microwave
JOURNAL

INTERNATIONAL EDITION □ VOL. 23, NO. 7 □ JULY 1980

Active Components

- Microwave Tube Conference Report
- Mini TWTA
- Earth Station Klystrons
- Swept mm Gunn Source

and

Microwave Journal Seminar Report
Military Microwaves '80 Preview

M/W TUBE
BUYERS GUIDE

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	50-70	60	± .5	1.0	1.2	+ 10	C/SMA
L450E	400-500	27	± .5	1.2	1.4	+ 5	C/SMA
W1GE	5-1000	20	± .5	1.6	1.8	0	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

Linear Medium Power 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
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	+ 30	+ 31	5.0	H/SMA	+ 42
P1000E	0.05-1.0 GHz	20	+ 23	+ 21	5.0	A/SMA	+ 32
P24GB	1.4-2.4	16	+ 20	+ 19	8.0	A/SMA	+ 32
P700S	0.6-0.8	40	+ 36	+ 34	3.5	FS/BNC	+ 47

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.

The devices above are just a sampling of TRONTECH's product line in state of the art low noise and medium power amplifiers. Our amplifiers are designed so that parameters such as gain, bandwidth, output power, noise figure, form factor, etc., can be tailored to your specifications. Our products also include: limiting amps, GaAs FETs, filters, detectors, etc.

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- **Alarm options**

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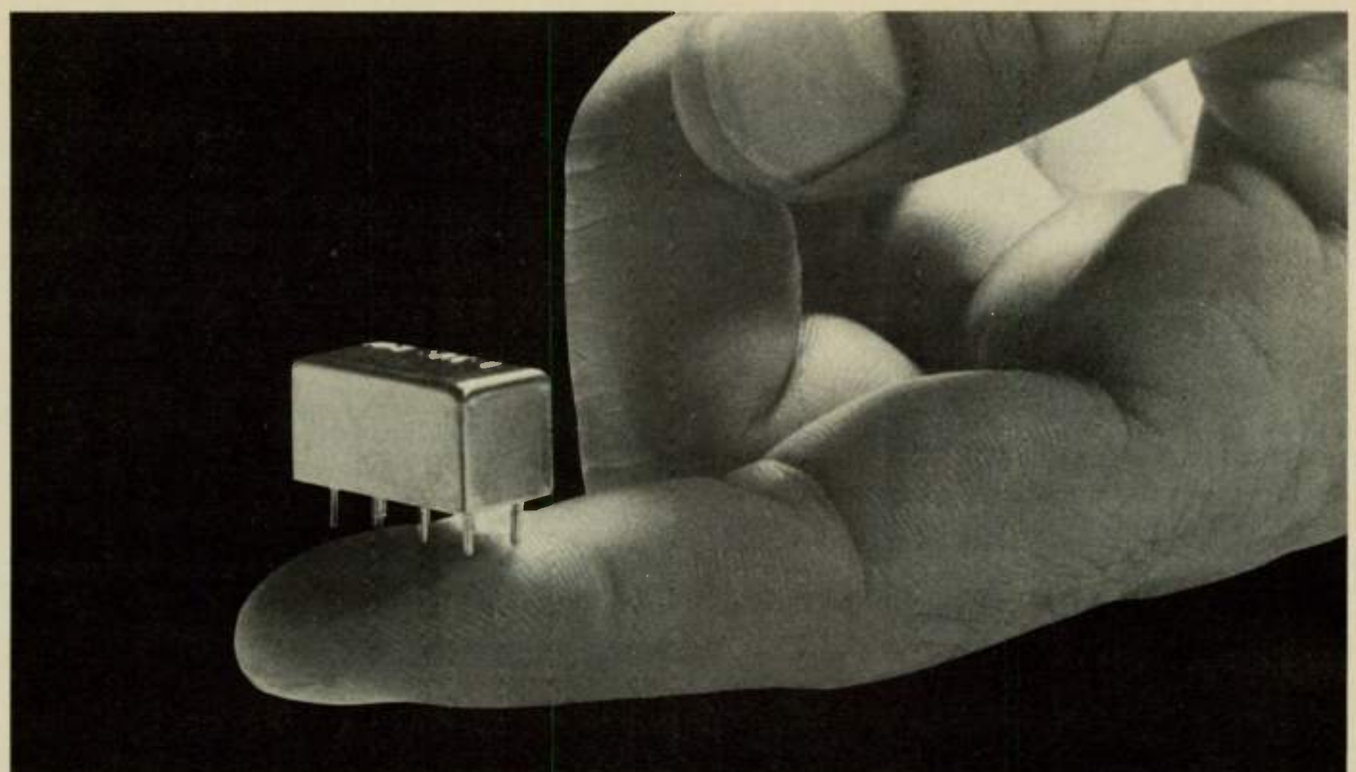
PLA-AA SERIES (100 ms Acquisition)

MODEL NUMBER	OUTPUT FREQUENCY (GHz)	POWER OUTPUT (MIN.) (dBm)	REFERENCE FREQUENCY RANGE (MHz)	MULTIPLICATION FACTOR
PLA-AA-3742	3.7-4.2	+13	123.3-140.0	X 30
PLA-AA-4449	4.4-4.9	+13	91.6-102.1	X 48
PLA-AA-4853	4.8-5.32	+13	100.0-110.8	X 48
PLA-AA-6570	6.55-7.05	+10	109.1-117.5	X 60
PLA-AA-7075	7.0-7.55	+10	116.6-125.8	X 60
PLA-AA-7277	7.2-7.7	+10	120.0-128.3	X 60

PLA-FA SERIES, FAST SWITCHING (1 ms Acquisition)

MODEL NUMBER	OUTPUT FREQUENCY (GHz)	POWER OUTPUT (MIN.) (dBm)	REFERENCE FREQUENCY RANGE (MHz)	MULTIPLICATION FACTOR
PLA-FA-3742	3.7-4.2	+13	102.7-116.7	X 36
PLA-FA-4449	4.4-4.9	+13	91.6-102.1	X 48
PLA-FA-4853	4.8-5.32	+13	100.0-110.8	X 48
PLA-FA-6570	6.55-7.05	+10	109.1-117.5	X 60
PLA-FA-7075	7.0-7.55	+10	97.2-104.9	X 72
PLA-FA-7277	7.2-7.7	+10	100.0-106.9	X 72

MITEQ INC., HAUPPAUGE, NY 11787, (516) 543-8873, TWX 510-226-3781



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Model No	Freq (MHz)	Conv loss (dB max.)	Signal 1 dB compr. level (dBm min.)	Connections	Size (in.) (W x L x H)	Price (1-9)
SAY-1	0.1-500	7.5	+20	8 pins	0.4 x 0.8 x 0.4	$54.95
SAY-2	0.1-1000	9.5	+20	8 pins	0.4 x 0.8 x 0.4	$59.95
SAY-11	10-2400	10.0	+18.5	8 pins	0.4 x 0.8 x 0.4	$64.95
ZFY-1	0.1-500	7.5	+20	*BNC, TNC, SMA, N	1.25 x 1.25 x 0.75	$74.95
ZFY-2	0.1-1000	9.5	+20	*BNC, TNC, SMA, N	1.25 x 1.25 x 0.75	$79.95
ZFY-11	10-2400	10.0	+18.5	*BNC, TNC, SMA, N	1.25 x 1.25 x 0.75	$84.95

Impedance: 50 ohms, isolation 20 dB min.
*BNC standard, TNC on request, Type N and SMA $5.00 additional
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- high isolation ... 45 dB
- PC and four connector versions available
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- suprisingly low priced ... from $54.95

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		Typ	Max	Typ	Min		Typ	Divider	Combiner		
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

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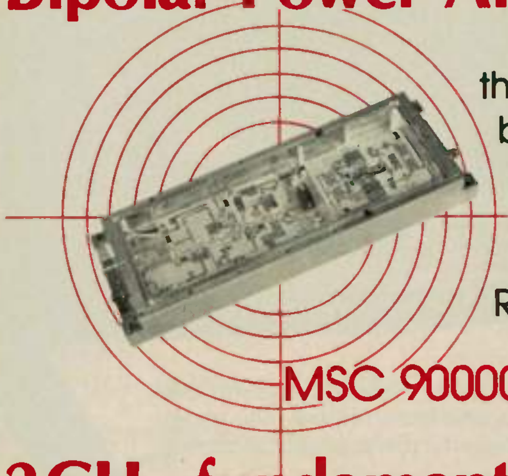

Coming Events

1980 EUROPEAN SOLID STATE CIRCUITS CONFERENCE SEPT. 22-25, 1980 Sponsors: EUREL, European Physical Society, Société Francaise de Physique, Société des Electriciens et Electroniciens. Place: Grenoble, France. Theme: Impact of semiconductors on industry. Contact: G. Grunberg, Chrmn., Thomson-CSF, B.P. 5, 92403 Courbevoie, France. Tel: (1) 788-50-01.

EASCON '80 SEPT. 29 - OCT. 1, 1980 Sponsors: IEEE-Washington Section and Aerospace and Electronics Systems Society (AESS). Place: Sheraton National Hotel, Arlington, VI. Theme: "The 1980s—Electronics Systems Decade." Contact: EASCOM '80, 608 H Street, S.W., Washington, D.C. 20024. Tel: (202) 347-7088.

1980 IEEE INT'L SYMPOSIUM ON ELECTRO–MAGNETIC COMPATIBILITY OCT. 7-9, 1980 Sponsor: IEEE Place: Baltimore Hilton Hotel, Baltimore, MD. Theme: "A Constellation of Ideas." Contact: Thomas J. Bode, Publicity, EMC '80, P.O. Box 1711, Annapolis, MD 21404. Tel: (301) 267-2898.

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

GaAs IC SYMPOSIUM NOV. 4-6, 1980 Sponsor: IEEE Electron Devices Society. Place: Imperial Palace Hotel, Las Vegas, NV. Topics: GaAs IC development and applications, device physics, modeling and simulation. Contact: Howard Phillips, Microelectronics Cent., Space Systems Div., Dept. 62-46, Bldg. 151, Lockheed Missiles & Space Co., P.O. Box 504, Sunnyvale, CA 94086.

GOVERNMENT MICROCIRCUIT APPLICATIONS CONFERENCE NOV. 19-21, 1980 Sponsors: DoD, Army, Navy, AF, ASA, Dept. of Commerce, NBS, etc. Place: Shamrock Hilton, Houston, TX. Themes: Signal Processing, Directions of Government Electronics for the 1980s, Terrestrial Applications of Aerospace Technology plus VHSIC program session. Contact: Palisades Institute for Research Services, Inc., 201 Varick St., NY, NY 10014.

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Frequency	Model Number	Power Output	Tuning Range Mechanical	Electronic
140GHz	B936FS	10mW	±100MHz	—
94GHz	B936WS-VCO	30mW	±100MHz	±300MHz
94GHz	W9400	10mW	±2000MHz	—
50GHz	B9500	80mW	±250MHz	±500MHz
35GHz	A9500	150mW	±50MHz	±250MHz

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MILITARY MICROWAVES '80

The technical program of the Military Microwaves Conference and Exhibition to be held in London in October of this year is previewed in this issue. The program emphasizes the application of microwave technology to weapon systems in the 1980s and stresses the interfacing of microwave modules and systems. Both system and subsystem topics are to be addressed by the individual papers.

Sum Up

1980 MICROWAVE JOURNAL SEMINAR

As it has since 1977, the *Microwave Journal* invited industry marketing and management executives to a seminar on the day preceding the opening of the MTT–S Symposium/Exhibition. In his report of that meeting, Consulting Editor Joe White reports on the presentations made by a distinguished panel consisting of Dr. Frank Brand, John "Rusty" Porter and Larry Thielen. Their discussions ranged widely over three topics of considerable interest to the industry executives present and covered the manner and extent to which technology drives the microwave marketplace, the microwave requirements of military electronic systems and the principles upon which the rapid growth of a high technology company in the industry has been based.

MINI-TWTA PHASE NOISE TESTS

The miniature TWT is particularly suited to the severe size and weight restrictions inherent in airborne radar applications. The paper describes the laboratory tests conducted to evaluate the phase noise characteristics of these RF power sources to determine if they were suitable for such applications in which low phase noise is also a requirement. The sources of phase noise in TWT's are described. Results of the testing of the tube structure as well as its power supply in a vibration environment simulating that of a missile are shown. Precautions in the test setup taken to eliminate spurious indications are discussed and some tube redesign to bring performance within specification is also described.

THE FOURTH MICROWAVE POWER TUBE CONFERENCE

The fourth in the series of Industry/DoD Power Tube Conferences, a biannual event, was held in May in Monterey. The report of the meeting, provided by its Technical Program Chairman, is somewhat hampered by the fact that some of the presentations were classified but it certainly identifies the significant topics which were addressed by the Conference. The meeting provides the most useful forum for the exchange of ideas and information among industry and DoD representatives. Its limited attendance format attracts high level representation from both sectors. Individual presentations ranged over such diverse topics as the business climate, DoD investment strategy and technology forecasts, to reports on technical progress and problems in specific areas. Industry/DoD and Industry/OEM interfaces were also reviewed during the three-day affair.

IMPROVED 6 GHz EARTH-STATION KLYSTRONS

The introduction of digital modulation techniques and Single Channel Per Carrier operation into satellite communications systems have significantly expanded the capabilities of the systems and, at the same time, imposed new requirements on earth station transmitters. The klystron with its high output power, high gain and flat gain characteristics is particularly suited to the earth station application. Its narrow bandwidth, however, posed problems for SCPC operation. The paper describes the design of a 6 GHz klystron fitted with a mechanical tuning system which provides operation in 6 or 12 preset channels. The achievement of high tuning repeatability is described. Amplitude and phase response characteristics, AM/PM conversion and the harmonic and noise characteristics of the new tube are shown. Principles of the new design are being applied to a tube for 14 GHz applications.

Howard Ellowitz

Workshops & Courses

SPREAD SPECTRUM COMMUNICATIONS

Sponsor: Hellman Associates
Lecturer: Dr. David Nicholson
Dates & Sites: August 11-13, 1980 – Los Angeles, CA
September 22-24, 1980 – Palo Alto, CA
October 20-22, 1980 – Woburn, MA
Fee: $595 per seminar
Contact: Hellman Associates,
299 S. California Avenue,
Palo Alto, CA 94306
Tel: (415) 328-4091

RADAR TECHNOLOGY COURSE

Sponsors: Benelux Section, IEEE and Eindhoven University of Technology
Boston IEEE AESS/IEE
Dates: August 26-27, 1980
October 20-21, 1980
Sites: Eindhoven University, Netherlands
Cunard Int'l Hotel, London
Lecturer: Dr. Eli Brookner, Consulting Scientist, Raytheon Company
Fees: Dfl. 295 (Dutch guilders)
£122 – IEEE/IEE members,
£135, nonmembers
Topics: Fundamentals of radar, trends in signal processing, components, tracking and detection.
Contacts: Dr. Eduard J. Maanders,
Dept. of EE, Eindhoven
University of Technology,
Eindhoven, Netherlands
Tel: 040 473427/473447

B. V. Atkinson, IEE
Savoy Place
London WC2R OBL
England
Tel: 01-240 1871

SHORT COURSE ON ELECTROMAGNETIC COMPATIBILITY ENGINEERING

Sponsor: Center for Professional Advancement
Date: September 22-24, 1980
Site: Sheraton Motor Inn,
Route 16, East Brunswick,
New Jersey
Fee: $545
Contact: R. Razzano, Dept. NR, The
Center for Professional Advancement, P.O. Box H,
East Brunswick, NJ 08816
Tel: (201) 249-1400

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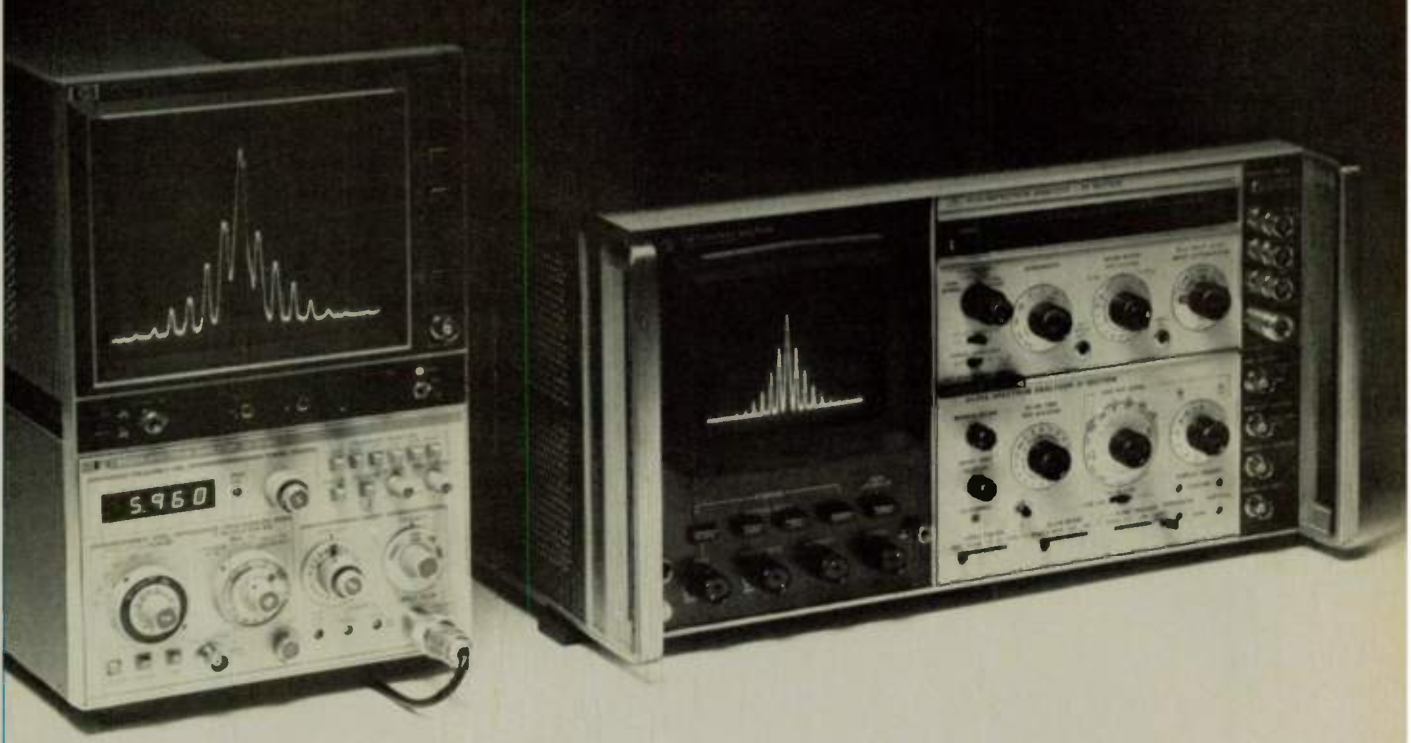
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Covering 10 MHz to 22 GHz and extendable to 40 GHz, this microwave spectrum analyzer gives you the combination of wide dynamic range, fully-calibrated measurement capability plus ease of operation. Frequency response is within ± 1.2 dB to 1.8 GHz and ± 3 dB at 18 GHz. Resolution bandwidths from 1 kHz to 3 MHz are standard, with 100 Hz resolution available as an option. From 1.7 to 22 GHz, there's a built-in preselector which permits measurement of distortion products as small as 100 dB down. The 8565A is easy to operate too. Just set three controls: tuning frequency, frequency span and amplitude reference level. Resolution, video filtering and sweep times are automatically set. Bright LED's in the CRT bezel give you all pertinent operating conditions in easy view. The price for all this performance and convenience is $19,400; add $800 for the 100 Hz resolution option. Reader Service No. 60

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Microwave Power Tube Conference Report

DAVID A. ZAVADIL
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Microwave Power Tube Conference

INTRODUCTION

On May 12-14, 1980, the Fourth Microwave Power Tube Conference was held in Monterey, California. A preview of the conference was presented by Jeff Grant (Conference Co-chairman along with Bob Woods – both of Hughes Aircraft Co. Electro Dynamics Division) in the April issue of *Microwave Journal*. As stated there, the first day of the conference was devoted to discussions of the tube industry/DoD interface, the business climate, DoD investment strategy and a forecast of where the technology is headed. The second and third days covered technical progress and problems and the tube industry/OEM interface.

The conference, with limited attendance, classified papers and no foreign nationals present, is "off the record." In this review, which is primarily derived from reports prepared by the session chairmen, some significant topics have been omitted at the request of the authors. Furthermore, in attempting to highlight significant conference themes, additional material has been omitted for the sake of brevity and continuity.

Dr. J. Feinstein (OUSDRE/E & Ps) in the keynote address reviewed the technical and financial challenges facing the microwave tube industry. For electronic warfare, extension of dual-mode and multi-octave traveling-wave tube performance is a primary concern. Radar applications require multi-function, multi-frequency capabilities with good coherence, complex modulation capability and high average power. The need for an alternative to the coupled cavity circuit for mm wave applications was stressed. In communications, better bandwidth for improved anti-jam capability is required. Improved efficiency for space application with versatile modulation capability also is a priority. Finally, as an alternative to laser and directed particle weapons, need for a high power mm wave device with good phase control and stability was expressed.

Maintenance of low cost per watt was cited as a key industry concern both to forestall solid state inroads and to retain microwave tube system affordability. To aid this, yield improvement through better understanding and control of tolerances, materials and processing is a key task along with improved subassembly test procedures and a search for alternatives to high precision structures.

He asked system designers (and government lab experts) to be more conservative when specifying tube characteristics, to better understand the relationship of reliability to the state-of-the art, and to promote standardization. Tube manufacturers were requested to use IR&D allowances on tube sales for tube work rather than for investment in non-tube areas. The DoD was requested to maintain an adequate level of support for the industry.

Brig. Gen. B. D. Ward (AFSC/DL), spoke at the conference on DoD investment strategies. The Air Force expends $11M directly in the microwave tube area. ECM is the major thrust because of the high quantities involved. Attempts to reduce the number of tube types involved and the search for novel means to generate power from 20 - 60 GHz are major concerns. Other priorities are the need for good terminal missile guidance where requirements exceed solid state capabilities and ultra long life for space applications. New space communication applications will require life extension from the current 9 years to as much as 20 years. Development of means to confirm achievement of these life figures is a key challenge. He called for closer management attention to critical materials availability and shortages. Repair of tubes must be simplified to reduce cost escalation and warranties configured to better insure reliability.

Dr. John Mendel, Hughes Aircraft Corp., discussed the "State of Microwave Tube Technology." He pointed out that the vital strengths of microwave tubes are achievement of very high power densities, since they employ distributed metallic circuits which allow excellent heat removal, high conversion efficiency and utilization of a vacuum which is a far purer, more consistent propagating medium than a solid state crystal. During the 1980s, he predicted continuing emphasis on the mm wave area, particularly in gyrotrons, free electron lasers and TWT's, and on tube life and reliability improvement. High power microwave tubes will be seriously threatened by active solid state phased arrays with the issue being settled primarily on the basis of ultimate cost and efficiency.

George Caryotakis, Varian Associates, discussed the "Microwave Tube Business Climate." He set the total market at $500M per year with 55% in North America and 45% abroad. Cooker magnetrons, which are the largest single device segment, account for sales of $60M per year. He anticipated that 0 - 5% real growth per year will be experienced over the next decade and expressed concern that foreign sources without regulation and control could seriously erode the domestic tube industry.

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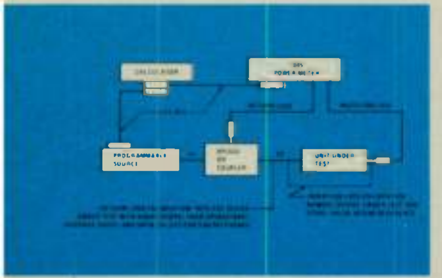

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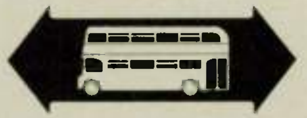

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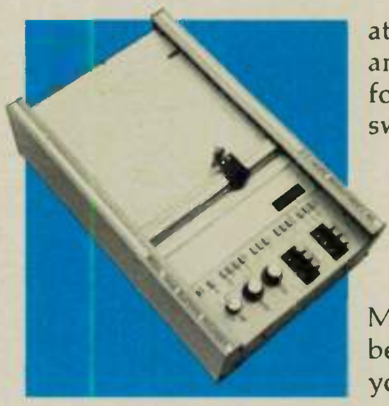

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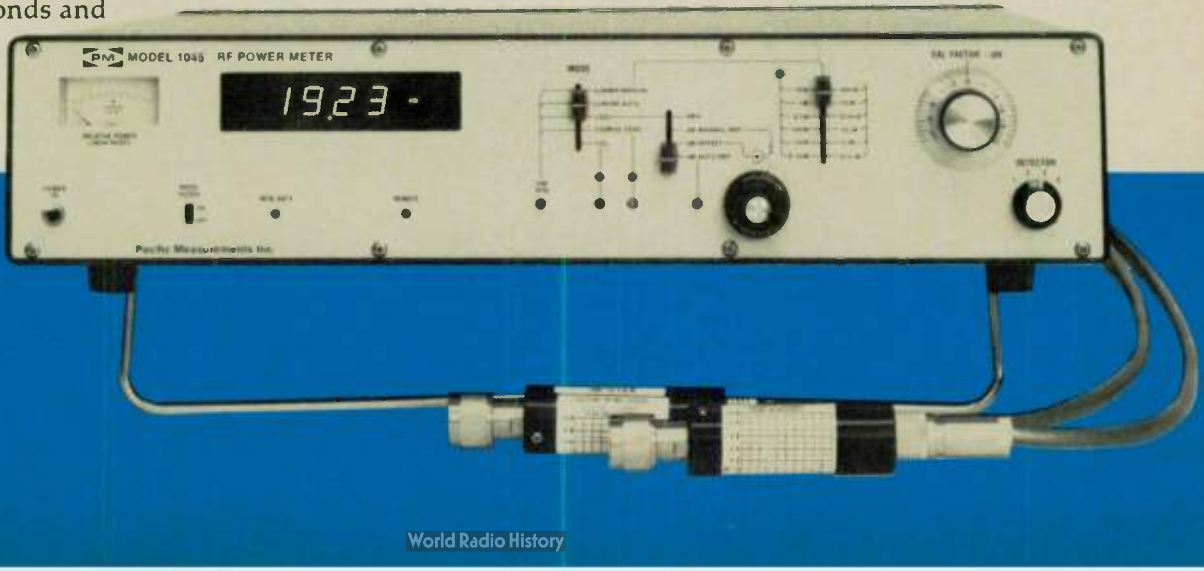

MM AND FAST WAVE DEVICES

The mm wave and fast wave device areas continue to be the most dynamic and exciting in the tube business today. In the session organized by Dr. Richard True of Litton, eight interesting and stimulating papers were presented.

The opening paper was delivered by Dr. Sidney Smith of NRL. He emphasized the need for wide-bandwidth high-power periodic-beam amplifiers in the millimeter wave region. Toward this end, he described a gain mechanism in gyrotrons (called the Weibel mode). Whether a practical Weibel mode device can be made will be settled in experiments planned for the near future.

The next paper was presented by Dr. Victor Granatstein also of NRL. He discussed the present state-of-the-art and planned future efforts in millimeter wave gyro-TWT's. An amplifier was described which delivers 34 kW of saturated output power at 35 GHz with 16% efficiency. Small signal gain in this device is 24 dB and bandwidth is 0.5 GHz. Analyses indicate a strong stabilizing effect from resistive wall loading. Also, new electron guns having a smaller velocity spread are being developed. These should result in significant improvements in amplifier performance. A new wide-bandwidth periodic beam amplifier also was described in which the waveguide is lined with dielectric so that slow waves, which interact with the transverse velocity component of the spiralling electrons, may be supported. Experiments are now planned for this latter device.

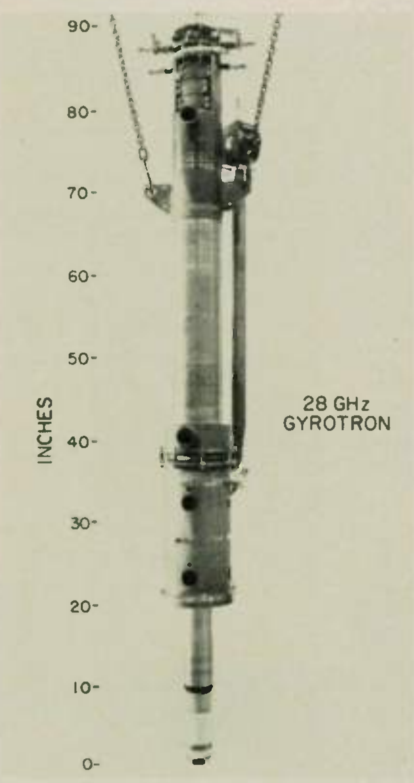

Fig. 1 28 GHz gyrotron.

Recent gyrotron developments were reviewed in a comprehensive paper by Dr. Howard Jory of Varian. He presented data on a 41% efficient gyrotron oscillator which produces 212 kW of CW power at 28 GHz. This was achieved by use of an axisymmetric overmoded output waveguide followed by a double disc window cooled with liquid fluorocarbon. A photo of this tube is shown in **Figure 1**. The graph **(Figure 2)** shows measured CW power output versus beam current for that tube compared to a calculated curve based upon ballistic theory. Also shown, is measured pulsed power output for an earlier pulsed oscillator tube. Design of a gyrotron oscillator for operation at 60 GHz was discussed. These devices are slated for use in plasma heating for controlled thermonuclear fusion reactors.

The next paper was given by Dr. Patrick Ferguson, also of Varian. He described experimental results on a gyro-TWT amplifier operating at 5.26 GHz, with a maximum power of 120 kW, 26% efficiency, 7.3% bandwidth, and 26 dB small signal gain. In addition, data on noise figure, AM and PM modulation sensitivities, phase linearity and intermodulation distortion were reported. Design of high resolution radar systems require knowledge of such parameters.

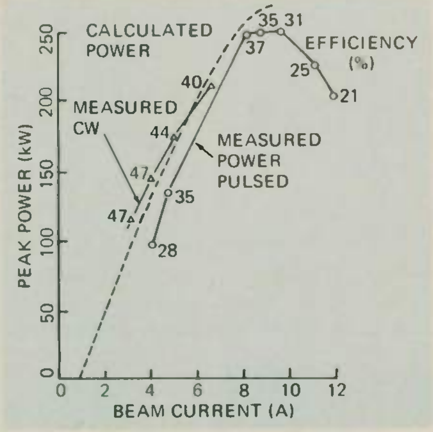

Fig. 2 Peak output and efficiency for pulsed and CW oscillators.

Fast wave tubes typically employ thin high-density hollow beams provided by doubly convergent magnetron injection guns. These beams are noisy and possess velocity spreads which limit the performance of fast wave devices. Guns are often operated temperature limited to minimize the velocity distribution of electrons but this results in non-uniform emitted current which is very sensitive to cathode temperature.

Gun problems were addressed in two papers. In the first, presented by Dr. Sidney Smith of NRL, various gun concepts which do not suffer from crossed-field noise were suggested. These have the promise of providing teams with lower velocity spreads and which can be operated space-charge limited.

In the second paper, presented by Dr. David Gallagher of Northrop DSD, a novel method of beam generation useful for the peniotron, a rectangular waveguide gyrotron, and possibly other fast wave devices, was described. It consists of a Pierce-type hollow beam gun having total magnetic confinement followed by a magnetic field reversal to spin the beam. An electrostatic lens was introduced at the position of the field reversal to reduce the beam ripple to low levels.

Professor Richard Grow of the University of Utah was the next speaker. He described progress in the development of an analytic small-signal Pierce-type theory for the traveling-wave gyrotron. Real frequency and complex propagation are assumed which lead to a wave-type solution. After presenting the basic equations of the analysis, Professor Grow showed computed results which were in favorable agreement with experimental data furnished by other researchers.

The final paper of the session on fast wave devices was presented by D. Paul Tallerico of LASL. He described progress on the gyrocon family of deflection modulated fast wave amplifiers. A prototype radial style gyrocon is being built which is slated to produce 650 kW of CW output power at 450 MHz with better than 80% efficiency. Also in this paper, a planar gyrocon having specially varying emission was described.

MM WAVE TECHNOLOGY

A second session on "Millimeter Wave Tubes/Technology," was chaired by Neil Wilson, Electronic Technology and Devices Laboratory, ERADCOM. The papers provided both a systems application outlook as well as innovative circuit and grid design, which pave the way to satisfactory operation at higher frequencies and lower voltage control of high current density beams. Finally, the culmination of two development programs were presented. Their direction showed great promise for higher power and broader bandwidth tubes using construction technology amenable to the tolerances required at mm wave lengths along with the promise of lower assembly cost.

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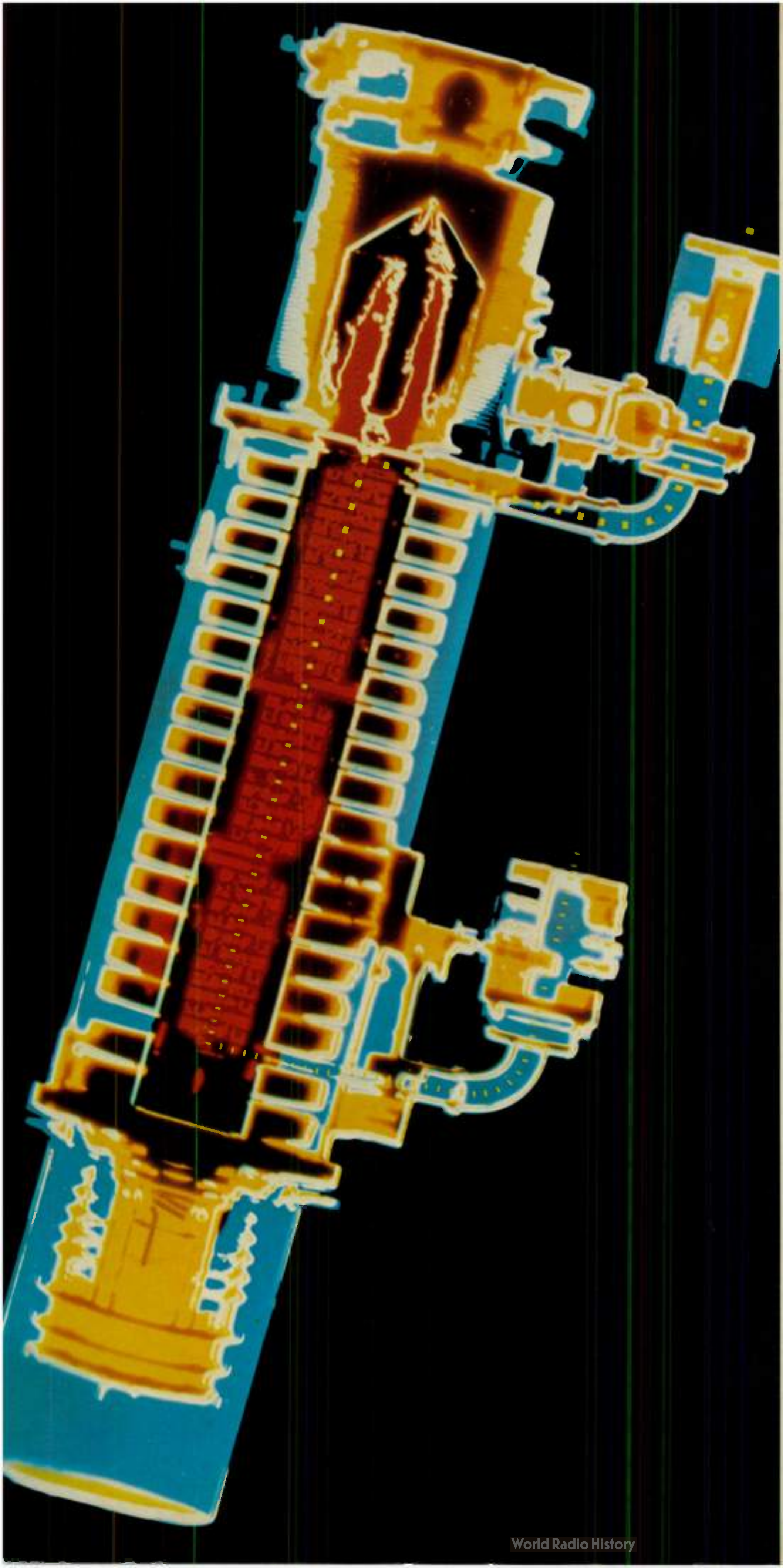

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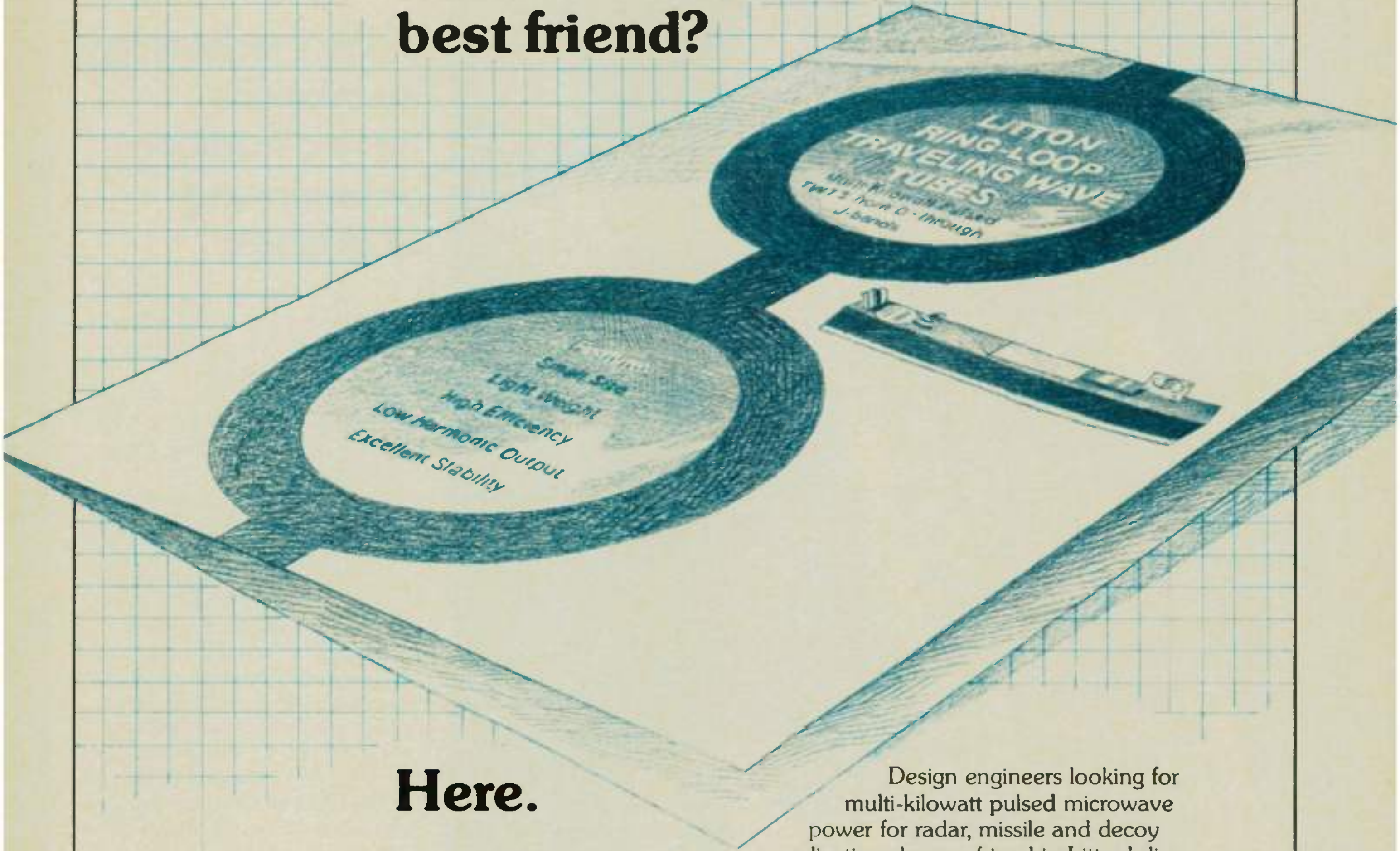

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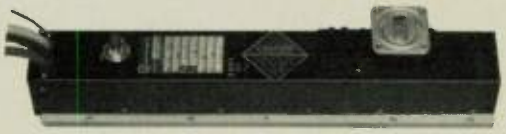

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Mr. Dirk Bussey, RADC, provided insight into advancements being made in tubes for space communications. The advent of brazed diamond supported helices and emerging composite beryllia oxide-copper tape helicies increase thermal dissipation and should result in space-qualified 25 W TWT's in five years. Although, high-power ground transmitters now have available 200-250 watt CW coupled cavity TWT's operating in the 30 GHz band that are PPM focussed and air cooled, simpler fabrication techniques remain a challenge for lower cost and also reproducibility.

Mr. Don Schenk, Ballistic Missile Defense Advanced Technology Center, reported on the BMDATC supported development programs in high power tubes at 35 GHz and 95 GHz. System RF power requirements cover a range from 1 to 30 kW peak and the programs supported include conventional coupled cavity TWT's, distributed interaction klystrons, as well as the emerging gyro-TWT concepts.

The paper illustrated the necessity of solving in the early stages the problems of RF window design, electron beam convergence and high efficiency as these tube related problems directly impact advanced systems concept development.

Dr. Arthur Karp, Varian Associates, delighted the audience with three papers that he authored or coauthored with G. Biggs, R. Walker, J. W. Fenwick and T. Grant. Two papers involving Dr. Karp's "Comb-Quad" circuit revealed that there is innovation and creativity within the tube community. Starting with Varian IR&D and under Air Force and Navy sponsorship, the "Comb-Quad" idea has been under development and is reaching the "hot test" stage.

The heart of the concept is the use of regular copper parts cut from a single copper strip. The design and construction lead to solution of two difficult problems in millimeter tubes, namely, mechanical robustness and reduction in errors in the axial dimension normally involved in the stacked assembly process. Narrowband and moderate bandwidth designs have been evolved. Cold test results presented by Dr. Karp established that the dispersion curves and interaction impedance are adequate for use in hot test exploratory development models.

In a similar vein Dr. Karp described the results of his NASA-supported "TUNNELADDER" circuit for use in the 40-50 GHz band at hundreds of watts of CW power.

The circuit is a fundamental "forward-wave" design and the study showed that a promising high power TWT is feasible as suggested by Dr. H. Kosmahl, NASA. The relatively short circuit length is amenable to use of a modestly sized yoke-type permanent magnet to focus the 21 kV pencil beam at a microperveance of 0.06. Although a relatively narrowband circuit, 1%, the advanced approach to mechanical support and heat dissipation leads to a design suitable for space communications applications.

To illustrate that practical hardware is forthcoming in the wideband millimeter-wave amplifier area, Mr. Paul Puri, Raytheon Company, presented the initial results of a company sponsored development to achieve a 20 watt CW TWT in the 20-40 GHz band. The key to success in the millimeter region is the ability to maintain tight helix tolerances, typically 0.1 mil, during high temperature brazing. Mr. Puri discussed a successful demonstration of a wire wrapped, 3-point boron nitride rod supported helix which resulted in 5-10 watts of CW power in this band (**Figure 3**). More importantly, the test and subsequent thermal studies provided adequate evidence that 100 watt devices utilizing cost effective technologies are feasible while maintaining, temperatures below 500°C within the vacuum envelope.

Electron beam control was the subject of Mr. G. Miram, Varian Associates, paper "Gridded Guns for Millimeter-Wave Linear Beam Tubes." Mr. Miram described the use of both negative grid and bonded grid guns for millimeter wave tubes. The bonded grid design has now been adapted to a millimeter Extended Interaction Klystron (EIK).

The last paper, presented by Mr. R. Carignan, Raytheon, was another example of design innovation and construction inventiveness aimed at lowering the cost of millimeter wave tubes. As the result of Air Force sponsorship, Mr. Carignan described the construction of an Electron Discharge Machined (EDM) circuit capable of hundreds of watts of CW power at frequencies above 40 GHz. The EDM machining process results in a mirror finished surface, serpentine, RF structure. Cold test established that the dispersion and interaction impedance are adequate for mm operation. These results coupled with a depressed collector, PPM focussing, liquid cooling and a BeO block window show promise of a high power mm amplifier that is amenable to low cost construction.

TUBE APPLICATIONS

A session on "Microwave Tube Applications" was chaired by Mr. John George of Raytheon Co.

Mr. Major Johnson of General Electric Co. surveyed transmitter require-

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Enter company name and page number for ads without R.S. numbers ments of a number of radar techniques currently in development and likely to be procured over the next decade. These are tabulated in **Table I**.

TABLE I – POSSIBLE "NEW TECHNIQUE TUBE TRANSMITTERS"

XMT. BEAM	FREQUENCY	PEAK POWER	AVG. POWER
Bistatic Radar **Broad**	L-X	1-200 kW	1-20 kW
Imaging Radar **Tracking**	S-K_a	10 kW - 1 mW	1-10 kW
Mmw AA Radar **Tracking**	K_a	15 - 130 kW	10 - 50 W
Mmw Surveillance Radar **Fixed**	94 GHz	100 W - 1 kW	10 - 100 W

Millimeter wave radars were discussed in some detail. He concluded that the majority of mm wave radars will utilize solid state devices, particularly missile seekers, tank radars, police and vehicular anti-collision radars. Millimeter magnetrons will probably be used for anti-aircraft fire control radar, especially for small ships. In the immediate future millimeter TWT's will probably be used for battlefield surveillance although solid state is expected to catch up.

Mr. John Christenson of Hughes Aircraft Co., in a paper "High Power TWT Transmitter Interface Improvements," pointed out that transmitter reliability improvements are better accomplished external to the tube. Tube "fixes" generally entail high risk, schedule delays, high cost schedule delays, high cost and often performance compromises and reduced yields. He described four specific interface improvements.

- automatic voltage adjustment via programming resistors built into the tube package.
- use of a grid pulse voltage feedback loop to maintain constant cathode current which can be used to extend tube life and to improve warm-up characteristics.
- use of an RF feedback loop to provide optimum input RF drive.
- use of an isolated anode to eliminate the need for transmitter crowbar arc protection.

Mr. Thad Stevens of Northrop DSD described an auto-correlation technique to compensate for multi-signal capture effects in broadband TWT's. The nonlinear characteristic of TWT's operating in the large signal region results in a "capture effect" which suppresses the RF output power of the higher frequency signal. For frequency separations greater than 10%, 15 to 20 dB suppression of the higher frequency signal has been measured. The technique described was capable of determining the power associated with one signal in the presence of the other and appropriately adjusting the input levels. Results of tests conducted against a generic dual beam track-while-scan (TWS) radar simulator at AFWAL clearly showed superiority of the compensation technique over others.

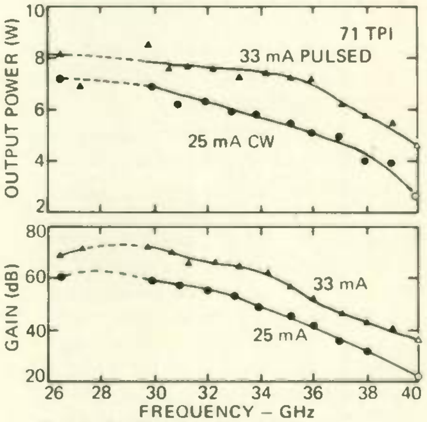

Fig. 3 Performance characteristics of a high-frequency mini TWT.

MATERIALS

The materials session, chaired by Mr. Walt Wood of Varian Associates, covered a variety of topics including brazed helix fabrication, periodic permanent magnet design, potting, and shelf-life studies.

Tim Mosser of Northrop DSD presented a paper on brazing of copper or tungsten tape helices to BeO support rods. Thermal dissipation capability in I/J band at least 20% greater than obtainable with the best heat shrunk circuits was claimed. A method for thin film deposition of helix attenuators also was described.

Factors which can improve PPM focusing of electron beams were presented by Marlin Walmer of Electron Energy Corporation. He discussed the influence of polepiece design, location of input and output couplers, polepiece saturation, flux leakage, and transverse fields on beam performance.

Analysis and test techniques for high voltage potting were the topics of Dr. Bob Fillers' paper. A partial discharge technique commonly used in tests of transformers, capacitors, cables, and other high-voltage components and systems was described. Us-

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ween partial discharge phenomena, precursive to high-voltage breakdown, and cracked and debonded regions within the potting and/or encapsulatng materials used in the high-voltage areas of the TWT, is emerging.

Gas permeation, metal-to-ceramic seal stress analysis, magnetic-field degradation, cathode poisoning, non-evaporable getters, and vacuum shelf-life evaluation methods were presented by Mr. Roger Carignan of Raytheon. Substantial reduction in internal tube gas pressure with time by the use of non-evaporable getters was shown.

CATHODES

The remaining papers were on cathodes. Dr. R. True of Litton presented the results of a fast warm-up dispenser cathode program. Dr. R. Greene of NRL reviewed the 1980 Tri-Services Cathode Workshop. The objectives of the conference were to: improve technical information exchange, develop agreed-upon standards for test and evaluation of cathodes, coordinate service cathode programs, and recommend cathode investment strategy. Specific areas discussed were overall progress of cathode technology, problem areas, identification of specific requirements, and recommendations and plans for future work. He cited improvements in surface analysis techniques, dispenser cathode chemistry and structure and the initiation of both the RADC Test and Evaluation Program and the NRL Shelf Life Reliability Program as solid achievements which have occurred over the past two years.

Other papers from NRL were "Reactivation of Shelf-Stored Cathodes for Expendable Tubes," by Dr. G. Haas, and "The Field Emitter Array Program at NRL" presented by Dr. H. Gray.

Dr. Haas discussed the problems presented by expendable tubes which require very fast (five seconds) turn-on. Since preliminary surface studies indicate that all available cathodes completely poison within a few hours or days after being shut down in a typical sealed-off tube environment, the kinetics of the turn-on step must also involve the kinetics of reactivation — apart from just bringing the cathode up to thermionic emission temperature. The paper included comparative emission characteristics of various cathode types in the active state as well as the changes in work function and gas desorption characteristics at turn-on following simulated shelf-storage.

Dr. Gray described a new field emitter array (FE) technology using standard found in the microelectronics industry. Using orientation-dependent etching of silicon (100) surfaces, such as that used to make vertical metal oxide-silicon (VMOS) transistors, NRL has fabricated arrays of very sharply pointed single-crystal field emitters. Employing conventional chemical vapor deposition (CVD) and metallization techniques, closely spaced field emitter structures consisting of self-aligned control grids and integral silicon field emitters have been made with tip-to-tip spacing of 10 μm.

M. Feinleib of Varian described various approaches to "High Current-Density Cathodes for Millimeter-Wave Tubes." A comparison of various types of cathodes was presented (**Figure 4**). Special attention was given to the Controlled Porosity Dispenser (CPD) Cathode. This work is based on the concept that a surface with a controlled pattern of openings will emit uniformly and, if the pattern is sufficiently small, the emission will also remain constant throughout the cathode life.

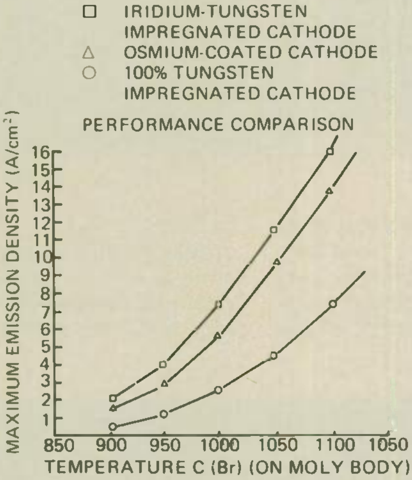


Fig. 4 Performance comparison.

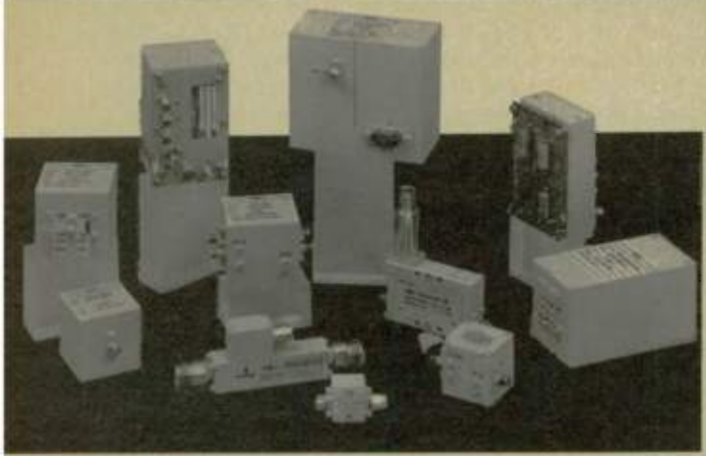
A "New Generation of Cross-Field Amplifier Cathodes" was presented by George MacMaster of Raytheon. This paper was concerned with the performance of gold/magnesium oxide (Au/MgO) secondary emitting cathodes in crossed field amplifiers (CFA's). During this program, deposition and fabrication techniques were developed to obtain a practical CFA cold cathode structure consisting of a fine-grained mixture of MgO and gold which provides a secondary emission ratio capability greater than 4. This emitting surface can be made thick enough to have a long operating life as a cold cathode. The presence of metal particles permits the removal of surface charge by tunneling and conduction to the base.

A session on "Low Cost Microwave Sources" was chaired by Dr. Stan Kaisel, consultant. Historical perspective was provided by two papers on cooker magnetron production experience by Mr. Sam Ameen, Raytheon MPTD, and Mr. Don Covert of Litton Industries. They pointed out the need for a substantial investment approaching $10M, in design, tooling and capital equipment to sustain low cost, high volume microwave tube production. Mr. Ameen compared cooker magnetron part count and complexity with that of a modern TWT to emphasize the problems that would have to be overcome in low cost manufacture of expendable devices. Mr. Bob Espinosa, Varian Associates, described experience producing the first 3000 mini TWT's for the SLQ-32 ECM system. He pointed out the impact that lack of production continuity can have on TWT cost. With a long-term production commitment an ultimate $1000 per tube price was predicted. Mr. John McCullough, Teledyne MEC, discussed an optimum means for development and procurement of large quantities of expendable devices further emphasizing the need for long term customer commitment. In a discussion following the presentations, it was concluded that present day expendable requirements call for a more complex device, procured in substantially lower quantities than cookers without a well developed long-term investment of procurement strategy. As such, it was difficult to see how expendable TWT's could ever break below the $1000/ to $1500 unit price barrier. The only apparent hope to achievement of substantially lower per unit cost would be in development of new broadband interaction structures, comparable to the gyrotron, which would lead to reduced device complexity and lower part count.

The question of future Monterey Conferences was treated by a questionnaire circulated at this meeting. A clear majority of the respondents favored joint IEEE, DoD sponsorship of a biennial conference with the present format. Recommendation for future conferences may be sent to Mr. C. W. Linn, Litton Industries — 960 Industrial Road, San Carlos, CA 94070.

Dave Zavadil received a B.S. (Physics) degree from the University of Wisconsin in 1966 and an M.S. (Physics) from Penn State University in 1969. As an engineer, he has worked on the design and development of a variety of TWT's at Raytheon MPTD, Microwave Associates & Teledyne MEC. Currently, he is manager of Electron Tube Engineering at Northrop DSD. He also was the technical program chairman of the 1980 Microwave Power Tube Conference.

Systron-Donner Advanced



Systron-Donner's setting the standards for:

- Yig-tuned devices
- Voltage-tuned oscillators
- Mechanical and voltage-tuned oscillators

Yig-tuned oscillators are available in transistor and Gunn-diode types.

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

MODEL:	Frequency Range (GHz)	Power Output Min. (mW)	Power Variation vs. Frequency	Spurious Signals:		Residual FM, 1 Hz—30 kHz	Frequency Stability:			
				Harmonic Min.	Non-Harmonic Min.		Vs Temperature	Vs Power Supply	Vs. Load Variation	Hysteresis
SDYX-3038	0.5—1.0	20	5 dB p-p	12 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	2 MHz
SDYX-3034	1.0—2.0	20	5 dB p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	2 MHz
SDYX-3034-114	0.5—2	20	6 dB p-p	12 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	1 MHz	4 MHz
SDYX-3036	2.0—4.0	20	5 db p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	4 MHz
SDYX-3036-125	1.0—4.0	20	7 dB p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	500 kHz	6 MHz
SDYX-3039-107	2.0—6.0	10	7 dB p-p	15 dBc	60 dBc	10 kHz p-p	0.03%/°C	1 MHz/V	6 MHz	7 MHz
SDYX-3000	8.0—12.4	25	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	10 MHz
SDYX-3001	12.4—18.0	25	6 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	15 MHz
SDYX-3001-111	8.0—18.0	10	8 dB p-p	30 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	25 MHz
SDYX-3003	18.0—26.5	10	6 dB p-p	20 dBc	60 dBc	10 kHz p-p	0.01%/°C	10 MHz/V	10 MHz	35 MHz
SDYX-3004	26.5—40.0	5	8 dB p-p	20 dBc	60 dBc	10 kHz p-p	0.01%/°C	20 MHz/V	20 MHz	100 MHz

YIG DRIVERS

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

VOLTAGE-TUNED OSCILLATORS

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

1) @ 20 mW leveled   2) Internal Detector

MECHANICAL AND VOLTAGE-TUNED OSCILLATORS

MODEL:	Mechanical Tuning Frequency Range (GHz)	Voltage Tuning Bandwidth (MHz)	Power Output (mW)	Power vs. Frequency (dB)	Spurious Signals:		Voltage Tuning Range (volts)	DC Power (VDC) See Note 1
					2nd Harmonic	Non-Harmonic		
SDYX-2015-105	5.925-6.425	120	50	1	30 dBc	70 dBc	2-25	+15 @ 500 mA
SDVX-2016-110	7.25-7.75	120	50	1	30 dBc	70 dBc	2-25	+15 @ 500 mA
SDVX-2016-114	7.9-8.4	120	50	1	30 dBc	70 dBc	2-25	+15 @ 500 mA
SDVX-2016-107	8.5-9.1	120	50	1	30 dBc	70 dBc	2-25	+15 @ 500 mA
SDVX-2016-108	9.0-9.6	120	50	1	30 dBc	70 dBc	2-25	+15 @ 500 mA
SDVX-2017-106	10.7-11.2	100	30	1	20 dBc	70 dBc	2-30	+15 @ 600 mA
SDVX-2017-107	11.2-11.7	100	30	1	20 dBc	70 dBc	2-30	+15 @ 600 mA
SDVX-2017-112	12.7-13.2	100	30	1	20 dBc	70 dBc	2-30	+15 @ 600 mA
SDVX-2017-120	14.0-14.5	100	30	1	20 dBc	70 dBc	2-30	+15 @ 600 mA

Note 1: Current is steady state. Surge current will be 70% higher.

Components: Update 1980

YIG-TUNED FILTERS

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

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

		MODEL:	Frequency Range *(GHz)*	Bandwidth *(MHz, Min.)*	Insertion Loss *(dB, Max.)*	O.R.I. *(dB, Min.)*	O.R.S. *(dB, Min.)*	PB Ripple & Spurious *(dB, Max.)*	Linearity *(MHz, Nom.)*	Hysteresis *(MHz, Nom.)*
BANDPASS	Two-Stage	SDYF-4021	0.5—1	12	6.0	40	25	2.5	±2	4
		SDYF-4022	1—2	20	3.0	40	25	2.5	±2	4
		SDYF-4023	2—4	20	3.0	50	25	2.5	±3	6
		SDYF-4024	4—8	25	3.0	50	25	2.5	±5	8
		SDYF-4025	8—12.4	30	3.0	50	25	2.5	±8	15
		SDYF-4026	12.4—18	30	3.0	40	30	2.5	±10	15
		SDYF-4027	18—26.5	35	4.0	40	30	2.5	±15	20
	Three-Stage	SDYF-4028	0.5—1	12	6.0	70	35	2.0	±2	4
		SDYF-4029	1—2	18	5.0	70	40	2.0	±2	4
		SDYF-4030	2—4	20	4.0	70	40	2.0	±3	6
		SDYF-4031	4—8	25	4.0	70	40	2.0	±8	8
		SDYF-4032	8—12.4	25	4.0	70	40	2.0	±10	15
		SDYF-4033	12.4—18	30	4.0	70	40	2.5	±10	15
		SDYF-4034	18—26.5	35	5.0	70	40	2.5	±15	20
	Four-Stage	SDYF-4035	0.5—1	10	8.0	70	40	2.8	±2	4
		SDYF-4036	1—2	15	6.0	70	50	2.8	±2	4
		SDYF-4037	2—4	15	5.0	70	50	2.8	±3	6
		SDYF-4038	4—8	20	5.0	70	50	2.8	±8	8
		SDYF-4039	8—12.4	20	5.0	70	50	2.8	±10	15
		SDYF-4040	12.4—18	25	5.0	70	50	2.8	±10	15
		SDYF-4041	18—26.5	30	5.5	70	50	2.8	±15	20
	Dual Two-Stage (Per Channel)	SDYF-4042	0.5—1	12	6.0	40	25	2.0	±2	4
		SDYF-4043	1—2	20	3.0	40	25	2.8	±2	4
		SDYF-4044	2—4	20	3.0	50	25	2.5	±3	6
		SDYF-4045	4—8	25	3.0	50	25	2.5	±5	8
		SDYF-4046	8—12.4	25	3.0	50	25	2.5	±8	15
		SDYF-4047	12.4—18	25	3.0	40	25	2.5	±10	15
		SDYF-4048	18—26.5	30	4.0	40	25	2.5	±15	20
	Multi-Octave	SDYF-4000	1.8—18	20	5.0	70	60	1.5	±10	15
		SDYF-4000-102	1.8—26.5	15	8.5	70	60	1.5	±20	20
		SDYF-4000-113	2—18	30	3.0	40	40	1.5	±10	15
		SDYF-4000-114	2—12	30	3.0	40	40	1.5	±10	15
WIDE-BAND		SDYF-4235	8—18	250	7.5	70	50	2.8	±15	20

SYSTRON DONNER
ADVANCED COMPONENTS DIVISION
A Member of the THORN EMI Group

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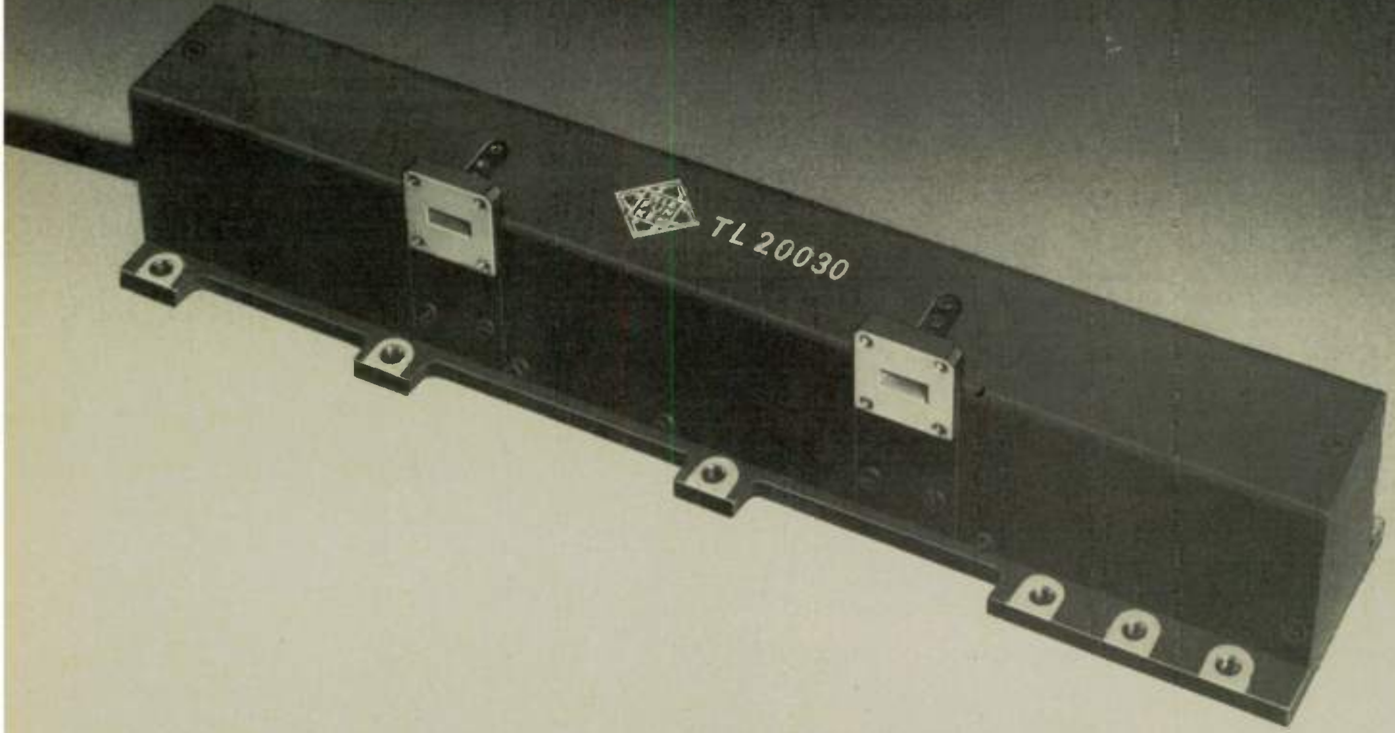
Circle 14 for Demonstration

AEG-TELEFUNKEN

Future
oriented

TL 20030

for Satellite Communications in the 20 GHz Band



In the foreseeable future the growing requirement for transmission channels in satellite communications will not be met by the transmission systems for the 4 GHz and 12 GHz bands. Consequently a further frequency band around 20 GHz was allocated.

With the TL 20030, therefore, AEG-TELEFUNKEN have already developed the next generation of satellite traveling-wave tubes.

The tube, fitted with a two-stage collector, achieves an overall efficiency of 38%. It weighs 900 g approximately. In the design of the tube a dispenser cathode proven in other space programmes was chosen.

The development of the TL 20030 was based on proven technologies. A life expectation, which is usually far in excess of the specified seven years, may thus be safely assumed.

Technical data:

Frequency range	18.5 ... 21.5	GHz
Efficiency	38	%
Gain	50	dB
Power output	22	W
Weight appr.	900	g

Further information from

AEG-TELEFUNKEN
Serienprodukte
Geschäftsbereich Röhren
und Baugruppen
Söflinger Strasse 100
D 7900 Ulm
W. Germany
Telephone: (0731) 191-1
Telex: 712 601

Microwave components from AEG-TELEFUNKEN

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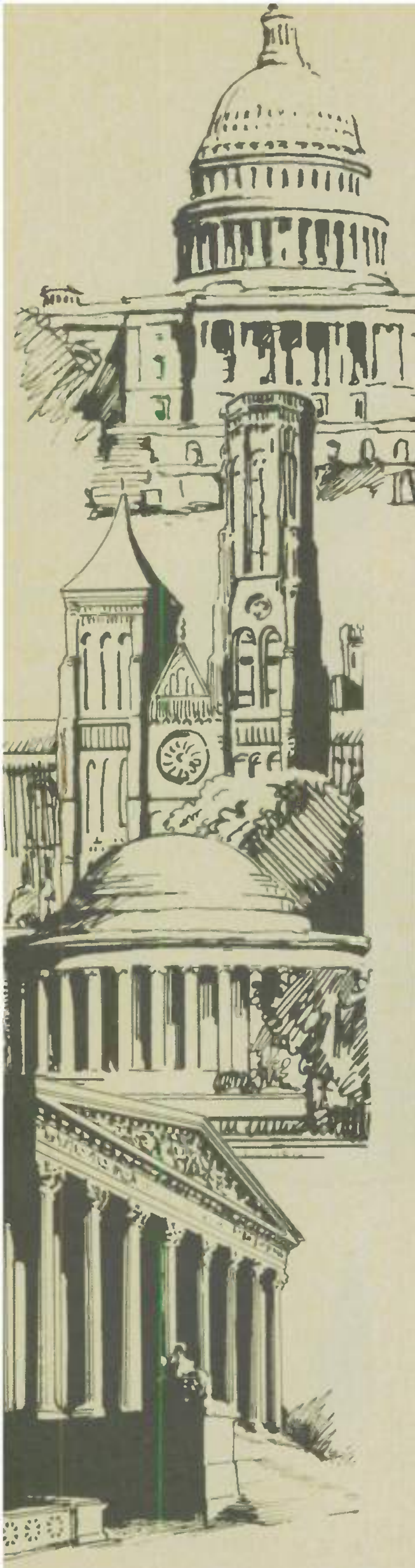
Circle 15 on Reader Service Card

MWJ Seminar Looks to the 80's

JOSEPH F. WHITE, Consulting Editor



Photography by Patricia A. Fisher.

For the last four years, the Microwave Journal has held a seminar and reception prior to the MTT-S Conference for the exhibitors and their friends. The talks presented at this seminar are not part of the MTT-S technical program nor are they of its genre. Rather, they are designed as a communication among the business interests of the field, intended to complement the highly technological papers which distinguish the MTT-S program, and they are an outgrowth of similar MWJ seminars given before IRE/IEEE conventions dating back to the early 1960s. These talks address the highly intangible, they are very subjective and personal, and, in short, reflect the feelings which prominent authorities in the field of microwave markets have about the businessplace which derives from the high technology papers to be heard in the symposium to follow.

Howard Ellowitz

While such talks necessarily are just as imprecise as the high quality technical papers which follow them are precise, they concern something critical to all of us, the future, the trends, the eventual flow of the business which microwave technology generates. Characteristic of these talks is no only their imprecision but also their individuality.

Following introductory remarks by Howard Ellowitz and greetings from Larry Whicker, Chairman of the 1980 Steering Committee and Steve Adam, President of MTT-S AD Com, thi Seminar's three speakers shared their different backgrounds and viewpoints.

Larry Whicker

From what follows, their optimism and pleasure at the present status of the microwave marketplace are evident.

Steve Adam

Dr. Frank Brand,
President, Microwave Associates, Inc.

Frank Brand addressed the markets of the 1980s with the theme that *technology drives the marketplace*. Technology drives the marketplace both when the technological advances are *real* and *illusionary*. What does this mean? Real technological advances can be defined from a marketing viewpoint as those which, when converted to a manufacturing base, result in a profit to the manufacturer and a reasonable acquisition price to the user. These are the better ideas for the marketplace, i.e. *real* advances. Illusionary technological advances evolve from the business strategy of introducing to the market new products and services at prices that are below what is consistent with their actual manufacturing cost. This is done quite simply because a manufacturer hopes to obtain a strategic lead in a market by selling his product at a low price, foregoing profit, perhaps even taking a loss, with the motive of thereby creating a sufficiently large market base for his product whereby he can make a larger eventual profit on the ensuing high volume. Furthermore, he thereby discourages competitors who would be reluctant to make the investment to get as far along the manufacturing learning curve as he appears to be. This strategy, although a proper and valid one when executed correctly, backfires when there remain technological barriers higher than he foresees, which prevent reaching the point on the learning curve to which he extrapolated in setting his initial (strategically low) prices.

In both the real and illusionary technological advances, the technology nonetheless drives the marketplace. In the case of real advances, newer and better products are made available at affordable and/or lower prices, no question about that. But how do illusionary technological advances drive the marketplace? When the advance is illusionary, the supplier cannot maintain the low prices for very long. When technical barriers are not surmounted on schedule, he is forced to withdraw the product. This creates disillusionment on the part of the consumers, it gives a bad name to the device, possibly even to the technology. Later, when real technological advances are made in the same area, the marketplace will demonstrate resistance to the new product, an added resistance which must be overcome (along with the natural inertia to accepting anything new) by the supplier who now appears with a real technological advance.

In addition to these considerations, today it takes much more cash — $50 to $100 million — than it did 20 years ago to field a new microwave semiconductor business. Debt-to-equity ratio for starting such businesses is limited by the ability to project a profit.

In the United States a 10-20% pretax profit is essential to an industry which hopes to grow.

ments, however, a more accommodating environment for growing a business exists. Outright collaboration between industry and government is possible on the foreign scene. There is no doubt, Frank Brand suggests, that this is now occurring in FET's and FET amplifiers. In the area of these fields, what is happening today occurred 10 years ago in the radio and television receiver industries. In any case, however, technology leads to products the profitable sale of which leads to new technology.


Frank Brand

ketplace. In the 1960s a key semiconductor microwave product was the varactor. This was followed in the 70s by the low power bipolar transistor. In the 80s we can expect this role to be filled by gallium arsenide products (IMPATT's, FET's and mixers, etc.). He points out that, "Bill Edwards (at Wright Patterson Air Force Base) and I were respectively proponents of monolithic and hybrid integrated circuits. Both of us turned out to be right, it's just that Bill's turn to be right is arriving now with the advent of more work in gallium arsenide monolithic IC's." He closed with these observations:

- Despite false starts, millimeter waves are coming to prominence in the 80s.
- Lightwave communications is a technology that will serve as both competitor and complement to microwave technology. The submicron geometries for FET transistors and Lithium Niobate lightwave switches are

fer. The technologies to make the devices are nearly identical.

- New 7 GHz synthesized oscillators used in precise receiver channelization for satellite communication offer digital frequency dial-up in 1 MHz steps over a 500 MHz bandwidth. They cost $5,000 now, but with VLSIC (Very Large Scale Integrated Circuits) we can expect in the 80s even higher frequencies at still lower prices.
- Often overlooked with new technologies is the need for a new breed of engineers. Who are they? Those who can blend several disciplines, digital technology with RF circuit expertise, semiconductor crystal growth with system technology.
- Real versus illusionary advances in technology may develop with FET's. On the face of it current "advances" are real but there are substantial barriers in the manufacturabil-

(continued on page 28)

efficient real-time target signature reduction methods.

Problem areas during the Vietnam conflict indicated we needed QRC (Quick Reaction Capability) Programs to support our activity in the 1966-1975 conflict. In one example, QRC was deployed very effectively. During the early part of the Vietnam conflict, every 2½ SA-2 missiles fired resulted in a kill. However, following a QRC application (in which it was determined that IRCM flares could be used effectively) 70 missiles, but then the more advanced SA-7, were required for one kill. This was despite the fact that during the latter part of the conflict the artillery batteries on the North Vietnamese side were more experienced.

In another example, during the Arab-Israeli conflict in 1973, the STYX missile, having a range of 50 miles, sank an Israeli destroyer. The Israeli missiles had a range of only 22 miles. A QRC maneuver called for the deployment of flares as a countermeasure to the STYX, with the result that 50 STYX missiles shot at the Isrealis scored no hits. The Israeli boat then moved in closer to within the range of its own missiles and sank all 9 of the opposition's patrol boats. Rusty observes that it is appropriate for us to evaluate the Vietnam threats encountered and the corrective action taken, for in no other experience is there such a wide practical background of real battlefield usage of sophisticated radar systems. To this end there has been selected a blue ribbon panel to evaluate the lessons learned in Vietnam.

All of us have heard that QRC, although expeditious, created reliability and maintainability nightmares. The result, Rusty noted, is that current system designs intentionally minimize the use of new technologies in order to ensure reliability. He feels, however, that such a procedure is not aggressive enough to counter the new threats we can expect, and that the solution to meeting these new threats is threefold in nature.

- Make a quantitive current assessment of EW acquisition practices.
- Assess the quantitive QRC activities just during the latter portion of the Vietnam War.
- Define specific changes required in DoD and service developments to enable electronic defense systems to counter these threats, since these represent the real threats of the immediate future.

As an aside, Rusty pointed out that, in his experience in the Gulf of Tonkin, most of the flights that took off from carriers embarked with all of their EW systems functioning and that the reliability of the systems may have received too bad an image in our industry. He emphasized that we should go back and audit the delays and cost overruns as they apply to systems developed during the Vietnam conflict, that we should enlist a group of eight to ten EW industry executives to take an objective look at the US defense industry performance in this regard, and that we should

material growth as well as many unanswered questions about reliability.

- Computer-aided design and manufacture will assume a greater role in the 80s (this point illustrated with a slide showing an auto loading microwave chip sorter and measuring device).
- In 1958, an analysis of the microwave component industry showed it to be a $300 million market, with tubes accounting for $108 million. By 1975, the component market had grown to $625 million, by 1980 to $1.2 billion, and projections are for continued growth to $2.1 billion in 1985, and $3.3 billion in 1990 (this excludes antennas as well as components made by the Western Electric Co.). While semiconductor devices occupied only 1% of the market in 1958 they have grown to 8% of it in 1975, 9% in 1980 and could be expected to be 10% nents however are expected to grow to 44% of this market in 1990.

***John M. Porter*, Dir. of EW and C^{3}CM, Office of the Sec. of Defense**

This talk detailed the microwave requirements of military electronics systems as they exist now and projections into the 80s. Electronic warfare has been broadened to include, not only the RF and microwave spectra, but the infrared and optical spectra, as well, and extends in its utilization to military aircraft, warfare budget has grown from $62 million in 1978 to $65.3 million in 1979 and $80.7 million in 1980. This is divided among the Army, Navy, and Air Force at about 12%, 43%, and 44% respectively in FY 1980.

John M. Porter

John (Rusty) Porter pointed out that the Warsaw Pact Nations have spent as much in electro-optics recently as they have in radar, with the consequence that we must match this threat in the same proportions. The Warsaw Pact, Rusty said, is dense in numbers of military equipment, is beginning to use more complex RF waveforms with more frequency agility, places increasing use on electro-optical modes of operation, shows more activity in the millimeter wave bands, and utilizes a multiplicity of target tracking schemes. To counter these threats are needed — detectors and locators (using pulsed Doppler and high PRF techniques), suitable jammers, deception methods, obscuration techniques (such as chaff, etc.), and

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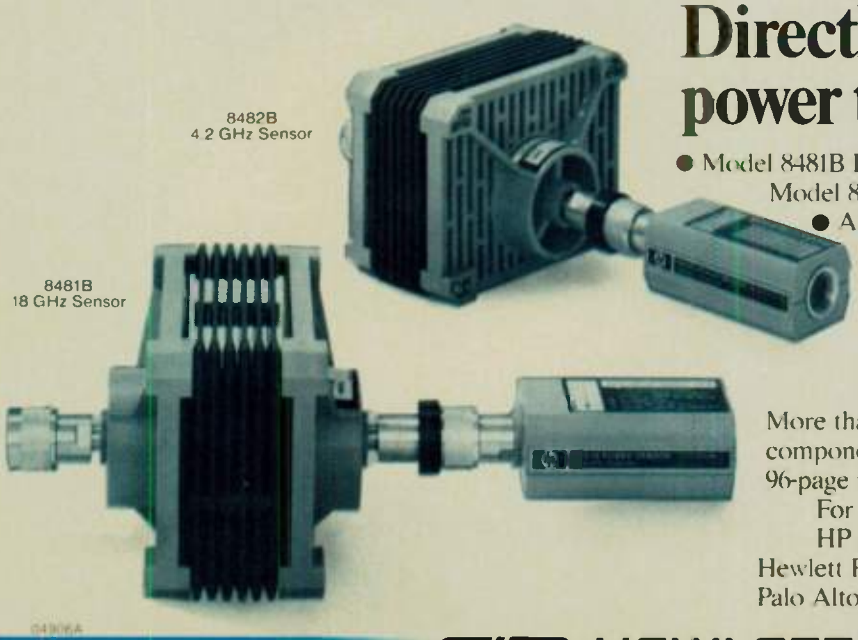


learn from the Vietnam experience. Recognize, too, that industry must not promise the Government more than it can deliver, for once a threshold for system performance is established, the introduction of the whole system tends to be held up until that threshold is met, and once met, the design becomes frozen. This latter characteristic, Rusty feels, is not sufficiently aggressive; rather we should design with update in mind. Jammers, for example, currently have to be totally replaced when new systems become available.

Another tendency during the Vietnam conflict was to design countermeasure systems based on specific intelligence-related inputs regarding enemy weaknesses. However, for the future we should shift to "generic countermeasures" as applied to cross polarization, terrain bounce, decoys, expendables and so forth, so that the equipment is not as specifically designed around what we perceive to be the enemy's weaknesses (since weakness may be inaccurately perceived and/or correctible).

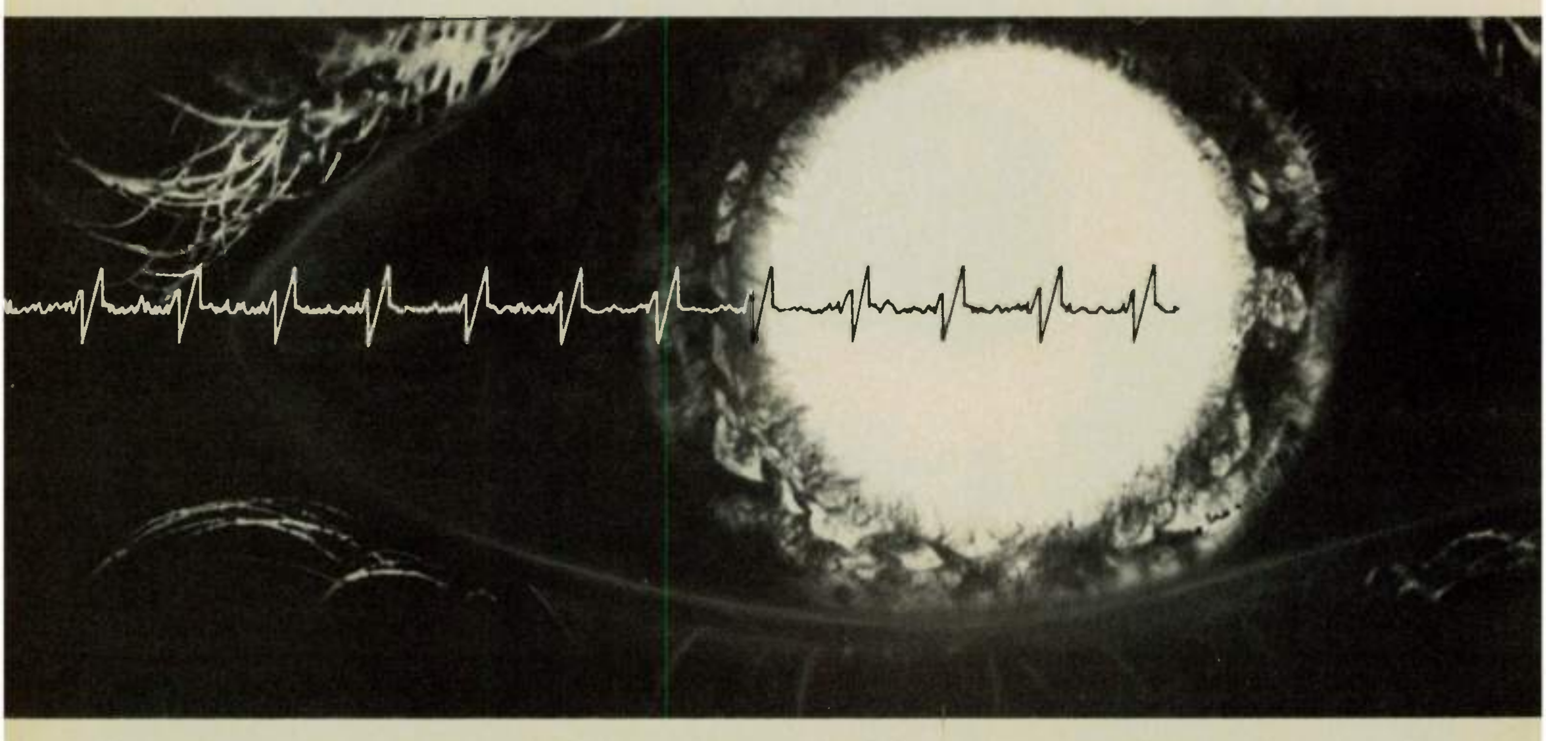
In summary, Rusty noted that current problems include handling signals in a dense electronic environment, availability of lower cost broadband, high gain antenna systems, high performance dual mode TWT's, lightweight lower power EW suitable for use in RPV's (remotely piloted vehicles) cruise missiles, and so forth. He ended by observing that phased arrays are still too expensive. Too few systems are able to enjoy the benefits of electronic agility that the phased array promises.

Lawrence Thielen,
President and Founder of Avantek

Lawrence Thielen

Larry's talk centered around the theme "How to Grow a Rapid Technology Development Company in the 80s." He confessed that his talk would sound like a Peter Drucker seminar. It boiled down to four points: focus clearly on objectives, plan well, minimize hip shooting, and work diligently. Certainly Avantek's growth, which fits a nearly perfect exponential curve showing 40% per year compounded growth since 1964, speaks well for these truistic guidelines. Extending these four principals, Larry cites eleven specific management direction techniques that Avantek uses:

1) Excellence in management, from top management down the line (i.e. attempt to acquire the best people in the business).
2) Aggressive annual operating plan (AOP) written three months in advance.
3) Monthly audit of the AOP.
4) Continuous profit stream.
5) Appreciation of stockholders equity. Avantek has produced a 30% return on stockholders equity compounded since its beginning. Avantek is in the 95th percentile of growth companies in the San Francisco Bay area.
6) Maintenance of a sound framework to serve several market segments with the ability to change as required.
7) No compromise on personnel quality (i.e. don't toler-



skill and ability decide who advances and also who is rewarded).

8) The best technical facilities.
9) Means to captivate market share and hold it.
10) Program to share (economic) success with all employees.
11) Performance of long-range strategic planning.

In addition:

- Avantek has provided telecommunication systems covering the OEM market in the 1.5 to 14.5 GHz up and downlink satellite systems.
- It's made 1.5 million transistors for INTELSAT, and it provides a $7,000 receiver for COMSAT.
- In the electronic warfare area, it has been involved with the F-15 (for power jamming) as well as the F-16 and F-18 (with MIC components in the $3,000 to $6,000 price range). It's been involved with Navy missile systems, (jamming equipment worth $1 million last year), AWAC's and low noise, medium power amplifiers to replace traveling-wave tubes.
- Avantek has designed a tunable scanning oscillator for OEM's for the CATV market.

tion amplifiers and down converters at ($8,000 - $12,000 per copy) have been furnished by Avantek.

- They design test equipment (to check out 12-30 channels) for cable operators as well as conditioning equipment for cable TV system for improving signal quality.
- Avantek has furnished many turnkey installations and has interfaced with the Bell Telephone systems (for up to 11,000 channel phone systems).
- Avantek is a highly vertically integrated company making everything from silicon and GaAs chips, up through packaged devices, thin film circuits, full printed circuit microwave circuitry, and, finally, digital radio systems.
- Avantek is presently investing in R&D work in the ion implant area.

Larry pointed out that, even during difficult economic times, Avantek has prepared for the future. For example, during the 1974 recession, some overhead cuts were made, but more money was allocated for marketing and radio as early as 1973, and most of the company growth occurred during the 1970 to 1980 time frame (to its present $15 million building facility) despite unfavorable economic barometers during this period. 1978 they had a public offering at $7 a share, following which, the stock rose to $21 within one year. This March, despite woes in the financial community, Avantek has raised $8.4 million as a "war chest to guard against recession." Larry Thielen's message seems to be, when the plan is good the times don't much matter.

William Bazzy

Following a question-and-answer session between the speakers and the audience and closing remarks by Bill Bazzy, the Microwave Journal hosted a cocktail reception for the group.

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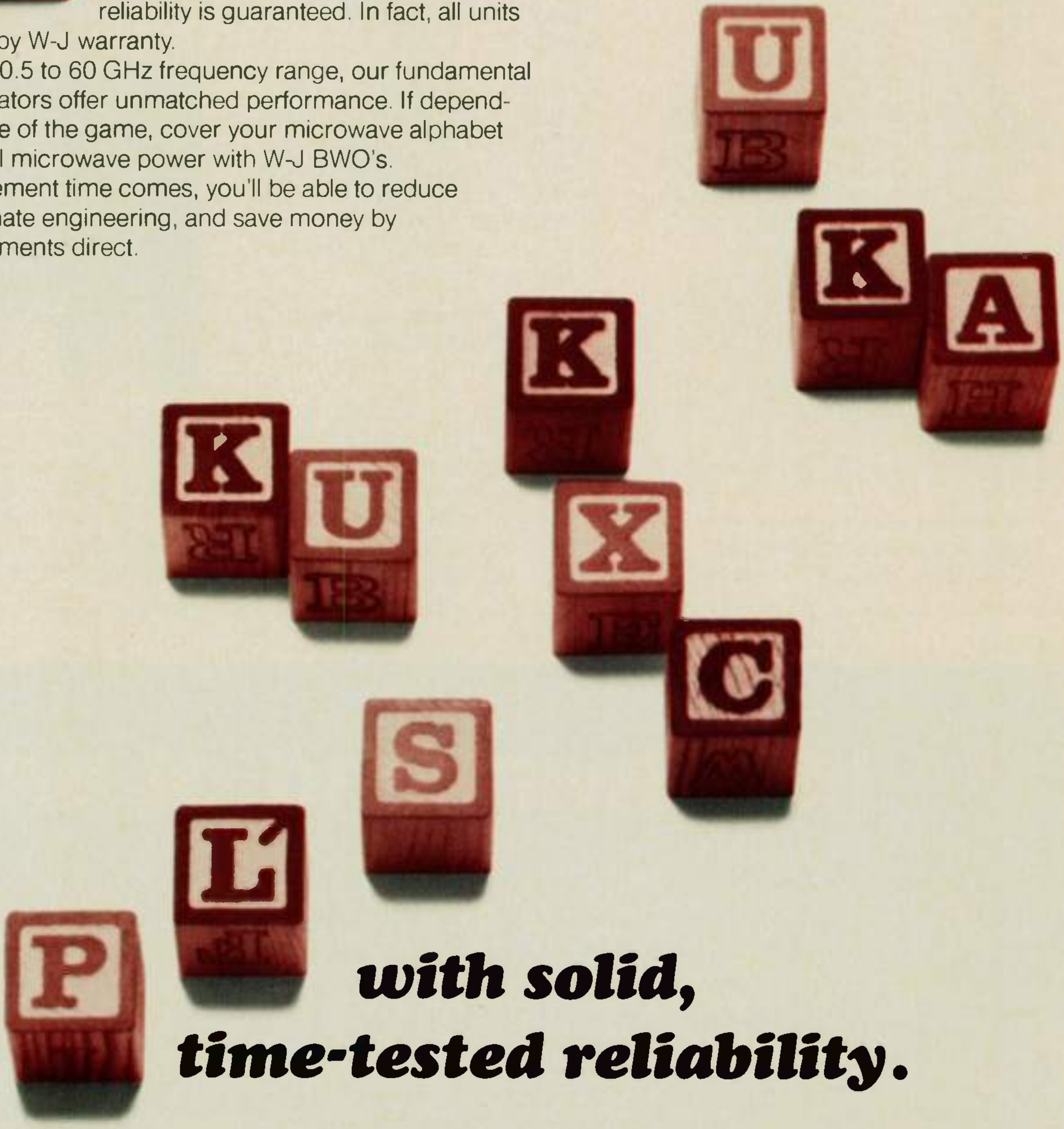

with solid, time-tested reliability.

For further details or an easy-reference, short-form replacement brochure and cross-reference guide, contact the W-J Field Sales Office in your area, or call Signal Sources Applications Engineering in Scotts Valley, California at (408) 438-2100, ext. 257.

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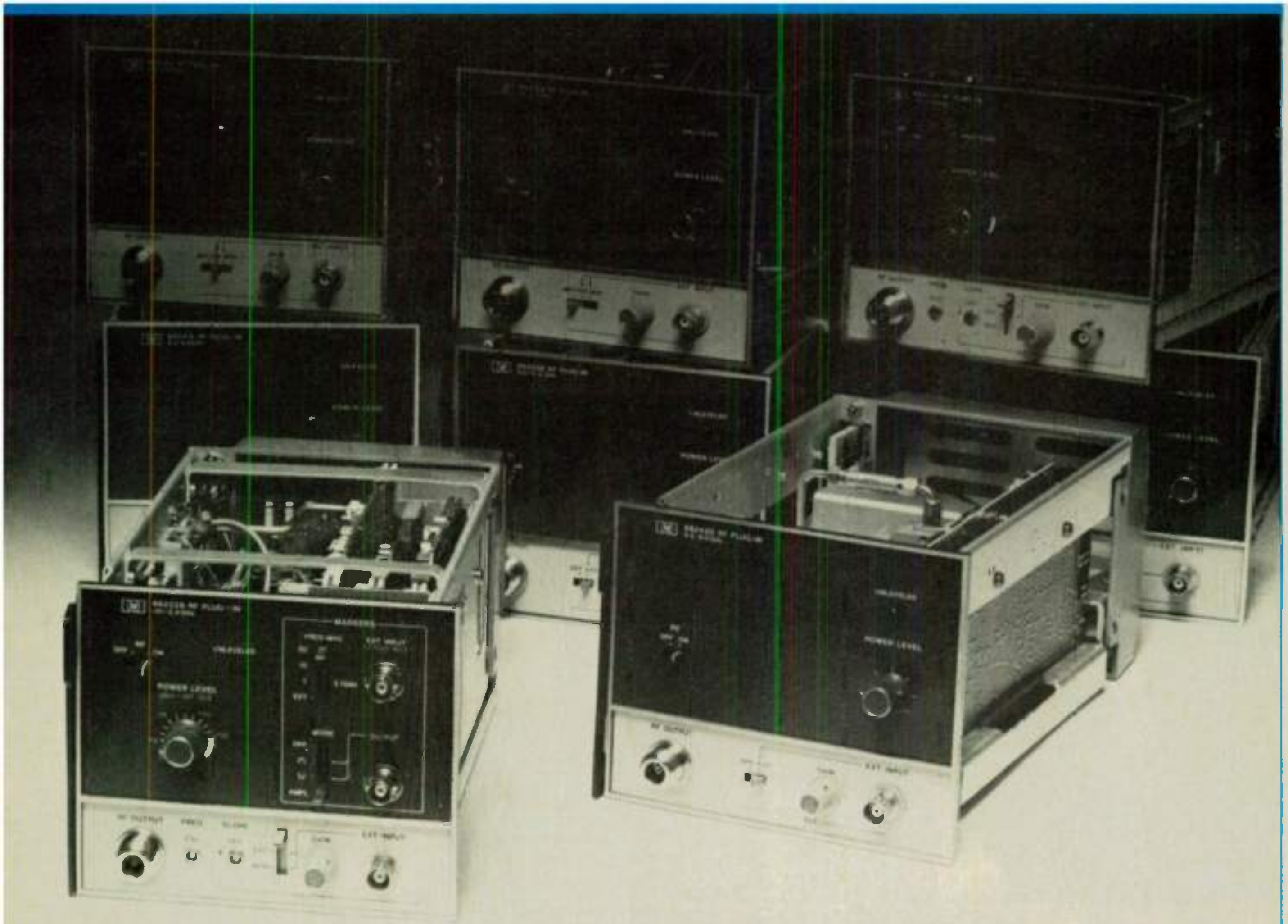
45006B



Popular plug-ins include:

Model No.	Freq. Range	Output Power	Price
86222A/B	10 MHz-2.4 GHz	20 mW	$4550/5450
86235A	1.7-4.3 GHz	40 mW	$3700
86240A	2.0-8.4 GHz	40 mW	$4550
86240C	3.6-8.6 GHz	40 mW	$5450
86245A	5.9-12.4 GHz	50 mW	$5100
86260A	12.4-18 GHz	10 mW	$4350
86290A	2-18 GHz	5 mW	$14,250
86290B	2-18.6 GHz	10 mW	$16.250
86290B opt. H08	2-22 GHz	2 mW	$19.250

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A real advantage of HP-IB is you get not only the bus architecture you need, but the documentation support that can help you get your system up and running in weeks, instead of months.

A prime example is the scores of HP-IB automatic microwave network analyzer systems now in use. Major elements of these systems are the 8620C/86290B Sweeper, HP 8410 Network Analyzer, and HP 9825A Desktop Computer. Systems like this are fully described in HP Application Notes 221 and 187 Series. You can get copies of these plus information on the 8620C from your local HP sales office, or write Hewlett-Packard, 1507 Page Mill Rd., Palo Alto, CA 94304.

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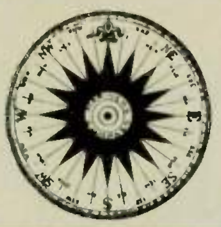
Around the Circuit



PERSONNEL

Stan N. Cohen has left English Electric Valve Co. to become Microwave Sales Engineer for the newly formed Anglia Microwaves Ltd. . .Microlab/FXR appointed **Betram R. Rashkow** as Vice President. . .**Richard C. Bangs** was promoted to western NY state account manager for Rogers Corp. . .Western Microwave, Inc. appointed **Victor Feldman** to its MIC engineering staff. . . At Uniform Tubes, Inc., **Warren W. Hamilton** has been named V.P., Finance and **H. Lawrence McKaig, Jr.** was appointed V.P., Engineering. . .**William Adikes** joined Lars Microwave, a Unaworld Corp. company, as V.P. of Sales and Marketing. . .Racal-Dana Instruments, Inc. announced the promotion of **Kenneth W. Harrison** to Nat'l Field Sales Mgr. and **Nelson A. Urdaneta** to Mgr. of Engineering Projects. . .**Richard M. Walker**, V.P. of Microwave Associates, Inc. and a Founder Dir. of M/A-COM, Inc. received one of the first Distinguished Engineering Awards presented to U. of Kansas graduates. . .At Microwave Associates Communications Co., **Patrick Nettles** became Line Mgr. of Data Products. . .**Robert A. Agnew** was appointed Chief Development Engineer for Terra-Com, a Div. of Loral Corp. . .**Harold (Hal) E. Edmondson**, Gen. Mgr. of Hewlett-Packard's Santa Rosa Div., has been named Gen. Mgr. of the co.'s new Microwave and Communication Group. . .**Merle L. Engle** was appointed President, Electronics and Space Div. of Emerson Electric Co. . .Electronic Space Systems Corp. appointed **Richard R. Strickland** Dir. of Marketing. . .**John N. Williams** joins American Electronic Labs as Southeast Regional Marketing Manager.

CONTRACTS

GTE received a $10.4M contract from **Petroleos Mexicanos** to provide and install a mw communication system for a gas pipeline along Mexico's east coast and another $17.9M contract from the US Army's Signals Warfare Laboratories for 11 tactical jamming systems (AN/MLQ-34) and related spare parts. . .**Scientific-Atlanta, Inc.** was awarded a $4.14M contract by **General Dynamics**, Ft. Worth Div. for radome and radar antenna test ranges for USAF F-16 aircraft. . .**Sperry Div. of Sperry Corp.** was granted one of two competitive contracts by USAF ASD for the system definition and validation of the AN/ALQ-131 (V). . .NASA's Lewis Research Center awarded parallel $1M 1-year contracts to **TRW's Defense and Space Systems Group** and to **Hughes Aircraft Co.**, for the design of an advanced commercial communications satellite system. . .**M/A-COM, Inc.** announced that **Microwave Associates, Inc.**, received a $2M contract from **Raytheon Co.** for phase shifters for the AF Cobra Judy phased array radar. . .**American Electronics Laboratories, Inc.** was granted a $1.79M contract by USAF ASD for the development of an AN/ALQ-131 Surveillance Radar Jamming Module. . .**EPSCO, Inc.** re-

NASC for signal data converters and spare modules.

INDUSTRY NEWS

General Instrument Corp., Clare Div., appointed **Micro-Now Instrument Co., Inc.** as US distributor for mm noise sources covering the 18-220 GHz range. . . **Pacific Measurements, Inc.** has signed an agreement with **Arva/Hudson Inc.** of Bellevue, WA to represent PMI's instrument line in the Pacific Northwest. . .**Frequency and Time Systems, Inc.** moved from Danvers, MA to larger quarters (32,000 sq. ft.) at 34 Tozer Road, Beverly, MA. . .**JFD Electronic Components Corp.**, the **Murata Corp.** subsidiary, has moved to new headquarters at 112 Mott St., Oceanside, NY. . .**M/A-COM, Inc.** announced that it and **Aetna Life and Casualty Co.** have formed a partnership, **Local Digital Distribution Co. (LDD)** to provide transmission and network access control equipment for local (within a building or city) distribution of voice, high-speed data and image communications. . . **Satellite Business Systems** has been advised by the Dept. of Justice that the DOJ will not ask the Supreme Court to review the US Court of Appeals March 1, 1980 decision which upheld the FCC's order authorizing SBS to proceed with its satellite system under its current tripartite ownership structure. . .**Times Fiber Communications, Inc.** will open its new plant (at the co.'s Wallingford, CT headquarters) for the production of optical fibers and cable this month. . .At **Varian's Microwave Components and Subsystems Div. (MCSD)**, two of its three operations and administrative groups have been consolidated into new offices occupying 80,000 sq. ft. at 3200 Patrick Henry Dr., Santa Clara, CA.

FINANCIAL NEWS

Scientific-Atlanta, Inc. reported third quarter results for the period ended March 31, 1980 of sales of $48.9M, net earnings of $3.5M or 67¢ per share. During the comparable 1979 quarter, sales totaled $32.9M, net earnings were $1.9M or 42¢ per share. . .**Harris Corporation** had third quarter net sales of $336M, net income of $20.6M or 68¢ per share, for the period ended March 28, 1980. For the same 1979 quarter, net sales were $274.5M, net income was $17.8M or 59¢ per share. . . For the three months ended March 31, 1980, **California Microwave, Inc.** reported a net loss of $958K, or 47¢ a share, on sales of $8.3M. For the comparable 1979 quarter, net income was $603K, or 30¢ a share, on sales of $10.2M. . .**Loral Corp.** has net income of $12.4M, or $1.84 per share, on sales of $153M for the fiscal year ended March 31, 1980. This compares with annual 1979 net income of $10.3M, or $1.65 per share, on sales of $130.8M. . .**AEL Industries, Inc.** reported a net loss of $177K, or 9¢ per share, on sales of $58.9M for the fiscal year ended February 29, 1980. This compares with 1979 annual results of sales of $60M, net income of $1.9M or $1.06 per share. . .For the year ended March 31, 1980, **Alpha Industries, Inc.** reported sales of $21.8M, net earnings of $1.87M, and earnings per share of 95¢. This compares with 1979 sales of $16.4M, net earnings of $1.33M and earnings per share of 69¢. Alpha filed an SEC Registration Statement May 13, 1980 offering 600K shares of common stock, of which 500K will be sold by the co. and 100K will be sold by certain stockholders. . .**Sealectro Corp.** announced net income for the first quarter ended March 28, 1980, of $535K, or 45¢ a share on sales of $10.4M. This compares with 1979 quarterly net income of $463K, or 40¢ per share, on sales of $8.2M. ■

Tube and Transmitter Technology Development

NELSON J. WILSON
US Army Electronics Technology and Devices Laboratory (ERADCOM)
Fort Monmouth, NJ

This report provides the status and progress of a series of microwave/millimeter-wave tube developments, and an update of modulator technology being pursued at the ET&D Laboratory, ERADCOM.

The tube division of Northrop Defense Systems Division under contract DAAB07-78-C-2981 has continued to demonstrate the applicability of the laser-cut BeO substrate to increase tube performance. In particular, Northrop Corp. has fabricated advanced models of E/F band crossed-field amplifiers using the BeO coupon concept bonded to a coexpansive ground plane. The copper meanderline is diffusion bonded to the BeO to form a 3- to 4-inch long, RF circuit. Hot test of two devices in E/F band have shown peak powers of 3.5 kW at 33% duty factor (1.2 kW average power) and 5.0 kW peak power and 10% duty factor (narrow band). At present, these devices are liquid cooled but design calculations show that with the improved thermal dissipation of the BeO coupon an air cooled, 500 watt average power amplifier is feasible. The gains of the two E/F band tubes were approximately 19 dB, which makes possible the use of solid state amplifier drivers to provide the desired peak power output. The lower cost construction technology coupled with the demonstrated 30 to 40% efficiency provides an RF performance level that is suitable for airborne and ground based transmitters.

Northrop has continued to develop the laser-cut substrate technology in the I/J band. Using the 0.006 slot and vane dimensions has resulted in a 60-section circuit with a total insertion loss of 8-10 dB. Although higher than expected, this loss value does not preclude operation at 1.0 kW peak power. Hot test results are expected by October 1980.

Hughes EDD under contract DAAB07-78-C-3015 is extending the coupled cavity traveling-wave tube technology at 94 GHz by developing a 100 watt peak power, 50% duty factor TWT that includes periodic permanent magnet focussing for lighter weight and a depressed collector for improved efficiency. Prior TWT designs used solenoids for electron beam focussing but solenoid designs for tactical field use are large and inefficient.

The 94 GHz tube under development will use a 120:1 area convergent electron gun, control electrode for modulation and will incorporate approximately 200 cavities to achieve large signal gain. A minimum bandwidth of 2.0 GHz is required although computer calculation shows that wider bandwidth may be realized. The design is expected to weigh less than 7 kg, far less than existing solenoid focussed TWTs. Hughes has completed cold test on a scaled X-Band model and has begun fabrication of a beam tester and hot test model designed to meet the 94 GHz technical guidelines. The first hot test is expected by October 1980.

Varian-Canada, under contract DAAB07-78-C-2948, continues to make progress with the development of the extended interaction amplifier (EIA) (*Microwave Journal*, July 1979, p. 43). Initial problems with competing modes and oscillations have been solved by the use of mode loading concepts. A four cavity tube has been hot tested and the performance is encouraging. Peak powers from 1.5 to 2.5 kW have been achieved at gain levels of 46 dB which exceeds the minimum value of 30 dB by a comfortable margin. The tube operates at approximately 21 kV and 0.65 A beam current which results in a respectable efficiency at 94 GHz of 18%. At present, the bandwidth is 200 to 300 MHz. Plans are to complete the 94 GHz design, package the tube with samarium cobalt magnets and begin extending the EIA design to the higher millimeter-wave frequencies.

ET&DL has implemented parallel advanced development contracts (6.3A) to improve high power TWT reliability and assure adequate sources of these critical components Varian Associates (DAAB07-78-C-3007) and Hughes EDD (DAAB07-78-C-3008) have embarked on improvements in 125 kW peak power TWTs for ground systems. The major emphasis is to incorporate isolated anodes for greater tube protection against arcing, reduce cathode temperature for longer operating life, improve operation at higher load voltage standing wave ratios (1.5:1 min) and improve amplitude linearity. Both Hughes and Varian have incorporated an isolated anode and have shown that with proper circuitry that expensive "crowbars" will not be required for tube protection. Further, cathode temperatures have been reduced as much as 50°C using osmium-ruthenium coatings of "B-type" cathodes, which paves the way for longer operating life (5000-hour objective). Proper internal matching and placement of in-band loss has upgraded the capability for operating into higher mismatches without impairing the tube performance. These programs have demonstrated that improved performance and affordability can be achieved through advanced development and that the system user will have a more reliable power transmitter available for both new design concepts as well as production.

As an adjunct to the two TWT improvement programs, an implementation program is in progress whereby the tubes will be fully evaluated in a

(continued on page 60)

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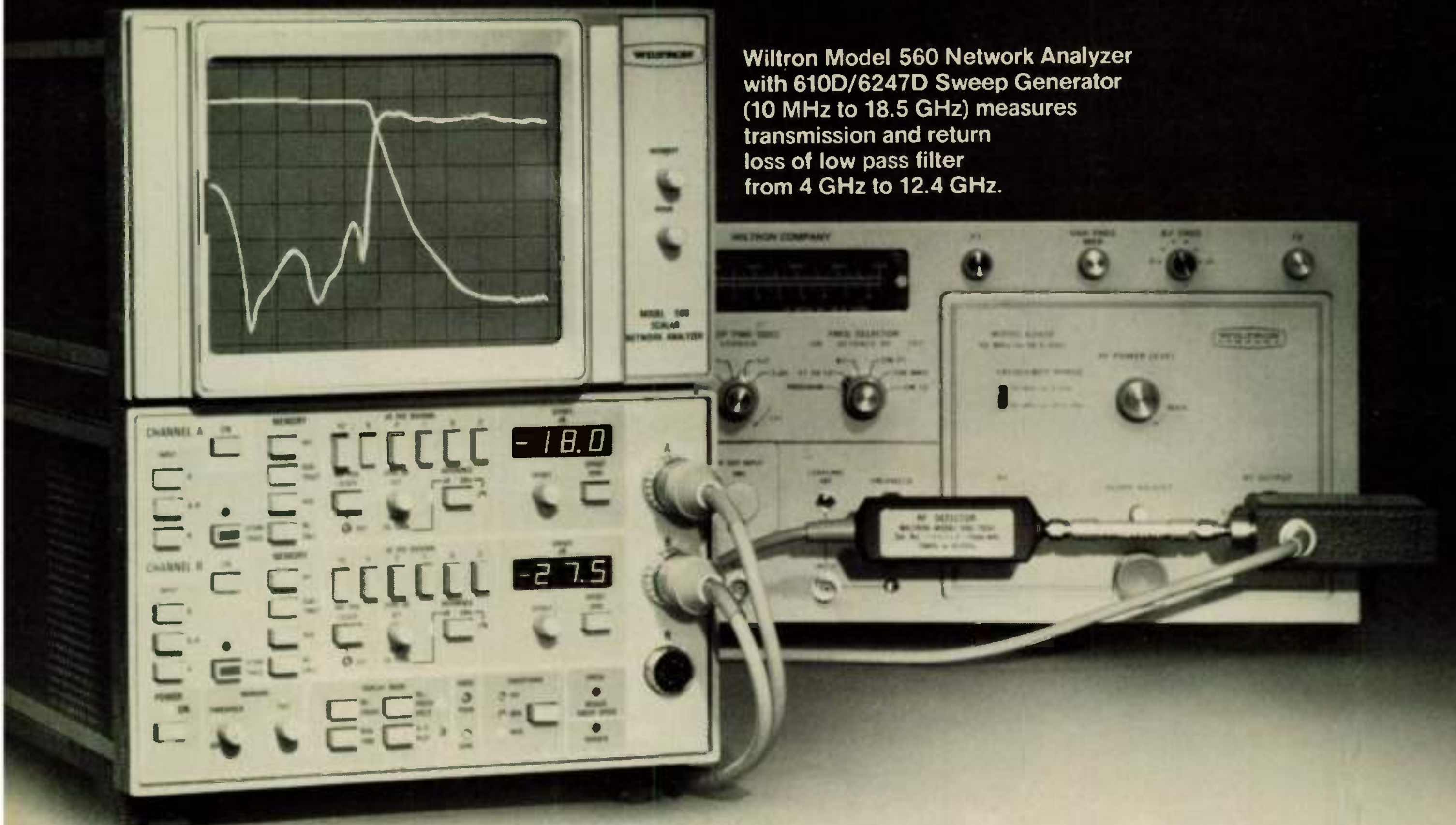

Wiltron Model 560 Network Analyzer with 610D/6247D Sweep Generator (10 MHz to 18.5 GHz) measures transmission and return loss of low pass filter from 4 GHz to 12.4 GHz.

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We've done a lot to stop errors and simplify measurements. For instance, there's a display mode for every application. Look at events in Real Time or in the Refresh display mode. In Refresh, data is digitized and updated each sweep for a steady flicker-free display, regardless of the external sweep speed. You can also freeze the display for analysis or photography. Press the X-Y Plot button for a 30-sec. sweep to drive a recorder.

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Wiltron's 560 offers GPIB programmability and 0.01 dB resolution. With 40 dB directivity from a 10 MHz to 18 GHz SWR Autotester, you get unmatched accuracy. Broadband components let you make uninterrupted measurements over more than 10 octaves. A new WSMA (SMA compatible) detector has an upper frequency limit of 34 GHz.

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

WILTRON

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THE MILITARY MICROWAVES CONFERENCE 1980

JOSEPH F. WHITE, Consulting Editor

The Military Microwaves Conference and Exhibition this year will be held October 22-24, 1980 at the Cunard International Hotel, on the outskirts of London, England. A Technical Program Committee made up of members from the UK, USA, Germany, Netherlands, Sweden, Norway, Italy, Japan, Canada and France have invited 100 papers which will be presented in 21 sessions over the three-day period of the conference. The exhibition will be free to engineers but there is a fee of about £125 (UK) to hear the conference papers. Delegates for the technical conference are expected to number 600 or more; also over 3,000 attendees at the exhibits from 35 different countries.

BACKGROUND

In alternate years the European Microwave Conference is held without a trade exhibit, and this is such a year. The European Microwave Conference will take place in Warsaw, Poland September 8-12, 1980. Complementing the EuMC, the Military Microwaves Conference has been organized by Microwave Exhibitions and Publishers Limited, an organization managed by Roger C. Mariott. This conference is unclassified, this year represented by technical committee members from nine countries, and consists of invited technical papers given in English by specialists who are felt to be leaders in their field. This technical conference is accompanied by a microwave exhibition.

The list of exhibitors includes manufacturers, manufacturer's representatives, publishers, research firms, and personnel placement services. According to Manager Roger Mariott, projections for electronic warfare systems alone for the period 1979 through 1984 indicate expenditures outside of the United States of more than $2 billion, half of which will be spent in western Europe. It is this activity which the Military Microwaves Conference and Exhibition is designed to address.

TECHNICAL CONTENT OF THE CONFERENCE

Technical papers have been invited around a theme of the interface between microwave modules and systems, emphasizing the microwave technology relating to weapon system programs anticipated for the 1980s. Accordingly, particular emphasis is given to millimeter waves, propagation, antennas, receivers, transmitters, circuit technology, radars and radiometers. These subtopics complement system papers which will be given on radar, communications and electronic warfare. The following listing gives the titles of the technical papers and their authors in the six major topic categories planned for the conference.

ELECTRONIC WARFARE

The Bragg Cell Receiver, Wideband Acquisition Processor in the 1980s
R. Croce, W. Regier, E. Quenschiel, R. Coppock
Sylvania Systems Group, California, USA

System Performance Trade-Offs — Responsive and Repeater Jammers
M. Pett
MEL, Crawley, UK

Improved Angular Discrimination for Digital ESM Systems
Stig Rehnmark
Anaren Microwave, Syracuse, New York, USA

Microstrip Rotman Lenses
A. Y. Niazi, M. S. Smith, D. E. N. Davies
University College, London, UK

Microwave Frequency Dividers — Devices and Applications
W. D. Cornish
Defence Research Establishment
Ottowa, Ontario, Canada

Airborne Self Protection Jammer
Daniel J. Rice, Alan S. Kaufman

Suspended Substrate Stripline Filters and Multiplexers
J. E. Dean, J. D. Rhodes
Filtronic Components, Leeds, UK

Design Aspects for ESM Systems
R. S. Andrews
Decca Radar Ltd, Walton-on-Thames, UK

Rapport Tactical Self-Protection Systems Design
John B. Sparno
Loral Corporation, New York, USA

(continued on page 44)

TRANSMITTERS & RECEIVERS

Annular Rotary Coupler
B. E. Kruger, J. C. Parr
ITT Gilfillan, Van Nuys, CA, USA

Rugged, Miniaturised Parametric Amplifiers for Military Applications
L. Fowler, N. Savage
Ferranti Electronics, Poynton, UK

Low Noise Image Rejection Mixers for Military Radars
T. H. Oxley, E. Smith
CEC Hirst Research Centre, Wembley, UK; AEI Semiconductors, Lincoln, UK

Rugged GaAs FET Amplifiers for Military Applications
J. Turner
Plessey Research Caswell Ltd, Towcester, UK

New Design and Technologies for Broadband Crystal Video Front Ends
Raffaello Rosati
Electtronica, Rome, Italy

Active Solid State Receiver Protection
A. W. Robinson, J. Clarke
EEV, Lincoln, UK; RSRE, Malvern, UK

The Evolution of Miniature Environmentally Rugged Magnetrons
B. Vyse, H. Levinson
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The Current Art of Millimeter Wave Solid State and Tube Type Power Sources
K. Amboss
Hughes (Electron Dynamics Division) CA, USA

A New Technique for Ultra-Broadband High Power TWT's
P. Galuppi, C. Lamesa
Elettronica SpA, Rome, Italy

Future Trends in Millimeter Low Noise Receivers
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The Influence of VLSI and VHSIC on Radar Architecture
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ONR, Arlington, Virginia, USA

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General Electric, Syracuse, USA

Monolithic GaAs Circuits for Millimeter-Wave Radar Applications
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An 8% Bandwidth 100 kW, L-Band Klystron Amplifier
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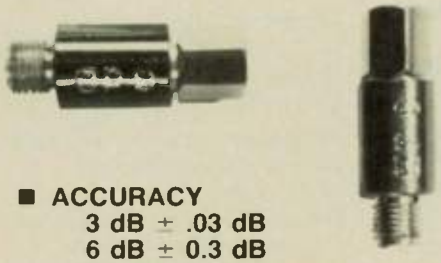

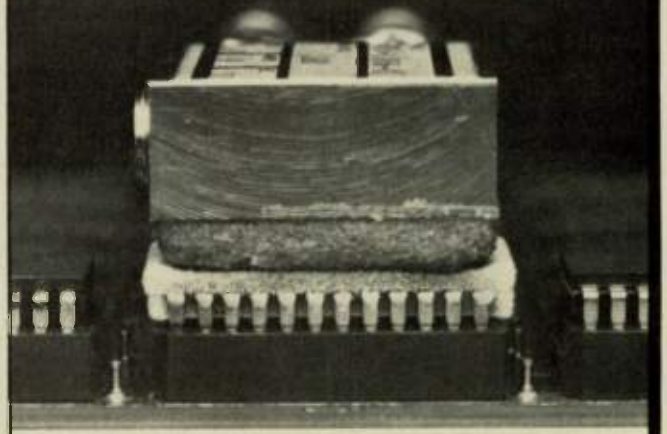

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These units are internally terminated circulators (isolators) with SMA female connectors and are available from stock*

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

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

POPULAR NARROW BAND — STANDARD DESIGNS

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

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Battlefield Surveillance
T. Hair
Marconi Research Labs, Great Baddow, UK

Modern Techniques in Radar Tracing Systems
L. Bianucci
Contraves, Italy

Santuary Radar
F. L. Fleming, N. J. Willis
Technology Service Corporation, Defense Advanced Research Projects Agency

Octave Bandwidth Dual Polarized Antenna
C. Nicolai, R. Scarpetta, P. Russon
Selenia SpA, Rome, Italy

S Band Delay Module
G. H. Swallow, P. M. Brigginshaw
GEC Hirst Research Centre, Wembley, UK

A Semi-Automatic Carrier Noise Analysis Test Equipment
W. J. McClintock, A. R. Faulkner, M. J. B. Scanlan
Marconi Research Laboratories, Great Baddow, Essex, UK

Automatic Controlled Terrain Following Flights
Reinald Rode, Achim Hessel
MBB Munich, Germany

Design Criteria for a Miss Distance Radar
Ruffe
Racal-MESL, Edinburgh, Scotland

A Field Deployable Radar Simulator for EW Training
H. D. Burns, R. B. Potter
Automation Industries, Inc., Florida, USA; Walmore Electronics Ltd, London, UK

Backscatter Measurement Radar Systems Operating at 140 GHz and 280 GHz
S. C. Woolcock, M. W. Plaster
EMIE Ltd., Wells, UK

A Novel Radar Altimeter
J. Tomlinson
EMI Electronics, Hayes, UK

Applications of Adaptive Polarization
D. Hammers, M. Fujita, A. Klein
ITT Gilfillan, Van Nuys, California, USA

ELRA – Experimental Phased Array Radars
W. Sander, W. D. Wirth
FFM, Wachtberg-Werthhoven, FRG

Recent Technical Developments in Ground-Based Air Surveillance Radar Systems
T. P. Kabaservice, H. C. Krason
The MITRE Corporation, Mass. USA

A Slotted Waveguide Antenna with Adjustable Polarization
R. Bloomendaal
Christiaan Huygenslaboratorium, BV, Noordwijk, Holland

Radar Threat Generator
W. T. Harpster
Emerson Electric Co., USA

GUIDED WEAPONS SATELLITES & COMMUNICATIONS

Multipurpose Radar Transceiver Modules Using Low Cost, Monolithic Techniques
Dr. Fraser
DARPA, Arlington, USA

Satellite Non-Nuclear Survivability
J. Fawcette
EW Communications, Inc., Palo Alto, USA

A Rugged Encapsulation for Suspended Microwave Substrates

Microwave Systems for Remotely Piloted Vehicles
M. R. B. Dunsmore, S. E. Gibbs
RSRE, Malvern, UK

Selectivity Predictions for Troposcatter Paths
M. Collin
Thomson-CSF, Bagneux, France

High Integration J Band Transmitter - Receiver Circuit for Missile Homing Head
M. Carbonne
Thomson-CSF, Paris, France

Conformal Arrays for Guided Weapons: A Review
P. J. Mitchell
Marconi Space & Defence Systems Ltd, Stanmore, UK

Recent Developments in Military Telemetry
R. G. A. Marzolini
EMIE Ltd, Feltham, UK

The Scot Shipborne Satellite Communications Terminal
C. D. Corbey, W. R. Wingnall
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Microwave Systems for Radar Guided Missiles
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Precision Low Mass Membrane Antennas
D. J. Mihora
General Research Corporation, Santa Barbara, USA

UK Military Satellite Transponders
J. W. Carter, C. J. Hearne
MSDS, Portsmouth, UK

TRIFFIED – Tactical Radio Relay for the 80's
R. I. Dow
Marconi Communication Systems, Chelmsford, UK

A Terminal Guidance Simulator for Evaluation of Millimeter Wave Seekers
K. L. Wisner, A. J. Witsmeer
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Millimeter Wave Antennas
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The RF Technology Centre at ERA, Leatherhead, UK

Low Coverage Surveillance Antenna System
F. S. Lomaglio, R. Evangelisti
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A Doubly Curved Reflector X Band Antenna with Integrated IFF Array
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Null-Steering Techniques for Application to Large Array Antennas
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ITT Gilfillan, Van Nuys, CA, USA

Progress in Phased Array Technology
R. J. Mailloux
Rome Air Development Center, USA

Recent Developments and Trends in Microstrip Antennas
J. R. James, P. S. Hall, C. Wood
RMCS, Shrivenham, UK

Radome Design and Performance: A Review
A. W. Rudge, J. E. Summers
ERA Technology Ltd, Leatherhead, UK; RSRE, Malvern, UK

Millimetric Aerials for Full Illumination Radars
M. Carter
EMIE Ltd, Wells, UK

Experimental Digital Ream Forming Antenna
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Linear Arrays for Centimetric and Millimetric Radars
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Martin Marietta Aerospace, USA

Radiometric Measurements at 80 GHz
G. R. Selby
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Passive Millimeter Wave Imaging in the Tactical Scenario
J. W. Dees, J. M. Schuchardt, J. M. Newton
Georgia Institute of Technology, Atlanta, USA
J. E. Malpass
Air Force Armament Laboratory, Eglin Air Force Base, USA

Atmospheric Effects on Near Millimeter Wave Systems Applications: An Overview
J. J. Gallagher, R. A. Bohlander, R. G. Schackelford, R. W. McMillan
Georgia Institute of Technology, Atlanta, USA

A Survey of Planar Integrated MM Wave Components
H. Meinel
AEG-Telefunken, Ulm, Germany

Hexaferrite Components — Tuneability at Millimeter Waves
M. Lemke, W. Hoppe
Philips GmbH Forschungslaboratorium Hamburg, Hamburg, FRG

MM WAVES

A Study of Potentially Low Cost Millimeter Wave Radiometric Sensors
S. J. Nightingale, R. N. Bates
Philips Research Labs, Surrey, UK

Millimeter Wave E-Plane MICs for Use up to 100 GHz
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Dielectric Waveguide Technology and its Implications for MM Wave Integrated Circuits and Antennas
M. Inggs, N. Williams
ERA RF Technology Centre, Leatherhead, UK

Millimeter Wave Propagation
B. G. Evans
University of Essex, UK

Millimeter Wave Components of Hybrid-Open Microstrip Form
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94 GHz Radar Propagation in Realistic Battlefield Environment
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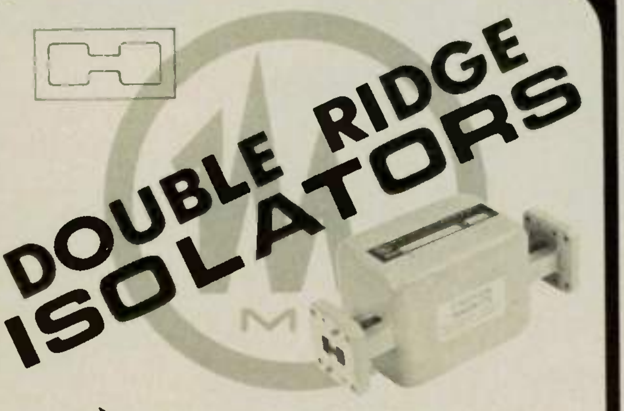

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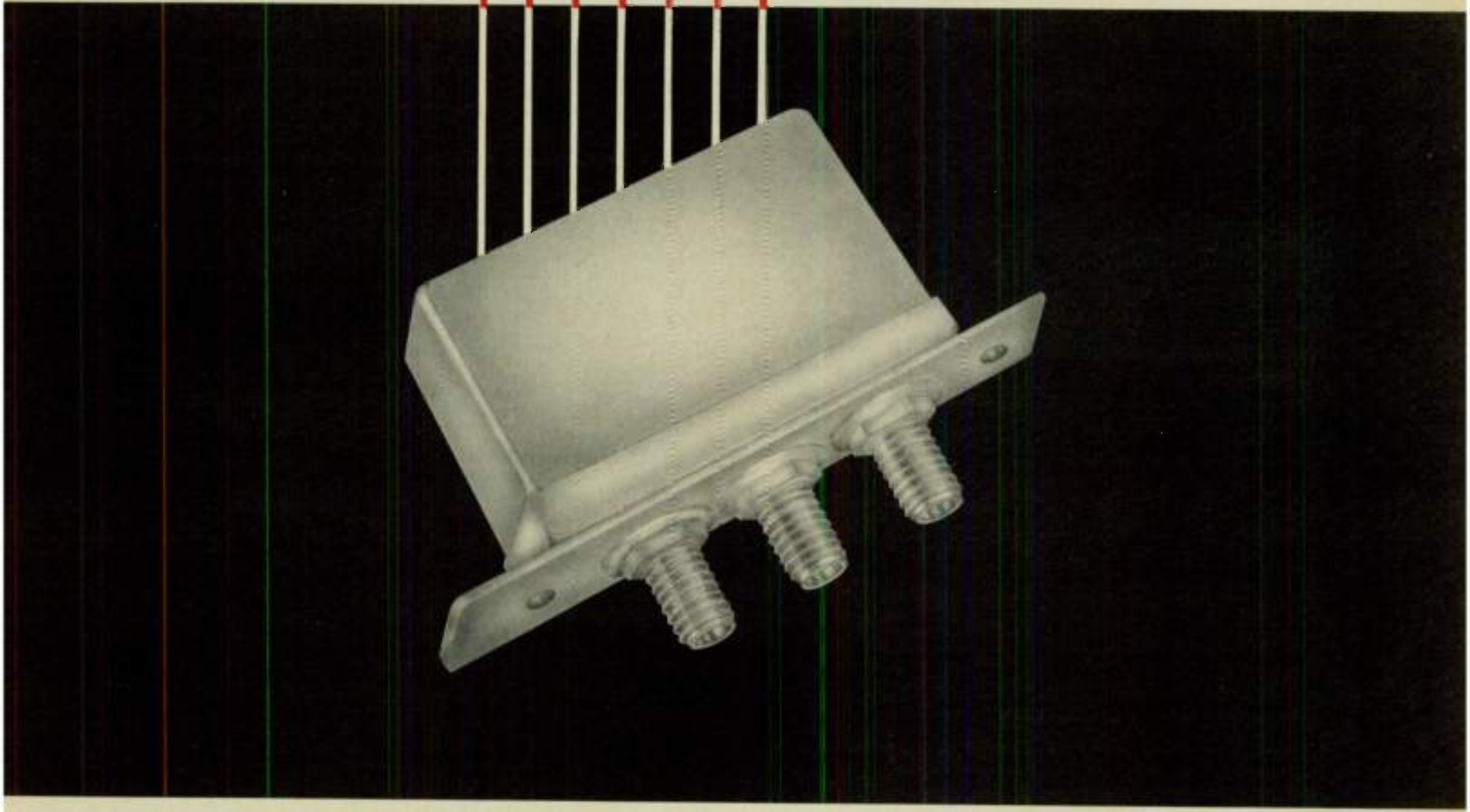

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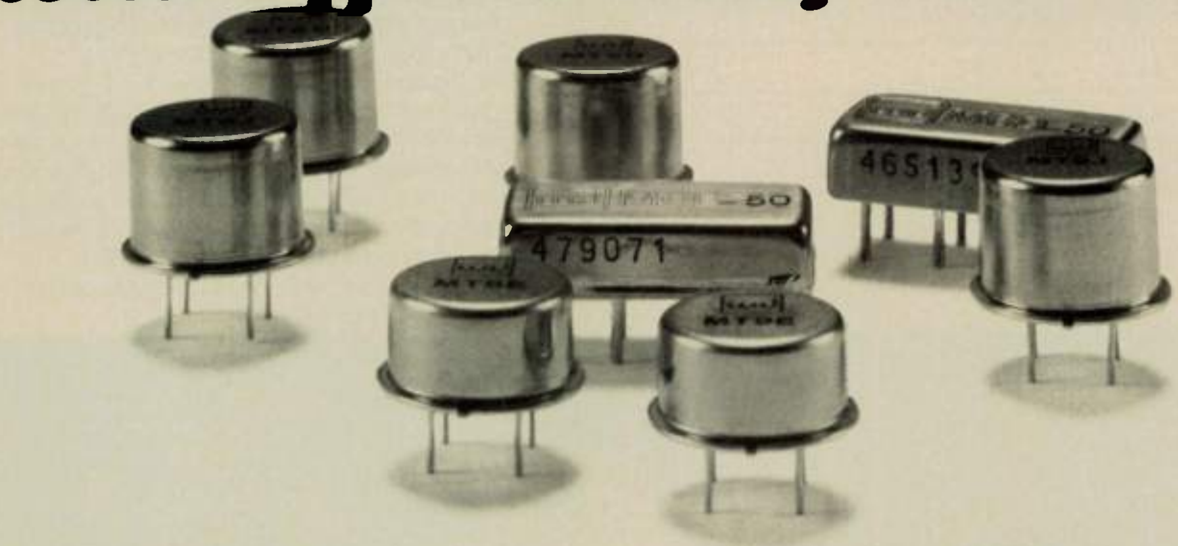

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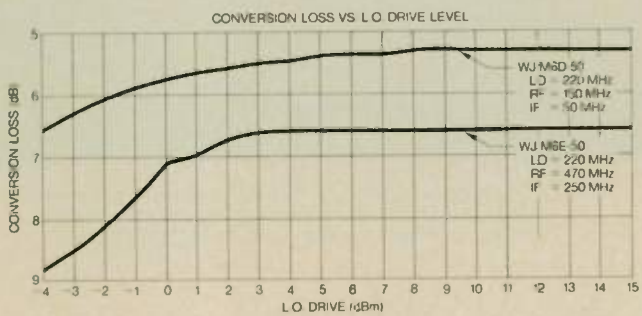

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Low Level	**MT6D**	DC–250	DC–200	+7	5.5	+10
	MT6E	DC–700	DC–700	+7	5.5	+10
	MT6J	DC–70	DC–70	+7	5.5	+10
High Level	**MT9D**	DC–250	DC–200	+13	6.0	+16
	MT9E	DC–700	DC–700	+13	6.0	+15
	MT9J	DC–70	DC–70	+13	6.0	+17

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Circle 31 on Reader Service Card

Phase Noise Test Results for 'Mini' TWTA'S

W. E. GARRIGUS
Ford Aerospace & Communications Corp.
Aeronutronic Division
Newport Beach, CA

INTRODUCTION

The use of samarium-cobalt magnets in traveling-wave tubes (TWT's) has resulted in the availability of very small tubes called "mini" TWT's. These devices are attractive microwave power amplifiers for missile and other applications where a premium is placed on space and weight. Many of these system applications, such as coherent radars, require an RF device exhibiting very low phase noise output.[1] Because of a lack of phase noise purity information relative to "mini" TWT's operating in such applications, it was found necessary to conduct a series of laboratory tests, the results of which are presented in this paper.

RF POWER DEVICE REQUIREMENTS

Typical performance characteristics and other requirements for RF power devices for coherent radars used in tactical missile applications are listed in Table 1. Many production TWT's meet the RF output power and efficiency performance specifications but only the recent "mini" TWT's meet the size and weight requirements indicated in Table 1. Table 2 indicates typical phase noise specifications. The phase noise purity of these "mini" tubes has not been previously established when the tube is being operated in either the laboratory or the missile vibration environment. Since the phase shift through the TWT is a function of beam voltage and also a function of the physical properties of the slow wave structure, several precautions have to be considered.

PRECAUTIONS TO MAINTAIN DESIRED PHASE NOISE PERFORMANCE

There are electrical and mechanical precautions to be observed to obtain the best phase noise performance possible.

Electrical

The phase shift of a signal being amplified by a TWT is a function of the beam voltage as follows:

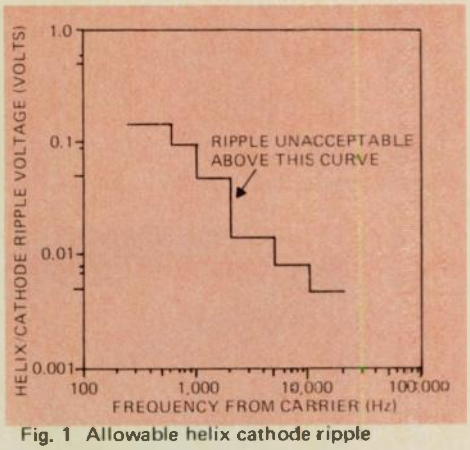


Fig. 1 Allowable helix cathode ripple voltage.
Notes: (1) Assumes 0.7 degree/volt phase shift characteristic of TWT
(2) Ripple indicated will produce phase modulation 20 dB below specification values of Table II.

$$\Delta \varphi \, \alpha \, \Delta E_B$$

where

$\Delta\psi$ = the incremental change in phase shift of the microwave signal through the tube

ΔE_B = the incremental change in the beam voltage (helix/cathode voltage) of the tube

If the helix-to-cathode voltage supplied by the power supply ha appreciable ripple, a form of phase modulation will result. Th level of modulation can readily be predicted using well known established relationships.[2,3] The microwave output magnitude of this phase noise (assuming the modulation to be very low level) is given by:

$$\left.\frac{V_{SB}}{V_C}\right._{dB} = 20 \log \frac{\Delta f}{2\, f_m}$$

Where:

V_{SB} = Voltage of sideband

V_C = Voltage of carrier

Δf = Peak frequency or phase deviation

f_m = Modulating frequency

The "mini" TWT's considere have measured phase sensitivitie of about 0.7 degrees per volt of the helix/cathode voltage. A reasonable assumption is that the

TABLE I

RF POWER DEVICE REQUIREMENTS FOR TACTICAL MISSILE APPLICATIONS

CHARACTERISTIC	REQUIREMENT	PRESENT "MINI" TWT
• RF Output Power (Pk)	50 - 500 watts	60 watts (100 watts has been demonstrated
• RF Output Power (Ave.)	5 - 50 watts	20 watts
• Frequency	X - Band (or K Band)	X Band
• Pulse Width	1 - 100 Microseconds	15 Microseconds (This application)
• Duty Factor	0.01 to 0.5	0.33 (This application)
• RF Input Drive Signal Level	0.1 to 1 watt (Upper limit of readily available solid state drivers)	0.01 watts (This application)
• Efficiency	High as possible to minimize the power supply/modulator size, weight and prime power requirements.	25-30% with depressed collector operation
• Residual RF Output	RF energy must be less than −100 dBm in a 0.1 MHz Bandwidth during transmitter "off" time to prevent interference with target return signal at receiver input.	Tube has a modulation anode to control the beam current off and on thus modulator does not need to supply full beam current which would require a large high power modulator.
• Size	5 - 50 in^3 (as small as possible)	Approximately 5 in^3
• Weight	10 - 60 oz. s (as light as possible)	Approximately 8 oz.
• Heater/Cathode Warm-up time	2 - 5 sec. desired, but 1-2 minutes is acceptable.	1 minute (2 seconds has been realized on other tube types)
• Phase Noise Purity	Requirement depends on characteristics of mission, i.e., antenna beamwidth, range required, terrain clutter characteristics and transmitted carrier power.	See follow-on discussion/meets Table II requirements
• Environment	Missile (0.015 $g^2/_{Hz}$ vibration)	See conclusions

phase noise contribution due to the power supply ripple should be at least 20 dB below the specified system noise level. This requires that the power supply must have a ripple voltage level as indicated in **Figure 1**. Sufficient filtering in the power supply must be included to keep the ripple levels below the desired specification.

The gun of the TWT also produces noise but the level is well below the specification as indicated below:

$$P_{out} = KTB \times NF_{gun} \times Gain$$

Where:

P_{out} = noise power output in dBm
K = Boltzmann's constant
T = Temperature
B = Bandwidth (1 Hz)
NF_{gun} = Noise Figure of the TWT gun (for the mini TWT's it is 35 dB)
Gain = Gain of TWT (40 dB)

$$P_{out} = -174 \text{ dBm} + 0 \text{ dB} + \ldots + 35 \text{ dB} + 40 \text{ dB}$$

$$= -99 \text{ dBm per Hertz bandwidth}$$

The RF carrier output of the tube is:

$$P'_{out} = 60 \text{ watts (peak)}$$

$$= +48 \text{ dBm}$$

The noise level below the carrier signal is calculated by:

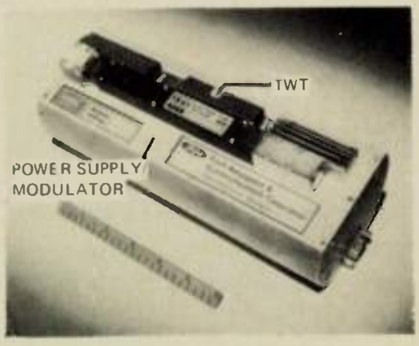


Fig. 2 Final TWTA package.

$$P_{out} - P'_{out} = -99 \text{ dBm/Hz} - 48 \text{ dBm}$$

$$= 147 \text{ dBc/Hz}$$

which is well below the required level.

Mechanical

The mechanically induced phase shift of a signal being amplified by a TWT is a function of the properties of the slow wave structure and gun of the tube. Modulation of the signal occurs if the propagation constant of the tube slow wave structure changes at a rate fast enough to produce signals in the receiver video bandpass (much of the missile vibration is in this band). If vibration produces a slight movement of the helix with respect to the dielectric support rods, phase shifts occur which represent undesired phase modulation. If vibration produces slight movement of the cathode structure, the electron path length will vary causing amplitude and/or phase modulation.

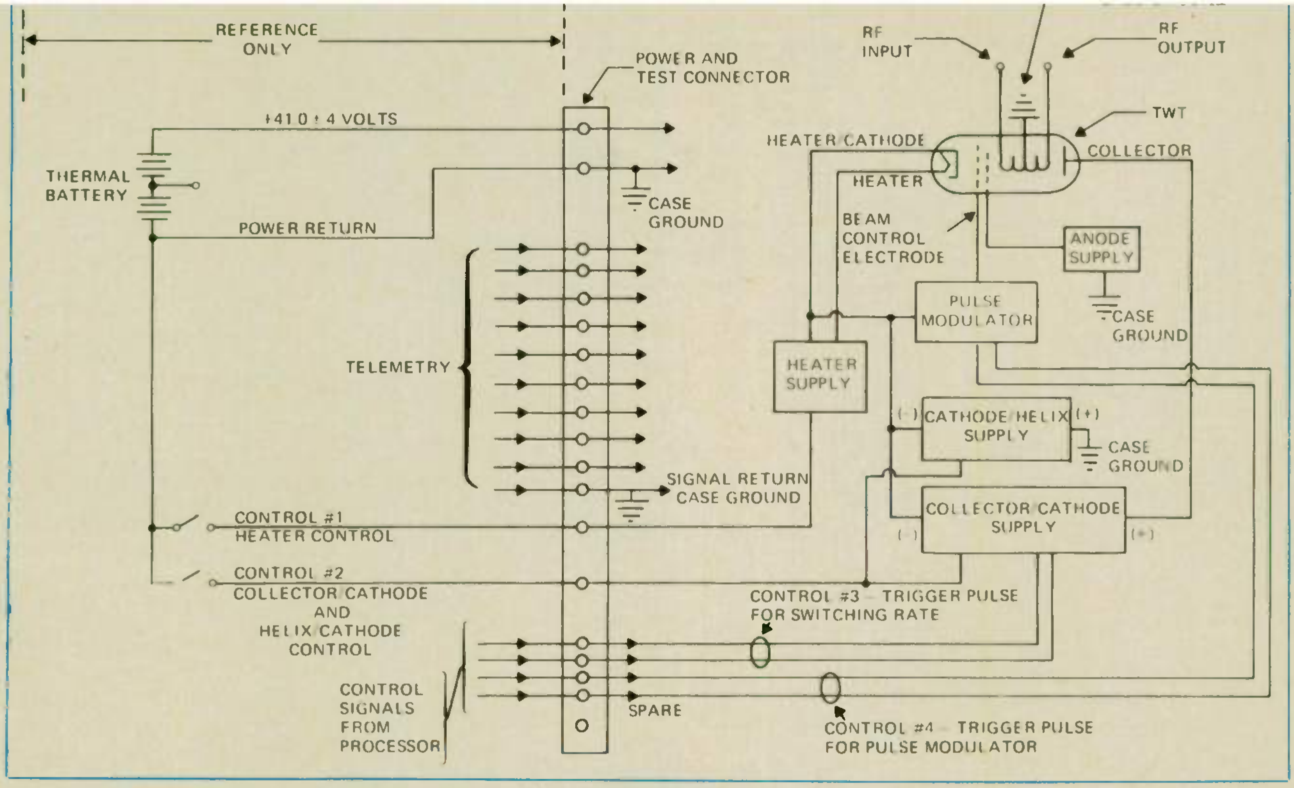


Fig. 3 TWTA block diagram.

LABORATORY TESTS

The TWTA's were designed, ouilt and tested in the laboratory, including random noise vibration, to ascertain the ripple levels of the Power Supply/Modulator and the phase noise levels of the TWT. The former parameters were satisfactory and the latter parameters on the initial units were marginal and in some cases beyond acceptable phase noise requirements in the vibration environment.

The TWT gun was redesigned to reduce cathode movement under vibration and the TWT mounting to the Power Supply/Modulator was made more rigid. Several TWTA's have been built with these modifications and all units have performed within the specified limits.

The final traveling-wave tube amplifier and power supply/modulator (TWTA) package weighed 3.8 pounds and was four inches n diameter by ten inches in ength. A photograph of the unit s indicated in **Figure 2**. The small package at the top is the TWT and is mounted to the power supply/modulator. Cooling air is blown over the fins during extended ground testing. Sufficient heat sink material is designed into the package to provide cooling during missile flight. The block diagram of the TWTA is indicated in **Figure 3**. The switching rate of the transistor regulator circuitry is synchronized with master system timing (PRF) by a pulsed signal on Control 3 to prevent electromagnetic interference between the switching transient signals and the radar processor. The TWT modulator is triggered "on" by pulsed signals applied to Control 4.

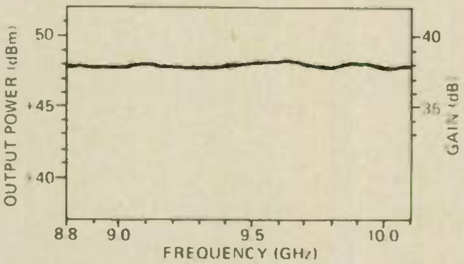


Fig. 4 RF performance of TWT.
Notes: (a) RF Power Input: +10 dBm, (b) Helix/Cathode Voltage: 3900 Volts, (c) Cathode/Collector Voltage: 1900 Volts, (d) Helix and body current: 2.4 Milliamperes, (e) Beam Current: 105 Milliamperes, (f) Efficiency: 30.1 percent (at 9.5 GHz).

Typical microwave performance of the TWT is indicated in **Figure 4**. The mini-tube delivers over 60 watts of power at about 25-30% efficiency. In these types of system applications, the TWT is normally operated in a pulsed mode. There is no standard instrumentation currently available to conduct phase noise measurements under pulsed conditions. Standard instrumentation for making these type measurements under CW operation is readily available with equipment such as the HP 5390A Frequency Stability Analyzer. Therefore, more complex test methods had to be considered.[4] This need resulted in the test set up configuration shown in block diagram form in **Figure 5**.

This set up is similar to the one proposed by Lance, Seal, et al.,[5] with some modifications. It should be noted that this set up has a "noise floor" some 20-30 dB higher than the HP 5390A. With the present instrumentation phase noise measurements under pulsed conditions cannot be made with the same precision as CW measurements. Further work is needed in this instrumentation

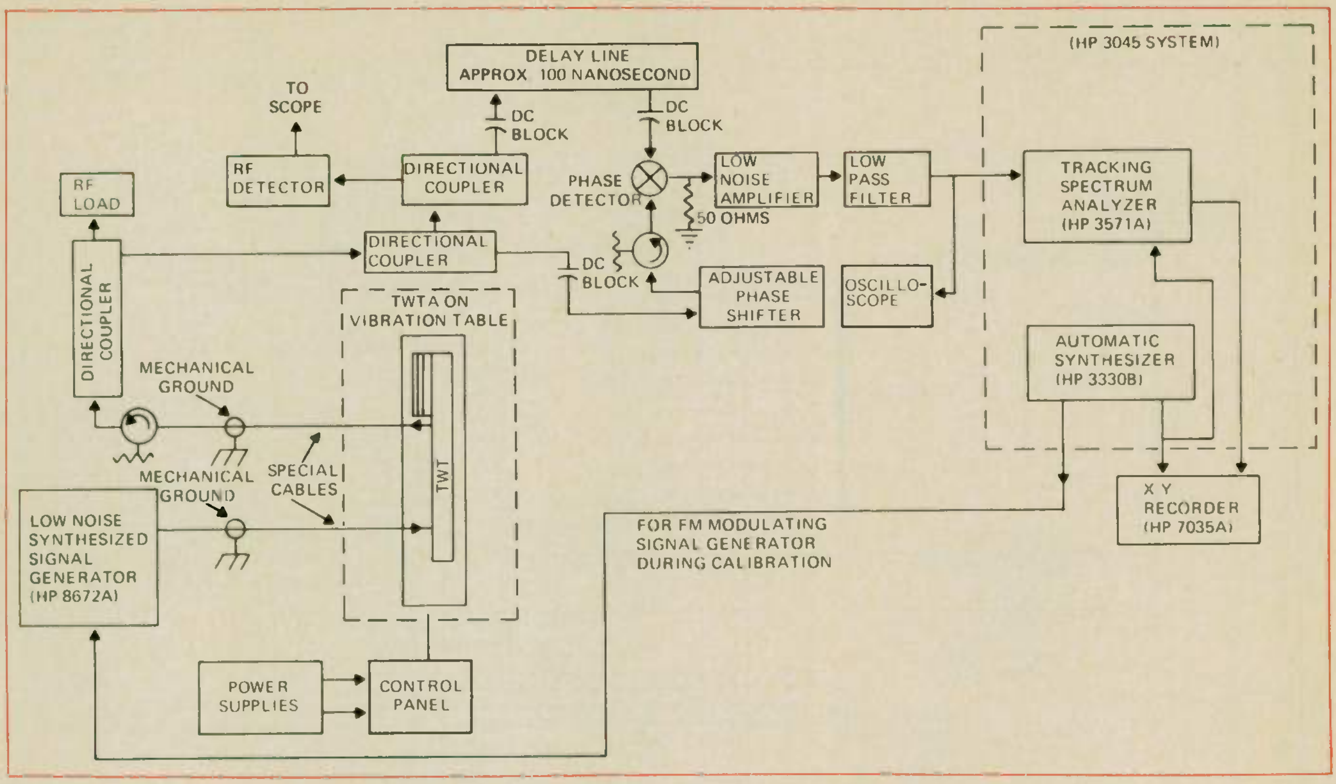


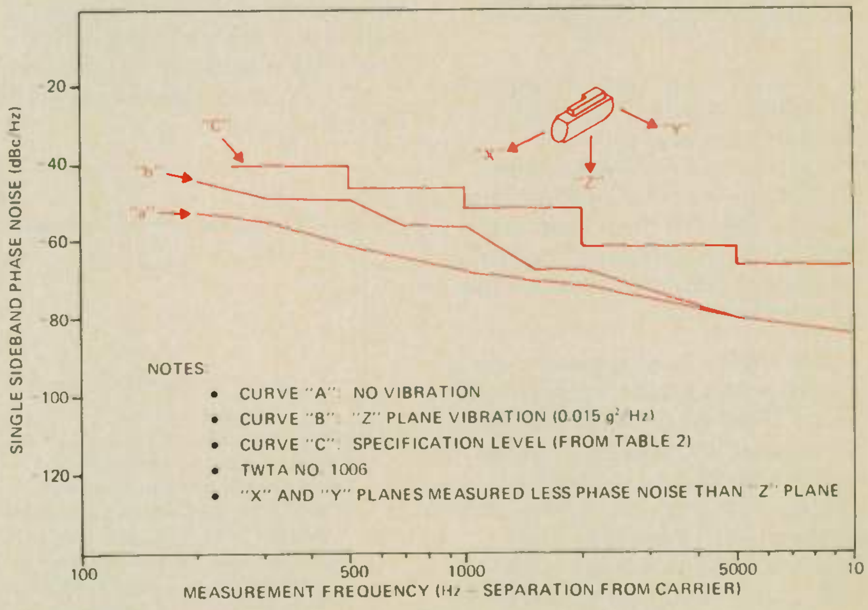
Fig. 5 Phase noise measurement test set-up.

area and improvements would be required to make absolute measurements on missile systems with more severe requirements.

The test set up worked quite well in the static laboratory environment but was sensitive to the random vibration when placed next to the test facility. The delay line and various other parts were isolated from the vibration of the facility by shock mounting provisions. Special cabling to and from the TWTA was required to prevent phase shifts in the cabling during vibration. These cables were "mechanically grounded" to prevent the test table vibrations from being conducted back to the delay line, etc. Calibration runs were first conducted with the assembled set-up without the TWTA to verify that no phase noise was introduced into the microwave cabling and/or the test set up by the vibration environment.

Measurements were made to ascertain if any ripple noise was introduced into the electrical output of the power supply by the random vibration. All three planes of vibration were tested. There was additional ripple when the supply was being vibrated but that ripple was 20-30 dB below the allowable specified levels. Continuous raw data was taken to be able to detect any vibration induced resonant spikes and none appeared.

Measurements were then made to determine the levels of AM and phase modulation in the TWT without and with vibration in all three planes. Once again continuous raw data was taken to examine for resonant peaks. This data was an absolute power measurement as presented by the HP 3571A tracking spectrum analyzer and was converted to dBc per Hz bandwidth by calculation. The raw data was corrected for measurement bandwidth, frequency offset from the carrier, the HP analyzer characteristics, the AM & phase detector sensitivities, etc. Typical calculated



NOTES
- CURVE "A" NO VIBRATION
- CURVE "B" "Z" PLANE VIBRATION (0.015 g^2 Hz)
- CURVE "C" SPECIFICATION LEVEL (FROM TABLE 2)
- TWTA NO 1006
- "X" AND "Y" PLANES MEASURED LESS PHASE NOISE THAN "Z" PLANE

Fig. 6 TWTA noise power performance.

(continued on page 56)

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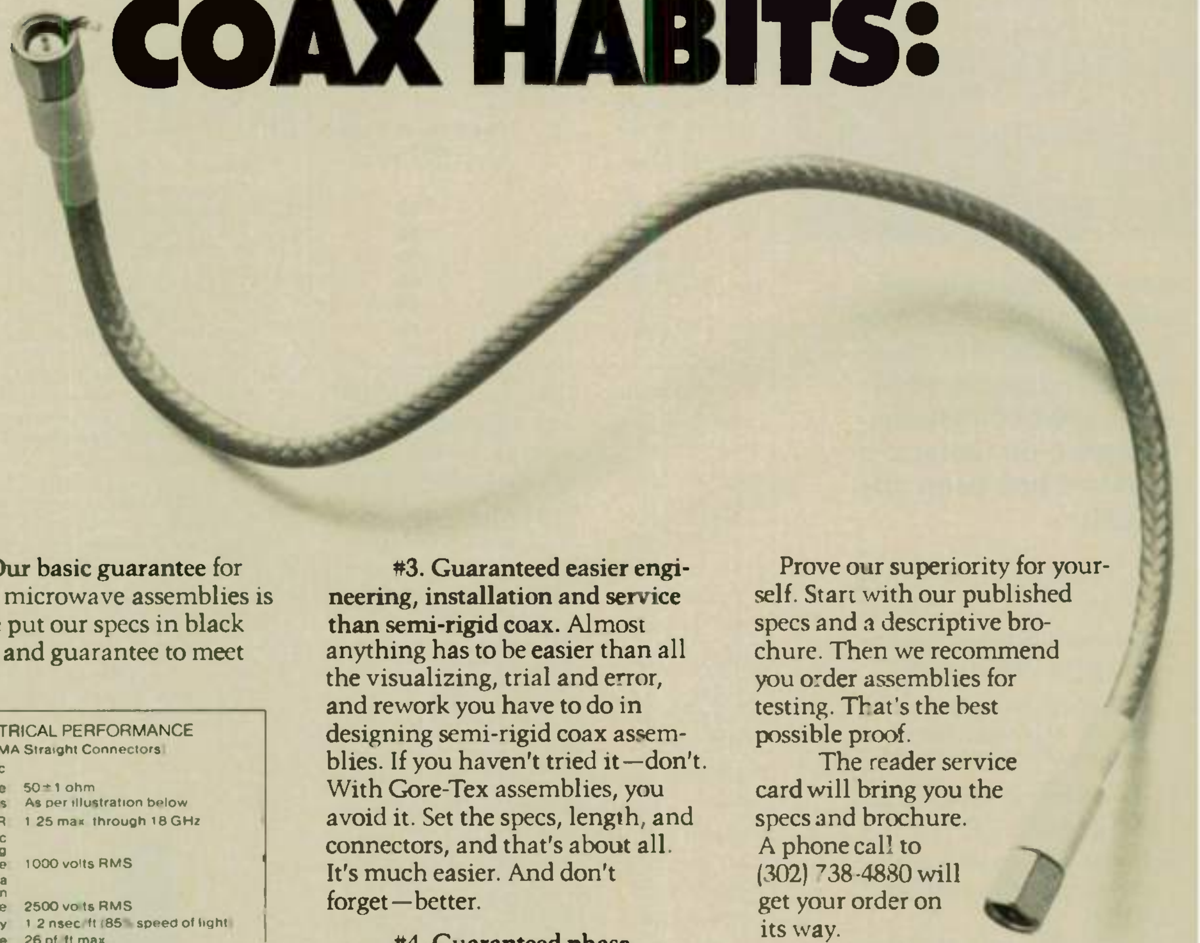

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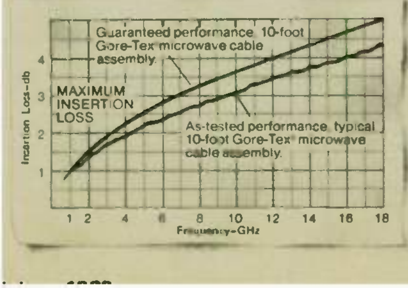

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Scotland: W. L. Gore & Associates (U.K. Ltd.), Queensferry Road, Pitrearie Industrial Estate, Dunsfermline, Fife noise power data when properly converted to dBc per Hz bandwidth is shown in Figure 6 (a) and (b). These data are considered to be somewhat pessimistic in terms of absolute values as the measurements are very near the noise floor levels of the present pulse instrumentation.

TABLE 2

PHASE NOISE PURITY REQUIREMENTS OF RF POWER DEVICE

Frequency From Carrier (Hz)	Phase Noise Output (dBc/Hz)
250	-40
500	-45
1,000	-50
2,000	-60
5,000	-65
10,000	-70
15,000	-75

The specification from Table II is also plotted as a convenient reference Figure 6 (c). As can be seen, the TWTA performance is better than required by the specification with or without vibration but there is an increase in noise power with vibration. Similar tests were conducted where the vibration was applied in the "X" and "Y" planes of the TWTA but these resulted in 5-10 dB lower noise output. The "Z" plane results were highest due to the TWT mounting provisions. By spot measurements with a small accelerometer, it was determined the tube body was not being held as rigidly in the "Z" plane due to the method of tube mounting used. The AM noise tests indicated levels 10-15 dB below the phase noise levels. In general, these results were 10-15 dB better than that obtained with the initial TWTA's prior to the design modifications.

CONCLUSIONS

A TWT and associated Power Supply/Modulator can be constructed to result in acceptable frequency stability performance (phase noise) for use as transmitter output stages for small radar guided tactical missiles provided that the necessary design precautions are taken to limit electrically and mechanically induced noise to the required levels.

ACKNOWLEDGEMENTS

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IMPROVEMENTS IN THE PERFORMANCE CHARACTERISTICS OF 6 GHz EARTH–STATION KLYSTRONS

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INTRODUCTION

The ever-growing telecommunications demands of modern society have led managers and engineers to push the existing systems to their maximum capacity and to search for new systems having even greater capacity. This has had a major impact on the earth-station transmitters of satellite communications systems, and in particular on their klystron amplifier tubes.

Until recently, such "conventional" systems as terrestrial point-to-point microwave links and tropospheric-scatter links relied upon the frequency modulation of a single carrier by a baseband signal occupying a bandwidth of several hundreds of kHz up to several MHz, or by a television signal whose bandwidth is 6 to 8 MHz. Satellite telecommunications have employed a similar technique, with signal separation by frequency (*F*requency-*D*ivision *M*ultiplex) and *F*requency *M*odulation (known as FDM/FM), using several carrier frequencies to achieve multiple access to the satellite.

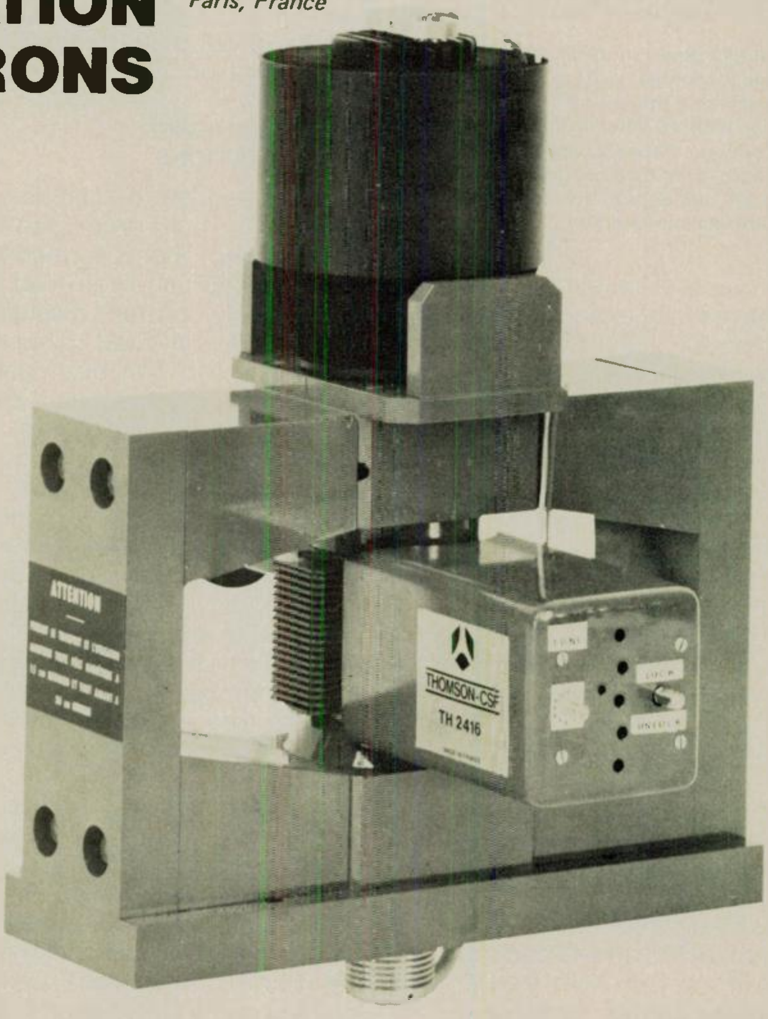


Fig. 2 The TH 2416 earth-station klystron.

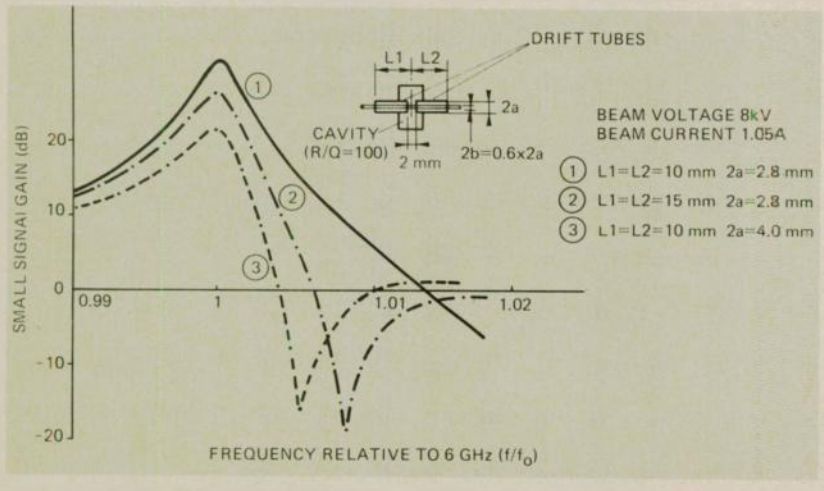


Fig. 1 Response of a "resonant cavity plus drift tube set."

The past few years have seen the introduction of digital modulation techniques, characterized by easier signal processing — especially switching. The transmission of digitally modulated signals, however, is more complex. For instance, to transmit a 4 kHz signal using an 8-bit code, the data rate must be 64 kbit/s. The train of modulating pulses is transmitted in the form of a phase-modulated carrier. Two-state modulation (0 and π) would necessitate a passband of ±32 kHz around the carrier frequency, f_o.

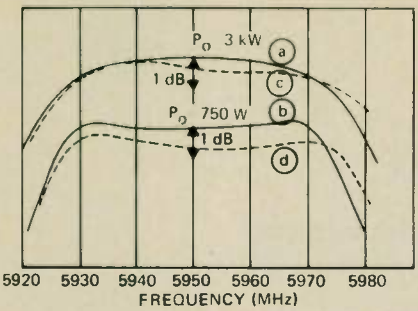


Fig. 3 Output power in the channel: ⓐ and ⓑ normal readings at saturation and with 6 dB backoff, ⓒ at saturation with a 0.050 mm error in the cavity no. 3 tuning piston position and ⓓ with 6 dB backoff and a 0.025 mm error in the cavity no. 3 tuning piston position.

Therefore, four-state modulation is preferred, since twice as much carrier power yields the same quality of transmission with a band half as wide. This solution is particularly favorable when using bandwidth-limited amplifiers, such as klystrons, which can easily deliver high levels of output power.

A recent innovation in satellite-communications systems, *S*ingle *C*hannel *P*er *C*arrier or SCPC, applies to analog FM signals but especially to digital signals. By doing away with fixed assignment of earth-station-to-satellite circuits, SCPC makes it possible to establish communications between any two stations as required (on demand) and thus improves the circuit-use efficiency by a factor of 3 or 4. In addition, SCPC allows communications from very light-traffic stations, so light in fact that it would be unthinkable to allocate them a full-time satellite circuit. Therefore, profitable service to such "marginal" stations can be developed without any inefficiency penalty to the whole system. But in addition to the constraints already evoked, SCPC reinforces or imposes other constraints on the amplifier tube: a 25 dB dynamic power range and extremely low intermodulation products.

Earth-station klystrons are known for their technological simplicity and their ruggedness, as well as for their high gain and the elevated levels of power that they can generate. On the other hand, some of their other characteristics, such as the limited instantaneous electronic bandwidth, are less desirable. Therefore, to meet the new requirements for digital modulation and SCPC, we have recently carried out a special program of analysis and tube development to broadly improve the transmission characteristics of our medium-power, 6 GHz klystron amplifiers.

KLYSTRON DESIGN CONSIDERATIONS

In brief, a klystron can be considered to be built around an electron beam that is formed in an electron gun and confined by an essentially constant magnetic field until it is allowed to expand in the collector. This beam passes through a series of resonant cavities, separated by drift tubes. Each "resonant cavity plus drift tube set" has a frequency response like that shown in **Figure 1**, where the influence of several parameters is represented. The maximum passband or "instantaneous electronic bandwidth" is obtained by choosing a sufficiently large number of cavities, whose resonant frequencies are judiciously shifted with respect to each other.

To select the right number of cavities, but also the optimum length of the different drift tubes, computer-aided design (CAD) methods are employed. The computations involve the use of both a small-signal CAD program and a large-signal program (unidimensional, rigid-disc computer model). For the best compromise between performance and cost, the computations have shown that the optimum number of resonant cavities for these 6 GHz medium-power klystrons is five, as in the TH 2416, shown in **Figure 2**.

Channel Tuning

To be able to cover the entire allocated uplink band, 5925 to 6425 MHz, these klystrons are equipped with a preset 6- or 12-channel mechanical tuning system. The non-tunable elements, such as the output window, the iris and the coupling loop, have all been designed to cover this 500 MHz bandwidth.

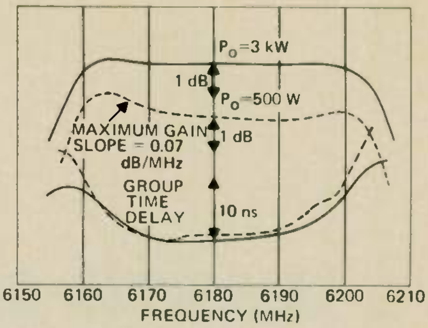


Fig. 4 Amplitude and group time delay responses of a typical TH 2416 earth-station klystron.

The tuning system is of the "stops" type. During operation, springs strongly press each of the five rods fastened to the moveable cavity-tuning pistons against a stop. These stops are positioned in the factory during optimization of the klystron performances in each of the 6 or 12 channels requested by the user. If necessary, however, the user can modify their position. Changing channels is accomplished by means of two knobs, one for unlocking the previous setting (the rods no longer press against the stops), the other for changing the stops, and the first one again to lock the tuning in the new position. Manually, this operation requires only 30 seconds, and it can also be remote-controlled and effected by motors turning the two shafts (locking/unlocking and tuning).

Obtaining High Tuning Repeatability

The most critical problem with this channel-tuning system is the repeatability, i.e., obtaining the same characteristics each time that the tube is tuned to the same channel. The severity of this constraint is appreciated better if one considers that a positioning error of *only one* of the five tuning pistons by just *0.025 mm* can cause an unacceptably large modification of the tube's frequency response characteristics (see **Figure 3**). (This effect is, however, three times less important when the klystron is saturated). Variations of the ambient-air temperature and of the temperature of the cooling air as well as variations in the input and RF-drive

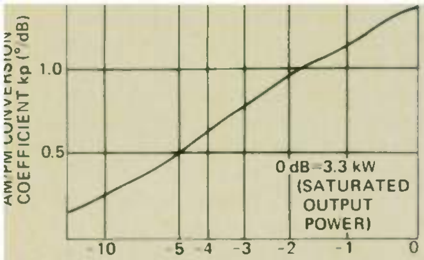


Fig. 5 Typical AM/PM conversion for the TH 2417 klystron.

powers cause variations in the cavity and tuning system temperatures. Because of thermal expansion, the tuning system can become misadjusted and cause translation of the frequency response.

To combat this problem, the mechanical deformations and expansion of the tube parts have been minimized by the choice of mechanically stable metals (molybdenum, tungsten, beryllium bronze, high-hardness stainless steel, etc.) and by providing thermally self-compensating systems. Consequently, the temperature-caused frequency drift of our klystrons is < 0.05 MHz/°C.

Amplitude and Phase Response

Like all filters, the klystron is characterized both by its amplitude/frequency response and its phase (ϕ)/frequency response or group-delay distortion, $\tau = d\phi/d\omega$. **Figure 4** summarizes these two responses for two very different output-power levels. This figure is particularly interesting for SCPC use of the tube, where the necessary output power levels can vary from 8 W up to 1 or even 3 kW. For an output power change from 3 kW to 500 W, as shown, the klystron's responses remain quite good, the -1 dB instantaneous bandwidth remains greater than or equal to 45 MHz, and the group-delay distortion remains below 0.2 ns/MHz and 0.03 ns/MHz^2 (linear and quadratic parts, respectively).

These results have been obtained by computing the optimum lengths for the different drift tubes, by using tight coupling between the beam and the cavities, and by damping the latter to round off the gain peaks.

The power density in the beam is 500 kW/cm^2, which necessitates a magnetic beam confinement field of greater than 2100 oersteds, aligned to better than 3 milliradians with the mechanical axis of the drift tubes. The quality of the machining and the magnetization of the magnetic circuit is judged by the beam transmission through the tube. Measured by the percentage of average cathode current arriving in the collector, this beam transmission is $\geqslant 97\%$ in these klystrons at full power.

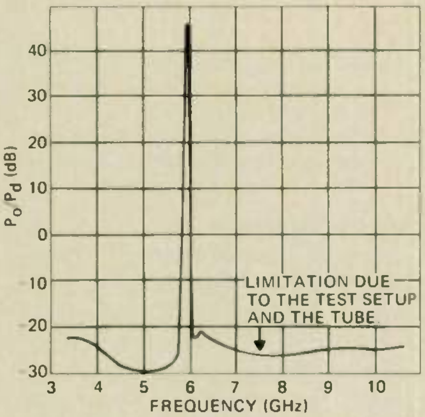


Fig. 6 Filtering effect of a klystron amplifier.

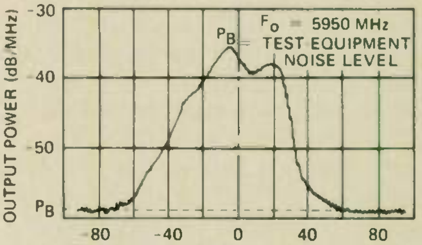
AM/PM Conversion

The amplitude modulation-to-phase modulation (AM/PM) conversion coefficient k_p characterizes the phase rotation caused by output-power variations. In klystrons, this coefficient is particularly small because of their small length and because the electrons remain grouped around the average velocity of the non-modulated beam. For example, k_p for the TH 2417 klystron (**Figure 5**) is slightly higher than one degree per dB at saturation and decreases steadily as the output power level is reduced.

This parameter is highly important in the application in question, for two reasons. First, low AM/PM conversion reduces the inter-symbol distortions occurring during filtering, when using digital modulation. The second reason concerns the intelligible crosstalk, for which the COMSAT standards translate into a maximum value for the $gk_p/2$ tangent to the amplitude/frequency response curve (in dB/MHz). But in klystrons, when the output power is increased by raising the drive-power level, g decreases while k_p increases, so there is an inherent compensation mechanism. Advantage is taken of this during the factory adjustments for optimum performances of our earth-station klystrons.

Harmonics and Noise

Figure 6, which gives the amplitude/frequency response over an extremely large frequency band, shows the klystron's filtering effect. There are no spurious signals except at the harmonic frequencies, and the level of the 2nd harmonic, for example, is at least 30 dB below the carrier at full power and at the most unfavorable point in the band. The harmonic-signal level can be higher if the load circuit leading to the antenna presents mismatching at a harmonic frequency. In **Figure 7**, we have shown the tube's own noise contribution, when the RF input is terminated with a 50 ohm resistor. Because this curve also includes the noise contribution of the test equipment (P_B), the tube noise, outside its passband, is actually less. The noise figure is on the order of 32 dB.



FREQUENCY RELATIVE TO A CHANNEL CENTE FREQUENCY (MHz)

Fig. 7 Klystron amplifier noise-power density in the channel, the RF input being terminated with a 50 ohm resistor.

SUITABILITY OF KLYSTRONS FOR ADVANCED SYSTEMS

In a klystron, the beam interacts with the stationary wave in each cavity and necessitates no synchronism between itself and the electromagnetic wave. Because in addition the magnetic confinement field is constant, these tubes are capable of operating over a wide range of high voltages V_B, within which many different parameters vary only slightly, including the instantaneous electronic bandwidth, the RF drive power required, the group delay time and the interaction (electronic) efficiency. Near a given high voltage value, for example 8 kV, the following saturated output power and phase variations are noted:

$$\frac{\Delta P_o}{\Delta V_B} < 0.01 \text{ dB/V};$$

$$\frac{\Delta \phi}{\Delta V_B} \leqslant 0.125°/\text{V}\,.$$

SCPC systems require extremely low intermodulation products in the signal. These products are created by the non-linearity of the RF transfer curve, especially near tube saturation. The intermodulation ratio, C/I (single-carrier power divided by the 3rd-order intermodulation product power), of an amplifier driven by two equal-amplitude carriers at frequencies f_1 and f_2 varies ideally in accordance with a slope of 2 dB/dB. At saturation, the C/I equals 12 to 14 dB for a total power with two carriers about 1 dB below the single-carrier saturated power.

All of this assumes that the RF transfer curve does not present any discontinuities and not even any slight deformations) and that the phase is constant at a given frequency. But because of AM/PM conversion and certain nonlinearities, which may vary from one tube to another, the klystron's C/I presents irregularities that must be eliminated. The non-linearities in question are due to electrons that are reflected or back-scattered by the output cavity and the collector, refocused, and directed toward the cathode. They modify the modulation process in the input (1st) cavity, resulting in the irregularities in the RF transfer curve hence in the intermodulation ratio mentioned above.

To counteract these effects, the magnetic field pattern has been modified appropriately and the cavity damping adjustment improved. In this way we have achieved the C/I performances illustrated by Figure 8. An effort to further improve this characteristic is continuing, but it is hampered by the difficulty of accurately measuring the intermodulation distortion.

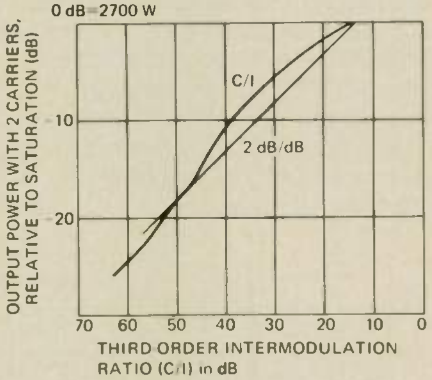


Fig. 8 Third-order intermodulation characteristics of the TH 2417 klystron, with two equal-amplitude carriers.

Collector Depression

Standard klystrons with non-depressed collectors have good inherent efficiency, on the order of 35% to 40%. One might be tempted, though, to operate these tubes with a depressed collector potential, for even higher efficiency. But to implement depressed-collector operation, the collector must be electrically insulated from the tube body, thus adding considerable complexity to the tube and the power supply, for only a few more per cent of electrical efficiency. Moreover, the depressed collector potential would further complicate the problem of reflected electrons, mentioned above. Therefore, for these klystrons we have decided that a non-depressed collector is the best choice.

CONCLUSION

The improvements in the fine transmission characteristics of 6 GHz earth-station klystrons presented here show that these klystrons are compatible with the new transmission systems now being implemented, such as SCPC. The results of this klystron-improvement program will also undoubtedly be beneficial for similar tubes, such as a 2 kW, 14 GHz earth-station klystron now under development.

(from page 40) DEVELOPMENT

test bed transmitter. Hughes Ground Systems Division, under contract DAAB07-78-C-3010, "Transmitter Test Bed Program," will evaluate an all solid state, floating deck modulator, and a microprocessor fault-isolation and control system to achieve "optimized" tube/transmitter performance. The solid state modulator operates at 2 kV and has shown that pulse risetime and PRF capability duplicate the present tube type modulator. Additional evaluation for reliability is underway. The most important aspect of this contract is the incorporation of sensing loops in the RF drive and the cathode current circuits, which under microprocessor control, maintain optimum performance of the traveling wave tube. This microprocessor control, and monitoring system will result in the elimination of hard wired circuits which are currently performing the functions and will ultimately lead to an increase in system reliability.

MODULATOR DEVICES

The renewed emphasis to develop millimeter wave tubes has prompted additional effort in the development of pulser subsystems for millimeter wave radars. Attention is being given to short pulsewidths and moderately high pulse repetition frequencies (PRF). Hughes Ground Systems Division, under contract DAAB07-78-C-2991, has been developing pulsers to achieve nanosecond wide pulsewidths at PRF's of 5 to 10 kHz. The program goals are set to attain pulse voltages at the 2 kV level to accommodate various tube types, such as magnetrons, gridded TWT's and extended interaction oscillator/amplifiers. Series-parallel combination of avalanche transistors is the prime technical approach. The transistors are basic units in the "MARX" circuit configuration. Recent modifications from a linear format to a circular format has led to reduction length from 12 inches to a ring 6 inches in diameter. The resultant pulser has produced a peak video voltage of 1000 volts with a risetime of 350 picoseconds which is a 2 to 1 improvement over earlier designs. The 1.0 kV pulse was generated into a 50 ohm load. Later test results provided a 1200 volt pulse 1.0 nanosecond risetime (ns), a 1.5 ns falltime and a pulsewidth of 5 ns.

Future designs are aimed at 2000 volt pulser for use in a grid drive modulator or as the superimposed pulsed on a "pedestal" pulse modulator.

ACKNOWLEDGEMENTS

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Technical Note

Sweeping a mm-Wave Gunn Oscillator
by Sideband Injection

HELMUT ESSEN
Forschungsinstitut für Hochfrequenzphysik
Wachtberg, West Germany

INTRODUCTION

Millimeter wave systems often require the capability to do sweep measurements of certain components. In such cases, it is sufficient to examine their behavior within the range of several hundreds of megahertz in the vicinity of the frequency operation. This paper shows an easy-to-install and low-cost means to do sweep measurements to about 300 MHz in the millimeter wave region.

PRINCIPLE OF OPERATION

Electronic tuning of a Gunn oscillator by variation of bias voltage is one way to generate frequencies in a relatively small band around the center frequency. Sweeping by variation of the bias voltage is not very promising because of the strong dependence of output power on bias voltage (see **Figure 4**) as well as nonlinear behaviour and hysteresis effects near turn-on voltage. The other method described here is the injection of a low frequency signal through the bias port of the Gunn oscillator and introducing a high Q idler cavity into the output waveguide. The mechanism of tuning[1] can be described as follows. The injected signal generates upper and lower sidebands against the Gunn frequency f_o. If one of the sidebands is close to the resonance frequency of the idler cavity it is trapped and held tight to the idler frequency f_i when the injected frequency is varied within certain limits. Consequently the frequency of the Gunn oscillator f_o' follows the variation of the injected signal f_{inj} and the following conditions are met:

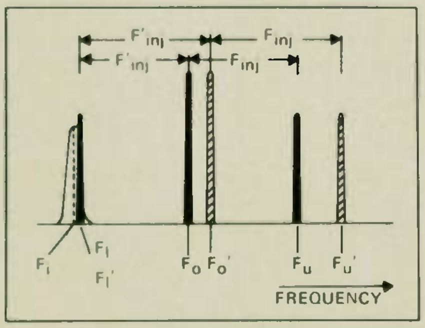

Fig. 1 Mechanism of lower sideband-catching.

lower sideband catching:
$f_i = f_l = f_o - f_{inj}$

upper sideband catching:
$f_i = f_u = f_o + f_{inj}$

If the injected signal is generated by a sweeper the Gunn frequency f_o' will be swept too.

EXPERIMENTAL SET UP AT 47 GHz

The experiments were performed at 47 GHz with a commercially available Gunn source with a maximum output power of +17 dBm. The idler cavity is a cylindrical copper cavity with a resonance frequency of 46.2 GHz. It is inserted into the output waveguide at 4 λg (λg = guide wavelength) from the Gunn diode. This enables sweeping of the output frequency over a range of about 300 MHz, whereby over a region of 200 MHz the output power varies less than 1 dB and is

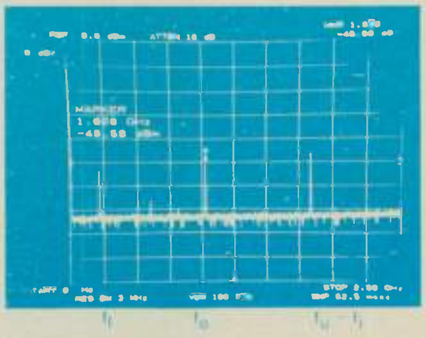

Fig. 2a Downconverted band structure on spectrum analyzer display upper sideband-catching.

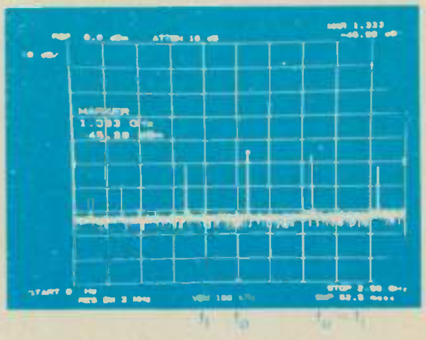

Fig. 2b Same as Fig. 2a, f_{inj} varied.

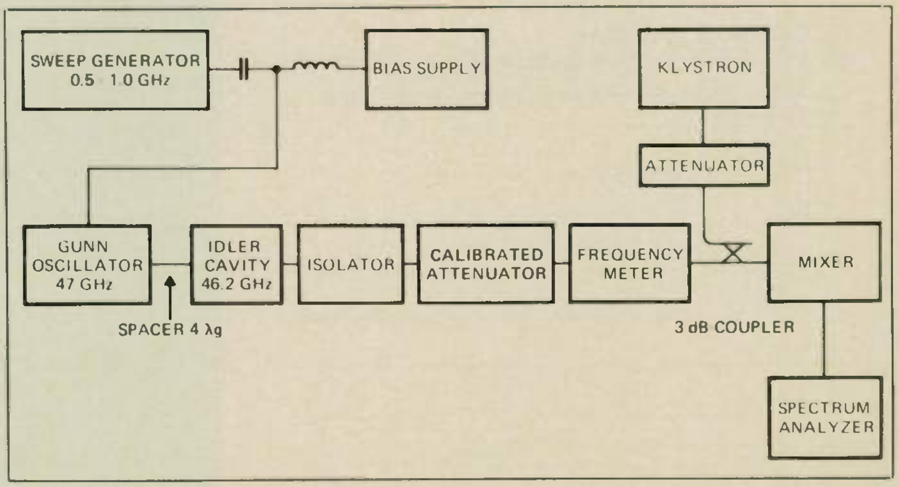

Fig. 3 Experimental set up.

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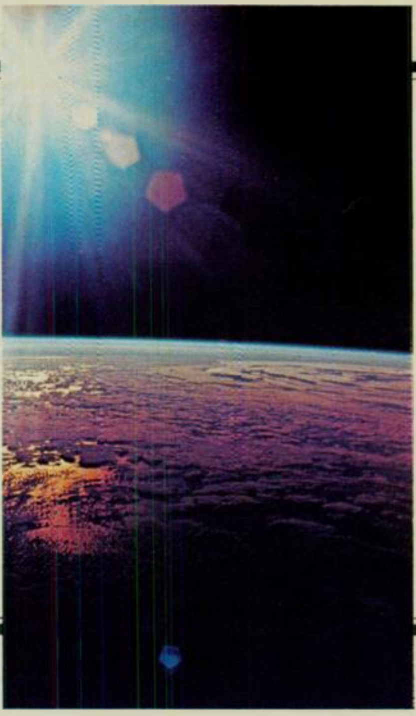

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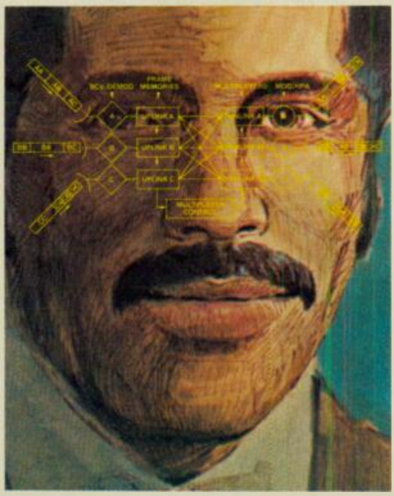

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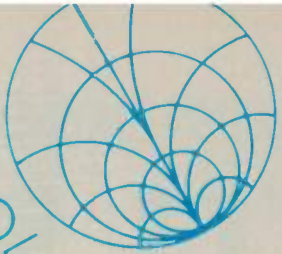

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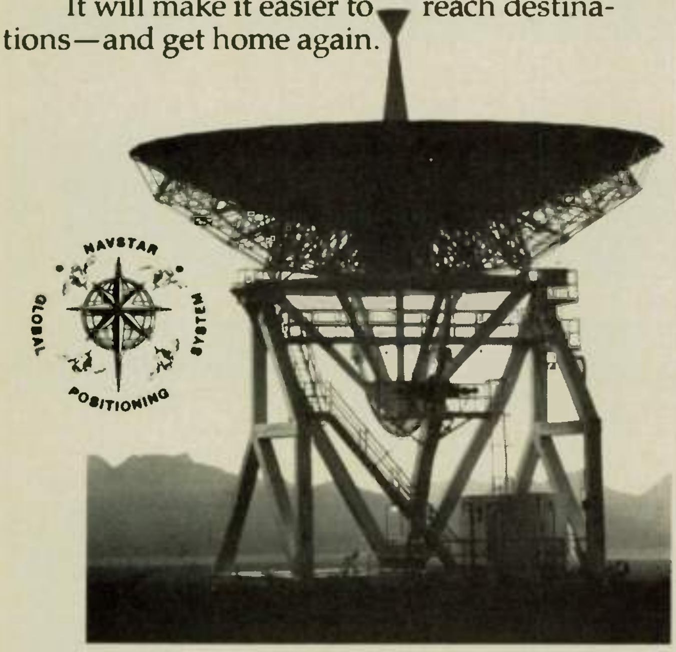

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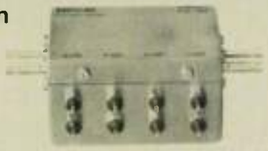

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Instrumentation

THERMAL NOISE STANDARD INSTRUMENT

Type 15376 is a resistive element thermal noise standard suitable for noise source calibration and noise figure measurements. It covers the dc to 18 GHz frequency range; has characteristic impedance of 50 ohms; output of -2 dB excess noise ratio; SWR of 1.25 maximum and input power of 115/220 Vac. A copper-constant air thermocouple with front panel connector enables element temperature to be monitored. Unit has precision type N (male) output connectors or APC-7 compatible connector. Weight: 8 lbs. Size: 4½"H x 8½" W x 14½" D. Price: $2,700, each. Del: 16 wks. ARO. **Micronetics, Inc., Norwood, NJ. Gary Simonyan, (201) 767-1320.**

Circle 127.

100 W RF POWER GENERATOR

Model 15222 is an RF power generator with a 100 W solid state main frame assembly with oscillator plug-in modules which give it a frequency range of 10-2500 MHz. RF power output for the generator is adjustable 20 dB below the maximum specified power for RF module in use. Frequency is read on a direct reading dial on the module front panel. Power generator has internal 1 kHz square wave modulation, external pulse modulation, and external AM modulation. Size: 19" D x 7" H x 18" W. (with 19" W. panel). Weight: 50 lbs., main frame; 10 lbs., (typical) plug-in heads. Price: $6,000-$7,000 for one plug-in and main frame. **MCL Inc., LaGrange, IL. (312) 354-4350.**

Circle 128.

GENERATOR FOR 0.4 - 1040 MHz BAND

A synthesized signal generator offers programmable (IEEE-488) AM/FM measurements, from 0.4-1040 MHz. Model SMS supplies precise crystally stable output signals calibrated from +13 to -137 dBm, with calibrated modulation capabilities for AM, FM and PM. Microprocessor control provides frequency resolution of 100 Hz on an 8-digit display and amplitude resolution of 0.1 dB on a 3½-digit display in µV, mV, dBµV or dBm. **Polarad Electronics, Inc., Lake Success, NY. Gene Kushner, (516) 328-1100.**

Circle 126.

SYNTHESIZED SIGNAL GENERATOR COVERS 0.1 - 990 MHz BAND

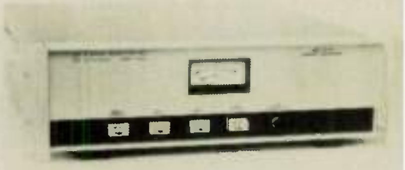
Model 8656A is a synthesized signal generator which spans the 0.1-990 MHz frequency range with absolute level accuracy of ± 1.5 dB and resolution of ± 0.1 dB over a +13 dBm to -127 dBm range. Internal AM to 99% or FM up to 99 kHz peak dev. at 400 or 1000 Hz rates are available. External AM and FM up to 25 kHz are also possible. Instrument has store and recall function, keyboard-entry and remote HP-IB programming. Single sideband phase noise is less than -122 dBc/Hz at a 20 kHz offset at 225 MHz. Output harmonics are < -25 dB and non-harmonic spurious is < -60 dBc. Price: Model 8656A, $6250; Option 001, $> 1 \times 10^{-9}$/day, Time Base, is $850. Del: 16 wks. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.**

Circle 129.

Model CL-1037 is a narrowband single sideband generator which features 7.5 dB maximum conversion loss and suppression carrier of 30 dB minimum. Other specifications include: carrier frequency of 3.0-3.4 GHz; IF input frequency of 30 MHz ± 5 MHz and single sideband (upper or lower) of 25 dB minimum. Input power of RF carrier is +10 dBm and IF is 0 dBm. Available with SMA (female) connectors. Size: 4" x 3" x 3/4". Price: $925. Avail: 6 wks. ARO. **Triangle Microwave, Inc., East Hanover, NJ. James Beard, (201) 884-1423.**

Circle 160

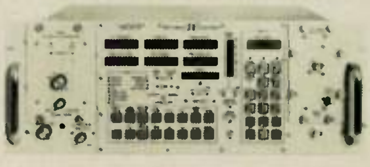
FREQUENCY SYNCHRONIZER



MS200 is a microwave frequency synchronizer capable of phase locking tw sweepers together as master and slave with a predetermined constant offset (Δf). Instrument provides dynamic sweeps with dual and multi-band sweeper heads. Features APC Dither and remote TTL control. **Niagra Scientific, Inc., East Syracuse, NY. David C Jennings, (315) 437-0821.**

Circle 130

COMPUTER CONTROLLED TELEMETRY RECEIVER



Model 1200 MR is a computer controlled telemetry receiver which features a built-in microprocessor with IEEE-448 and optional RS-232 interface for computer control. Keyboard entry also provides for manual control of all receiver functions. **Microdyne Corporation, Rockville, MD. Richard B. Elsea, (301) 762-8500.**

Circle 131

Materials

CONDUCTIVE PLASTIC MATERIAL

ECCOSHIELD® SV is a highly conductive plastic material which can be formed into flat sheets, gaskets, o-rings and other extrusions. This vinyl resin and pure silver mixture has the conductivity of many metals plus the versatility of an elastomer. Material provides a hermetic and RF seal and it can be joined to itself to make continuous gaskets from extruded stock. As an electrical conductor at 60 Hz, a current density of 400 A per sq. in. (62A per sq. cm) has been sustained in still air for an extended period of time. **Emerson & Cuming, Canton, MA. Jeanne B. O'Brien, (617) 828-3300.** **Circle 137.**

SI SHIELDING GASKETING

A silicone rubber shielding gasketing, PMP-II, features wires throughout the body of the material as well as at both top and bottom surfaces which can act as a substitute for silver-loaded conductive elastomers. The embedded wires eliminate abrasion problems and there are no powders or conductive particles to degrade the tensile strength of loaded silicone elastomers. Life span of the gasketing material is estimated to be ten times that of equivalent materials. Size: .015" to .092" in sheet widths up to 20". Durometers can be varied from 40 to 70. **Metex Corporation, Electronic Shielding Group, Edison, NJ. (201) 287-0880.** **Circle 136.**

HIGH-DIELECTRIC-CONSTANT LAMINATE

A high-dielectric-constant microwave laminate, Di-Clad 810, is offered for use as a substrate for stripline and microstrip circuits. This ceramic-loaded, Teflon soft substrate has a dielectric constant of 10.2 in .025" thickness, 10.5 in .050" thickness and is intended to replace ceramic substrates in high-frequency applications. The material possesses excellent adherence to metal, high-dimensional stability, and it is vibration resistant. Dissipation factor is 0.0015 for .025" thickness and 0.005 for .050" thickness. Size: 9" x 9" sheets. **Keene Corporation, Chase-Foster Div., Bear, DE. Frank Yoerg, (302) 834-2100.** **Circle 138.**

Devices

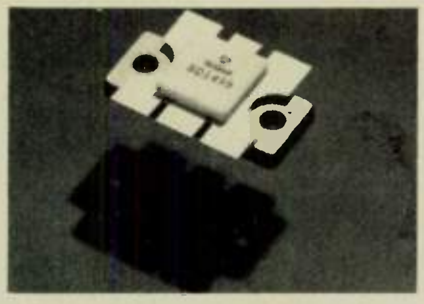
LOW-NOISE BIPOLAR TRANSISTOR

Model NE645 is a low-noise bipolar transistor which employs a self-aligning mask to achieve optimum RF performance, repeatability and reliability. Unit operates from 0.5-4 GHz, noise figure at 2 GHz is 2.0 dB max and G_a is 11.0 dB. Price: $13, for 1-9 qty. **California Eastern Laboratories, Inc., Santa Clara, CA. Jerry A. Arden, (408) 988-3500.** **Circle 133.**

FAMILY OF 5-40 W TRANSISTORS FOR 800 MHz BAND

A series (DMB) of RF transistor amplifiers for the 800 MHz band are offered. The devices all operate from 12.5 V supplies. Each transistor is a common base device with input matching to simplify design and provides full rated output over the 806-866 MHz frequency range. Transistors have power output (min.) range of 5-30 W; power input (min.) range of 1-8 W; BV_{ces} (min.) is 36 V; BV_{ebo} (min.) is 4.0 V and I_c ranges from 2-10 A. **Communications Transistor Corporation, San Carlos, CA. B. J. McDaniels, (415) 592-9390.** **Circle 134.**

65 W RF POWER TRANSISTOR



Model SD 1499 is an internally matched, 65 W, 12.5 V RF power transistor designed for 100 W UHF land mobile radio applications. Device delivers a minimum of 65 W of power across the full 440-512 MHz band. It features diffused emitter resistor ballasting and will withstand infinite SWR loading at high line collector voltage (15.5V) conditions. It is supplied in a low inductance .400" square package using gold metallization and gold bonding wires. **Thomson-CSF Components Corp., Solid State Microwave Division, Montgomeryville, PA. Bob Tyson, (215) 362-8500.** Circle 135.

L-BAND RADAR NPN POWER TRANSISTORS

A series of L-Band 1200/1400 MHz pulse NPN power transistors provide power outputs of 10, 40 and 100 W. Designed for radar applications, these transistors offer RF performance that is 100% tested and guaranteed in a wideband test fixture. Operating conditions for the devices are: F = 1200/1400 MHz; V_{CC} = 32-40 V; pulse width = 10-50 μs; and duty factor = 1-10%. Use of gold thin-film metallization and gold controlled loop wire bonding provides protection against operational degradation and consistent RF performance. **Acrian, Cupertino, CA. (408) 996-8522.** Circle 132.

(continued on page 74)

THE MARKET FOR MICROWAVE COMPONENTS, DEVICES, & SUBASSEMBLIES

Marketdata's penetrating 157-page, April 1980 study combines economic/marketing data into a comprehensive report tailored to microwave components producers. Six sections cover: The Market, End-Users (74 pp.), Competition, Industry Structure, Reader Worksheets, Technology & Developments.

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50.000	1.15	11.93/ 167.1	-40.53	1.05
100.000	1.16	11.89/ 152.2	-35.87	1.05
150.000	1.16	11.87/ 137.7	-32.78	1.07
200.000	1.16	11.85/ 123.3	-30.53	1.08
250.000	1.17	11.85/ 108.8	-28.83	1.10
300.000	1.17	11.88/ 94.5	-27.42	1.10
350.000	1.17	11.94/ 79.6	-26.22	1.11
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Components

MINIATURE FILTER LINE

A line of miniature RF and microwave filters, Ultramin^{TM} offers high performance in the 10-1000 MHz range in a small, lightweight package. Filters range in size from T5 (T05 cases) R Series (0.31" x 0.44" with rectangular case), and S Series (0.31" x 0.31" square in metal case). All filters meet MIL-E-5400 and MIL-STD-202 standards and come in glass-to-metal hermetic seal packages. Filters have 0.01 dB Tchebychev or Butterworth response, typical and come with 3 dB bandwidths from 2% to 70% of center frequency. **Wavetek Indiana, Inc., Beech Grove, IN. (317) 783-3221.** Circle 145.

FREQUENCY DOUBLERS

Model FD 101 and 102 are frequency doublers covering the 0.1-600 MHz and 0.5-2100 MHz input frequency ranges, respectively. Spurious output (F_1) is 34 dB for the FD 101 and 25 dB for the FD 102. Units available with N, BNC, TNC or SMA connectors. **Technical Research and Manufacturing, Inc., Manchester, NH. Art Marin, (603) 668-0120.** Circle 155.

CHIP RESISTORS SERIES FROM .05 - .5 W

A series of six chip resistors are offered with power ratings ranging from .05-.5 W. Units are available in all standard resistor values between 10 ohms and 1 meg ohm in tolerances of 1, 2, 5, and 10%. Components have TCR's typically better than ± 250 ppm/°C over the -55°C to $+125$°C range. Units with TCR's $< \pm 100$ ppm/°C also offered in some resistance values. The PC style features solder-coated terminals on the top surface only; the PCW style has gold-plated terminals wrapped around the edge of the body to the bottom surface. Both meet MIL-R-55342 specifications. **KDI Pyrofilm Corp., Whippany, NJ. Bill Dodge, (201) 887-8100.** Circle 147.

MINIATURE PHASE SHIFTER

Model 6509E is a phase shifter which minimizes panel space by locating RF connectors on the end opposite the adjustment shaft. Typical performance for the unit is SWR of $< 1 + .05f$ (f in GHz) and insertion loss of $< .04$ dB/GHz minimum and an insertion phase adjustment range of 40° per GHz. **Sage Laboratories, Inc., Natick, MA. Tony Cieri, (617) 653-0844.** Circle 141.

TUNABLE BANDPASS FILTER KITS

Kits containing six tunable bandpass filters in the RF and microwave frequency range are offered. These filters, which individually cover up to an octave tuning range, are selected to provide continuous coverage within a particular frequency range. Bands within the total range of 24 MHz to 18 GHz may be selected. Nominal performance for individual kit filters if ½ to 1 octave tuning range: 3 dB bandwidth of 5% of tuned frequency; 50 ohm impedance with 1.5:1 max. SWR; 50 W power handling capability and 1% dial accuracy. Price: from $3200. Avail: 6 wks. **K & L Microwave, Inc., Salisbury, MD. (301) 749-2424.** Circle 139.

PRECISION VARIABLE ATTENUATOR FOR dc to 4 GHz BAND

A continuously variable attenuator, Model 910, for use from dc to 4 GHz, is produced in two calibrated attenuation ranges of 10 and 20 dB plus an uncalibrated unit for level set applications. Calibrated units have dials reading in 0.5 dB increments and attenuation can be reset to an accuracy of ± 0.2 dB to full range. Built-in constant impedance line-stretcher provides a low phase shift vs. attenuation of 1°/dB x f (GHz). Model has SWR of $< 1.15 + [0.15 \times f\,(\mathrm{GHz})]$, maximum, and a minimum insertion loss of 0.7 dB to 2 GHz; 1.0 dB to 4 GHz. Price: 910-10 (10 dB unit) – $450; 910-20 (20 dB unit) – $475; and 9101S (level set unit) – $450. Avail: stock to 90 days ARO. **Weinschel Engineering, Gaithersburg, MD. (301) 948-3434.** Circle 144.

POWER LOAD SERIES FOR WR28, WR42

A series of WR28 and WR42 mm waveguide low and medium power loads are offered. Medium power loads have a maximum SWR pf 1.15:1 and power handling of 50 W CW. Special shapes and configurations available. **Microtech, Cheshire, CT. (203) 272-3234.** Circle 158.

APG-4000 are GaAs FET intermediate power amplifiers which offer 1 W output (1 dB gain compression) and cover the 2-4 GHz frequency range. Units have 6 to 32 dB of gain and noise figures as low as 3.0 dB, ± 1.0 dB full-band gain flatness and 2.0:1 maximum input and output SWR. Series has a wide dynamic range with +40 dBm intercept point for third-order intermodulation products. Amplifiers operate from +15 Vdc (± 1% regulation) and consume 900-1200 mA. Size: 6.43" x 3.72" x 1.45", including baseplate and fin extensions; all models packaged in finned Al cases. Series features balanced amplification — each stage consists of two GaAs FETs with hybrid couplers at the input and output and amplifiers can meet applicable military specifications. Price: under $2500. Del: 120 days ARO. **Avantek, Inc., Santa Clara, CA. Bob Jones** (408) 727-0700. Circle 149.

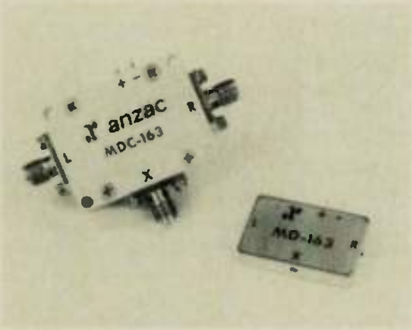
LOW SWR SMA TERMINATIONS

An SMA precision termination with plug (705467-001) and jack (705482-001) configuration provides 1.05 + .005F (GHz) SWR max. and operates over the dc-18 GHz frequency range. Average power ratings: 2.0 W at +25°C, 1.0 W at +125°C; power-peak (max.) of 50.0 W and temperature rating of -55°C to +125°C. Units have an SMA interface and conform with MIL-C-39012B specifications. They are made of passivated stainless steel with BeCu gold-plated center contacts: Size: plug, .547" L; jack, 578" L. Price: $8.55, for 1,000 pieces (plug). Avail: from stock. **Cablewave Systems, Inc., North Haven, CT. Steven Raucci, Jr.,** (203) 239-3311. Circle 150.

9.5 GHz DIELECTRIC RESONATOR OSCILLATOR

A dielectrically stabilized oscillator (DSO) is offered for operation in the 9-10 GHz frequency band. Unit is a fundamental oscillator which requires 40 mA current and functions in either CW or pulsed modes. Harmonics are -35 dBc maximum with a load SWR of 1.5. Model 6601-1901 DSO has a frequency stability of 5 ppm/°C, maximum at 9.5 GHz. Pulsed mode is TTL compatible and the DSO operates from a -15 Vdc power supply. Performance is guaranteed from -54°C to + 85°C. Size: 2.2" x 1.3" x .69", shielded configuration. Price: $1500, single unit; $1250, single unit operating only in CW mode. Del: 90 days ARO. **TRAK Microwave Corporation, Tampa, FL. Thomas L. Roberts,** (813) 884-1411. Circle 143.

INSENSITIVE MIXER



Model MD-163 is a *T*ermination *I*nsensitive *M*ixer (TIM) which covers the 1-7 GHz region. Mixer offers 7 dB typical, 9.5 dB max. conversion loss with a 0 dBm LO drive. Unit features a 1 dB compression point of -2 dBm and third order intercept of +8 dBm. Model provides flat conversion loss, regardless of sum frequency match, and flat, predictable third order intermodulation performance even into high IF mismatch and when using a system which requires starved LO. Price: $550, Flatpack; $630, SMA connectorized versions. Del: From stock. **Anzac Division, Adams-Russell, Inc., Burlington, MA. (617) 273-3333.** Circle 148.

A series of bandpass filters embedded in semi-rigid coaxial cable operate over frequencies ranging from 1,000 to 18,000 MHz. Miniaturization of design is accomplished by implanting fiber elements in a continuous section of .141" diameter semi-rigid coaxial cable. Completed filters can be bent or shaped as required. **Uniform Tubes, Inc., MicroDelay Division, Collegeville, PA. Eugene Woehr,** (215) 539-0700. Circle 154.

C-BAND FREQUENCY SYNTHESIZER

Model 6754 is a frequency synthesizer which covers the 4.4-4.8 GHz range in 2.5 MHz steps with +10 dBm output. An integral ferrite isolator is included and frequency accuracy is 2 ppm for 6 months. FM deviation is up to ± 300 kHz at rates between 100 Hz and 1 MHz and FM noise is -70 dBmO in a 3 kHz band from 25 kHz to 2 MHz. Spurious outputs are -100 dBc between 200 MHz and 400 MHz from the carrier and -45 dBc elsewhere. The dc inputs are +28 and +5 V. Size: 5.8" x 3.5" x 4.75". **Zeta Laboratories Inc., Santa Clara, CA. (408) 727-6001** Circle 146.

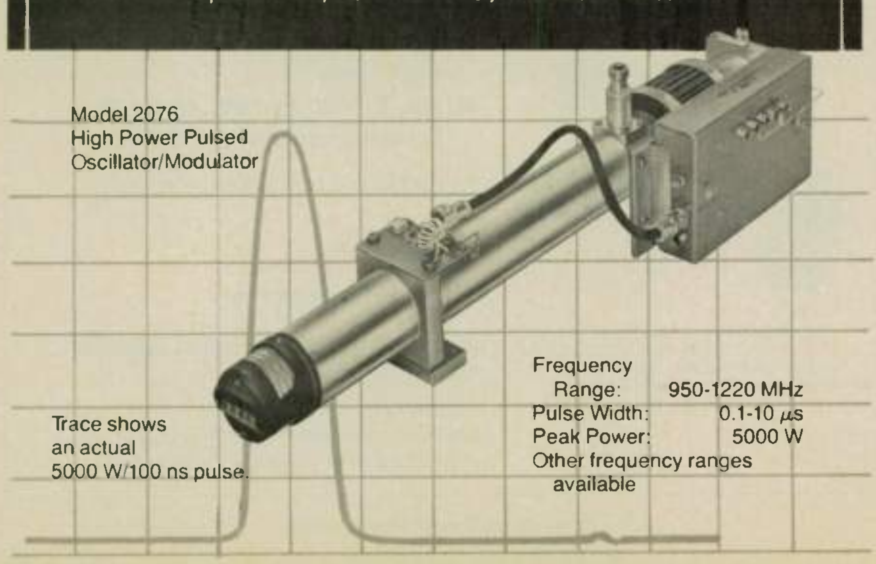
(continued on page 76)

WAVEGUIDE SWITCH FOR WR-75

A waveguide switch for WR-75 offers an insertion loss of 0 05 dB; an isolation of 75 dB min. within the 10-15 GHz bands; and a power handling capability of 3 kW CW max. Within the 10.95 to 12.75 GHz and 14.00-14.50 GHz frequency ranges, minimum isolation is 80 dB. **Logus Manufacturing Corporation, Deer Park, NY. (516) 242-5970. Circle 157.**

SERIES OF MIXERS AND MIXER/PREAMPLIFIERS

Mixer Series M2C offer LO and RF frequency coverage from 2-18 GHz and IF frequencies of 0-500 MHz. Has conversion loss of 7 dB typ., 8 dB max. (9 dB max. from 1.5-18.5 GHz). LO to RF isolation (1.5-18.5 GHz), 20 dB min.; (1.5-12 GHz), 25 dB min. and LO to IF isolation, 1.5-18.5 GHz is 15 dB min.; 1.5-12 GHz, 25 dB min. Mixer/preamplifier series M2C-2A-0110 and M2C-2A-0150 also cover 2-18 GHz with RF and IF gains of 22 dB minimum (higher gains offered) and noise figures 7.5 dB typical, 9.0 dB maximum (M2C-2A-0110) and 8.0 dB typical, 9.5 dB maximum (M2C-2A-0150). Price: M2C – $395; M2C-2A-0110 and M2C-2A-0150 – $725. Avail: Stock to 30 days. **MITEQ, Inc., Hauppauge, NY. R. Pflieger, (516) 543-8873. Circle 142.**



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approximately linearly dependent on the injected frequency f_{inj}.

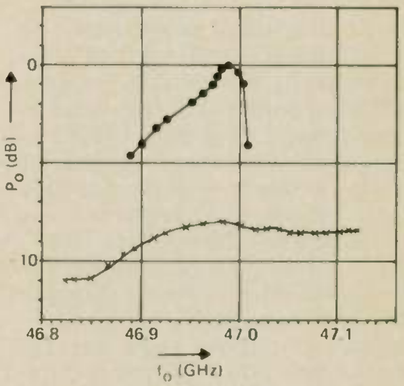

Fig. 4 Power variation during sweeping for lower sideband-catching (cavity-pulling, below) and bias voltage variation (pushing, above).

CONCLUSION

A simple and quite helpful method of sweeping a millimeter-wave Gunn oscillator by sideband injection has been shown. Most of the requirements for signal stability can be achieved by just introducing a properly designed idler cavity into the output waveguide and by injecting an adequate signal from a sweep source.

REFERENCES

1. Okamoto, H. and Ikeda, M., "Cavity Stabilization and Electronic Tuning of a Millimeter-Wave IMPATT Diode Oscillator by Parametric Interaction," *IEEE Trans. on MTT*, Vol. MTT-26, No. 6, June 1978, pp. 420-424.

Helmut Essen received his Diploma in Physics in 1973 and his Ph.D. in Nuclear Physics in 1976 both from the University of Bonn, West Germany. In July 1977 he joined the mm-wave division of Max-Planck-Institut for Radioastronomy in Bonn. There he was engaged in studies concerning Schottky barrier mixer development. Since then he has been with the FGAN-Forschungsinstitut für Hochfrequenzphysik in Werthoven, where he works on mm wave systems.

New Literature

BETWEEN SERIES ADAPTOR CATALOG

Between-series coaxial connector adaptors are featured in catalog No. BSA-2. The literature lists coaxial connector type adaptors, including SMB, SMC, 75 Ω ConheX, SMA, microminiature, TNC, BNC, N, APC-7^{TR}, GR-900^{TR}, GR-874^{TR} and the Kwick-Konnect. **RF Components Div., Sealectro Corporation, Mamaroneck, NY.** (914) 698-5600. Circle 119.

GCE PRODUCT LINE BROCHURE

A revised edition of the Ground Communications Equipment Brochure describes product line, gives specifications, photographs and diagrams. Products detailed include receivers and exciters, up and downconverters, modulators/demodulators, modems, IF filters/equalizers, test translators, frequency converters and test sets. **LNR Communications, Inc., Hauppauge, NY. Jeannie Piotrowski,** (516) 273-7111. Circle 120.

BULLETIN ON MW DETECTOR MOUNTS

Bulletin #001 is a four-page guide to microwave detector mounts. Pamphlet includes product description, circuit diagram and specifications for tunnel, Schottky and zero-bias Schottky diode detectors. **Litchfield Microwave Laboratory, Campbell, CA. Mike Litchfield,** (408) 378-0377. Circle 114.

RF COMPONENT CATALOG

A component catalog provides product specifications and illustrations for a full line of attenuators including fixed pads to 18 GHz, rotary attenuators to 12.4 GHz, and programmable attenuators for computer controlled test applications. A second section of the 68-page brochure includes graphs and descriptions of tunable, cavity, tubular and miniature lumped component filters. A third section provides theoretical and application information for oscillators operating from 5 MHz to 18 GHz. **Texscan Corporation, Indianapolis, IN. Raleigh B. Stelle,** (317) 357-8781. Circle 124.

A 40-page catalog covers the NEC line of microwave transistors, GaAs FET's and diodes. Brochure includes performance curves, specifications and detailed package outline drawings; also, it is divided into small signal, medium power and power categories. **California Eastern Laboratories, Inc., Santa Clara, CA. Jerry A. Arden,** (408) 988-3500. Circle 116.

MILITARY COMMUNICATIONS ANTENNA MAST BROCHURE

A brochure describing a family of quick-erecting military communications antenna masts contains information on backup and safety systems, a variety of configurations, a block diagram and technical specifications. These masts are designed to increase the mobility of C^3 systems for tactical field commanders. **Ground Systems Marketing, GTE Sylvania Systems Group — Western Division, Mountain View, CA.** (415) 966-9111. Circle 117.

BULLETIN ON SCHOTTKY BARRIER MIXER DIODES

A series of Schottky barrier mixer diodes are described in Bulletin 4218B. These low LO drive mixer diodes for low IF applications are designed for Doppler radar systems. Brochure includes complete specifications. **Microwave Associates, Inc., Burlington, MA.** (617) 272-3000. Circle 118.

MILLIMETER COMPONENTS CATALOG

A 20-page catalog features technical and descriptive information concerning bandpass and bandstop filters. Other components covered include wavemeters, mixers, noise sources. **Frequency Engineering Laboratories, Farmingdale, NJ. A. E. Steinhauer,** (201) 938-9000. Circle 115.

BROCHURE ON MICROWAVE PRODUCTS FOR SPACE

High-reliability microwave components for applications in space are identified and described, along with the military and NASA specifications employed. Four-page pamphlet also gives information about company Hi-Rel Department as well as a summary of past high-rel/space program involvement. **Eaton Corporation, Communications Products Division, Addington Microwave Components Plant, Sunnyvale, CA. Jim Wilson,** (408) 738-4940. Circle 121.

A 19-page catalog describes a line of field-repairable rapid switching programmable attenuators, as well as audio and RF toggle (miniature and standard) in-line attenuators, OEM miniature and standard size toggle switches, rotary attenuators, pulse and sweep generators, real-time fundamental frequency extractor and an audio spectrum analyzer. Includes applications, specifications and photograph for each product. **Kay Elemetrics Corp., Pine Brook, NJ. Carol A. Devitt** (201) 227-2000. Circle 123

MICROWAVE COMPONENT LINE CATALOG

An 88-page catalog contains information on microwave components and devices. Organized in the form of a selection guide, this brochure gives essential product characteristics for high performance semiconductors, microelectronic subassemblies, transmitters and receivers for fiber optic communications, bulk wave delay lines, ferrite devices, and isolators and circulators. **Thomson-CSF, Microwave Component Division, Paris, CEDEX, France.** (1) 743-96-40. Circle 122

APPLICATION BROCHURE ON MODULATION ANALYZER

Application Note 286-1 describes the operation and uses of the HP8901A modulation analyzer. This 50-page note describes how the instrument is used for transmitter testing, signal generator calibration, broadcast monitoring, measuring VCO differential tuning linearity and residual FM noise of oscillators, separating residual AM or FM, or measuring peak modulation transients. HP-IB (IEEE-488) programming techniques with annotated software examples and subroutines are also provided. **Hewlett-Packard Co., Palo Alto, CA.** (415) 857-1501. Circle 125

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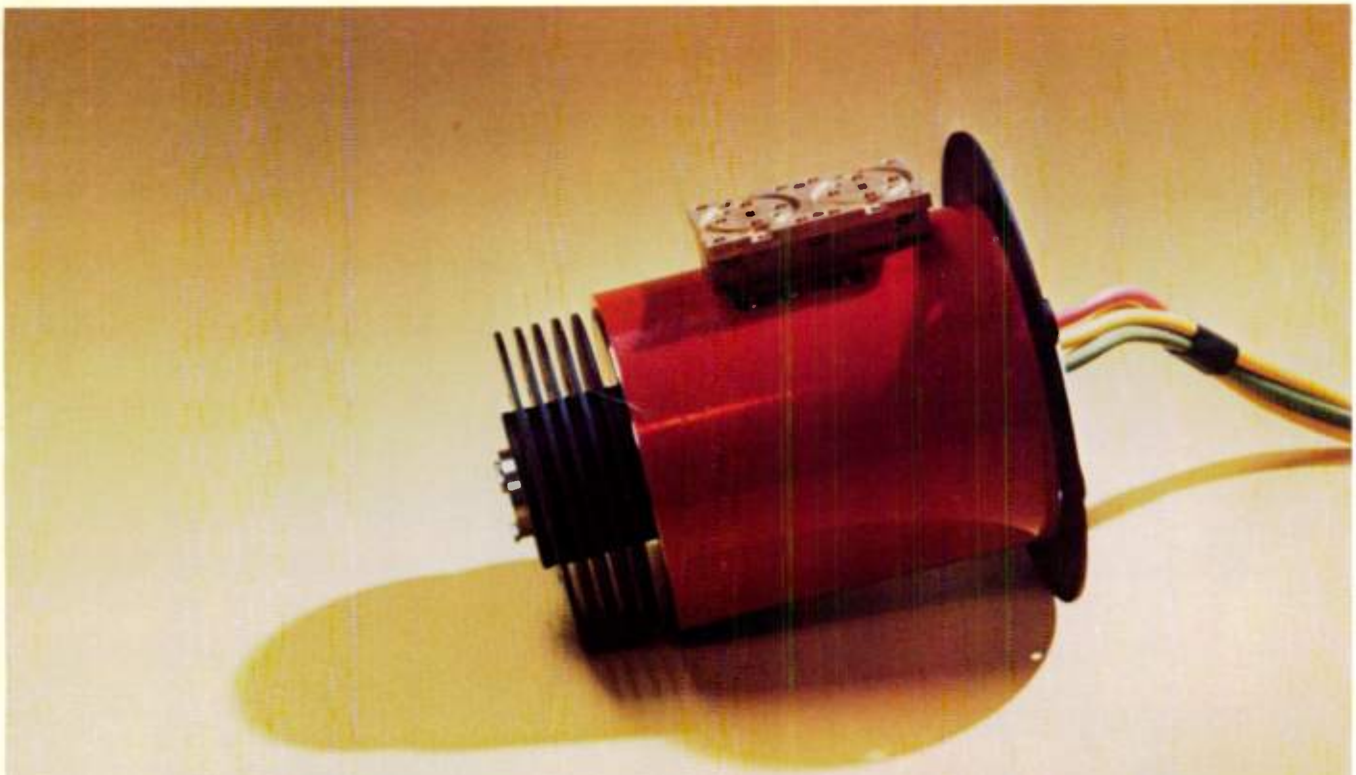

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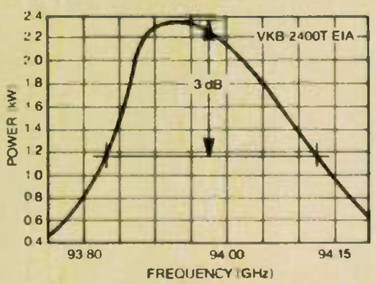

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