\rho_3 - \rho_1)} \qquad (8)$$

Here, $\rho_1 \rho_2$ and ρ_3 are the measured results and Γ_1 Γ_2 and Γ_3 are the known calibration standards. It should be noted that both ρ and Γ are complex quantities.

From Equation 6 it is seen that a general solution for S_{22} is

$$S_{22} = \frac{\Gamma_1(\rho_2 - S_{11}) + \Gamma_2(S_{11} - \rho_1)}{\Gamma_1\Gamma_2(\rho_2 - \rho_1)} \qquad (9)$$

Also, Equation 1 now is itself a general solution for $S_{12}S_{21}$:

$$S_{12}S_{21} = \frac{(1 - S_{22}\Gamma_1)(\rho_1 - S_{11})}{\Gamma_1} \qquad (10)$$

A simplification of these equations is possible if the standard reflections are defined as short-circuit with various phase offsets:

$$\left.\begin{aligned} \Gamma_1 &= -e^{-j2\beta 1_1} \\ \Gamma_2 &= -e^{-j2\beta 1_2} \\ \Gamma_3 &= -e^{-j2\beta 1_3} \end{aligned}\right\} \quad \text{if } 1_1 = \text{zero} \quad \left\{\begin{aligned} &-1 \\ &-e^{-j2\beta 1_2} \\ &-e^{-j2\beta 1_3} \end{aligned}\right.$$

Hence Equations 8, 9 and 10 become:

$$S_{11} = \frac{e^{+j2\beta(1_3 - 1_2)}\rho_3(\rho_1 - \rho_2) + e^{-j2\beta 1_2}\rho_1(\rho_2 - \rho_3) + \rho_2(\rho_3 - \rho_1)}{e^{+j2\beta(1_3 - 1_2)}(\rho_1 - \rho_2) + e^{-j2\beta 1_2}(\rho_2 - \rho_3) + (\rho_3 - \rho_1)}$$

$$S_{22} = \frac{e^{+j2\beta 1_2}(S_{11} - \rho_2) - S_{11} + \rho_1}{\rho_2 - \rho_1}$$

$$S_{12}S_{21} = (1 + S_{22})(\rho_1 - S_{11})$$

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1

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2

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COMPACT Engineering, Inc. 297 pages. Hardcover. 1980. $40.00

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2-STAGE IF AMPLIFIER (2A SERIES)*							
1-150 MHz IF AMPLIFIER							
MLO-2A-0115	1-2	22	6.5	7.5	0	40	2
M45-2A-0115	1.8-6.5	22	7.0	8.0	0	40	6
M35-2A-0115	3-10	22	7.5	8.5	0	40	6
M30-2A-0115	4-15	22	7.5	8.5	0	40	6
M20-2A-0115	6.5-18.5	22	8.0	9.0	0	40	6
M2C-2A-0115	2-18.5	22	8.0	9.0	0	40	6
1-500 MHz IF AMPLIFIER							
MLO-2A-0150	1-2	22	7.0	8.0	8	55	2
M45-2A-0150	1.8-6.5	22	7.5	8.5	8	55	2
M35-2A-0150	3-10	22	7.5	8.5	8	55	6
M30-2A-0150	4-15	22	8.0	9.0	8	55	6
M20-2A-0150	6.5-18.5	22	8.5	9.5	8	55	6
M2C-2A-0150	2-18.5	22	8.5	9.5	8	55	6
5-1000 MHz IF AMPLIFIER							
M45-2A-000510	2-6	17	8.5	9.5	0	35	6
M35-2A-000510	3-10	17	9.5	10.5	0	35	6
M30-2A-000510	4-15	16	9.5	10.5	0	35	6
M20-2A-000510	6.5-18.5	16	10.5	11.5	0	35	6
400-2000 MHz IF AMPLIFIER							
M35-2A-0420	3-10	14	8.0	9.0	5	35	6
M30-2A-0420	4-15	14	8.5	9.5	5	35	6
M20-2A-0420	6.5-18.5	14	9.0	10.0	5	35	6

MIXERS

Model	RF & LO Band (GHz)	IF Band (GHz)	Conv. Loss (dB) Typ.	Conv. Loss (dB) Max.	Min Isolation LO/RF	Min Isolation LO/IF
OCTAVE BAND DESIGNS						
MLO	1-2	0-0.5	5.0	6.0	25	15
MSO	2-4	0-1.0	5.0	6.0	25	20
MCO	4-8	0-2.0	6.0	7.0	25	20
MXO	8-12.5	0-3.0	6.5	7.5	25	20
MKO	12-18.5	0-3.0	6.6	7.5	20	15
M2D	4-8	8-16	7.5	8.5	25	25
M4D	2-4	4-8	7.5	8.5	25	25
WIDEBAND MULTIOCTAVE DESIGNS						
M45	1.8-6.5	0-1.0	6.0	7.0	25	20
M35	3-10	0-2.0	6.0	7.0	20	20
M30	4-15	0-2.5	6.5	7.5	20	15
M20	6.5-18.5	0-3.0	7.0	8.0	20	15
M2C	2-18.5	0-.6	7.0	8.0	20	15
M2C	3-12	0-.6	6.5	7.5	25	25

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Fig. 1 Model 7000A with Model 7105 bench top setup.

INTRODUCTION

System consists of a measurement instrument (Model 7000A) and a microwave unit (Series 7100) interconnected with a shielded ribbon cable (**Figure 1**). The system weighs below 11 lbs. including battery. Power can be 115/230 V ac a 12 V nickel cadmium battery system which provides 6 hrs. of operation between charges, or a cigarette lighter adapter to allow the unit to operate continuously from 12 V negative ground automotive system.

The processor unit (7000A) is used in conjunction with one of the interchangeable microwave units covering specific frequency bands, from 0.01 through 18 GHz. For example, the 7100 series microwave unit for radar and communications consists of a swept microwave oscillator, a high directivity coupler, an isolator, and low pass filter. Oscillators use a varactor-tuned Gunn, FET or bipolar transistor device, depending on the model.

Fig. 2 Model 7000A-01 with Model 7103 microwave unit.

The isolator eliminates frequency pulling and makes the output impedance of the unit independent of the oscillator SWR. Harmonics of the oscillator are reduced by the low pass filter. The high directivity (40 dB) and low test port SWR ($\leqslant 1.1$) of this coupler are the key to the system's measurement accuracy, as will be seen.

ACCURACY

There are two sources of error in a microwave measurement: instrumentation error and mismatch uncertainty. With most instruments, mismatch uncertainty is the predominant source of error, except for power measurements, wherein calibration uncertainty also contributes significantly.

Instrumentation error is the result of the accuracies associated with the analog to digital converter, range to range scale factor errors, and the detector linearity algorithm.

Residual zero errors of the detector and amplifier are nulled out during the calibration cycle in two steps. First, without any RF power applied to the detector, an auto-zero digital to analog converter is adjusted by the system's internal microprocessor until a power meter reading in the lower 20% of the most sensitive range is obtained. After this, the residual zero voltage is measured and stored in the RAM (Random Access Memory) for every power meter range, eliminating range to range zero carryover errors. This zero error is subtracted from future readings, cancelling zero reference errors from the measurements.

Since the detector is used from -50 dBm to $+13$ dBm, its characteristics change from a square law power sensor at levels below -20 dBm to a linear amplitude sensitive device at the higher powers. To compensate for these variations which are unique to each diode, a calibration PROM (Programmable Read Only Memory) is included with each detector containing the diode linearity data. This data when used by the microprocessor to compute RF power, yields an accuracy of $\pm$ .05 dB. The sensitivity of the detector diode as a function of frequency (usually called calibration factor) is also stored in the detector calibration PROM. The calibration factor is used by the microprocessor according to the frequency entered in the power meter mode. The detector calibration PROM is located in the microwave unit allowing compatibility among the various microwave units.

The analog to digital converter accounts for a possible error of ± .05 dB and the range to range errors could add another ± .04 dB for an overall instrumentation accuracy of ± 3% or ± .15 dB, comparable to existing scalar microwave test systems.

Mismatch uncertainties are introduced in the measurement or calibration of equipment because of the mismatch of the devices connected together, because the mismatch of a device prevents it from absorbing all the power incident upon it reflecting a percentage of the incident power back to the source. These uncertainties exist for power, insertion loss or reflection measurements as described below.

POWER MEASUREMENT UNCERTAINTY

The following equation describes mismatch uncertainties caused by the reflection coefficient of the power sensor and the sources of power being measured (Refer to **Figure 4**).

$$MU_{db} = 20 \log (1 \pm \rho_g \rho_L) \qquad (A)$$

Where MU = Mismatch Uncertainty (maximum) in dB.
ρ_g = Generator Reflection Coefficient
ρ_L = Detector Reflection Coefficient

See **Table 1** for worst case uncertainties when making power measurements of a power source having SWR's listed.

REFLECTION MEASUREMENT UNCERTAINTY

To understand the uncertainty for reflection measurements (SWR, Return Loss, and RHO), consider the measurement cycle. First the instrument is calibrated by connecting the detector to J2 and a microwave short to J1 (See **Figure 3**). With the short at J1, the instrument performs a self-zero check and then measures the detected RF power reflected from the short at 51 equally spaced frequencies across the selected frequency range. When this is complete, an open is connected to J1, and the reflected voltage is measured at the same calibration points. The power detected is converted to RF volts and averaged with the RF voltage reflected from the short at each of the calibration frequencies. This calibration data is stored in the RAM and used for future reflection measurements. Since the open and short are 180° out of phase, this procedure inherently cancels out test port SWR errors during calibration. The device is then connected.

A typical reflection measurement setup is shown in **Figure 5**. The measurement uncertainty in terms of the reflection coefficient, ρ, is:

$$MU = d \pm \frac{\rho_g T_1 T_2 + \rho_1}{1 - \rho_g \rho_2} \rho_L^2 \qquad (B)$$

where d is the directivity of the coupler

T_1, T_2 are the forward and reverse transmission coefficients of the coupler.

ρ_g is the generator reflection coefficient.

ρ^1, ρ^2 are the output and input reflection coefficients of the coupler.

ρ_L is the reflection coefficient of the device under test.

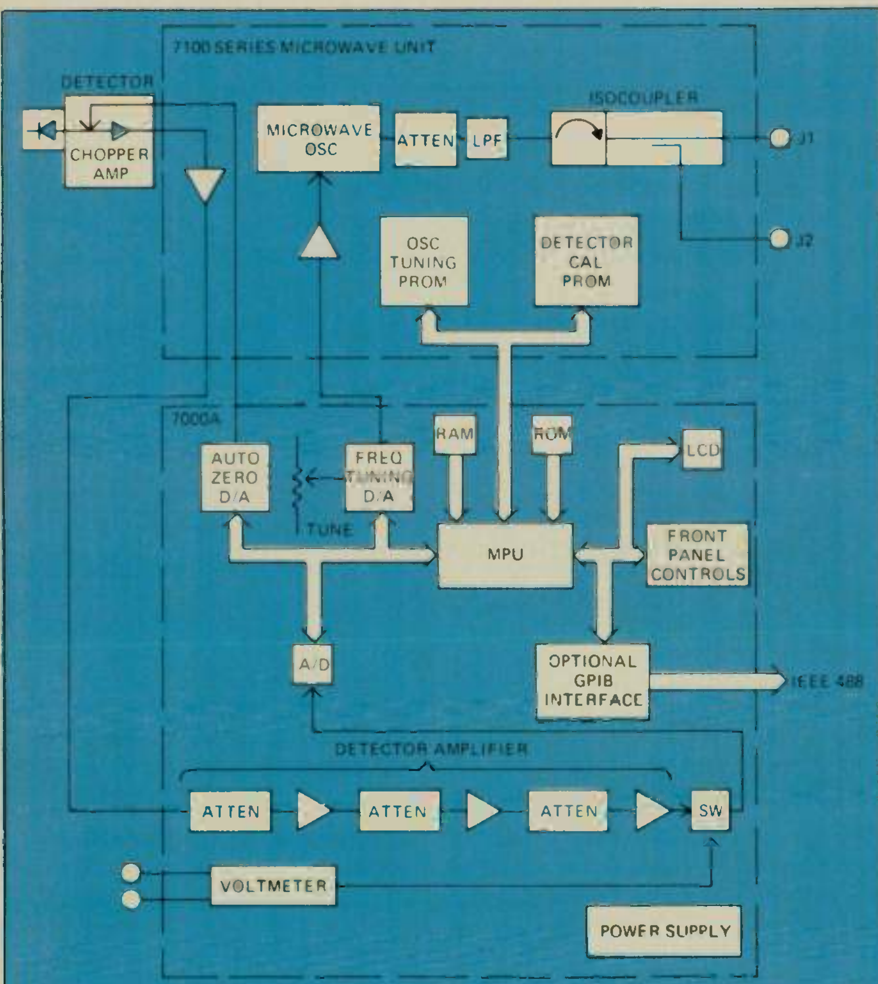

Fig. 3 System block diagram.

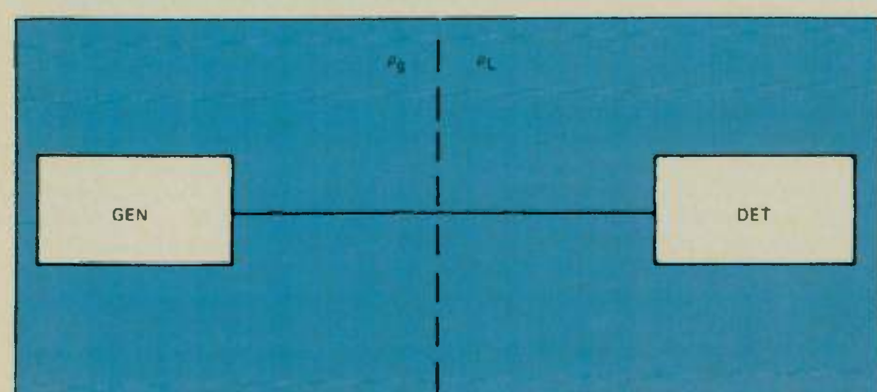

Fig. 4 Power meter measurement set-up.

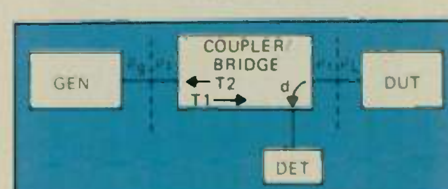

Fig. 5 Typical reflection measurement setup.

(continued on page 76)

772 STR

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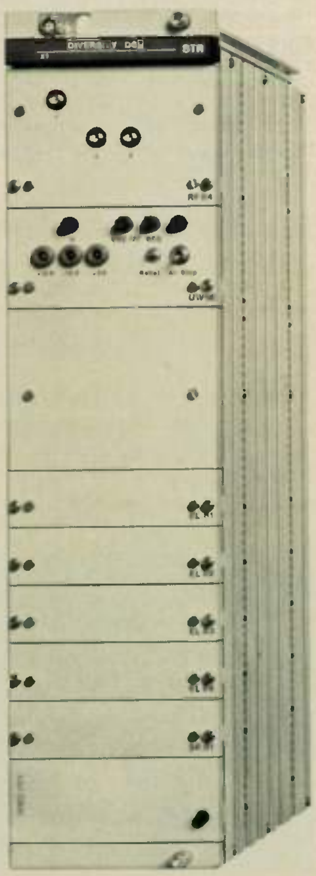

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A special advantage of the STR system for digital transmission
is a dramatic reduction in the frequency of errors caused by selective multipath propagation fading.

Only one receiver
for the handling of signals from the two separate antennas is necessary thanks to combination at the RF level. That means that the STR system is simple. And it can be combined with virtually any receiver.

Lower operating costs
make the STR system exceptionally attractive in both new and modified installations. It is indisputably more economical than an IF diversity system with a second receiver. And STR's RF space diversity system is so compact that it is the ideal low-cost supplement for any installation.

Full information
is now available on the new fully electronic RF space diversity system from STR. Ask for literature from:
Standard Telephon und Radio AG
CH-8055 Zurich/Switzerland
Friesenbergstrasse 75

Company ______________________

Address ______________________

____

Executive ______________________

Standard Telephon und Radio AG **STR**
An ITT Associate

Dr. Juchli

CIRCLE 42 ON READER SERVICE CARD

TABLE I

POWER MEASUREMENT WORST CASE MEASUREMENT UNCERTAINTY

(7100 and 7200 Detectors)

SWRg	ρ_g	Freq. < 4 GHz $\rho D = 0.091$	Freq. 4 GHz < 18 GHz $\rho D = 0.167$
1.10:1	.048	± .04 dB	± .07 dB
1.20:1	.091	± .07 dB	± .13 dB
1.40:1	.167	± .13 dB	± .24 dB
1.50:1	.200	± .16 dB	± .30 dB
2.00:1	.333	± .26 dB	± .50 dB

TABLE 3

TRANSMISSION MEASUREMENT UNCERTAINTIES FOR MODEL 7105

DEVICE UNDER TEST

Description	Input/Output SWR	Insertion Loss Uncertainty (dB)
Attenuator 10 dB	1.10:1	± .17
Attenuator 10 dB	1.20:1	± .25
Attenuator 6 dB	1.20:1	± .26
Attenuator 3 dB	1.20:1	± .28

The 7100 series units have an isolator or attenuator integrated into the coupler and pretuned for minimum SWR to reduce the generator output mismatch contribution, in effect reducing the

$$\frac{\rho_g T_1 T_2 + \rho_1}{1 - \rho_g \rho_2}$$

term in Equation B to less than 0.05. Combining this with a 40 dB directivity (d = .01) coupler gives a measurement uncertainty of:

$$MU = 0.010 \pm 0.05\,\rho_L{}^2 \qquad (C)$$

Comparing the measurement uncertainty of the 7100 Series microwave units with that obtainable with conventional separate laboratory components, assume a source output SWR of 2:1 and a high directivity (35 dB) coupler with insertion loss of 0.5 dB and SWR of 1.2:1. Equation B becomes:

$$MU = .018 \pm 0.4\,\rho_L{}^2$$

It can be seen that signal generator impedance and test port SWR cause a significant part of the uncertainty for measurements of high reflection coefficient, while the directivity of the coupler most influences measurements of low values of reflection coefficient.

Table 2 shows a comparison of uncertainties for the assumed conventional measurement system compared with the Model 7000A with 7105 microwave unit, for a measurement of reflection coefficient (RHO) and Return Loss. The improvements obtained using the integrated test system are apparent.

TRANSMISSION MEASUREMENT UNCERTAINTY

A similar analysis can be made for transmission measurements. When the system is calibrated, there is a mismatch error in the calibration measurement. **Figure 6-A** shows the calibration setup. Then, when the device under test is inserted, there are mismatch errors at both interfaces, as shown in **Figure 6-B**. The total uncertainty equation for transmission (insertion loss/gain) is:

$$MU/dB = 20Log \frac{1 \pm \rho_g \rho_L}{(1 \pm \rho_g \rho_3)(1 \pm \rho_4 \rho_L) \pm (\rho_g T_1 T_2 \rho_d)} \qquad (D)$$

Where ρ_g = Generator reflection coefficient.
ρ_L = Detector reflection coefficient.
ρ_3 = Input reflection coefficient of device under test.
ρ_4 = Output reflection coefficient of device under test.
T_1 = Forward transmission ratio of device under test.
T_2 = Reverse transmission ratio of device under test.

In order to ascertain the accuracy of an insertion loss measurement, it is essential to know the reflection coefficient of all the components involved. Substituting the Model 7105 tolerance into Equation D, the uncertainty equation for insertion loss becomes:

$$MU = (dB) = 20Log \frac{1 + .008}{(1 \pm .05\,\rho_3)(1 \pm .167\,\rho_4) \pm .008\,T_1 T_2} \qquad (E)$$

Table 3 gives the mismatch uncertainties which would be associated with typical attenuators.

OPERATING DETAILS

Figure 3 shows a block diagram of the microwave multimeter. The microprocessor (MPU) controls the instrument, sequencing through the measurements and displaying prompts for the operator when required. The instructions for the microprocessor are contained in a read only memory (ROM). As the instrument makes measurements, the data is temporarily stored in the RAM. The RAM is also used to store intermediate results of calculations as well as calibration data and instrument status. When a measurement is complete, the data is converted to the required units and displayed on the LCD.

Each time power is applied to the system, the microprocessor initiates a self-check sequence. First, all segments on the liquid crystal display are illuminated to verify the display. Concurrently, the RAM is repetitively written into and read from with pseudorandom data. After every byte of RAM is checked, the contents of the ROM are read and verified. Further checks on the operation of the microprocessor are performed and then the microwave unit is interrogated. The LCD indicates

TABLE 2

7105 VERSUS STANDARD MICROWAVE TEST SETUP UNCERTAINTY

RHO: Actual	RHO: Measurement Using Standard Microwave Components	RHO: Measurement Uncertainty Using Narda 7105	RETURN LOSS: Actual Return Loss	RETURN LOSS: Measurement Using Standard Microwave Components	RETURN LOSS: Measurement Uncertainty Using Narda 7105
.05	± .019	± .0101	−26dB	+2.78 dB −4.17 dB	+1.6 dB −2.01 dB
.1	± .022	± .0105	−20dB	±1.73 dB	± .96 dB
.3	± .054	± .0145	−10.5dB	±1.5 dB	± .43 dB

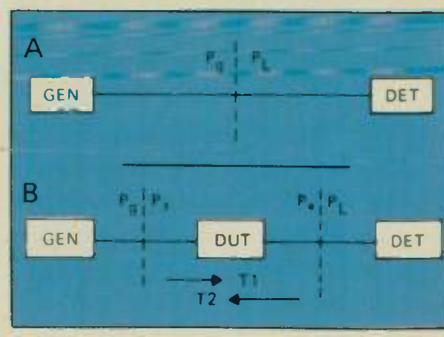


Fig. 6 Insertion loss measurement setup.

(continued on page 79)

(from page 76)

the frequency limits of the microwave unit during this time. If any of the above checks fail, an error code is displayed, indicating which test failed and inhibiting the instrument in use. If these self-check diagnostics are satisfied, the microprocessor generates the initial status conditions and calibration tables from data stored in the microwave unit.

The tuning of the microwave oscillator is controlled by the microprocessor. The microprocessor reads the frequency range being used from the microwave unit. The oscillator's tuning curve is stored in a tuning PROM included in the microwave unit. This oscillator tuning PROM is read during the initial phase and used to produce a table of tuning voltage versus frequency in the RAM. Replacement oscillators are supplied with a new calibration PROM containing their own individual tuning characteristics. In the signal generator mode of operation, the process is reversed, and oscillator tuning voltage is controlled by the front panel tuning control while the microprocessor measures this voltage and computes and displays the frequency.

A zero-bias Schottky detector is used for the microwave power sensor. The power meter has a sensitivity of −55 dBm (about 3 nanowatts). To measure this low level, an ac-coupled amplifier is used to eliminate amplifier dc voltage drifts.

The power measurement sequence starts with the microprocessor measuring the voltage out of the detector amplifier. If the voltage is out of range, the microprocessor adjusts the range of varying the detector amplifier attenuators. Once the correct range is established, the amplifier output voltage is divided by the gain of the amplifier to determine the voltage from the detector. The microwave power level is computed from this voltage and the detector data which is stored in the calibrated PROM for the corresponding detector voltage and frequency. This process is repeated continuously.

Insertion loss measurements use the same power meter sequence as above but first the detector is connected to the oscillator output, J1 on the microwave unit, and a calibration made. After the detector is zeroed, the oscillator is set to the first frequency to be measured and a power meter reading is made and stored in the RAM. The frequency of the oscillator is incremented and another power measurement is made and stored. This sequence of measurements is continued until the oscillator power delivered to the detector is stored in RAM at all 52 calibration frequencies. This is the reference level for insertion loss measurements. The calibration requires 35 seconds when the device under test is then inserted between the detector and J1; detected power is measured and subtracted from the reference level, permitting the actual insertion loss of the device to be calculated. This can be done repetitively at one frequency controlled by the tuning control (SINGLE FREQ) or stepped across a selected frequency band (AUTO STEP). The detector zero is measured before each measurement cycle, so that there is no need to recalibrate between measurements.

Reflection measurements are made in a similar manner except that the calibration is performed with the detector on J2 of the microwave unit monitoring the reflected power. A microwave short is placed on J1 and the voltage reflected from the short is measured and stored at each calibration frequency. After the short is measured, an open is placed on J3 and the voltage reflected from the open is measured at each calibration frequency. Since reflections from the short and open differ by 180°, a SWR error at J2 adds to the measured power in one case and subtracts in the other. By taking the average of these two reflected voltage for the calibration level, the residual SWR error is cancelled for the calibration run. The device under test then is connected to J2 and measurements are made of reflected power. The microprocessor converts all reflected powers to voltages and takes the ratio of the reflected voltage to the voltage reflected from the short/open. The ratio is the magnitude of the reflection coefficient, ρ. If SWR is to be displayed, it is calculated from

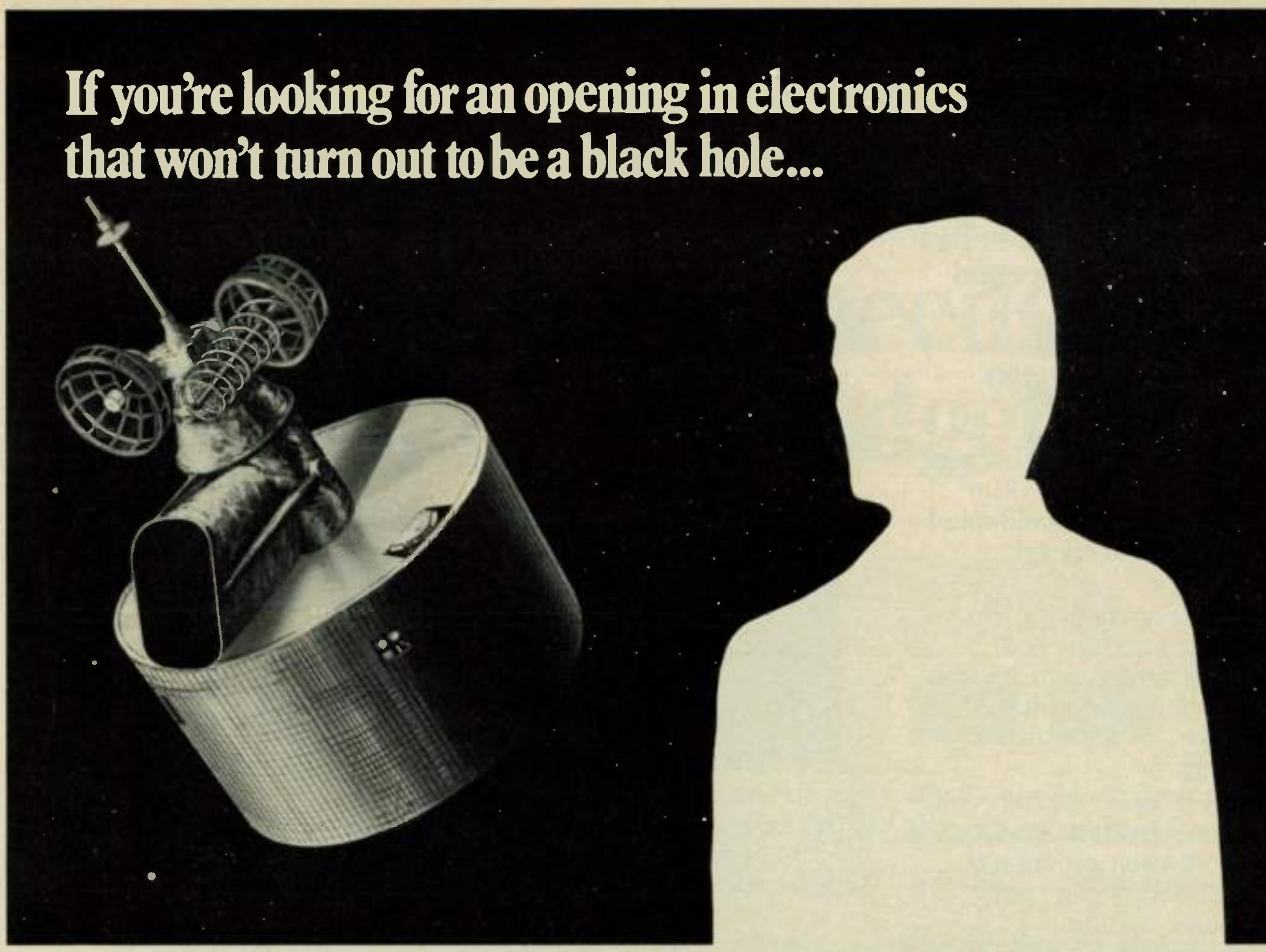
$$\frac{1+\rho}{1-\rho}.$$

Return loss is calculated by taking 20 LOG (ρ) by the microprocessor.

ACKNOWLEDGEMENT

The author wishes to acknowledge all of the people at Narda Microwave who helped with this project. In particular, Jim Boncore and Bob Fuchs who worked on the design of the instrument and Chuck Buntschuh who helped with the preparation of this paper.

Robert P. Coe joined Narda Microwave Corporation in June 1977. He is currently a Principal Engineer responsible for the design of microprocessor controlled microwave test instruments. Prior to joining Narda, Mr. Coe designed microwave test equipment including frequency synthesizers and spectrum analyzers. He received his B.E.S. degree from Johns Hopkins University in 1968 and an M.S.E. E. degree from Polytechnic Institute of Brooklyn in 1972. He is a member of the IEEE, Tau Beta Pi, and Eta Kappa Nu.



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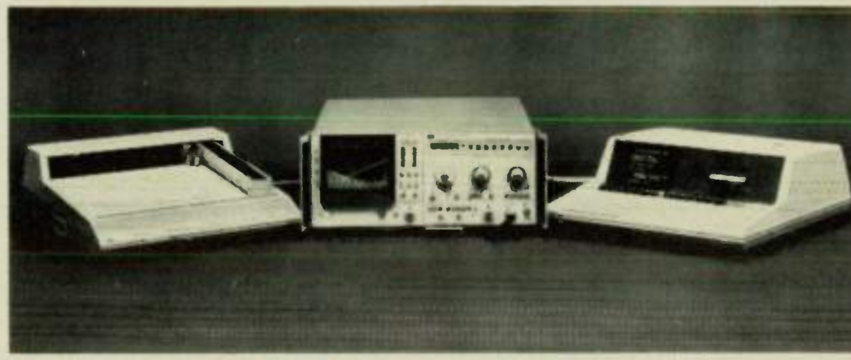
Digital Display Enhances Microwave Spectrum Analyzer Performance

HEWLETT PACKARD
Santa Rosa, CA



The new Hewlett-Packard 8569A Spectrum Analyzer covering 10 MHz to 22 GHz (extending to 170 GHz with external mixers) claims these three major benefits:

- RF performance designed to accommodate a very broad range of demanding measurement applications;
- Microprocessor-controlled digital display with input/output capabilities that invite semi-automatic production test and data logging applications;
- An extremely competitive price for the performance and operating features offered.

RF PERFORMANCE

Contributing to the HP 8569A's performance are an advanced mixer design for high sensitivity plus flat response, and a clean, stabilized local oscillator that permits close-in, high resolution measurements. The Company believes the HP 8569A can readily handle all microwave signal applications except those that truly require the precision and stability of an analyzer employing a fully-synthesized local oscillator. The 8569A also has built-in YIG preselection in the 1.8 to 22 GHz bands.

The analyzer offers sensitivities of -113 dBm (1 kHz bandwidth) up to 1.8 GHz, -110 dBm at 4.1 GHz for fundamental mixing and -95 dBm at 18 GHz. Its frequency response is ± 3 dB to 18 GHz and, in the preselected bands, the dynamic range exceeds 100 dB. Ten resolution bandwidths (100 Hz to 3 MHz) with Gaussian filter shapes are provided for high resolution of adjacent signals as well as maximum signal-to-noise ratio for pulsed spectra. With its 1-3-10 bandwidth selection, the HP 8569A offers faster sweep speeds commensurate with prevailing sensitivity and frequency span conditions.

DIGITAL DISPLAY SYSTEM

The HP 8569A's microprocessor controlled digital display system provides two independent traces, each with 480-point horizontal and 800-point vertical resolution. This brings the flexibility to store trace data and still monitor signal changes. All major control settings are indicated on the CRT, above the graticule to avoid interfering with observed signals. Additional capabilities of the trace processing system include "Digital Averaging" to extract low level signals from noise without sacrificing sweep speed, "Normalization" (or "Trace Arithmetic") that simplifies observation of signal changes within a crowded spectrum, and "Maximum Hold" that facilitates measurements such as signal drift.

Another useful feature derived from the digital display system is the ability to plot the entire display (trace, graticule, and annotation) directly on a digital plotter. This is done with the HP 8569A's front panel push buttons; an instrument controller is not needed.

The new analyzer also has built-in HP interface bus (IEEE-488) input/output capability that permits such actions as full "Read/Write" and sweep trigger. Programming aids for the HP 85 and HP 9825 controllers are provided.

HP 8569A PERFORMANCE SUMMARY

FREQUENCY RELATED

Internal Mixing Range: 10 MHz to 22 GHz.
External Mixing Range: 14.5 to 40 GHz with the HP 11517A External Mixer, extendable to 170 GHz with other commercially available mixers.
Input Preselection: 1.8 to 22 GHz.
Resolution Bandwidths: Gaussian filters of bandwidths 100 Hz to 3 MHz.
Residual FM: < 100 Hz peak to peak (fundamental mixing to 4.1 GHz).
Noise Sidebands: < -75 dBc, 30 kHz from the carrier in a 1 kHz bandwidth.

AMPLITUDE RELATED

Maximum Input Level: +30 dBm (1 watt).
Gain Compression Level (< 1 dB): < -7 dBm at mixer.

DIGITAL DISPLAY

Traces: Dual trace, digitally stored display with a resolution of 480 horizontal by 800 vertical points for each trace.
Control Readout: Major control settings annotated area on the CRT.
Signal Processing: Maximum Hold, trace normalization, sample detection mode and digital averaging are available.

HP-IB

Direct Plotter Control: Uses three front panel pushbuttons to transfer all displayed information to an HP-IB plotter.
Controller Interface Functions: Semiautomatic applications such as data logging and production test sequences can be accomplished using the 8569A with the HP 85F. Other controllers such as the HP 9825T, 9835A or 9845A can also interface with the 8569A.

PRICE AND AVAILABILITY

Domestic US price of the HP 8569A Spectrum Analyzer is $26,500, and first deliveries will be made in April.

Contact: Inquiries Manager, Hewlett-Packard Company, Palo Alto, CA.
Circle 133 on Reader Service Card

Product Feature

Satellite Communications Test Set

POLARAD ELECTRONICS, INC.
Lake Success, NY

The Model 1309-2 Satellite Communications Test Set enables testing of satellite communication receivers in both the C and K_u-band frequency ranges. It provides test signals from 3.7 to 8.4 GHz, 10.7 to 12.2 GHz and 14 to 14.5 GHz so that both the downlink and uplink frequencies in both C and K_u band are covered. The test set output levels may be varied with great precision over a 130 dB range in C band and 100 dB in K_u band so that the dynamic ranges of the receivers may be measured very accurately.

The signal source providing the output signals is a klystron cavity tuned oscillator. This type of oscillator generates a signal singularly low in sideband FM noise. This characteristic makes it suitable for measureing noise levels in the SSB channels of FDM communication systems.

Its important features include: broad frequency coverage; stable, spectrally pure calibrated signals and low noise sideband levels; digital frequency readout, ± 0.5% accuracy; output levels adjustable 130 dB in C band and 100 dB in K_u band; internal CW, square wave and FM; and detected signal output and sweep (time base) output which facilitates scope traces of bandpass tests and modulated waveforms.

The satellite communications test set consists of a Model 1107E-S Signal Generator combined with a Model 1509-2 Frequency Doubler. The Model 1107E-S is a signal generator designed for low single sideband phase noise throughout its frequency range. It is presently used by many manufacturers of this particular characteristic. It covers the overlapping C band range of 3.7 to 8.4 GHz. The frequency doublers are passive devices using a harmonic generator which doubles the frequency of the input signal, then filters and calibrates the level of the output signal. The selection of the doubler is dependent on the maximum calibrated output level required. The output port of the Model 1107E-S is a type N coaxial connector and that of the doubler is WR75 waveguide. If a coaxial output is desired, a waveguide to coaxial transition is provided as an option.

Circle 132 on Reader Service Card

SATELLITE COMMUNICATIONS TEST SET
MODEL 1309 2

CHARACTERISTIC	C Band	K_u Band
Frequency Range	3.7 8.4 GHz	10.7 12.2 GHz and 14.0 14.5 GHz
Frequency Accuracy	± 0.5% (digital readout)	± 0.5% (x 2 digital readout)
Frequency Stability	± 0.0008% per volt change in line voltage ± 0.005%/ C ambient	Same as for C Band
Calibrated Power	+3 to –127 dBm	–3 to –103 dBm (0 to –100 dBm) switched CAL reference @ or –3 dB
Absolute Accuracy	± 2 dBm from 3.7 to 7.6 GHz ± 2.5 dB 7.6 to 8.4 GHz	± 2.5 dB plus attenuator accuracy
Attenuator Accuracy	–	± 2% of attenuator reading or ± 0.2 dB whichever is greater
M Spectral Noise Density	< 2.5 pwo in 3.1 kHz BW 70 kHz from carrier, ≥ 200 kHz rms 1 mW reference	
Output SWR	2 1 maximum	2 1 maximum

COMMON SPECIFICATIONS

Output Signals	CM, FM, Square Wave, Pulse
Modulation Capabilities	
Internal	
Square Wave	950 to 1050 Hz
On Off Ratio	Infinite
Synchronization	Internal
FM	Power line frequency
Sweep Width	Continuously adjustable, typically
C Band	0 10 MHz
K_u Band	0 20 MHz
External	
FM	Any wavelength having frequency components between 10 Hz and 500 kHz
Sweep Width	
C Band	10 MHz
K_u Band	20 MHz
Pulse	Model 1020A Recommended
Modulation	Pos. 15 50 V peak
Pulse Required	Single pulse to 100 kHz
Rate	0.2 to 2500 μs
Width output	
Output Pulse Rise & Decay Time	0 15 μs
Horizontal Sweep	Output for scope 2 V p p power line freq Phase Control Range adjustable to 90 min
Power Requirements	115/230 V ± 10% 50 60 Hz, 140 W (50 400 Hz, F option)
Dimensions	11 3/4" H x 16 3/4" W x 17" D
Weight	62 lbs.

(from page 60) RATIO METER

in conversion loss of about 8 dB.

Stability of the conversion loss is obtained for the 10 MHz - 2 GHz range by the use of leveling loops which keep the LO power constant. For the 2-18 GHz range closed loop feedback bias circuits are employed which control the rectified diode currents and diode bias voltages.

Greater than 160 dB of attenuation is provided for the coherent leakage path between both channels by the insertion of broadband isolation amplifiers into the LO signal paths. The reduced bandwidth requirement due to the used harmonic mixing technique makes this low leakage possible for the higher microwave frequencies. Good signal to LO port isolation of the mixers also contributes to the coherent leakage attenuation.

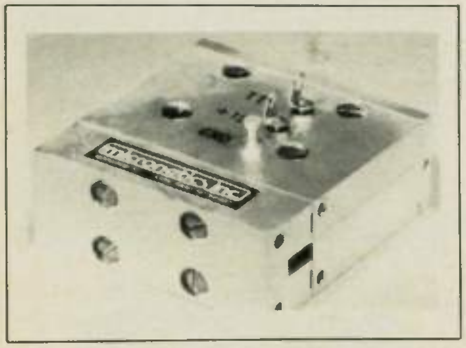
SIGNAL SOURCE

Any signal source can be used for manual operation. Weinschel's Engineering Model 4312 Phase Locked Multiband system 0.01-18 GHz is used as signal source for the internal program mode. The signal source is digitally tuned over the IEEE-Standard-488 General Purpose Interface Bus and measured data is stored in the instrument. When under external program control by an IEEE-STD-488 bus compatible computer or programmable calculator, such as the HP 9825, an IEEE-STD-488 bus compatible signal source or frequency synthesizer is employed.

REFERENCES

1. Weinert, F. K., and B. O. Weinschel, "A 1-18 GHz Attenuator Calibrator," *IEEE Trans. Instr. Meas.*, Vol. IM-25, Dec. 1976, pp. 298-306.
2. Fitzpatrick, J., "Error Models for System Measurement," *Microwave Journal*, May 1978, pp. 63-66.
3. Hines, M. E., and H. E. Stinehelfer, "Time Domain Oscillographic Microwave Network Analysis Using Frequency Domain Data," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-22, March 1974, pp. 276-282.
4. Little, W., J. Wakefield, L. Heim, C. Allred, T. Zapf and C. Manney, "An NBS Developed Automatic Network Analyzer," *CPEM Conference Digest*, June 28 - July 1, 1976, pp. 130-133.
5. Hewlett-Packard Catalog, 1980, pp. 474.
6. Cohn, M., J. E. Degenford and B. A. Newman, "Harmonic Mixing with Antiparallel Diode Pair," *IEEE Trans. MTT*, Vol. MTT-23, August 1975, pp. 667-673.

33 GHz Integrated Noise Source



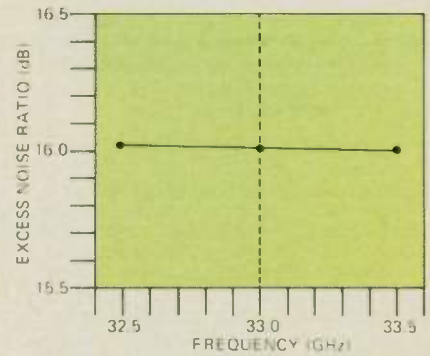
MICRONETICS INC.
Norwood, NJ

The new Model NSC-KA is a solid state noise source-directional coupler combination. It is designed to inject a 16 dB excess noise ratio of white noise into WR-28 waveguide at 33 GHz.

The noise source consists of a broadband waveguide diode in a hermetically sealed package which is actuated by an integrated TTL driver. A 5 V TTL input turns the diode on; total power required is 15 mA at 15 V.

The directional coupler is a sidewall multi-aperture design with a coupling of approximately 10 dB and a directivity greater than 20 dB. Its SWR is less than 1.3 and the coupling array is ≈ 1" long", total assembly length is 2".

The noise source has a total output of 30 dB ENR. The sidewall directional coupler design is capable of 7 dB coupling in a 1 in. array and it has a 5% bandwidth. These basic capabilities permit designs for other frequencies and values of excess noise ratio.

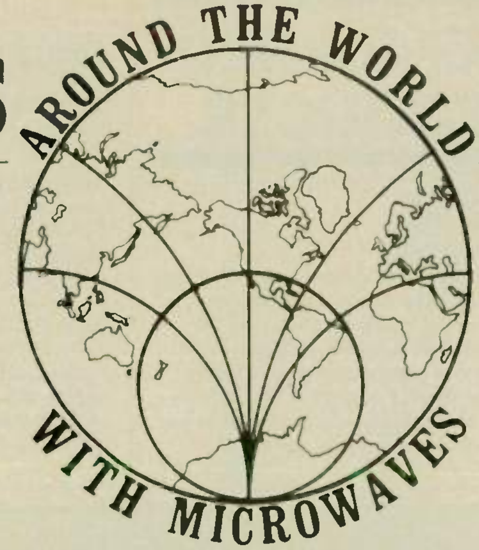


TYPICAL OPERATION CONDITIONS

Operating Frequency:	33 GHz
ENR Output:	16 dB
Insertion Loss:	0.6 dB
Directivity:	20 dB
SWR:	1.3 max
Drive Power:	15 volt, 15 ma
TTL Control:	0, +5 volts

Circle 131 on Reader Service Card

LOS ANGELES



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Microwave Products

Materials

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A line of 4-inch SOS wafers, produced from the ribbon process by the edge-defined growth method, is offered for use in the EPI process. The company also supplies 3" wafers with epitaxial coatings and 5 μm flatness can be maintained for the 3" material. **Kyocera International, Inc., Cupertino, CA. John Thiemann, (408) 257-8000.**

Circle 167.

Devices

LOW BARRIER MIXER DIODE SERIES

Series A2S270, are microwave mixer diodes which employ low barrier Schottky junctions designed for use without biasing in starved LO (−20 dBm through −6 dBm) applications. At −10 dBm LO drive, typical noise figures are 6.5 dB at 2.0 GHz and 8.0 dB at 9.375 GHz. Diodes present relatively uniform RF and IF impedances to varying local oscillator drive levels. Units come in a variety of package styles or as individual chips. **Aertech Industries, Sunnyvale, CA. William S. Patton, (408) 732-0880.**

Circle 168.

Antennas

9-METER EARTH STATION ANTENNA

A 9-meter satellite earth station antenna, Model 5251, features a high efficiency Cassegrain feed system and kingpost pedestal, adjustable to view any domestic visable synchros satellite. Antenna complies with the FCC requirements for transmit/receive earth stations. Options include a motor drive system that will simultaneously drive azimuth, elevation, and polarization at the rate of one degree per second. Drive system control is capable of being pre-set to all angles of satellite positions. Cassegrain feed options include dual polarized receive only, dual port transmit/receive, linear or circular polarization, linear co-polar and frequency reuse linear or circular polarized transmit/receive. **Harris Antenna Operations, Kilgore, TX. (214) 984-0555.** **Circle 166.**

Instrumentation

MICROWAVE LIMITER PROTECTS MICROWAVE COUNTER INPUT CIRCUITS

Option 006, a microwave limiter, protects instrument input circuits from damage from excessively high signal levels. Unit operates up to 26.5 GHz and provides protection for inputs up to 8 W (+39 dBm) CW and up to 100 W (+50 dBm) peak pulsed. Can be field installed in existing counters or installed at the factory when company counters are ordered. Price: $400. Del: 60 days. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.**

Circle 165.

Hardware

CONTACT SPRING LINE

A line of nine gold-plated bellows contact springs, Series 2012, is offered. Produced from electrodeposited nickel in diameters of 0.037-0.245" O.D., all models offer constant resistance and path length within their rated strokes. Model P/N 2012 (.125" O.D.) has a compression stroke of 0.065" and exerts a 4 oz. minimum force at this point. Overall length (including end cup) is 0.197". Its dc resistance is 0.009 Ω and its self-inductance is 9.5×10^{-10} H. **Servometer Corporation, Cedar Grove, NJ. Donald Walker, (201) 785-4630.** **Circle 169.**

Shielded Room

RF SHIELDED TEST ROOM

A modular RF-shielded test room provides isolation at frequencies up to 96 GHz with attenuation better than 100 dB. One hundred rooms are available in any size, and be field tested and certified to 100 GHz. Optional accessories include anechoic materials, lighting, heating, air conditioning, architectural finishes and computer floors. Internal surfaces can be covered by a special mm-wave absorber material that provides an internal reflectivity level of more than −40 dB at frequencies up to 100 GHz. Del: installation in new or existing buildings in under 6 wks. **Keene Corporation, Ray-Proof Division, Norwalk, CT. Bob Barbour, (203) 838-4555.** **Circle 170.**

Waveguide

ELLIPTICAL WAVEGUIDE SPANS 5.925-6.424 GHz BAND

Types WE60 and WEP60 Wellflex® elliptical waveguides are designed for the 5.925 to 6.425 GHz frequency range for common carrier applications. Attenuation per 100 ft. is 1.14 dB at 5.925 GHz, 1.10 dB at 6.20 GHz, and 1.08 dB at 6.425 GHz. Waveguides consist of a welded, high conductivity copper tube, corrugated and precision formed into an elliptical cross section. Minimum bending radius in the E plane is 20" and 40" in the H plane. Recommended twist is 1.0°/ft.; operating pressure is 10 PSI maximum and installation temperature range is 0° to 140°F. **Cablewave Systems, Inc., North Haven, CT. Mac Lundberg, (203) 239-3311.** **Circle 171.**

Components

DC TO 300 MHz BAND POWER AMPLIFIER

Model CLC102 is a power amplifier which covers the dc to 300 MHz frequency spectrum. It offers over 300 MHz bandwidths at outputs of 5 V_{pp} and over 200 MHz at 10 V_{pp} when driving 50 ohm loads. Both the input and output are dc coupled and biased at 0 Vdc so that amplifiers can be cascaded. Rise and fall times are less than 1.7 ns at full output; pulse overshoot and aberrations are less than 5% for a duration of less than 10 ns. Linear amplifier gain is 15 dB. At 100 MHz and +24 dBm out, the distortion products are below −30 dBc. Unit's input and output impedance is 50 ohms, SWR at either port is 1.02:1 at low frequencies (50 ± 1 Ω at dc) and rises to less than 2:1 at above 300 MHz. RMS noise measured in a 10 Hz to 300 MHz bandwidth is less than 46 µV. Power consumption is 140 mA at ± 15 Vdc. Available with BNC, TNC, SMA or N type connectors. Size: 3" x 3" x 1.175", case dimensions. Price: $270. Del: 4 wks. **Comlinear Corp., Loveland, CO. David Nelson, (303) 669-9433.** **Circle 147.**

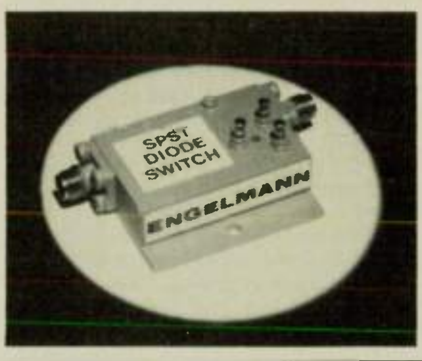
20 W CW MINIATURE COAX LOAD

Model PCX-050-M-29 is a 200 W peak, 20 W CW average conduction-cooled broadband dummy load. It covers the dc to 18 GHz frequency range with a SWR of 1.35 maximum; impedance is 50 ohms. Unit's maximum heat sink temperature is 100°C. Connector is stainless steel SMA male type conforming to MIL-C-39012. Price: $105, 1-9 qty. Avail: 12 wks ARO. **KDI Pyrofilm Corp., Whippany, NJ. Pat Daniels, (201) 478-0302.** **Circle 152.**

TO-8 DOUBLE BALANCED MIXER FOR 3.7-4.2 GHz BAND

Model MC24T is a TO-8 package double balanced mixer designed to operate in the 3.7-4.2 GHz satellite communication band. Mixer typically features 4.5 dB conversion loss, L-R isolation of 33 dB, L-I isolation of 20 dB and SWR of 1.6. Price: $39.75, qty. of 100. Del: 2-3 wks. **Magnum Microwave Corporation, Sunnyvale, CA. David Fealkoff, (408) 738-0600.** **Circle 156.**

SPST SWITCH RATED FROM 0.3-18 GHz



A single pole, single throw switch, Model SWO316, is offered for use over the full 300-18,000 MHz range. Unit provides 40 dB minimum isolation, with typical figures greater than 60 dB over most of the band. Insertion loss varies with frequency between 1 to 4 dB maximum. Worst case switching speed is 50 ns maximum for rise and fall times for 10-90% points. Switches are rated at 50 W peak, 1 W average. Externally supplied voltages required are +5 Vdc at 100 mA and −5 Vdc at 30 mA, in addition to the logic drive. Size: 1.5" sq. x 0.44" thick, including mounting flange. Price: $250, small qty. Avail: 45-60 days ARO. **Engelmann Microwave Company, Montville, NJ. Carl Schraufnagl, (201) 334-5700.** **Circle 149.**

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GaAs FET AMPLIFIERS FOR 18-26.5 GHz BAND

Series AMT-26030 are GaAs FET amplifiers which cover the 18-26 GHz frequency range. Performance specifications for the series include a choice of 10-44 dB minimum gain (standard values are 17, 26, and 35 dB), with ± 2.0 to ± 2.5 dB full-band gain flatness and +12 dBm minimum output power (at 1 dB gain compression). Amplifiers offer +22 dBm typical intercept point for intermodulation products; a 2.2 maximum input and output SWR (at 50 ohms) and they operate from +12 Vdc at 200-500 mA. They can be qualified to MIL-E-5400, MIL-E-16400, and MIL-E-4158 and meet EMI requirements of MIL-STD-461. Del: 90 days ARO. **Avantek, Inc., Santa Clara, CA. James Orr, (408) 727-0700.** Circle 145.

SERIES OF DIELECTRIC RESONATOR OSCILLATORS

The DO-Series dielectric resonator oscillators are available in the 4, 6, 12, and 16 GHz frequency ranges. Oscillators incorporate either Si bipolar transistors or GaAs FET's; they are intended for local oscillator applications. Frequency is set by a screwdriver/locking adjustment after applying a ± 12 V supply to the oscillator. Size: 1.0" x 1.5" x .75", a larger configuration (3" x 4" x 2.5") includes controller. **Frequency Sources West Division, Santa Clara, CA. E. Brown, (408) 727-8500.** Circle 151.

HPA COMBINER FOR SAT, UPLINK STATIONS

High power amplifier (HPA) combiners which combine the outputs of two 3.5 kW HPA's are offered for use in the 5.925 to 6.425 GHz uplink band. Combiners offer a minimum of 28 dB isolation between HPA inputs. Switches used in the combiners require no cooling, terminations receive cooling through a dual blower system. A combiner serving 3 HPA's (holding one as a redundant spare) is also available. **Logus Manufacturing Corporation, Deer Park, NY. Robert Vanson, (516) 242-5970.** Circle 155.

TUNABLE WAVEGUIDE FILTER

A six-section waveguide filter, #501575, which features direct frequency readout and incorporates a lowpass filter to eliminate all frequencies except the band of interest up to 18 GHz. Tuning range is 8.0-9.6 GHz and 3 dB BW is 55 MHz. Rejection is 35 dB minimum at 100 MHz maximum, insertion loss is 1.9 dB maximum and SWR is 1.65 maximum. Price: $2175. Avail: 8-10 wks. ARO. **Coleman Microwave Co., Edinburg, VA. Ken Coleman, (703) 984-8848.** Circle 146.

DUAL OUTPUT MIXER PREAMPLIFIERS

A series of mixer preamplifiers, FMA2638, offer overlapping coverage of the 600 MHz through 2.8 GHz frequency bands. Model FMA2638-1 covers the 0.6-1.25 GHz frequency range; FMA2638-2 covers 1.05-1.75 GHz and the FMA2638-3, 1.6-2.8 GHz. Standard IF is 70 MHz and 1 dB IF bandwidth is 20 MHz for the series. Two isolated 50 ohm outputs at 70 MHz are provided. **Sage Laboratories, Inc., Natick, MA. Ken Paradiso, (617) 653-0844.** Circle 158.

MINIATURE WIDEBAND DOUBLE BALANCED MIXER SERIES

Series 12100 are wideband double balanced mixers with a volume of .109 cu. in. Mixers are designed to operate and meet specifications in the RF/LO range of 4-18 GHz and an IF range from dc to 750 MHz. Series offers a conversion loss of 5 dB typical over the entire frequency band while maintaining maximum conversion loss of 8 dB over the 4-18 GHz frequency spectrum. Design conforms with the requirements of MIL-E-5400 Class 1 and 2, including operation over the temperature range of −54°C to 100°C. Price: $300 each. **Norsal Industries, Inc., Central Islip, NY. Norman Spector, (516) 234-1200.** Circle 163.

STEP ATTENUATORS WITH INTERNAL DRIVERS

Two 7-section connectorized solid state step attenuators, #100C1585 and #100C1595, offer 63.5 dB total attenuation in 0.5 dB steps. Devices incorporate hermetically sealed thin film construction with internal drivers operating from 30-500 MHz. Part No. 100C1585 uses CMOS drivers requiring +5 to +15 Vdc @ 25 mA; Part No. 100C1585 uses CMOS drivers requiring +5 to +15 Vdc @ 25 mA, Part No. 100C1595 employs TTL compatible drivers requiring +5 Vdc @ 50 mA. Components offer 5 μs nominal switching speed; +13 dBm RF power, plus 7-line control and SMA connectors. Size: 1.75" x 3" x .54". **Daico Industries, Inc., Compton, CA. Jim Adamson, (213) 631-1143.**
Circle 148.

GaAs FET AMPLIFIER FOR 3.7-4.2 GHz BAND

Model MC2016 GaAs FET amplifier covers the 3.7-4.2 GHz and features a minimum gain option of 50 dB, with noise figure options from 85°K (1.12 dB) to 120°K (1.5 dB). In/out SWR is 1.20/1.5 maximum, and gain flatness is ± 0.5 dB maximum. The third order intercept is +20 dBm minimum and the 1 dB compression point is +10 dBm minimum. Housing is a weatherproof low profile A1 brazed case; power conditioning circuits are also provided. **M/A Electronics Canada Ltd., Mississauga, Ontario, Canada. (416) 625-4605.**
Circle 157.

POWER DIVIDER FOR 3-18 GHz BAND

Model PD-4018 is a power divider designed for use in the 3.0 to 18.0 GHz frequency range. Unit offers a 0.5 dB typical insertion loss at 3.0 to 16.0 GHz, with 0.6 dB typical at 3.0 to 18.0 GHz. SWR is 1.6 at 3 to 18 GHz, typical (1.4:1 at 3-16 GHz). Typical isolation is 15 dB over the full band; 22 dB is typical at 4-18 GHz. Price: $246, 1-24 qty. Del: Stock to 4 wks. ARO. **Western Microwave, Sunnyvale, CA. (408) 734-1631.**
Circle 161.

BANDPASS FILTER FOR 2155 MHz BAND

Model 3746 is a bandpass filter with center frequency of 2155 MHz with a bandwidth of 25 MHz, to pass both channels of the MDS band. Selectivity is 30 dB (minimum) ± 65 MHz. Unit is weatherized and has N type connectors. **Microwave Filter Company, East Syracuse, NY. Emily Bostick, (800) 448-1666.**
Circle 162.

SATELLITE TV RECEIVER/MODULATOR

Model 1000 TVRM is a satellite TV receiver/modulator which combines 24-channel synthesized receiver circuitry with a high performance modulator. The 3.7-4.2 GHz receiver features ± 0.001% synthesizer stability from 0° to 50°C and linear distortion of less than ± 1.5%. The modulator has a video response of ± 0.5 dB (10 Hz-4.2 MHz). Output frequency at any standard VHF channel at +40 to +60 dBmV with spurious outputs −60 dBc. Both receiver and modulator input/outputs can be accessed through the back panel. Unit has a 30 W power consumption and uses 115 Vac, 50 to 400 Hz prime power. **Microdyne Corp., Ocala, FL. (904) 687-4633.**
Circle 164.

DUAL CHANNEL ROTARY JOINT

Model 2222 is a non-contacting dual channel rotary joint which operates over the 1.03-1.09 GHz frequency band. Unit operates at 300 W average power, 2.5 kW peak power. Life is 36,000 hrs. at 10 RPM. **Kevlin Manufacturing Company, Woburn, MA. Ernest Lattanzi, (617) 935-4800.**
Circle 153.

DUAL MODE FILTER SERIES FOR X-BAND

A series of dual mode filters are designed for use in the X-band region. Special coupling and tuning elements excite TE111 mode orthogonally providing the isolation of a 2-section design from a single cavity. Filters can be specified with 2, 4, or 6 sections in the 1-18 GHz frequency range. Bandwidths can range from 0.1% to 1.5%. Insertion losses of the waveguide resonator filters are typically near 1 dB. RF terminals can be waveguide or coaxially (SMA is standard) coupled. Price: from $400. Avail: from 60 days. **K & L Microwave, Inc., Salisbury, MD. Charles Schaub, (301) 749-2424.**
Circle 154.

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VOLTAGE TUNABLE BANDPASS FILTER

Model ETF-400-600-2 is a constant bandwidth, two-pole voltage tuned filter covering the 400-600 MHz frequency band. Bandwidth is 50 ± 5 MHz at the -3 dB point. Insertion loss is 3.5 dB, max. Unit has impedance of 50 ohms, SWR is 1.8 maximum. Third order intercept point is +18 dBm referred to the output and power handling is +20 dBm maximum. Linearity is ± 3%, ± 1% with optional linearizer. Tuning time between any two points is 20 ns, typical, and tuning voltage is 1.5 - 10 V. Available with SMA female type connectors for RF and solder pin for tuning. Size: 0.75" x 2.0" x 1.5" exclusive of connectors. Price: $335, 1-9 qty. Avail: 30 days. **American Microwave Corp., Damascus, MD. Raymond Sicotte, (301) 253-6782.** **Circle 143.**

COMPUTER-CONTROLLED TUNABLE FILTER

A line of digitally-addressable tunable RF filters are offered in 22 standard models (3 or 5 sections) covering 11 frequency bands between 48 MHz and 4 GHz. Each model tunes over a 2:1 frequency range for a full octave coverage. Featuring microprocessor-based control, filters tune in less than 2 seconds. Applications include antenna co-location interference elimination and preselection in IFM systems. Price: Approximately $2,500 each. Avail: 60 days, production qty.; 1 wk., small qty. **Telonic Berkeley, Subsidiary of Berkeley Industries, Laguna Beach, CA. Adam Reed, (714) 494-9401.** **Circle 159.**

DOUBLE BALANCED MIXER SPANS 2-4 GHz BAND

Model MD-176 is a double balanced mixer covering the 2-4 GHz band. It features 4.5 dB, typical, 6.0 dB, max. conversion loss, 0 dBm starved LO operation without bias, and isolation typically greater than 25 dB. Unit is available in a 3-pin hermetic module or SMA connectorized models which can be screened to MIL-STD-883. Price: $225, module; $300, connectorized version in 1-5 qty. Avail: from stock. **Anzac Division, Adams-Russell Co. Inc., Burlington, MA. Mark Rosenzweig, (617) 273-3333.** **Circle 144.**

TUBULAR AND LC FILTERS

A line of tubular and LC filters are available for the 2 MHz to 10 GHz frequency range which can be optimized for each application by a CAD system. Filters exhibit a typical 0.01 dB Tchebysheff or Butterworth response. Filters that operate outside of the 2 MHz to 10 GHz frequency spectrum and filters with Gaussian, Bessel or linear phase responses are also available. Tubular bandpass filters have 3 dB bandwidth ranges from 1 to 100% of center frequency; LC bandpass filters have 3 dB bandwidth ranges from 2-125% of center frequency. Standard filters come with 2-12 sections, 50 or 75 Ω impedances, 17 connector types, and average power ratings up to 200 W. Filters conform to MIL-E-5400, MIL-STD-202, MIL-E-8189 and MIL-F-18327. Del: 4-6 wks. **Wavetek Indiana, Inc. Beech Grove, IN. John Duval, (317) 787-3332.** **Circle 160.**

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New Literature

POWER MEASURING EQUIPMENT BROCHURE

A brochure describing a complete line of microwave power measuring equipment is offered. A self-calibrating digital power meter, a self-calibrating analog power meter, and a series of coaxial and waveguide power heads for measurements to frequencies of 40 GHz and power levels to 3 W are featured. **General Microwave Corporation, Farmingdale, NY. Moe Wind, (516) 694-3600. Circle 137.**

TERMINATION INSENSITIVE MIXER TECHNICAL REPORT

A technical report on Termination Insensitive Mixers (TIM) features circuit design analysis, performance comparisons as well as actual test results, unit specifications and mechanical outlines. The 16-page report compares TIM devices to other double balanced mixers. Detailed specifications covering dc to 8 GHz models are provided. **Anzac Div., Adams-Russell, Burlington, MA, Mark Rosenzweig, (617) 273-3333. Circle 135.**

APPLICATIONS MANUAL FOR AUTOMATED SWEPT ANALYZER

AN-20 is an applications note which describes the operation of the Model 1038/N-10 automated swept measurement system. The 16-page manual provides instructions for system use with or without IEEE bus control. Step-by-step measurement procedures are outlined which assist end-users in making more accurate measurements. **Pacific Measurements, Inc., Sunnyvale, CA. Ed Mendel, (408) 734-5780. Circle 140.**

CATALOG ON EARTH STATION FILTERS

Catalog MTV/81 describes filters used with 3.7-4.2 GHz earth stations. Bandpass filters for single transponders and for 70, 700, 820 and 1200 MHz IF are included. IF traps for ± 10 MHz terrestrial interference are also shown. **Microwave Filter Company, Inc., E. Syracuse, NY. Emily Bostick, (315) 437-3953. Circle 138.**

SHORT FORM CATALOG OF PASSIVE RF COMPONENTS

This catalog for a line of passive RF components has 16 pages of information on fixed attenuators, high power fixed attenuators, OEM and variable attenuators, step attenuators, resistive power splitters and dividers, terminations and loads, connectors and adapters. In addition, the catalog contains specification summary tables on each product category and a summary of the company's instrumentation product line. **Weinschel Engineering, Gaithersburg, MD. Julian D. Parker, (301) 948-3434. Circle 142.**

IMPROVED "RG" TYPE COAXIAL CABLE BROCHURE

A four-page full color brochure describes an improved line of "RG" type coaxial cables and assemblies which utilize a new form of PTFE (Teflon) insulation. Trademarked GORE-TEX Expanded PTFE, the unique microporous structure of this insulation material preserves the premium properties of PTFE while reducing the dielectric constant to 1.3. Reduction in weight, lower attenuation, and improved phase and loss stability are the primary advantages inherent in these cables. Standard cables are compared to RG types. **W. L. Gore & Associates, Inc., Newark, DE. (302) 738-4880. Circle 172.**

WIDEBAND AMPLIFIER LINE DATA SHEETS

A line of high performance dc to 500 MHz dc coupled wideband amplifiers is described in a series of data sheets. Appropriate applications include digital telecommunications and general instrumentation work. **Comlinear Corp., Loveland, CO. (303) 669-9433. Circle 136.**

SHORT FORM CATALOG OF ELECTRONIC COMPONENT LINE

A 28-page short form catalog which provides electrical and mechanical specifications for a line of electronic components includes specifications and applications for JFD Electronic Components Corp.'s line of variable and fixed microwave capacitors. Capacitance values from 0.1 to 1000 pF are offered in a variety of fixed value styles. Variable models provide ranges of 4:1 to 7:1 in two styles. **Murata Corporation of America, Marietta, GA. (404) 952-9977. Circle 139.**

SOLID STATE AMPLIFIER PRODUCT GUIDE

This is a 32-page, 1980/1981 Product Guide to a line of solid state microwave amplifiers for wideband and narrowband applications from 5 MHz to 18 GHz. Multi-octave models for EW applications, an 80°K 4 GHz amplifier and a 3.0 dB 12 GHz model are featured in the Guide. **Amplica, Inc., Newbury Park, CA. Nick Pena, (805) 498-9671. Circle 134.**

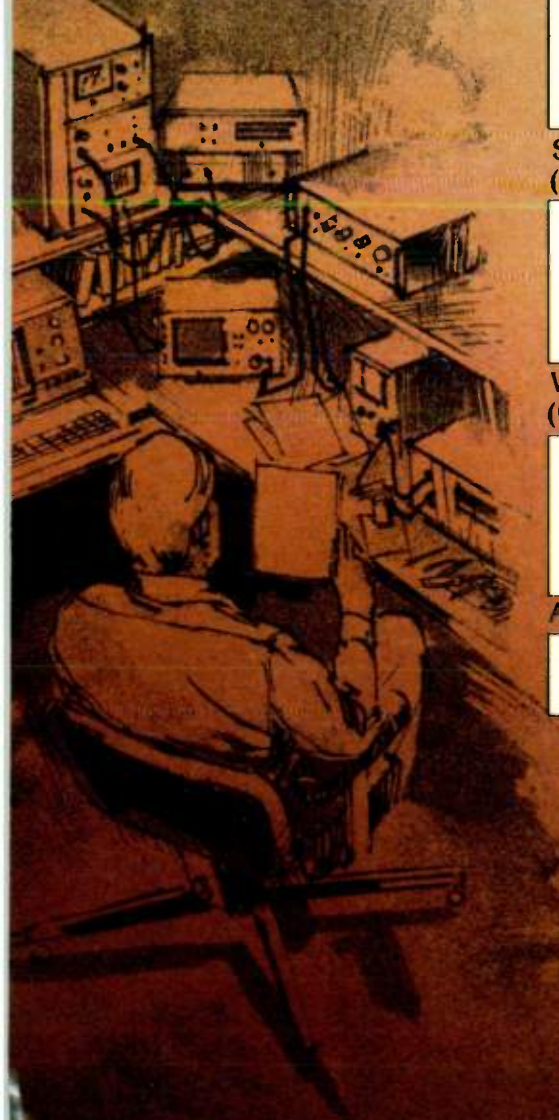
BROCHURE ON SIGNAL SOURCES

A 6-page brochure describes the "E" series of microwave signal sources, a line consisting of four units with overlapping frequency ranges, from 0.8 GHz up to 11.0 GHz. Specification data for the four klystron cavity tuned oscillator sources and their features are highlighted. Available options and accessories are described. **Polarad Electronics, Inc., Lake Success, NY. (516) 328-1100. Circle 141.**

MSC

Solid State Noise Sources

Products for Noise Measurement from 1MHz to 40,000 MHz



INSTRUMENT NOISE SOURCES

WIDEBAND COAXIAL SOURCES (1 to 18000 MHz)

Model Number	Frequency Range (MHz)	ENR	Flatness	Power Req. Max
MC 200	1 - 500	42.0 dB	± 1.50 dB	+ 24V, 1mA
MC 201	1 - 500	42.0 dB	± 1.50 dB	+ 12V, 1mA
MC 1000	10 - 1500	35.0 dB	± 0.50 dB	+ 28V, 10mA
MC 1100	10 - 1500	15.5 dB	± 0.50 dB	+ 28V, 10mA
MC 1040	10 - 4000	25.5 dB	± 0.50 dB	+ 28V, 15mA
MC 5112	1000 - 12400	25.5 dB	± 0.50 dB	+ 28V, 15mA
MC 5118	1000 - 18000	25.5 dB	± 0.50 dB	+ 28V, 15mA
MC 50018	5 - 18000	25.5 dB	± 0.75 dB	+ 28V, 15mA

STANDARD BAND COAXIAL SOURCES (1000 to 26500 MHz)

MC 5012	1000 - 2000	30.0 dB	± 0.50 dB	+ 28V, 15mA
MC 5024	2000 - 4000	30.0 dB	± 0.50 dB	+ 28V, 15mA
MC 5048	4000 - 8000	30.0 dB	± 0.50 dB	+ 28V, 15mA
MC 5812	8000 - 12400	30.0 dB	± 0.50 dB	+ 28V, 15mA
MC 51218	12400 - 18000	28.0 dB	± 0.50 dB	+ 28V, 15mA
MC 51826	18000 - 26500	25.5 dB	± 0.75 dB	+ 28V, 15mA

WAVE GUIDE BAND SOURCES (GAS TUBE REPLACEMENTS) (4000 to 40000 MHz)

MC 5046W	3950 - 5850	15.5 dB	± 0.50 dB	+ 28V, 15mA
MC 5068W	5850 - 8200	15.5 dB	± 0.50 dB	+ 28V, 15mA
MC 5812W	8200 - 12400	15.5 dB	± 0.50 dB	+ 28V, 15mA
MC 51218W	12400 - 18000	15.0 dB	± 0.50 dB	+ 28V, 15mA
MC 51826W	18000 - 26500	25.0 dB	± 2.00 dB	+ 28V, 20mA
MC 52640W	26500 - 40000	23.0 dB	± 3.00 dB	+ 28V, 20mA

ADAPTORS (COMMERCIAL NOISE FIGURE METERS)

MC 601A	ADAPTOR FOR HP 340 and HP 342 Series Automatic Noise Figure Meters
MC 602	ADAPTOR FOR AIL Model 74 Noise Figure Meter

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The MSC series of Solid-State Noise Sources allow you to achieve one-step broadband noise-figure measurements superior to many octave-bands of gas discharge noise tubes. Please call or write for a complete Noise Measurement Product Data Packet, and the MSC 24-Page Product Guide.

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When it comes to mixing millimeter-waves or millimeter-wave components, nobody does it better than Hughes.

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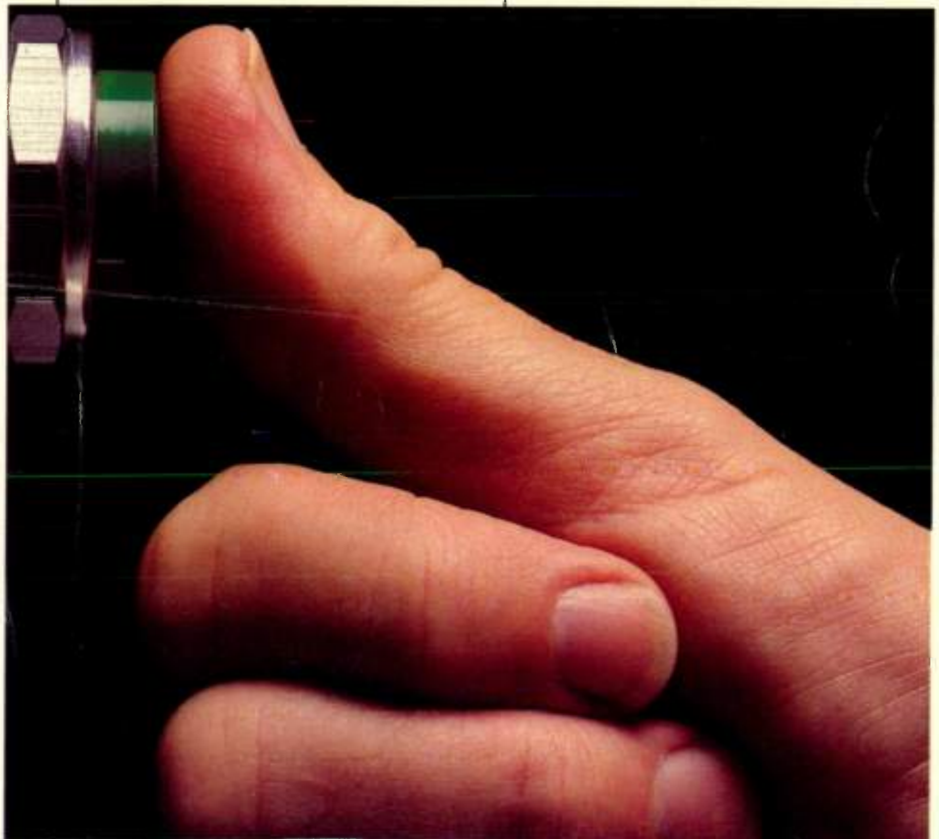

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