microwave JOURNAL

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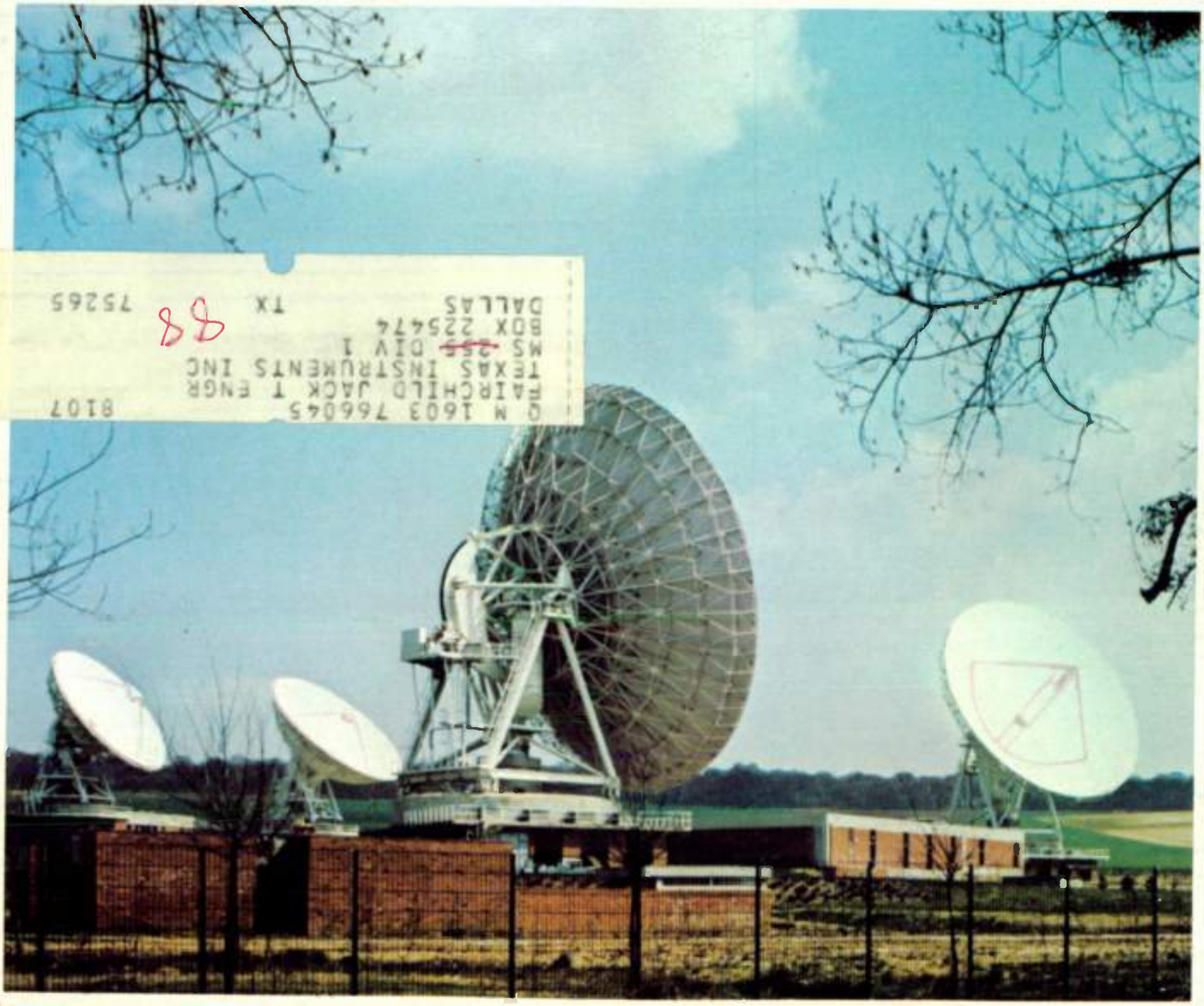

Communication/Bioeffects Applications

- Low Cost K-Bank Links
- Direct Broadcast TV-SAT Antenna
- Implanted Radiator Cancer Therapy

SPECIAL REPORT

The European Microwave Industry

horizon house

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- Automatic locking to input reference frequency
- Low phase noise
- Fast acquisition time (1 ms) (PLA-FA Series)
- Alarm options

The Miteq series of frequency-agile phase lock sources automatically lock to and track the input reference signal. These units exhibit low phase noise through use of a high Q microwave oscillator. Acquisition times to 1 ms are available with the PLA-FA Series.

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

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$4.50 (10-49)

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

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Model SBL-1

metal case, non hermetic-seal

Frequency Range, MHz
LO 1-500 RF 1-500 IF DC-500

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

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

World's largest manufacturer of Double Balanced Mixers

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MINI-CIRCUITS LABORATORY
A Division of Scientific Components Corp 21 Rev IBL

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JANUARY 1981

ON THE COVER: A large earth station at Bercenay en Othe (France) built by TELESPACE, a joint venture of Thomson CSF and CIT Alcatel, for Intelsat and Symphonie satellite communications. Photo courtesy of Thomson CSF.

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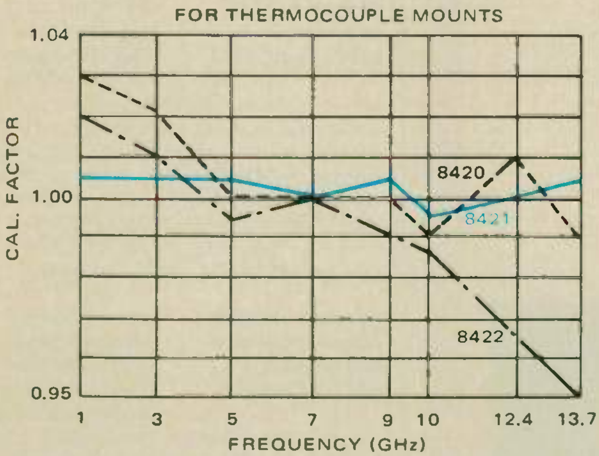
BPA Horizon House also publishes Telecommunications and Journal of Electronic Defense.

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

TYPICAL CALIBRATION FACTOR CURVES
FOR THERMOCOUPLE MOUNTS



Makes accurate measurements from .01 to 13.7 GHz Inexpensively

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

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Coming Events

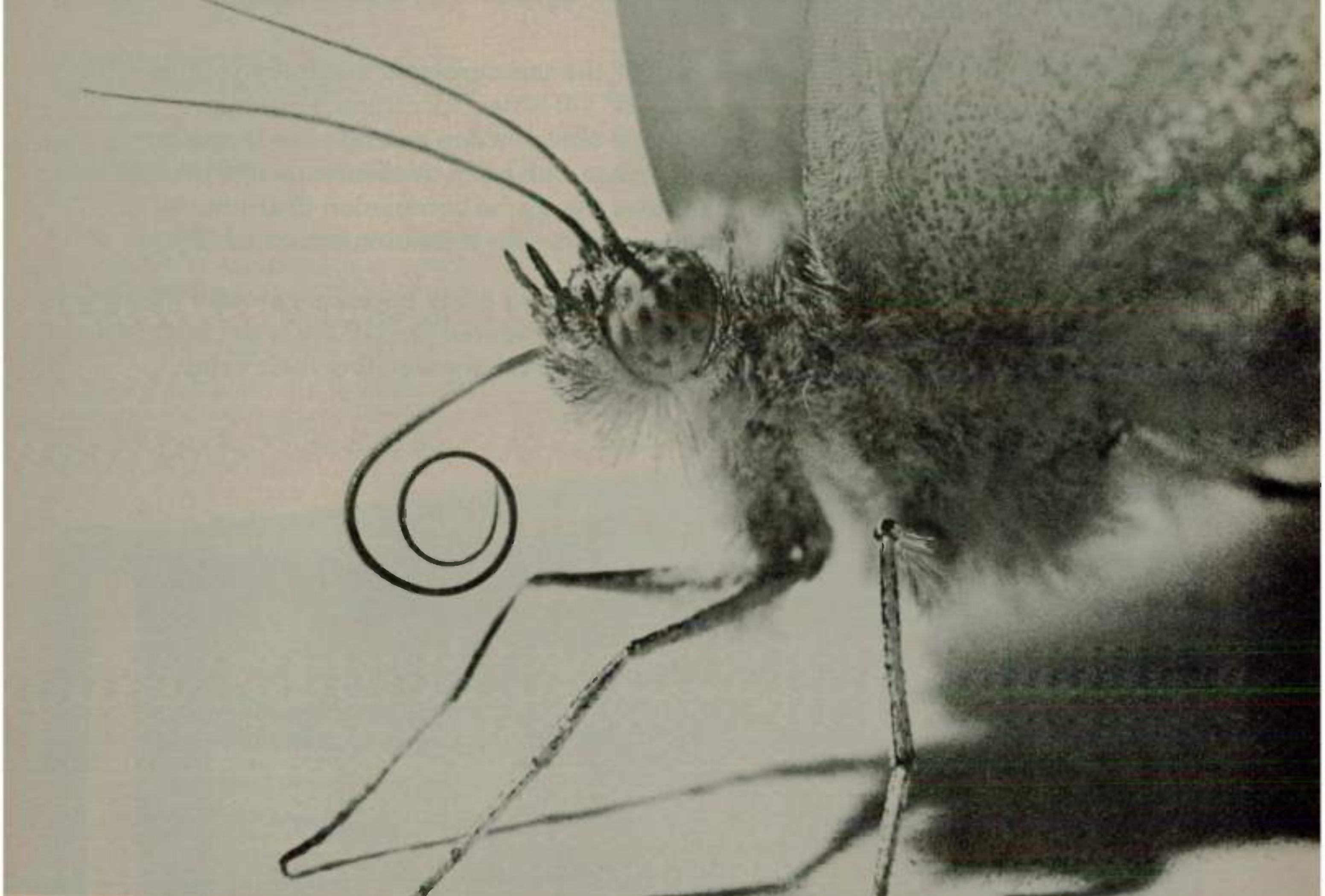
1981 IEEE/MTT-S INT'L MICROWAVE SYMPOSIUM JUNE 15-17, 1981 Sponsor: IEEE MTT-S (held jointly with IEEE AP-S on June 17-19, 1981). Place: Bonaventure Hotel, Los Angeles, CA. Theme: "Around the World with Microwaves," includes such topics as CAD and measurement techniques, microwave and mm-wave solid-state devices, IC's, etc. Contact: Al Clavin, Hughes Aircraft Company, Bldg. 268/A-55, Canoga Park, CA 91304. Tel: (213) 702-1778.

11TH EUROPEAN MICROWAVE CONFERENCE SEPT. 7-11, 1981 Call for Papers. Sponsors: EUREL, IMPI, URSI, IEEE-Region 8, in association with Microwave Exhibitions and Publishers Ltd. Place: Amsterdam, The Netherlands. Topics: Communication systems and broadcast, mw radio propagation and techniques in radar, remote sensing and radio astronomy, biological, medical, and industrial applications, antennas and arrays, active and passive components and circuits and CAD, mixers, new materials, mm-wave components and circuits and mw measurements. Submit 5 copies of 300-500-word summary by March 15, 1981 to: Dr. T. G. van de Roer, Secretary, EuMC 81, Eindhoven Technical University, P.O. Box 513, 5600MB Eindhoven, The Netherlands. For exhibitor and registration information, send to Microwave Exhibitions & Publishers Ltd, Temple House, 36 High St., Sevenoaks, Kent TN13 1JG, UK.

14TH ANNUAL ELECTRONIC CONNECTOR STUDY GROUP, INC. NOV. 11-12, 1981 Call for Papers. Sponsor: Electronic Connector Study Group, Inc. (ECSG) Place: Franklin Plaza, Philadelphia, PA. Topics: Sessions will cover flexible/flat cable circuitry, fiber optics, test methods and evaluation, RF & EMI applications, materials, finishes, and platings, terminations and connector techniques, IC packaging, etc. Submit 200-word abstract by March 20, 1981 to Papers Chrmn., ECSG, P.O. Box 167, Ft. Washington, PA 19034. Tel: (215) 279-7084.

6TH INT'L CONF. ON INFRARED & MM WAVES DEC. 7-12, 1981 Call for Papers. Sponsors: IEEE MTT-S and IEEE Quantum Electronics and Applications Society. Place: Carillon Hotel, Miami Beach, FL. Topics: Millimeter sources, devices or systems, mm and sub-mm propagation, atmospheric physics and propagation, plasma interactions and diagnostics, guided propagation and devices, etc. Submit 35- or 40-word abstract by June 30, 1981 to: Mr. K. J. Button, Program Chrmn., MIT Francis Bitter Nat'l Magnet Lab, 170 Albany St., Cambridge, MA 02139. Tel: (617) 253-5561.

THERE ARE STILL SOME ANTENNA SYSTEMS WE DON'T MAKE A RADOME FOR.



The ones we do cover can be found all over the world. With good reason.

Experience in the field has proven that a radome-enclosed antenna system performs better over significantly longer periods of time than an exposed antenna.

Radomes dramatically reduce antenna failure rates, prolong system life, and allow routine maintenance without weather interruptions.

From the standpoint of cost-effectiveness, a radome is a wise investment, indeed. When you specify a radome during the design and planning stages of your antenna, the initial cost savings will virtually pay for its inclusion in the system.

Antenna maintenance and repair costs are cut considerably. Severe damage from strong winds, heavy snow, and massive ice build-ups are eliminated. As are the corrosive effects of sand, dust, salt, and chemical pollutants.

And electrical degradation from wind, rain, snow, and thermal loads will be reduced.

Best of all, you'll get performance as well as protection. The unique structural design and high efficiency membrane materials allow optimum electromagnetic performance over extremely broad frequency bandwidths.

Since 1961, we've designed and delivered more than 700 fully operational radomes for all types of communications antennas and radar systems. Our fabrication and installation process enables us to build a radome for any antenna at any time.

Let us design one for you. Call or write: Electronic Space Systems Corporation, Old Powder Mill Road, Concord, MA 01742. (617) 369-7200/Telex: 92-3480.

ESSCO

CIRCLE 8 ON READER SERVICE CARD

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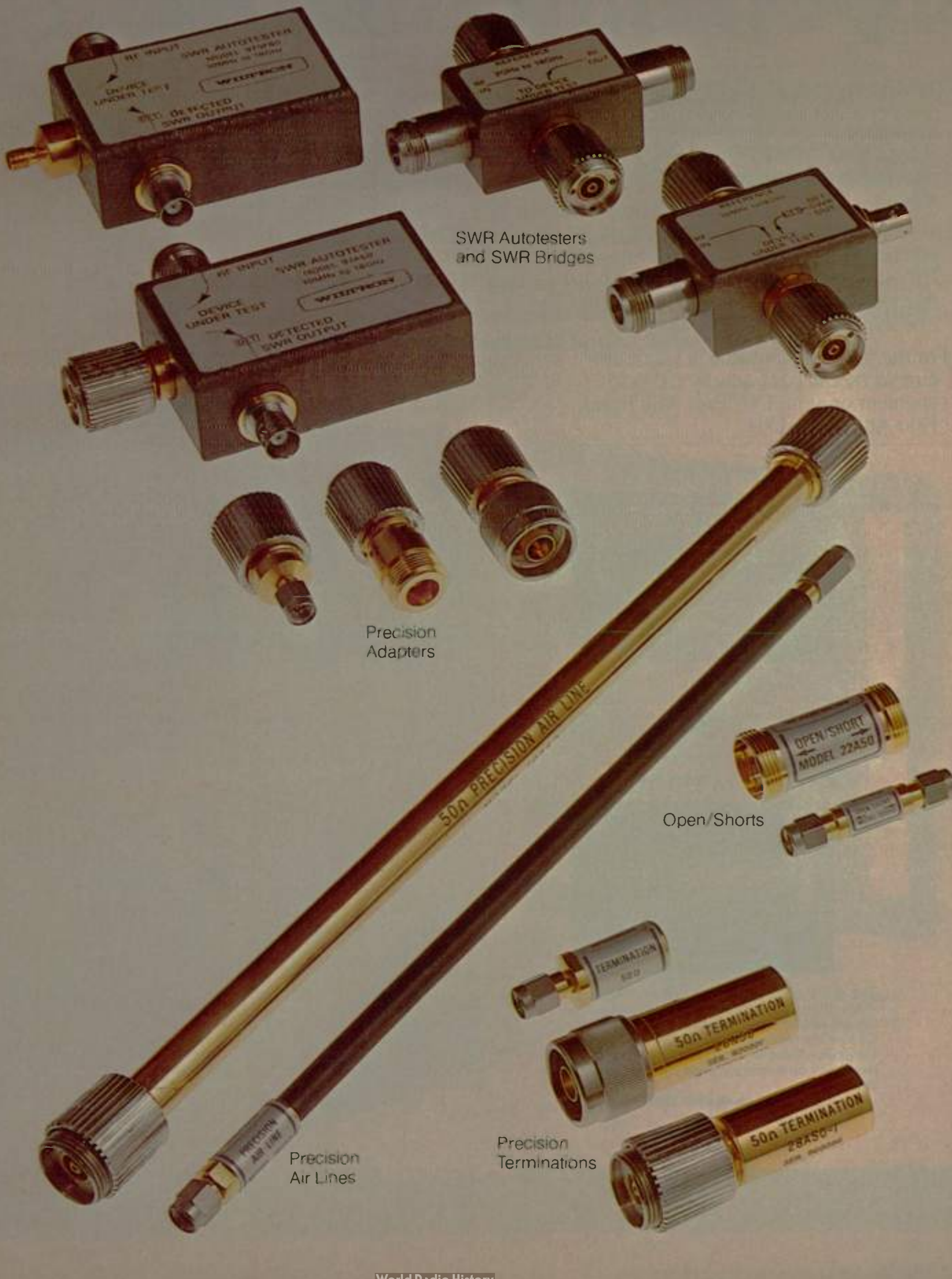
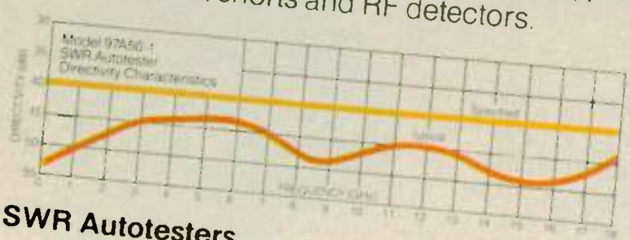


With Wiltron.

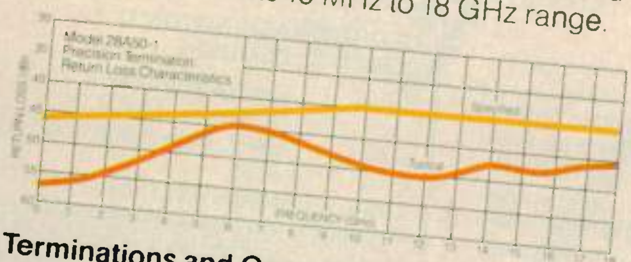
And you thought we only made quality microwave instrumentation. The U.S. National Bureau of Standards, the standards labs of Japan, West Germany, Great Britain and quite a few others know better.

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



SWR Autotesters

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

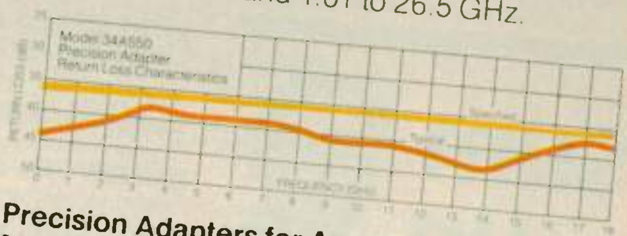


Terminations and Open/Shorts

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

Precision Air Lines

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



Precision Adapters for Accurate Measurements

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

Other Wiltron Calibration Lab Quality Components

Wiltron also offers the industry's most extensive line of RF detectors with coverage up to 34 GHz.

So go for the Gold Standard

Go Wiltron and your microwave measurements will be as good as pure gold. Remember, Wiltron offers you one source shopping for production or development measurement systems and cal lab reference standards.

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

See us at Microwaves Communications '81, Tokyo. Seki Booth #4005

WILTRON

Were You Zapped?

JOSEPH F. WHITE, Consulting Editor

THE ZAP – A MEDIA FEAR PRODUCT?

It is four years since the publication of *The Zapping of America, Microwaves, Their Deadly Risk and The Cover-Up.*[1] Behind us are the newspaper stories of citizens opposing the PAVE PAWS Radars at Otis Air Force Base on Cape Cod, MA and Beale AFB, in CA. Now all those undefined fears of microwave have died out – *or have they really?* Were you zapped? That is, were you left with the gnawing fear of as yet undiscovered hazards of microwaves as they emanate from cooking ovens, communication towers, radars, intrusion alarms?

You can tell if you were zapped by your response the last time one of your nonengineering friends greeted you at a cocktail party with the question "Should I buy a microwave oven?" Those of you who don't keep your occupation a secret recognize the question. You've heard it often. How did you answer? I can tell you how I answered just after being zapped. Of course, I didn't realize I'd been zapped at the time. I answered scientifically, objectively, and said "Well, all the facts aren't in yet." What I hadn't done, however, was answered *usefully*. All of the facts are never in on this or any other subject, and my answer then would not have helped anyone either to decide to buy a microwave oven or even to reschedule his decision (within his lifetime that is). We'll get into facts (the cure for being zapped) shortly, but what produced the micro waves-are-dangerous fear (code name *zap*) initially? Where were the dead, diseased or maimed bodies? How much broken sky did Chicken Little find?

While I've encountered few who actually read Brodeur's book, nearly all of my acquaintances have heard of its message through the Press and TV coverage of its exposé-like treatment of microwaves-the-unknown-risk. As I read it, the essence of that thesis was that . . . the facts are not all in about the safety of microwave radiation, and therefore one can't be too careful. The backlash from this kind of reasoning is fear, i.e. "painful agitation in the presence *or anticipation of danger.*" (Webster, italic added). Whether inspired by Brodeur's book and/or any other source, a surprisingly large number of us (I checked on how my colleagues answered the test question) were zapped into a condition dictating that the prudent individual should exclude himself from the near vicinity of any strong microwave sources, whatever "strong" and "the near vicinity" might prove to be.

Suppose the zap had been applied to the emerging light bulb. An imaginative reporter might have argued at that time that if the electric light should come into wide use, its effect on the human situation (being unprecedented) would be cause for fearful consideration, with, of course, the slow deliberation before action such fear engenders. The scenario might continue, people would be likely to stay up late at night reading by the electric light, induced to do this by its convenience and durability in comparison to the candle. Furthermore, the spectrum of incandescent light would be different from that of either the sun or of whale sperm candles for which some experience exists (albeit also obtained at considerable hazard to the human condition). This different spectrum might result in people using higher or lower intensities in order to see printed material clearly enough. Who could tell how this might have affected human vision, psychology, and behavior? Indeed, who can say that we aren't all off balance today, already unwitting victims of artificial illumination, long hours of nightime study, days made artificially long or short in windowless buildings through the ready availability of electric lights. The facts aren't even in yet about the electric light. Where was a controlled experiment conducted, two groups living to maturity, one with, the other without electric lights?

> *"Fortunately for Edison, in his time communication wasn't as efficient as it is today."*

Fortunately for Edison, in his time communication wasn't as efficient as it is today. Those concerned about the hazards of incandescent lights didn't have the wide and instantaneous audience provided by today's com-

(continued on page 19)

PLUG IN TOTAL SWEPT MEASUREMENT AUTOMATION.

On the production line, on the bench, or in the most complex ATE system, no other swept measurement system even approaches the total automation of our new 1038/N-10.

PLUG IN TOTAL BUS CONTROL

Plug the new N-10 Scalar Network Analyzer into your Pacific Measurements 1038/D-14 Mainframe. And you turn on total bus control. All data and function inputs are digital, and can be entered via the bus or manually on the front panel. Driven via IEEE STD 488 bus by your host computer, the 1038/N-10 completely automates all insertion loss/gain, return loss and absolute power measurements. And with your 1018B Power Meter, it even automates swept pulse power measurements. Plus, all the automatic features are available in the manual mode.

TURN ON THESE ADVANCED FEATURES

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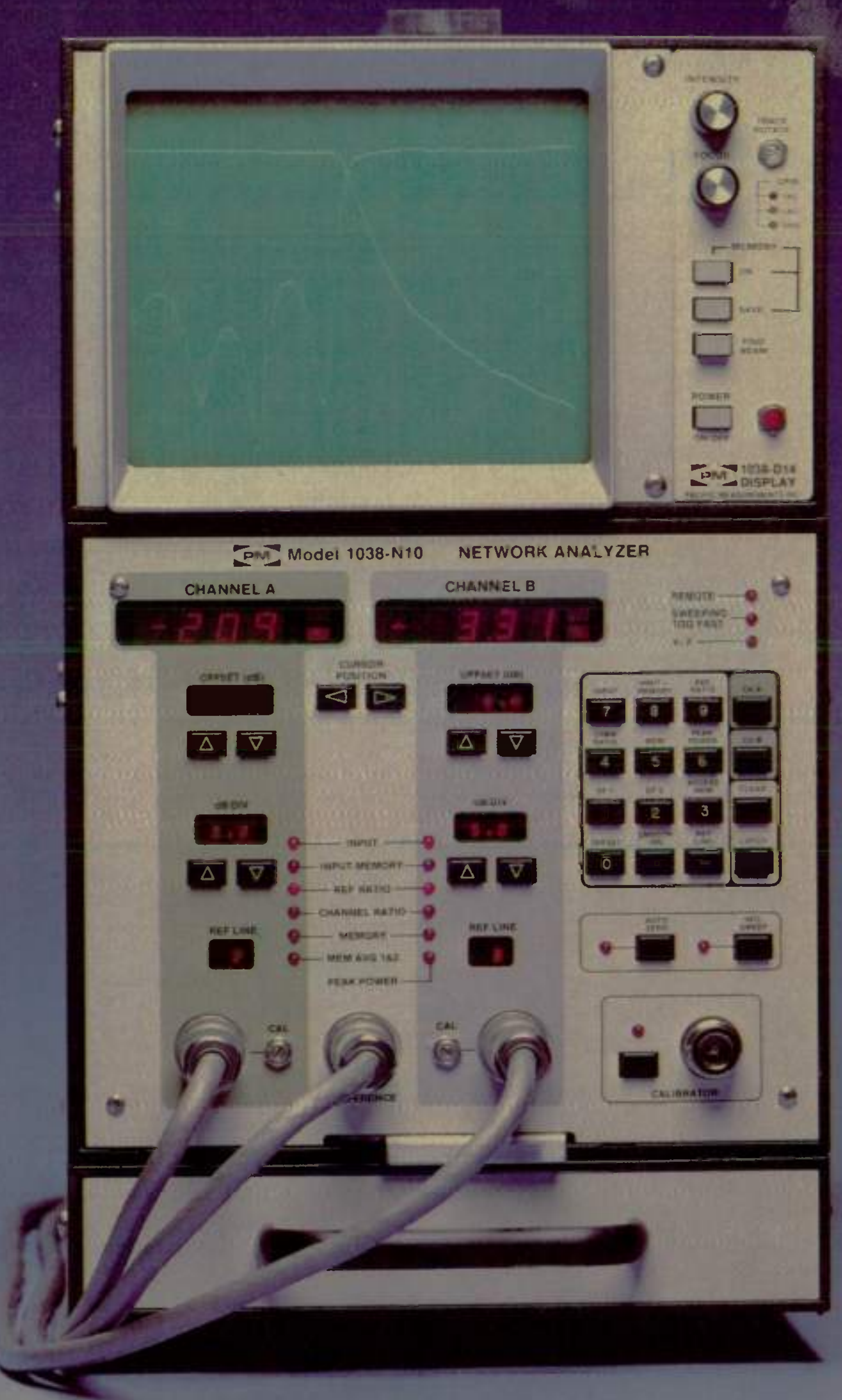
- Over 100 GHz range
- .02 dB data resolution on A channel
- .002 dB data resolution on B channel
- LED's display memory-corrected test data
- LED's display offset and scalar sensitivity
- Automatic instrument zeroing
- No recalibration required when changing frequency limits
- System residuals memorized without display adjustments
- Memory-refreshed CRT display

AND MICROPROCESSOR FLEXIBILITY

The microprocessor-based 1038/N-10 includes a standard software package compatible with almost any combination of sweep generator and computer/calculator. In addition, you can plug our 1044A response recorder into the system to produce memory-corrected hard copy test records. There's a lot more we could tell you about the advantages of the 1038/N-10, but there simply isn't room. So for the full story call our Marketing Manager, Ed Mendel, at (408) 734-5780. Or contact your local Pacific Measurements representative.



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CIRCLE 12 ON READER SERVICE CARD

Amplifiers

• Ultra Low Noise • Wide Dynamic Range • Custom Design

Ultra Low Noise Amplifiers

Model Number	Frequency (MHz)	Min. Gain (dB)	Flatness (dB)	Noise Figure (dB) typ.	Noise Figure (dB) max.	Pwr. Out @ 1 dB Compression Pt. (dBm)	Case/ Connectors*
W50ETD	0.01-50	50	±.5	1.3	1.5	0	C/SMA
W50ETC	0.01-50	20	±.5	4.0	4.5	+ 23	C/SMA
W250G	5-250	43	±.5	1.3	1.5	+ 25	B/SMA
W500E	5-500	30	±.5	1.3	1.4	0	C/SMA
L60E	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

Wide Dynamic Range Amplifiers

Model Number	Frequency (GHz)	Min. Gain (dB)	Pwr. Out @ 1 dB Compression Pt. (dBm) typ.	Pwr. Out @ 1 dB Compression Pt. (dBm) min.	Noise Figure (dB)	Case/ Connectors	Typical Intercept Pt. (dBm)
P60F	30-90 MHz	30	+ 32	+ 31	5.5	H/BNC	+ 43
P150H2	0.1-150 MHz	27	+ 31.5	+ 30	6.5	H/BNC	+ 44
P400C	10-400 MHz	20	+ 31	+ 30	7.0	H/BNC	+ 42
P500N	2-500 MHz	17	+ 31	+ 30	8.0	H/BNC	+ 42
P10GL	0.5-1.0	30	+ 31	+ 30	5.0	H/SMA	+ 42
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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nunication media. But had they, feel sure that someone would ave had the electric light side-racked to an unending series of tudies. Furthermore, as Mr.Broleur's book points out in the ase of microwaves, many of hese studies would have shown 'negative" results, only eroding he credibility of those who had onducted the studies, those who ad funded them, even those vho simply were powerful nough *to have influenced* them.

IORE QUESTIONS YOU HEAR

Another test of whether, or ow much, you were zapped is y your response to a second ocktail party question, "Why id the Russians irradiate the American Embassy with microvaves if not to cause its inhabiants serious harm?" My unpreared response to that question vas, "Well, you don't know wheher everything you hear about olitical events is accurate." Again, very scientific; again, very *useful*. What I wish I had said vas, "If, indeed, American authrities were concerned about mirowave radiation beamed at the American Embassy by the Sovets (probably because the Sovets were trying to jam our recepion of their intercountry microvave messages), then the simple ecourse of installing copper creening to reflect the radiation vould have been immediately pparent to the US Embassy oficials through their electronics pecialists. And what of the aleged higher incident of cancer nd other mysterious ailments of he diplomats? "Well (I wish I ad said) diplomats' lives are not ypical of the population. Think f the number of parties they atend, their alcoholic consumpion opportunities, their unique iving habits abroad, and so orth; and therefore one would eed data for a control group vhose lives were known to be imilar, with the exception of the nicrowave radiation, to those of he US Embassy personnel before oncluding which, if any, of their erceived maladies might have een microwave induced."

A really persistent cocktail interrogator can introduce a number of incidents about which you, the microwave engineer, should be conversant. No less than the *Consumers Union* (CU), in its reports on microwave ovens[2] rated them all "unacceptable" because " . . . we have been unable to uncover any data establishing to our satisfaction what level of microwave radiation can unequivocally be called safe." It cited the fact that the US standard was 10 milliwatts per square centimeter whilst the Soviets claim to apply a standard a thousand times smaller, 10 microwatts/cm^2. Though not unmindful of their wit, I am nevertheless reluctant to give the Soviets so much credit as to assume that they, in their wildest dreams, could have anticipated just how much confusion the simple announcement of a 10 microwatt standard would cause in the United States. Doubtless the 10 microwatt level usually is met in the civilian sector of the Soviet Union by virtue of the limited usage of microwaves therein. However, it is generally accepted[3] that the "standard" does not apply to the military sector.

Indeed, if the Soviets were certain that exposure to more than 10 microwatts/cm^2 were hazardous, we should score a point for détente at their having shared this concern with us. More about the basis of the Soviet standard later.

> *". . .if the Soviets were certain that exposure to more than 10 μW/cm^2 were hazardous, we should score a point for détente. . ."*

FACTS & FIGURES

To help you prepare for the next cocktail party (concerning microwaves and the environment) I've gathered some information from which to begin formulating enlightened opinion.

Microwaves are Non-Ionizing

The photon energy of even the highest frequency microwave signals (viewed broadly as the range 0.3 to 300 GHz) is only 0.001 electron volts (eV) not enough t disassociate protons from the nu cleus of biological tissue molecules, which requires 1,000,000 eV, nor even to ionize tissue molecules, thereby breaking the chemical bonds, which requires 10-12 eV. In fact, microwaves' 0.001 eV maximum photon energy is even an order of magnitude below the 0.03 eV thermal energy associated with molecule at room temperature; and, as such, microwaves definitely are to be considered *nonionizing.*[4,5]

The consequence of microwaves' nonionizing nature is tha any injury they can inflict must be presumed to be thermal in na ture, and therefore exhibit *threshold behavior below which effects are noncumulative.* By contrast X-rays, radiations at 10,000 times as high as the high est microwave frequencies, are ionizing. Yet, while there is mu recent controversy about micro wave radiation, the public sensitivity to the risk of X-rays is evidently not nearly so great.

> *"The consequence of microwaves' nonionizing nature is. . .* **threshold behavior below which effects are noncumulative."**

> **" . . . According to John Villforth head of the Bureau of Radiologica Health in the Department of Heal Education and Welfare, 'X-rays ar used in more than half the medica diagnoses in this Country.'[6]**
>
> **"This increase is a source of concern because scientific investigations indicate that low-level exposure to ionizing radiation produce biological damage, both genetic and somatic and also that *exposur is cumulative, with effects growin linearly as dosage increases* (italic added). Moreover, when the risk i to the whole population, as in the case of medical X-rays, biological damage becomes a public health is sue of major proportions."**

When your dentist puts a leac apron on you in preparation for X-rays and then leaves the room to activate the machine, you can't help but be impressed witl X-ray's potential hazards. Yet, how were the safe levels for X-rays ever determined? Who even asks such a question today at cocktail parties?

The Soviet "No Effect" Limit

One might ask, Why not set the microwave exposure limit below that which causes any discernible effect? This is effectively the basis for the Soviet standard. The answer to this question, as well as a reference point from which to consider standards in general, is expressed well by this DOE/NASA report excerpt.[7]

> ". . . The question of benignity or peril goes to the heart of the issue of philosophy of standards. In the Soviet Union and in several other countries the operating principle (apparently) is to invoke a maximal permissible limit (MPL) of exposure below which *no* effects are assumed to occur. The rationale is that any effect *might* be an adverse effect. While the principle of no-effect has intuitive appeal, it runs counter to practicability. Such an MPL for electromagnetic radiations in the visible spectrum would leave the human race and most other forms of life starving in darkness. A no-effect MPL for the neighboring infrared spectrum would amount to a decree of death by freezing. But why not a no-effect MPL for the microwaves, upon which the flora and fauna presumably do not depend for nurture and warmth? The answer lies in a well-confirmed datum, which is the limiting case for a biological effect: A single 10-μsec pulse of microwave energy that is absorbed in the head at a dose of no more than 10 μJ/g can result in an acoustic response, the phenomenon known as radio-frequency (RF) hearing, or the Frey Effect (*cf.* Frey, 1962, with Justesen, 1975a). Given the plausible assumption that a no-effect MPL for occupational exposure would be based on the limiting case of demonstrable perturbation irrespective of the character of the field, i.e., whether continous wave (CW), or sine- or pulse-modulated, one's attention is directed to the Frey effect. That single, acoustically detectable pulse — which can be construed as a very brief CW transmission—when averaged conservatively over the 8-hour working day, extrapolates to a maximal permissible power density near 350 picowatts per square centimeter. To place this quantity in perspective, one should note that an adult human being *emits* microwaves* at frequencies between 300 MHz and 300,000 MHz at a rate near 540 nanowatts per square centimeter (Kraus, 1966), a rate that is more than three orders of magnitude greater than would be a no-effect MPL based on the Frey effect.
>
> "A no-effect MPL for microwaves is putatively impractical; more desirable by far is a *no-hazardous-effect* MPL — or at least a scientifically sound body of threshold data on hazardous effects by which to make enlightened judgments of benefit and risk."

Threshold Effects & The 10* mW/cm² Limit

For humans, the eyes and the testes are the most sensitive to thermal damage. Both have limited circulatory capacity for heat dissipation. For the eyes, past a threshold temperature damage occurs due to lenticular clouding (opacity, i.e. cataract, formation); for the testes, prolonged heat can cause temporary sterility (so, too, can hot baths) but just how much heat for how long and what the extent of the resulting sterility might be is not known.

For the eyes, however, the information is fairly definitive. Russell Carpenter**[8] points out that in 1948 reports were made of the observation of opacities in the crystalline lenses of dogs and rabbits exposed to microwave radiation at 2.45 GHz (the frequency commonly used for microwave cooking).

In the 30 years since, the phenomenon has been extensively investigated. Examining this, as well as his own data, Carpenter notes:

> ". . . It appears that so far the rabbit eye*** is concerned, the maximum safe exposure level of 10 mW/cm² recommended by the American National Standards Institute and generally accepted by most of the Western world, is satisfactory. In our experience an incident power density of 250 mW/cm² acting on the eye for 35 to 40 minutes is required for cataract induction by a single exposure.
> . . . Multiple exposures at 180 mW/cm², each of one hour's duration for 20 consecutive days, are also cataractogenic . . . Right now (however) we can speak with authority (only) for the rabbit."

Thus the 10 mW/cm² limit is more than a factor of ten below the eye damaging level of 180 mW/cm² — and even that level need be sustained for very protracted periods to induce full eye damage.

". . .the 10 mW/cm² limit is more than a factor of ten below what the eye damaging level of 180 mW/cm². . ."

Thermal Effects Aren't New — and Can Be Beneficial

Many human diseases and ailments are ameliorated or cured by raising the temperature of the affected organs by a few degrees centigrade.[9] Electrically induced currents provide this heating; this treatment is called *diathermy*. Decades old,[10] the methods have been used medically without the observation of any effects not related to the intended heating. Nor were physicians dealing with weak sources of power, diathermy machines then, as now, are available from one megahertz to 2450 MHz (the microwave oven frequency) with power levels of 80-400 watts. Diathermy treatments have been given at levels between 50-1000 mW/cm². Consider just this excerpt:[9]

"Diathermy treatments have been given at levels between 50-1000 mW/cm²."

> "In 1923 Stewart wrote an entire book in the use of diathermy in pneumonia (it) reached its greatest publicity when in 1929, the King of England, who had worsened on ultraviolet ray treatment, improved by (1 MHz) diathermy. At almost the same moment, across the Channel, short-wave diathermy was born."

(continued on page 22)

* For even added safety The American National Standards Institute (location) is proposing a new standard (ANSI-C95) in which the exposure standard would be 5 mW/cm² for frequencies above 1500 MHz.

** With the Bureau of Radiological Health, Food and Drug Administration, Winchester, Mass.

*** Such cataract formation irradiation experiments cannot, of course, be performed on living humans.

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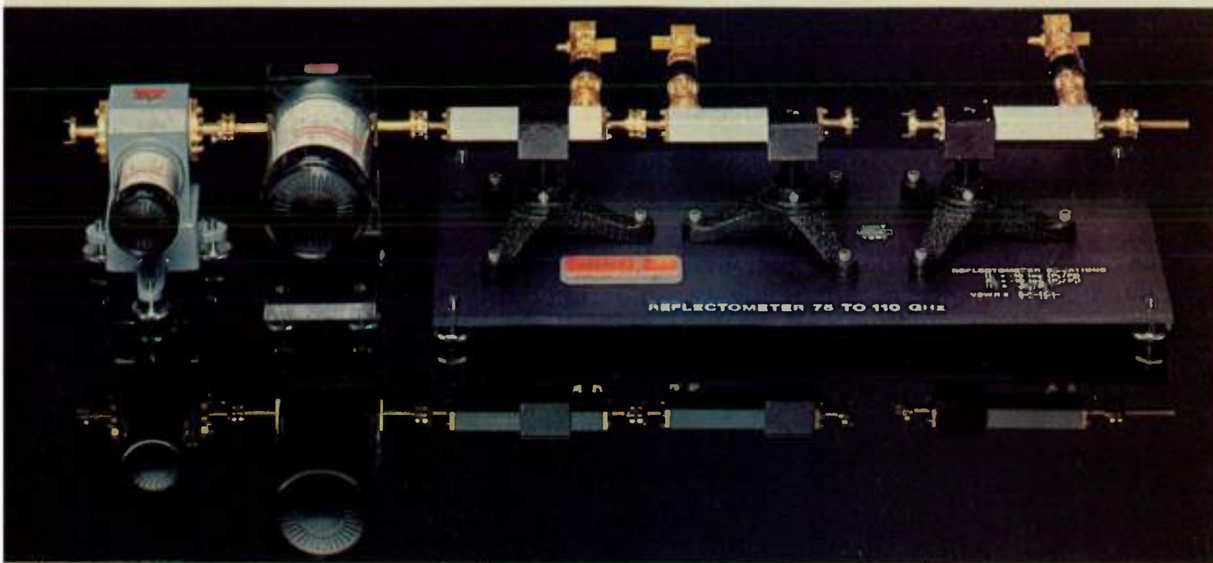

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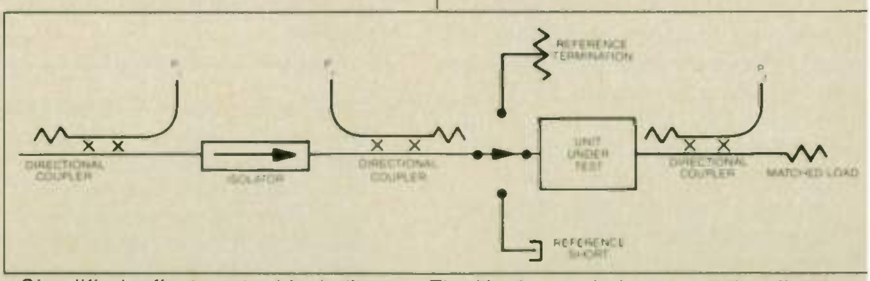

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"In 1928 Esau, a physicist at Lena, constructed . . . a machine which delivered a 3 M (100 MHz) wave at 400 watts . . . In the early days, overenthusiasm and lack of precautions resulted in moderate and occasionally severe burns; but with improvement (these) became increasingly uncommon."

"Perhaps the first physician to use microwave diathermy (for more selective body heating) was Denier[11] . . . a 60 cm (500 MHz) device at 80 watts."

COMAR – IEEE Committee on Man and Radiation

In 1972, the IEEE established COMAR as " . . . an objective scientific body with the charge to establish and maintain a realistic and balanced perspective+ toward the hazards and benefits of non-ionizing radio frequency electromagnetic radiations . . ."[3]

D. R. Justesen, Chairman of COMAR as well as Director of the Neuropsychology and Behavioral Radiology Laboratories at the Medical Center, Kansas City, MO, published a thoughtful response to common microwave radiation hazard questions[12] in which he pointed out that:

"Regarding oven leakages, 10 µW and 10 mW standards. . .apples-and-oranges comparison." – D. R. Justesen

a) Regarding oven leakages, part of the controversy between the Soviet (10 µW) and the (US) Food and Drug Administration's (10 mW) standards arises because they represent and apples-and-oranges comparison. The Soviet's is a *whole body exposure* standard, requiring, for example, that a person's entire body should not receive more than an average of 10 µW/cm² due to microwave emanation from an oven or other microwave device. The FDA's (highly conservative) standard* for ovens requires that they have no more than 5 mW/cm² (1 mW/cm² when new) *emission* at a distance of 5 cm. But this radiation from essentially a point, or at worst, a short line source, would drop off rapidly with distance to less than 10 µW/cm² at a distance sufficient to illuminate a person's whole body. Acknowledgement that the FDA microwave oven standard would also meet the Soviet standard has been made by Soviet specialists.[13,14]

b) Actually, "the heaviest infiltration of RF energy in the urban environment is from FM and UHF-TV stations. . . " not from microwave sources.

This is particularly significant because the human body's fundamental resonance is in the 30-300 MHz range. Actually, the microwave oven frequency of 2450 MHz, although used for years in diathermy, has been found recently to be inferior to UHF frequencies (500-1000 MHz) for effective penetration in the human body. The primary resonant frequencies are obtained roughly when the freespace wavelength equals the major body dimensions. Thus maximum penetration can be expected as follows:[15]

Fruitfly:	over	10,000 MHz
Hamburger:	over	2,450 MHz
Turkey:	over	900 MHz
Adult human:	over	100 MHz

c) The present Chairman, D. R. Justesen, in a supporting appendix to[15] said:

". . . assumption of hazardous non-thermal effects. . .fabrication from the whole-cloth of fear." – D. R. Justesen

"The assumption of hazardous non-thermal effects at low densities of (microwave) radiation, which are suspected by some but are as yet unsubstantiated by anyone, is a fabrication from the whole-cloth of fear. This fear, which feeds on the *absence* of verified or verifiable evidence, is hampering basic studies and may therefore restrict medical development and application of radio-frequency radiations."

10 mW/cm² Applies to Whole Body Exposure, Too

The human body dissipates under normal conditions 100W and has an absorbing surface of 20,000 cm².[16] Allowing for an absorption factor of no more than 50% (the high water content of the body makes for a poor match to radiation incident in air), supports a reasonable whole body exposure standard of up to 10 mW/cm². It was this reasoning which led to the first US guideline for permissible dosages of radiation† in about 1953.

Cancer Detection & Treatment – à la Microwaves

Some may say that microwaves are a jet-set luxury and therefore do not warrant the assumption of risk, any risk, just to facilitate warming cocktail hors d'ouvres or providing satellite links for home box office movies.

Not so. Microwaves are being used to detect tumors deep within the body through microwave (passive) radiometry.[17,18] Cancerous tumors are usually 1-2°C hotter than surrounding tissue, possibly because they are less well irrigated by the blood supply. By measuring the body's own microwave "blackbody" radiation in the microwave spectrum (which propagates better through subcutaneous layers of fat and muscle than infrared) some breast tumors have actually been located which were not detected by conventional methods (manual palpation, X-ray and infrared).[18]

"Microwaves. . .detect cancerous tumors. . .microwaves kill tumorous tissues selectively. . ."

Furthermore, once identified, microwaves kill tumorous tissue selectively, by virtue of its poor heat dissipating capability, through heating. Above 42.5°C the sensitivity of cells to destruction doubles for every 1°C increase;[19] consider the following:

"Last June Michael Salcman, a neuro-surgeon at the University of Maryland, implanted an antenna in the brain of a 28-year-old European businessman with glioblastoma

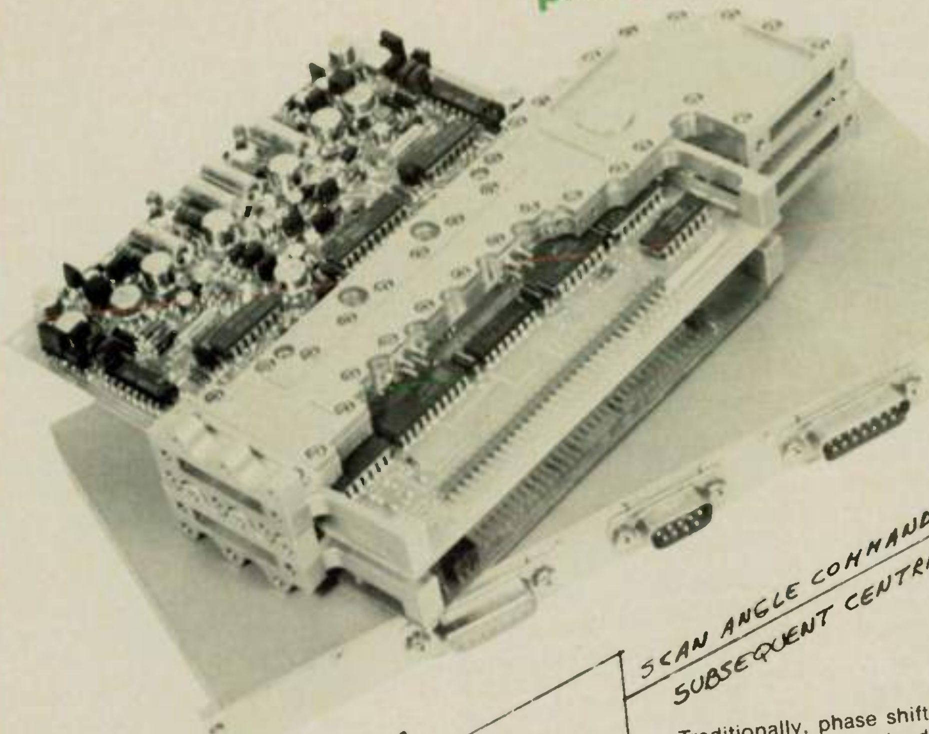
+ COMAR is planning a 30-minute film for public broadcast describing the risks and benefits of microwaves, only a small portion of which will be funded by IEEE, the remainder by private contributions.

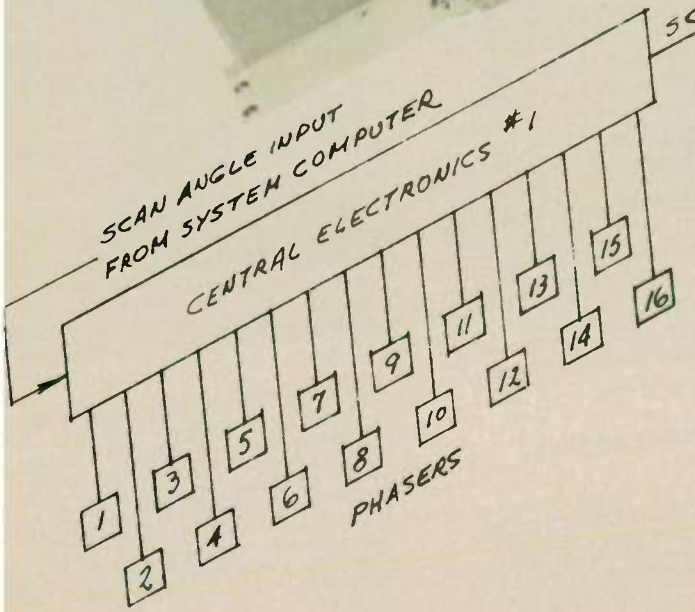
* This is the maximum allowable leakage. Most ovens leak far below this limit (e.g., 0.1 mW/cm²).[15]

† A value of 100 mW/cm² was first chosen, due to miscalculation, but later this was corrected to 10 mW/cm²; see Reference 16 for a discussion of the development.

(continued on page 24)

phase shifting subsystems for phased array applications





Traditionally, phase shifters have been sold as individual self-contained units. In some cases, however, an improvement in performance *and* overall system simplicity can be achieved if a portion of the digital processing required by the electronic driver is accomplished in a microprocessor based central electronic unit. An example of such a subsystem developed previously by EMS for one customer is illustrated on this page. Obviously, subsystems of this type must be individually tailored to exact customer requirements but, in general, this approach can allow for a significant improvement in phase accuracy (by compensating for both frequency and temperature) while simplifying greatly the cabling and digital processing requirements placed upon system circuitry. As an example, one phase shifter within a subsystem of this type might be designed to exhibit the performance presented below:

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R. F. Power:	1 kW peak, 50 W ave.
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Insertion Loss Variation:	0.05 dB rms
Total Phase Error:*	On the order of 0.5° rms, 1° peak over restricted temperature ranges
Phase Repeatability:	Less than 0.1°
Reference Insertion Phase Change with Temperature:	0.1° per °C maximum
T/R Time:	12 microseconds

*Includes insertion match and tracking unit-to-unit, differential phase shift error (both with frequency and temperature as well as calibration accuracy. Insertion phase errors due to temperature variation across the array are not included.

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multiforme, a lethal brain tumor that usually leaves its victim dead within 24 months of diagnosis. Salcman removed as much of the cancer as he could, then inserted an antenna and a tiny thermometer directly into the remaining tumor and sewed up the man's head with the antenna still in it. Two times during the next 48 hours Salcman sent microwaves directly into the tumor, heating it to 45°C (113°F). The patient was awake and reported no pain, says Salcman, who has recently repeated the operation on a 30-year-old woman.

"There appear to be indications of a decrease in tumor size," says George Samaras, the biophysicist who developed the technique with Salcman, "but we'll have to wait six months to a year to really tell."[20] ‡

Risk and Who Should Assess It

Of course, no one can say that an activity is risk free, regardless of its benign history. Numerous examples of carcinogens in foods and industrial processes, of mishaps in chemical and nuclear processes, of design flaws in buildings and bridges, autos and aircraft point to the fact that our modern lifestyle is not maintained without the encumbrances

". . .As our understanding. . .grows. . . the question. . .is not whether we will have risk. . .but how much risk and from what source." — David Bazelon, Senior Circuit Judge

of risk. Consider how David Bazelon,[21] Senior Circuit Judge, US Court of Appeals, Washington, DC assesses this condition:

> " . . . Ironically, scientific progress not only creates new risks but also uncovers previously unknown risks. As our understanding of the world grows exponentially, we are constantly learning that old activities once thought safe, in fact pose substantial risks. The question then is not whether we will have risk at all but how much risk and from what source. Perhaps even more important, the question is who shall decide.
>
> " . . . we have learned that even our experts often lack the certain knowledge that would ease our decision-making tasks. Often the best we can say is that the product of an activity poses a *'risk of a risk.'*
>
> " . . . Some well-meaning scientists question the wisdom of leaving risk regulation to the scientifically untutored. . .They observe the public's alarm at the prospect of nuclear power and note that the same public tolerates 50,000 automobile deaths a year.
>
> " . . . To those who feel the public is incapable of comprehending the issues, and so unable to make informed value choices, I respond with the words of Thomas Jefferson:
>
> > 'I know of no safe depository of the ultimate powers of the society but the people themselves; and if we think them not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion.'
>
> " . . . Delay from unjustified fear of the future can in the long run cause more harm than the risks it prevents (although) . . . delay that is necessary for calm reflection, full debate, and mature decision more than compensates for the additional costs it imposes."

‡ As of December, 1980, the first patient to receive this treatment has returned to an active life and the second patient, who came into the hospital bedridden before surgery and walked out two days later, is also doing well. The surgeon performing this procedure has increased his case load from one patient a month to one patient a week.

ARE WE MICROWAVE SPOKESPERSONS?

If the informed public is to be the final judge of the risk-benefit tradeoffs of microwaves, then I submit that the basis for this information must come from us, who practice in the microwave field daily. This means that the cocktail party question is not unimportant to the microwave field, despite its apparently casual incidence; and, to answer it, we need to acquaint ourselves with as much information as possible about the hazards, myths, political implications and related considerations of microwaves that confront the public awareness. In short, we must each have an informed viewpoint about microwave radiation hazards.

This spokesperson role is a new one for professionals whose customary reaction to questions outside of their immediate sphere of expertise is to defer to the experts in the field, e.g., "I'm a filter specialist, not microwave bioeffects." In this case, that won't suffice. There just aren't enough spokespeople like John Osepchuk[15,22] to cover all of the cocktail parties, Kiwanis talks and other events at which the broad public interest must be addressed. Everyone of us, microwave professionals, must accept responsibility for the public presentation of our field's strengths as well as weaknesses and to do so we must as individuals have our own informed opinions about microwaves in the environment.

". . .microwave professionals, must accept responsibility for the public presentation of our field's strengths. . . ."

Hope to hear of your oratory at the next cocktail party.

REFERENCES

1. Brodeur, Paul, *The Zapping of America, Microwaves, Their Deadly Risk and The Cover-Up*, Norton Co., New York, 1977.
2. *Consumer Reports*; "Not Recommended: The popular models we tested leaked radiation at levels we can't be sure are harmless," April 1973, pp. 221-230; "Microwave ovens: still not recommended," August 1973, pp. 489-491; "Microwave ovens: we can tell you how well they performed but no one really knows how safe they are," June 1976.
3. Position Statement, Dec. 6-7, 1979, IEEE Committee on Man and Radiation (COMAR), Institute of Electrical and Electronics Engineers, NY.
4. *Patty's Industrial Hygiene and Toxicology*, Third Revised Edition, J. Wiley, N.Y., 1978, pg. 362.
5. Gandhi, Om. P., Sc.D., "Dosimetry — the absorption properties of man and experimental animals." Buffalo, *N.Y., Academy of Medicine*, Vol. 55, No. 11, Dec. 1979, pp. 999-1017.
6. Nader, Claire, "The Dispute Over Safe Uses of X-Rays in Medical Practice," *Health Physics*, Pergamon Press 1975, Vol. 29 (July) pp. 181-206, printed in Ireland.
7. Justesen, Ragan, Rogers, Guy, Hjeresen, Hinds and Philips, (of Pacific Northwest Laboratory, Richland, Washington, 99352); "Compilation and Assessment of Microwave Bioeffects,"

(continued on page 26)

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(from page 24) ZAPPED?

Final Report on Contract No. EY-76-C-06-1830, May 1978, DOE/NASA, pp. 5-6.

8. Carpenter, Russell L., "Ocular Effects of Microwave Radiation," *Bull, N.Y. Acad. Med.*, Vol. 55, No. 11, December 1979, pp. 1048-1057.
9. Licht, Sidney, M.D., *Therapeutic Heat and Cold*, Waverly Press, Inc., Baltimore, Md., Second Edition, 1972.
10. Dark, E. P., *Diathermy in General Practice*, Sidney, 1929.
11. Denier, A., "Les Ondes Hertziennes Ultracourtes de 80 cm.," *J. Radiol Electrol.*, 20: 193, 1936.
12. "Microwave Hazards," a Special Report, *IEEE Spectrum*, May 1979, pp. 66-68.
13. Barasiski, S., and P. Czerski, *Biological Effects of Microwaves*, Dowden, Hutchinson and Ross, publishers, Stroudsburg, Pa., USA, 1976, pp. 183-187.
14. Michaelson S., et al., Editors, *Fundamental and Applied Aspects of Nonionizing Radiation*, Plenum Press, N.Y. (1975), page 432.
15. Osepchuck, J., IEEE Technical Activities Board, Committee on Man and Radiation (COMAR) Statement before the United States Senate Committee on Commerce, Science, and Transportation, June 17, 1977.
16. Steneck, Cook, Vander & Kane, "The Origins of US Safety Standards for Microwave Radiation," *Science*, Vol. 208, 13 June 1980, pp. 1230-1237.
17. Hindin, H., "Microwaves Help Detect Tumors," *Electronics*, April 12, 1979, pp. 85-86.
18. Carr, El-Mahdi and Schaffer, "Dual Mode Microwave System to Enhance Early Detection of Cancer," *IEEE 1980 Symposium Digest*, pp. 347-350. (Will be published soon in *IEEE MTT Transactions*).
19. Silberner, J., "Hyperthermia, Hot Stuff in Cancer Treatment," *Science News*, Vol. 118, Aug. 30, 1980, pp. 141-142. Also see this issue L. Taylor, p. 66.
20. Taylor, L. private communication.
21. Bazelon, David L., "Risk and Responsibility," *Science*, Vol. 205, 20 July 1979, pp. 277-280.
22. Osepchuk, John, "The Conning of America," *Microwave Journal*, October 1978, p. 18, J. Osepchuck is with the Raytheon Co. and has been a leading spokesperson for the rational evaluation of microwave usage.

Joseph White is the Technical Director of Semiconductor Operations at Microwave Associates, Burlington, Mass. and Consulting Editor of the *Microwave Journal*. His doctoral thesis at Rensselaer Polytechnic Institute described the first application of bulk semiconductors to high power periodically loaded line phase shifters, a phase shifter design which he invented. The IEEE Microwave Theory and Techniques Group awarded Dr. White its 1975 Application Award for "The development of practical high power PIN diode phase shifters utilized in various phased array radars."

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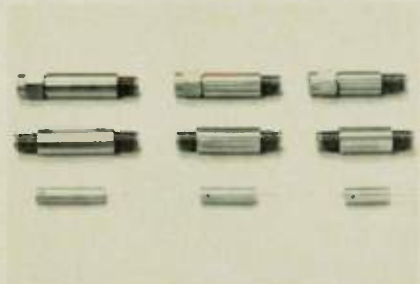

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DT9A1P	2.0-18.0	450	−48
Schottky*			
DS1C1N	0.5- 1.0	2000	−54
DS6A1N	8.0-16.0	1500	−52
DS9A1N	2.0-18.0	1000	−51

*Bias = 100 - 200 μamp

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OMNIYIG MODEL NO.	FREQUENCY RANGE (GHz)	INSERTION LOSS (dB)	STOPBAN REJECTI (dB)
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OFC-280	2.8-3.5	0.5	40
OFC-290	3.7-4.2	0.5	40
OFI-190	2.0-4.0	0.75	60
OFI-200	4.0-8.0	0.75	60
OFI-210	8.0-12.0	0.75	60
OFH-300	1.08-1.12	0.65	50
OML-104	2.09-2.15	2.5	30
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The European Microwave Industry

HOWARD I. ELLOWITZ, Publisher

INTRODUCTION

Consider the fact that US microwave component and subsystem companies have seen their sales grow by an average of 25%/year and their profits by 35%/year for at least the past two years. Consider, also, that sales into Europe generally represent a larger proportion of their total business now than they did two years ago. How, then, would you expect the business of their British, French and German counterparts to have fared during that time? And what are their prospects for the next few years?

Answers to those questions and others were collected in a series of interviews conducted in October 1980 during plant visits and in meetings during the Military Microwaves Exhibition in London. The picture that emerges from the replies is that of a European microwave industry which is every bit as vibrant as that of the US. Long-established European companies have posted growths comparable to those reported in the US. In addition, newer ventures, either those involving relatively new companies or new market efforts by established companies, have experienced the well-above-average growths that are common to new ventures in the US.

MICROWAVE TUBES

While the nature of the microwave tube business precludes growth at the rates possible for semiconductor and component activities, Dr. Christian Schenk, Marketing Manager for AEG Telefunken, Dr. Roger Agniel, Thomson CSF Marketing Director, Peter Butcher, Microwave Sales Manager at English Electric Valve, Werner Salecker of Siemens and J. M. Low, Ferranti, Dundee indicate that each of their operations has grown at a very acceptable rate during the past year. In some instances, there were specific contributors identified. In AEG's case, delivery of tubes to four satellite programs involved twice the number delivered in 1979. A new high power TWT line is beginning to contribute heavily to

Giga Instrumentations's 8-12.4 GHz source offers pulse modulation with rise and fall times of 5 nS and pulse widths down to 50 nS.

EEV's results and a new factory occupied by this line during 1980 is expected to maintain its effect. Finally, Siemens has benefited rapidly from a Bell Telephone/AT&T decision to buy 6 GHz tubes from outside suppliers.

Most significant growth in Thomson's tube business during the past year has come from expanded requirements for militar system and commercial communications TWT's. The same is true at EEV where, in addition, strong increase in the demand fc receiver protection devices has been noted. On the debit side as far as the tube industry is concerned, according to Peter Butcher, most of this demand will b satisfied with solid state rather than gas discharge designs and EEV is making a strong effort tc continue to serve that market.

Ferranti Dundee's power tub growth was an outsized 50% in 1980 but Low ascribes that performance to some maturing pro grams which took faster-than-normal delivery of high power klystrons and TWT's. He also notes a 50% growth in his expor sales which consisted largely of lower priced gas discharge receiv er protection tubes. The largest portion of that growth was in th US; Japan was also a very signifi cant customer.

Solid state continues to make inroads into the low power tube business. Both Dr. Agniel and Dr. Schenk project a continuing decline in the reflex klystron market of about 20%/year and AEG further sees an early end tc the demand for replacement pla nar triodes. European marine ra dar magnetron markets are similarly impacted by the successful Japanese effort to market syster which use their own tubes.

For the future, European tub manufacturers are looking at the

(continued on page 3(

Design and development, long or short-term projects...

(from page 29) INDUSTRY

European domestic satellite systems as a major growth opportunity for them. Beyond that, there is continuing interest in higher power millimeter-wave sources, military satellite communication systems and the potential for amplifier-type transmitting systems for sophisticated radars.

A NEW INSTRUMENT SUPPLIER

While genuine new ventures in the microwave business are more the exception than the rule in Europe, Giga Instrumentation, founded five years ago, has a start-up history which is very impressive. Through September 1980, its sales amounted to 10M FF, an increase of more than 70% over last year and a 50% growth next year is anticipated. 25% of that volume is export business. According to Christophe Barbier, its President, the company currently supplies approximately 90% of the French military requirements for microwave sources for 1-18 GHz applications. Further, he sees his best growth potential in a continuing demand for military radar test sets for which the Giga instruments are particularly well suited.

Because the generator designs rely heavily upon components imported from the US, it is impractical to consider US sales. The company enjoys a unique position in Europe, however, and its success addes to the overall brightness of the European microwave picture.

PASSIVE COMPONENTS

In the passive component area, European company overall growth rates appear to parallel those of US suppliers. Their experience in new product areas is similar, as well, with growth exceeding 100%/year in start-up situations. Dominique Joannes Boyau, Marketing Manager of Tekelec-Airtronic, the French Johanson licensee, forecasts a growth in his air trimmer line of 25-30% in 1981. He enjoyed a 100% growth of new GIGA-TRIM capacitor sales in 1980 and expects a similar expansion of his new waveguide tuning element sales in 1981. Eugene Eisenberger, Radiall's Commercial Director, indicates a growth exceeding 30%/year and considers the fact that their product capabilities compare favorably with US offerings to have influenced these result heavily.

Looking at future growth, both companies consider Germany and England to offer the best opportunities for increased export sales in Europe during the next few years. In product areas, Tekelec-Airtronic is relying on its new GIGA-TRIM capacitors and new tuning elements to con-

(continued on page 31)

Model 455/1 phase locked Gunn oscillator from G & E Bradley's Microwave Division delivers 100 mW at 30 GHz.

ribute significantly to its growth. Dominique Pochard, Technical Microwave Manager of Radiall, expects that the expansion of their attenuator and termination, coupler and rotary joint lines, the last of which is particularly well suited to the mechanical design and fabrication strengths of the company, will make the major contributions to growth. At the same time, he indicates that the Radiall measurement component line, which has not been marketed aggressively, will continue to be deemphasized as will their waveguide work so that production volume coaxial business can be emphasized.

ACTIVE COMPONENTS

At RTC in Paris, an operation involved in microwave bipolar transistors and YIG oscillators beginning its fourth year has had impressive results. Jacques Barbier, Product Manager for the Department reports that transistor sales during his third year were seven times his first year's shipments and oscillator sales tripled during the same period. He expects both lines to continue to grow at a 100% per year rate during the coming 2-3 years. A medium power GaAs FET line is currently being introduced with the expectation that it will enjoy a similar growth.

The TH 3608 is an 11 GHz, 20 W TWT for digital microwave links, developed by the Electron Tube Division of Thomson-CSF.

Existing business is primarily in the military market and includes some US sales of JAN-TX qualified devices through Amperex. Barbier views Italy as his most promising export growth opportunity and considers Germany and the UK to be good prospects.

Discussions with four UK producers of active components and subsystems indicate a growth pattern very similar to that shown by comparable US operations. Both John Clifford, Sales Director for Continental Microwave and John Penny, General Manager of Ferranti's Microwave Division report sales increases of the order of 25% over last year. Peter Harwood, Division Manager, indicates that this year's sales of G&E Bradley's Microwave Division were up by 41% and, according to Stephen Matykiewicz, Marketing Manager for Marconi Electronic Devices Power and Microwave Division (formally AEI Semiconductor), his sales were up 100% over the previous year.

With the exception of G&E Bradley which counts 40% of its business in exports to other EEC countries, the bulk of the sales of this group is within the UK. As John Penny pointed out, the export market for UK producers has been adversely impacted by the strength of sterling during the past two years and, in his case, export sales have been flat during the past year.

(continued on page 3

While each of these producers focuses on rather different specific products, an increasing military system production activity in Europe has fueled much of the growth of all four. Increasing demand for solid state linear power amplifiers up to 4.2 GHz including a specific requirement for 40 W up to 2 GHz has been a major contributor to Continental's results. John Clifford also believes that the time and talent available to system houses to do this kind of design work in-house is becoming scarcer and that more of the business will be available to subcontractors.

Brian Hutchins, Assistant Sales Manager at G&E Bradley, pointed to increasing military system demands for his phase modulated phase locked oscillator as a major factor in last year's growth. He also expects that new Q-Band Gunn sources (100 mW at 26 GHz and 80 mW at 40 GHz) will make significant contributions during the next few years.

A complete in-house semiconductor capability reinforces an experienced circuit design group and enables Marconi to respond effectively to a growing demand for its mixers, PIN switches and other standard and custom components for applications extending into the mm bands. The custom design portion for military applications is largely responsible for Marconi's dramatic growth during the past year.

None of the suppliers notes a serious reduction in demand for any particular product in the past year. However, John Clifford notes the growing use of synthesizers in place of phase locked oscillators in satellite communications applications. He forecasts that as much as 80% of the earth station oscillator business in 1981 will involve synthesizers.

While there are many reasons for optimism when European microwave companies consider their prospects for 1981, a few notes of discord can be heard. The full effect of the British MOD spending moratorium is uncertain. Originally expected to expire in November, its extension to April 1981 has been announced and, at this point, it is not possible to predict its total impact on 1981 business levels. In addition, European companies are beginning to suffer from a shortage of engineering staff. Since there was no concern on this subject voiced during a similar round of meetings in September 1979, the shortage has developed in a remarkably sudden manner. Its existence is further evidence of the excellent present health of the industry but it will certainly affect the rate at which it can continue to grow.

SMALL EARTH STATION TERMINALS

Brightening prospects that a number of European domestic satellites (TDF-I, TV-SAT, Telecom I, ECS) will indeed be launched during the early '80s have stimulated a vigorous interest in the small earth station component market. Virtually every company interviewed whose product line is at all applicable is working actively on the development of components for small earth station applications. Siemens is developing an 11.5-12.5 GHz GaAs FET amplifier and a 0.9-1.7 GHz IF amplifier which uses a dual-gate FET, both of these for satellite TV receivers. Siemens also has a 14 GHz uplink tube ready for ECS ground station applications. Thomson CSF will supply a 160 W 14 GHz tube for Telecom I ground stations and a 17 GHz klystron for TDF-I stations. Radiall expects to supply 95% of Telecom I's earth stations components. Ferranti's microwave division has demonstrated a complete mobile 2-way 11/14 GHz small earth station intended for the professional portion of the market, i.e., remote broadcast pickup, teleconferencing, high speed data traffic. That division also supplies down converters, up converters etc. G & E Bradley is exploring oscillators for millimeter-wave satellites system ground terminals. Marconi Electronics is working toward components and subsystems for the small earth terminal market. EEV considers the market a major growth area for its TWT's and has amplifiers designed for small military terminals. Continental Microwave has supplied components for large earth stations during the past 6 years and has 11/14 GHz designs completed. And Ferranti, Dundee is developing a line of multiplexers for earth station use.

Beyond their prospects in the satellite earth station market, the European companies are actively exploring other opportunities for growth. Konrad Pobl at Siemens discussed that company's present capabilities in silicon Schottkys and varactors and their 1 μm GaAs FET currently in production. According to Pobl, Microwave Semiconductor Inc., the Siemens' New Jersey subsidiary, will continue to concentrate on power GaAs FET's and it will market the Munich-produced low noise devices. Noting that more than 50% of new 4-6 GHz link transmitters are now solid state, Siemens looks to designs employing paralleled GaAs FET's to replace IMPATT-equipped transmitters when performance requirements are compatible. With the widespread conversions of links to digital operation, a 7-11% per year radio link growth estimated. In its first major effo to penetrate the military market Siemens is developing a line of multi-octave low noise GaAs FE amplifiers for applications to 8 GHz which will use its devices.

In anticipation of requiremen for millimeter-wave communication satellite system component AEG is continuing its development of 20/30 GHz space segment tubes. Also, in an unrelate application of its metal/ceramic vacuum technology experience, AEG has developed an extensive line of vacuum power station switches intended for use in plac of the usual oil-immersed designs.

Thomson's tube exports to th US continue to increase at a slov rate. While few new opportunities for tube sales have materialized during the past year within the industrial heating and mm markets, they are still considere

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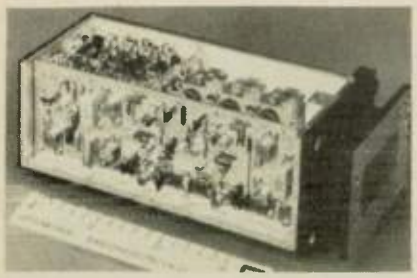


EEV BS313 high power solid state receiver protection unit is biased during transmission by a pulse which completely envelopes RF pulse.

One of Continental Microwave's line of mechanically tuned microwave synthesizers.

Ferranti's 16 THD Isotran.

areas of significant growth.

RTC expects to begin to deliver 250 mW 8 GHz GaAs FET's by the middle of 1981. Its development of Gunn-based YIG oscillators for ECM applications continues and wider bandwidth FET-based YIG tuned designs are being explored. The company is also watching the 900 MHz mobile telephone market and anticipates a strong demand for either devices or modules, both of which they would be able to supply.

Ferranti's Microwave Division sees the decision that all UK telephone nodes be refitted to handle 48 K bits/sec within 2-3 years as an opportunity for a significant amount of component business. There was concern here about possible Japanese interest in microwave components, especially commercial equipment GaAs FET amplifiers. There was also some speculation that links with European firms are being explored.

G & E Bradley's Microwave Division is looking at 64 GHz Gunn oscillators for high data rate millimeter satellite system ground stations. In addition, fast switching synthesizers for frequency agile radar applications are under study.

MO Valve's new miniature magnetron capability is a major consideration in its future planning. An integrated modulator/magnetron assembly will also be offered shortly. The small tubes are particularly suited to guided weapon applications. An available X-band version is to be followed by S-, K- and Q-band designs.

Marconi Electronic Devices expects to expand its line of low-noise GaAs FET amplifiers for EW applications. A monolithic GaAs IC program is also underway at Marconi Research Laboratories. Their mm-wave component line, particulary mixers, will be expanded; commercial models are available up to 94 GHz, research is being done to 200 GHz. In addition, SAW low loss filters and oscillators for military and high quality commercial applications are in development.

Continental Microwave has a 1 1/2 octave low-phase noise synthesizer with switching speeds of 200 μs ready for phase-locked oscillator replacement in military applications. It also expects to introduce a ferrite product line and is exploring possible entry into some passive component markets.

Ferranti, Dundee is developing TWTA's for military radars and also plans to offer power supplies compatible with other manufacturers TWT's. The company plans to continue its high power ferrite work which takes advantage of its special test capabilities in that area. A line of microstrip mixers is contemplated and additional staff has been added to handle their sponsored research programs in filters, TR's and ferrites.

MILITARY MICROWAVE '80

The Military Microwaves '80 Convention at the Cunard Hotel in London on October 22-24 supplied final confirmation of the vigorous health of the microwave industry, both in the US and Europe. Products of 238 companies, the largest number ever to participate in the series of European Microwave Conference/Military Microwaves Exhibitions, were on display at this year's event.

Dr. John Clarke of the Royal Surface Radar Establishment chaired the Technical Program Committee which prepared a program of 92 papers in which nine countries were represented. Over 700 delegates representing 30 countries registered for the conference. The applications-oriented program and the broad display of devices, components and subsystems were particularly well matched and interaction between conference delegates and the Exhibition was excellent.

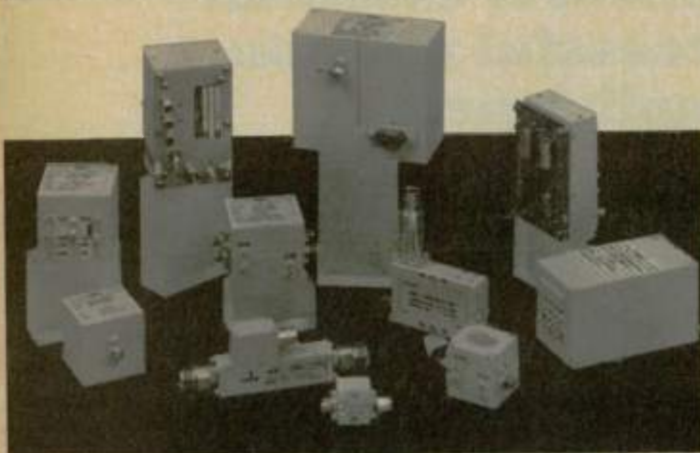
The 1981 Exhibition is scheduled for September 8 - 11 in Amsterdam in conjunction with the European Microwave Conference. The next Military Microwaves Convention will be held in 1982 in the UK.

CONCLUSION

The series of interviews in October of last year together with the final flurry of activity at Military Microwaves '80 paints a picture of a European microwave industry that is difficult to distinguish from the present US image if sheer size differences are discounted. Available existing markets are expanding and new markets are emerging to support growth rates in Europe akin to those being enjoyed in the US. Acquisitions of US subsidiaries by some large European companies during the past two years serve clear notice that they may not be content with simply keeping pace with those rates. Few of any size did not indicate some desire for more sales into the US. That pressure can only increase during the coming years. ■

CIRCLE 36 ON READER SERVICE CARD

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[2]	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[2]	30	<4 dB	30 dBc[1]	60 dBc	2.5 kHz p-p	−5 V @ 15 mA	0 V @ 0 mA
SDVX-2111	25-305	20	±0.2 dB[2]	30	<4 dB	30 dBc[1]	60 dBc	1.5 kHz p-p	−15 V @ 15 mA	0 V @ 0 mA
SDVX-2112	90-510	20	±0.2 dB[2]	30	<4 dB	30 dBc[1]	60 dBc	1.5 kHz p-p	−5 V @ 15 mA	0 V @ 0 mA
SDVX-2000	235-515			50	<4 dB	20 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 assembly meeting specific system applications.

		MODEL:	Frequency Range *(GHz)*	Bandwidth *(MHz, Min.)*	Insertion Loss *(dB, Max.)*	O.R.I. *(dB, Min.)*	O.R.S. *(dB, Min.)*	PB Ripple & Spurious *(dB, Max.)*	Linearity *(MHz, Nom.)*	Hysteresis *(MHz, Nom.)*
BANDPASS	Two-Stage	SDYF-4021	0.5–1	12	6.0	40	25	2.5	±2	4
		SDYF-4022	1–2	20	3.0	40	25	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

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CIRCLE 30 FOR LITERATURE
CIRCLE 31 FOR DEMONSTRATION

Around the Circuit

PERSONNEL

Carlton V. Phillips was elected to the Board of Directors of Ad-Tech Microwave, Inc. . .Datron Systems, Inc. appointed **Dr. Robert H. Stivers** as Manager of Communications Systems. Dr. Stivers leaves ITT Defense Communications Div. where he served as Manager of Satellite Communications. . .**Frederick G. Suffield**, Manager of Radar Programs for Teledyne Micronetics has been elected Director of Region 6 (West) of IEEE and a Member of its Board of Directors. . .Sealectro Corp.'s Board of Directors elected **Leonard Kamsky**, Senior Vice President of W.R. Grace & Co. as one of its Directors, which total nine in number after a recent admentment in Sealectro's by-laws. . .Kyocera Int'l, Inc. announced the appointment of three regional sales representative for its Electronic Component Division. **Major St. John** was named Regional Sales Coordinator of Southern Calif., **Don Smithanna** becomes representative of sales of the Midwest and **Marty Kazula** will coordinate sales for the Central/Western Canadian Regions. . .Narda Microwave Corp. appointed **William M. Reich** as its Publications Manager. . .**William A. Johnston** has re-joined Omni Spectra, Inc. as Sales Manager of its Microwave Cable Assembly Div. . .**Rodger Billings** was appointed Engineering Mgr. of Ferrite Devices for Western Microwave Inc. . .Western also announced the appointment of **Richard G. Sanders** as its Director of Marketing. . .In a recent reorganizational move, Scientific-Atlanta, Inc. divided its Satellite Communications Div. into two separate divisions. **Ray Stuart** was named General Mgr. of the new Commercial Telecommunications Div. and **James S. Gray** was appointed General Mgr. of the Business Telecommunications Div.

CONTRACTS

Hazeltine Corp. received a $1.2M US Navy contract from Naval Sea Systems Command for the development of a digitally programmable communications buoy and buoy interface unit for use in submarine communications via satellite. . .**Sperry Corp.**'s **Sperry Div.** was granted orders for 50 CAS II collision avoidance systems valued at $2M from several Japanese shipowners, with **Sanko Steamship Co. Ltd.** of Tokyo as the largest single purchaser. . .**Ray-Proof Div. of Keene Corp.** received a contract from Walter Reed Army Institute of Research, Microwave Research Lab., for the first 96 GHz RF anechoic chamber for medical applications. The $107K contract is to design, install and test the chamber to shield animal tissue experiments from extraneous RF signals. . . **RCA** was granted a $203M Navy contract from Naval Sea Systems command for additional AEGIS Weapon Systems. . .**ITT Avionics Div.** announced the award of $16.3M contract for AN/ALQ-136 radar jammer ECM sets from the US Army ERADCOM.

NEW MARKET ENTRY

Radant Systems, Inc. is a newly formed US corporation chartered to design, develop and produce electronically scanned antennas which utilize diode lens techniques, radar ECCM devices, radomes and other associated products. Company is headed by Gilbert Bony, C.E.O. and Richard Park, President and has George Randig as Chief Engineer and Fred Goodrich as Marketing Manager. Radant occupies a new 70,000-square-foot facility located at 255 Hudson Road, Stow, MA 01775. Tel: (617) 562-3866.

INDUSTRY NEWS

T-CAS America, Inc., a communications engineering firm in Falls Church, VA, has purchased **REL, Inc.**, a supplier of troposcatter radio equipment based in Boynton, FL, and REL will be a wholly-owned subsidiary of T-CAS America. . .At the **Hewlett-Packard Santa Rosa Division**, a corporate reorganization has resulted in the formation of two new divisions and a "technology center" – the **Signal Analysis Div.**, managed by Richard C. (Rit) Keiter, the **Network Measurements Div.**, headed by Wilhelm L. (Bill) Wurst, and the **Microwave Technology Center** managed by George E. Bodway. . .A 110,000 sq. ft. R&D facility was dedicated in Reston, VI by the **Sperry Div.** of **Sperry Corp.** Some 350 employees there will be engaged in designing and developing shipboard electronic and combat systems, EW systems and performing various defense support services. . . **Narda Microwave Corp.** has commenced construction of a new main 150,000 sq. ft. manufacturing plant and office facility on a 17-acre tract in Hauppauge, Long Island, NY. . .**Ad-Tech Microwave, Inc.** has moved its engineering and manufacturing operations to larger facilities at 7755 East Redfield Road, Scottsdale Industrial Airpark, Scottsdale, AZ 85260. Tel: (602) 998-1584. A 125,000 sq. ft. building is under construction in Mountain View, CA to consolidate key administrative and engineering functions at the **GTE Western Division of Sylvania Systems Group**. Some 450-500 employees will be working adjacent to the division's main complex. . .**Rockwell Int'l Corp.** announced the reorganization of its Electronic Operations into Defense Electronics, with Donald J. Yockey as President and Commercial Electronics, with Paul G. Stern as President.

FINANCIAL NEWS

Alpha Industries, Inc. reported second quarter results for the period ended September 30, 1980 of net sales of $6.45M, net income of $1.1M on earnings per share of 23¢. This compares with 1979 second quarter net sales of $4.7M, net income of $735K on earnings per share of 20¢. . .**Radiation Systems, Inc.** has first quarter results of 1980 for the period ended September 30, 1980 of sales of $1.76M, net earnings of $180K on earnings per share of 23¢. During the comparable quarter of 1979, sales totaled $1.3M, net earnings were $162K and earnings per share were 21¢. . .For the nine months ended September 30, 1980, **Raymond Industries, Inc.** reported sales of $29.98M, net earnings of $4.69M or $4.83 per share. During 1979, nine-month sales were $24.9M, net earnings totaled $1.0M or $98¢ per share. . .**Adams Russell** reported year-end results for the period ended September 30, 1980 of net sales of $36M, net income of $2.7M or 94¢ per share. This compares with 1979 annual net sales of $28.4M, net income of $1.9M or 71¢ per share. . .**Sealectro Corp.** announced third quarter results for the period ended September 26, 1980 of sales of $10.4M, net income of 693K or earnings per share of 47¢. This compares with 1979 third quarter sales of $8.3M, net income of $940K of earnings per share of 64¢.

Your brains.

Our brawn.

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For EW/ECM/ECCM high power jamming, our solid state add-on amplifiers will give your low power radio transmitters/transceivers a big boost.

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Question: How about EW/ECM? Is there a practical way to increase power output, thus expanding operational versatility and allowing it to also be used as an ECM jammer? (and/or ECCM jamming override to reduce vulnerability while in communication mode). Replacing the equipment with an entirely new, higher power system would work, but the cost could create a problem. What to do?

Answer: Don't give up on your "brains"! Instead, call in our "brawn", in the form of a solid state add-on booster amplifier to increase your power output. MPD's specially designed amplifiers, complete with automatic T/R switching, are available for frequency bands of 20-100, 100-500, 500-1000 and 1000-1400MHz, with output powers from 200 watts up to 2KW, in fully militarized configurations.

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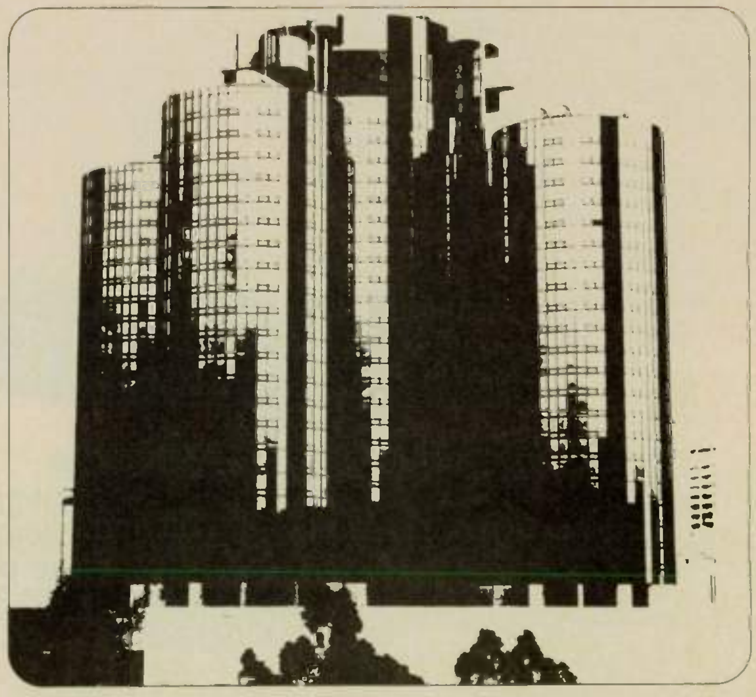


FCC Opens Up K-Band for Low Cost Communications

DR. JEFFREY A. KRAUSS, Director, Regulatory Polici
M/A-COM Laboratories, Germantown, M

There is a public need for low power communications devices in the 24 GHz band that can operate without the cost of licensing and frequency coordination. Available bandwidth, propagation effects, and low output power will result in a service with a low probability of unacceptable interference. The user will have the flexibility to trade off bandwidth, cost and equipment complexity in order to achieve the level of signal quality that is acceptable for his specific needs. Because the equipment will be based on microwave semiconductors produced in high volume by a number of US manufacturers, the equipment costs will be kept low. At the same time, the creation of this new market will help to maintain the competitive vigor of the US semiconductor and communications equipment manufacturing industries.

The Federal Communications Commission, acting in response to petitions submitted by M/A-COM and General Electric Company, is making it easier, cheaper and faster for business users to get on the air with point-to-point microwave communications links in the 21-24 GHz range. The FCC has already adopted GE proposals that would cut equipment costs by allowing equipment with a relaxed frequency stability of ± 0.05%, as compared with the previous requirement of ± 0.03%. Now, in response to a M/A-COM request to eliminate the unnecessary costs and delays of frequency coordination and licensing, the FCC has proposed to allow uncoordinated operation and temporary licensing in a portion of the band. In addition, M/A-COM has asked the FCC to create a new personal radio service with even more flexibility in the 24.05-24.25 band, which is now used by police radars and intrusion alarms. This service would have equipment that is technically and economically compatible with the range of consumer electronics products that will impact our lives over the next decade. An FCC decision on these proposals is expected around the middle of 1981.

BACKGROUND

While low cost K-band Gunn oscillators have been commercially available for some years, the only commercial use of the band has been police radars and intrusion alarms. Even though the FCC has allocated a huge band of spectrum (21.2-23.6 GHz) for commercial communications use, it is only very recently that there has been any interest in using this band for communications. The reason, primarily, is the relatively short path length that is feasible, due to absorption of the signal by water vapor and occasional rainstorms. While there are a number of valuable uses for short distance point-to-point mi crowave links, traditional micro wave communications technology has been too expensive for these applications. The GE and M/A-COM proposals will result in very low cost equipment, anc will let users get on the air quicl ly with a minimum of paperwork.

THE GE PETITION

GE filed its petition in November, 1978, asking the FCC to allow low cost, low power micro wave transmitters (up to 100 m liwatts output power, 55 dBm effective radiated power) with 50 MHz channel bandwidth and relaxed frequency stability (± 0.05% rather than ± 0.03%). The 21.2-23.6 GHz band is split into four 600 MHz subbands, two for common carriers and two for private use; the GE request pertained only to the two 600 MHz subbands allocated fo private use.

MARKETPLACE NEEDS

This low cost microwave equipment has a great number c uses, and appears to meet marketplace needs that, until now, could not be served economically. As a video link it would allow remote surveillance of parking lots and satisfy related safety/ security and video conferencing needs. These needs exists because it is virtually impossible to get municipal approval to run a cable across a public street or thoroughfare. As a data link, the low cost microwave equipment would support local data networks running between buildings on a campus or office park. It would offer an alternative to the high speed data channels offered by (but often unavailable from) the telephone company. Other uses include vehicle location monitoring and flow control.

INITIAL FCC ACTION

Filing a petition asking the FCC to change the regulations is only the first step in a long process. The second step is for the FCC to issue a Notice of Proposed Rulemaking that informs the public that it tentatively favors the proposal. The FCC issued its Notice of Proposed Rulemaking (FCC Docket 79-337) in December 1979, proposing to allow the technical specifications that GE requested, but only within one-third of the two 600 MHz subbands. This amounted to 8 50 MHz channels or 4 channel pairs (for duplex operation).

The purpose of a Notice of Proposed Rulemaking is to solicit comments from the public and interested parties regarding the proposed new rules. M/A-COM filed comments supporting the marketplace need for low cost, short distance microwave links at K band, but pointed out that the costs and regulatory burdens of licensing and frequency coordination would still exist. Frequency coordination is the process whereby a potential microwave user calculates the likelihood that his microwave link will cause interference to other nearby microwave licensees. Understandably this can be a very expensive and time-consuming process. In fact, it was M/A-COM's view that the cost of frequency coordination could be about the same as the cost of the equipment itself. M/A-COM felt that interference at K band between different users was extremely unlikely because of the low power of the transmitters and the inherent attenuation of the band; thus, frequency coordination would impose a substantial unnecessary cost upon users. Similarly, it appeared that licensing would serve no useful purpose, and merely result in extra costs and extra delays of two to three months in getting on the air.

THE M/A-COM PETITION

Since M/A-COM felt that the administrative burdens of licensing and frequency coordination would be so substantial as to defeat the intent of the FCC Notice of Proposed Rulemaking, M/A-COM submitted its own proposal in the form of a totally separate petition. The M/A-COM petition asked the FCC to allow unlicensed, uncoordinated communication operation in the band 24.05-24.25 GHz, a band now used only for police radars and intrusion alarms. (Intrusion alarms are low power microwave transmitters that the FCC allows to operate without the need for licensing.)

M/A-COM proposed a maximum output power of 50 milliwatts for its communications equipment, a level that is consistent with that of intrusion alarms and far below police radars; thus the communications equipment would be no more likely to cause interference to existing users than equipment already allowed in the band.

The keynote of the M/A-COM proposal was user flexibility. Under its proposal, the sophisticated user would be able to trade off bandwidth, frequency stability, antenna gain, modulation and interference rejection in order to optimize for specific needs. The unsophisticated user would be able to go into his local video equipment store or personal computer store and buy a standard design off-the-shelf, then set it up wherever it was needed (including, possibly, his back yard), turn it on and use it. There would be no need for li-

 CIRCLE 27 ON READER SERVICE CARD

ensing or frequency coordina-
ion, because of the small likeli-
ood of interference. In those
ases where interference did oc-
ur, the equipment would be
mall enough to relocate or
hield.

'HE FCC FURTHER NOTICE OF 'ROPOSED RULEMAKING

Although the M/A-COM peti-
ion dealt with a somewhat dif-
erent frequency band than that
riginally specified by GE in its
arlier petition, the proposed
ises and marketplace needs were
imilar. Consequently, in a Fur-
her Notice of Proposed Rule-
naking issued August 19, 1980,
he FCC incorporated the M/A-
COM petition into the ongoing
roceeding and proposed to ap-
ly some of the M/A-COM ideas
o the 21-23 GHz band.

In particular, the FCC pro-
osed to allow operation in one
0 MHz channel pair (21.800-
1.850, 23.000-23.050 GHz)
vithout the need for frequency
oordination. The FCC also
isked for comments on the idea
of "temporary licensing" in this
and; the user would fill out a
emporary permit that would
erve as a license while the FCC
s processing the regular mailed-
n license application. This ap-
roach is already applied to CB
nd recreational boating mobile
adio licenses.

The traditional requirement
or a license is tied to the FCC's
raditional role of guaranteeing
reedom from interference to its
icensees. The license is an en-
orcement tool. However, M/A-
COM presented the view that at
K band, with such low power
hat made interference very un-
ikely, the licensing process was
n unnecessary burden that sim-
ly added delay and produced
o benefits. On the other hand,
he FCC's notion of temporary
icensing could eliminate that de-
ay, and thus M/A-COM supports
emporary licensing as a reason-
ble alternative to unlicensed
peration.

Frequency coordination is
till a burden, and the one 50
MHz channel pair that the FCC
as proposed for uncoordinated
peration will not be sufficient.

One channel pair may be ade-
quate for users that fix their
equipment permanently in place
(GE has said that two channel
pairs should be allotted to unco-
ordinated, fixed operation), but
there are also mobile and tempo-
rarily-fixed requirements. A typi-
cal mobile application would in-
volve low power microwave
transmitters mounted on buses
for controlling traffic signals; in
this way, the bus can keep a
green signal from changing to red
until the bus has cleared the in-
tersection. There will also be a
need for temporarily-fixed video
links to handle conventions, vid-
eo conferences, sports events and
to meet seasonal peak loads on
fixed links. Consequently, M/A-
COM told the FCC that addition-
al channels should be allocated
for uncoordinated operation of
these mobile and temporarily
fixed links.

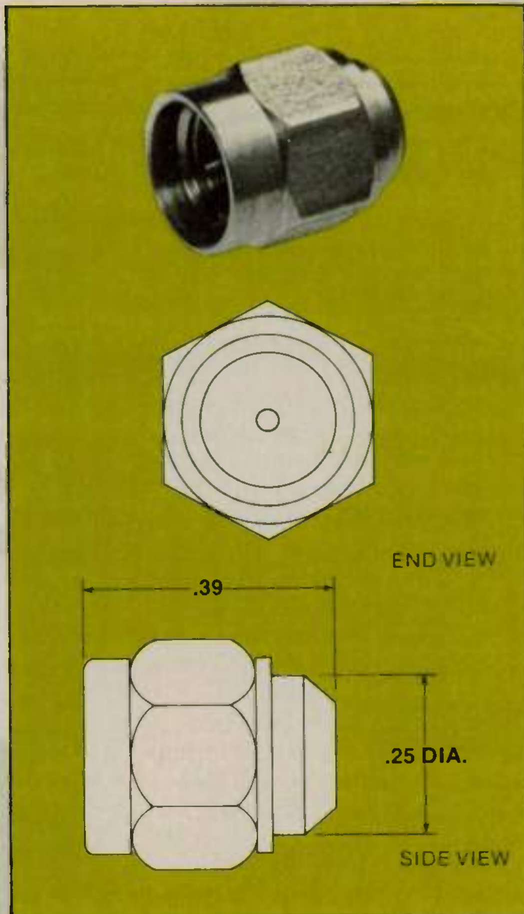
A NEW PERSONAL RADIO SERVICE

Since the original M/A-COM
proposal for unlicensed operation
would not impose any eligibility
requirements, anyone would be
allowed to own and operate the
microwave links. The FCC's re-
cent proposal in its Further No-
tice, however, would impose the
same eligibility limitations that
now apply to other private mi-
crowave, found in Part 94 of the
FCC Rules. While these eligibility
requirements are complex and
cover a diversity of categories,
the categories are all institutional
or business-related. A private in-
dividual would not be eligible for
a low power microwave license
under the FCC's proposal.

M/A-COM believes that there
will be a real need for a personal
radio service in the microwave
band. There will be video appli-
cations: links between a satellite
earth station or an MDS receiver
and the home TV set, and links
between a videotape camera and
a videotape recorder, for making
the modern version of "home
movies." There will also be data
applications, links between home
computers. These consumer elec-
tronics applications could not be
satisfied under the proposal in
the FCC Further Notice.

(continued on page 47)

SMA TERMINATIONS



0.5, 1, 2, 5 AND 10 WATTS

- DC to 18.0 GHz
- SMA Connectors
- 1.05 + 0.008 fGHz Maximum VSWR
- -54°C to +125°C
- Excellent Reliability
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These high performance SMA Terminations have been designed for today's sophisticated Microwave Systems. The connectors are fabricated from stainless steel and do meet the requirements of MIL-C-39012. The close tolerance machining plus the precise captivation techniques ensure an excellent match over the complete frequency range. All MMI Terminations are production tested using the latest state-of-the-art swept frequency techniques.

MMI 2444* **

Input Power @ 25°C:	0.5 watt
Frequency Range:	DC to 18.0 GHz
Connector:	SMA M/F
Impedance:	50 ohms
VSWR, Maximum:	1.05 + 0.008 f(GHz)
Temperature Range:	-54°C to + 125°C
Construction:	
Connector:	Stainless Steel
Body:	Stainless Steel
Length, Maximum:	0.44"
Diameter:	0.25"
Delivery:	Stock to 30 days ARO

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MMI MODEL 2055* **

Input Power @ 25°C:	1.0 watt
Frequency Range:	DC to 18.0 GHz
Connector:	SMA M/F
Impedance:	50 ohms
VSWR, Maximum:	1.05 + 0.008 f(GHz)
Temperature Range:	-54°C to +125°C
Construction:	
Connector:	Stainless Steel
Body:	Stainless Steel
Length, Maximum:	0.58"
Diameter, Maximum:	0.29"
Delivery:	Stock to 30 days ARO

MMI MODEL 2013* **

Input Power @ 25°C:	10.0 watts
Frequency Range:	DC to 18.0 GHz
Connector:	SMA M/F
Impedance:	50 ohms
VSWR, Maximum:	1.05 + 0.01 f(GHz)
Temperature Range:	-54° to +125°C
Construction:	
Connector:	Stainless Steel
Body:	Black Anodized Aluminum
Length, Maximum:	1.62"
Diameter, Maximum:	1.30"
Delivery:	Stock to 30 days ARO

MMI MODEL 2057* **

Input Power @ 25°C:	2.0 watts
Frequency Range:	DC to 18.0 GHz
Connector:	SMA M/F
Impedance:	50 ohms
VSWR, Maximum:	1.05 + 0.008 f(GHz)
Temperature Range:	-54° to +125°C
Construction:	
Connector:	Stainless Steel
Body:	Black Anodized Aluminum
Length, Maximum:	0.92"
Diameter, Maximum:	0.50"
Delivery:	Stock to 30 days ARO

MMI MODEL 2010* **

Input Power @ 25°C:	5.0 watts
Frequency Range:	DC to 18.0 GHz
Connector:	SMA M/F
Impedance:	50 ohms
VSWR, Maximum:	1.05 + 0.01 f(GHz)
Temperature Range:	-54° to +125°C
Construction:	
Connector:	Stainless Steel
Body:	Black Anodized Aluminum
Length, Maximum:	1.30"
Diameter, Maximum:	1.00"
Delivery:	Stock to 30 days ARO

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CIRCLE 32 ON READER SERVICE CARD

rom page 43) UP K-BAND

Consequently, M/A-COM has enewed its call to the FCC to al- ow communications use of the ?4.05-24.25 GHz band. This vould be an ideal band in the pectrum for a new personal ra- lio service, technically and eco- iomically compatible with the ange of new consumer electron- cs for video and data uses. Once igain, the likelihood of interfer- ence to existing users would be ery small because of the low power, but the short links (up to perhaps 3/4 of a mile) would neet a need that is expected to grow.

THE NEXT STEP

When the FCC Further Notice was issued, it specified dates for comments to be filed in Septem- per and October, 1980. It nor- nally takes the FCC staff at least six to nine months after the com- nents are received to prepare a recommendation for the seven FCC Commissioners to vote on. (The FCC has in the past been willing to receive additional com- nents filed later than the speci- fied dates, so long as the com- nents supply useful information and there is some reasonable jus- tification for them being late.) Thus it appears that a final deci- sion from the FCC can be ex- pected in mid-1981.

In recent years the FCC has adopted a general policy of de- regulation and increased users' flexibility and diversity. The FCC has had the opportunity to apply these philosophies to common carrier commu iications, cable television and broadcasting. Un- til now, it has not really had the opportunity to address private point-to-point microwave. M/A- COM is hopeful that the FCC will deregulate by eliminating the unnecessary regulatory burden of frequency coordination and licensing delays; we are hopeful that the FCC will enhance user flexibility by instituting a new personal radio service in the 24.05-24.25 GHz band. Finally, in spite of the long tradition of government foot-dragging when it comes to removing regulatory burdens, we are hopeful that these changes will be adopted and implemented quickly. ■

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Weinschel high power attenuators and terminations are just another result of our innovative engineering, state-of-the-art manufacturing and quality control standards. For example: resistive films deposited on high thermal conductivity substrates eliminate the need for heat conducting liquids, thus reducing size and improving reliability. The substrates also withstand high-levels of shock and vibration. A proprietary film process produces resistive elements with outstanding qualities like: low temperature coefficients, very low aging rates and immunity to momentary overloads. Our design also offers good thermal isolation to connector center conductors, avoiding damage to mating connectors and cables. Conservatively rated, they handle at least 24% more power than specified. At Weinschel Engineering we make no compromise with quality and performance, why should you?

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Frequency Range — dc — 1.5 GHz
Average Power — **150 W**
Peak Power — **10 kW**
Standard Attenuation Values — 3, 6, 10, 20, 30, 40 dB Deviation — ± 0.5 dB Max
Connectors — Stainless Steel Type N — Mate with N per MIL-C-39012

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Frequency Range — dc — 1.5 GHz
Average Power — **150 W**
Peak Power — **10 kW**
VSWR — 1.10 Max
Connectors — Stainless Steel Type N — Mate with N per MIL-C-39012

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- Standard Values — 3 and 6 dB and 10 thru 60 dB/10 dB increments
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- Power Rating: 10 W Avg., 1 kW Peak
- Standard Values — 3, 6, 10 and 20 dB
- Calibrated at Five Frequencies thru 18 GHz
- Stainless Steel WPM Connectors — Mate with SMA per MIL-C-39012

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High Power Fixed Coaxial Attenuators
Models 33, 34 & 35

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

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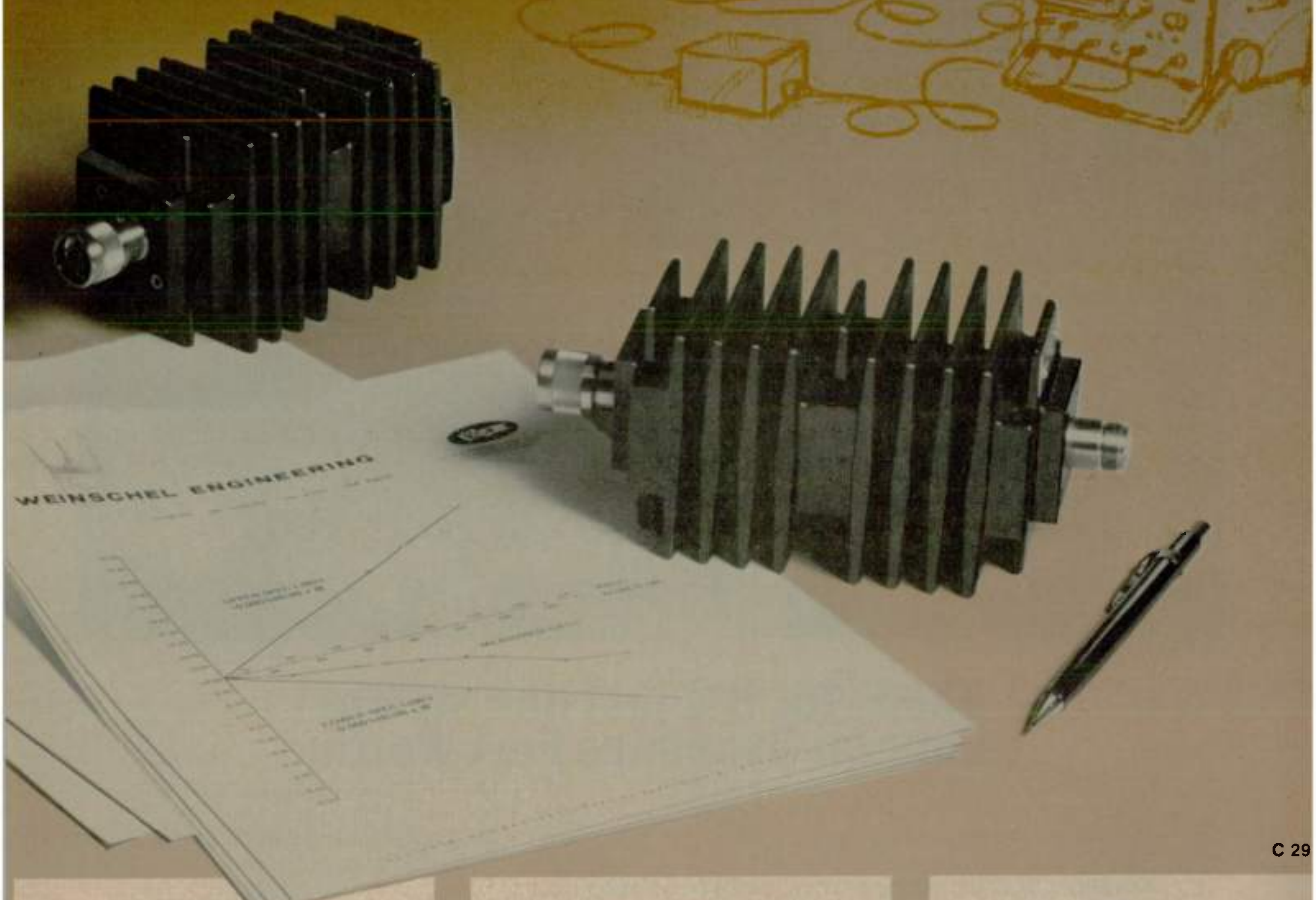
Terminations...
Others are



C 29

High Power Coaxial
Fixed Attenuators
Models 24, 25 & 26

50 WATTS

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

Circle Reader Service 104

High Power Coaxial Terminations
Models 1426 & 1427

50 WATTS

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

Circle Reader Service 105

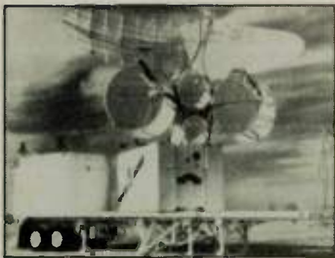
Miniature Medium Power
Termination
Model 1419

10 WATTS

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

Circle Reader Service 106

ELECTRONICS ENGINEERS: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Broadcasting TV-Satellite Antenna System

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Cologne, W. Germany

INTRODUCTION

The antenna subsystem, described here, is part of a direct broadcasting TV-satellite. System design and development of the individual components was carried out by the German industry and managed by Deutsche Forschungs- und Versuchsanstalt fur Luft- und Raumfahrt e.V. (DFVLR), located in Cologne. Prime contractor was Messerschmitt-Bolkow-Blohm GmbH (MBB), located in Munich.

Compliance with the requirements established by the WARC 77/79 (Figure 1) served as a basis for conceiving and designing the antenna subsystem. In particular, suppression of copolarized signals radiated in the antenna sidelobe region and of crosspolarized signals radiated within the earth field of view (FOV) was of prime importance. The antenna system performs the following major tasks:

- Reception of the useful RF signals transmitted by a ground station;
- Retransmission of the useful output RF-signals of the satellite transponder to an exactly defined area of the earth's surface, this area is called the "supply ellipse"; and
- Exchange of telecommunication data between ground sta tion and satellite.

The antenna system consists of separate Transmit (Tx)- and Receive (Rx)-antennas because with the great difference in frequency (17 GHz up-link and 12 GHz down-link), realization of single Tx/Rx-antenna, meeting the WARC 77/79 requirements, was considered extremely difficult if not impossible. To assure the required pointing accuracy for the transmit beam, the Tx-antenna system provides trackir signals. Transmission and reception of the telemetry data is ac-

TABLE 1
ANTENNA SUBSYSTEM SPECIFICATIONS

SPECIFICATION \ SYSTEM	Tx-ANTENNA SYSTEM	Rx-ANTENNA SYSTEM	TM/TC-ANTENNA
FREQUENCY	DOWN-LINK: 11.7-12.1 GHz TELEMETRY: ≈ 12.5 GHz BEACON: ≈ 17.3 GHz	UP-LINK: 17.3-17.7 GHz TELECOMMAND: ≈ 18.3 GHz	TELEMETRY: 2.279 GHz TELECOMMAND: 2.099 GHz
POLARIZATION	DOWN-LINK: LHC TELEMETRY: LHC BEACON: RHC	UP-LINK RHC TELECOMMAND: RHC	TELEMETRY: LHC TELECOMMAND: RHC
DIAGRAM	COPOLARIZED SIGNALS: CURVE A (FIGURE 1) WITH - 12% TOLERANCE FOR MINOR ELLIPSE AXIS - 6% TOLERANCE FOR MAJOR ELLIPSE AXIS CROSSPOLARIZED SIGNALS: BELOW CURVE A (FIGURE 1) BEAMSHAPE: QUASI-ELLIPTICAL 3 dB BEAMWIDTH: 1.62° x 0.72°	COPOLARIZED SIGNALS: BELOW CURVE B (FIGURE 1) CROSSPOLARIZED SIGNALS: BELOW CURVE C (FIGURE 1) BEAMSHAPE: QUASI-ELLIPTICAL 3 dB BEAMWIDTH: ≈ 1.13° x 0.5°	QUASI-ROTATION SYMMETRIC AROUND THE AXIS SATELLITE-TO-GROUND FACILITY (YAW AXIS)
GAIN	DOWN-LINK: ≈ 43.8 dBi IN BORESIGHT DIRECTION	UP-LINK: ≈ 45.2 dBi IN BORESIGHT DIRECTION	0°-30°: 10 dBi TM, TC 30°-60°: 15 dBi TM, TC 60°-120°: 10 dBi TM 12 dBi TC (ANGLES RELATED TO YAW AXIS)

REMARKS: LHC (LEFT HAND CIRCULAR): ANTI-CLOCKWISE CIRCULARLY POLARIZED IN DIRECTION OF PROPAGATION
RHC (RIGHT HAND CIRCULAR): CLOCKWISE CIRCULARLY POLARIZED IN DIRECTION OF PROPAGATION

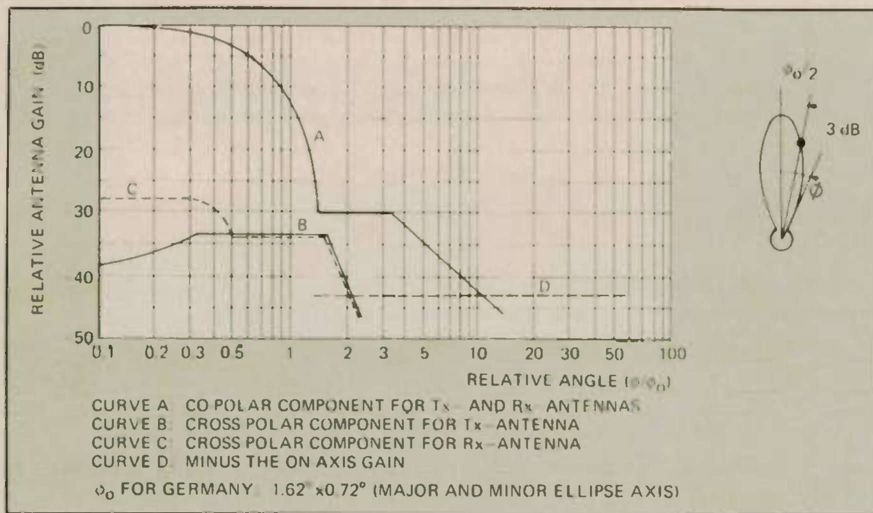

Fig. 1 Reference pattern for co- and cross-polar components of the satellite antennas.

complished by the TM/TC-antenna.

SYSTEM

The antenna system (see Figures 2, 3) is arranged on that part of the satellite body facing the earth. The essential part of the system is an antenna tower on which are mounted the antennas, the optical sensors and the thermal control elements.

When in orbit, four infrared sensors arranged at the top of the antenna tower provide coarse orientation of the satellite's Tx-antenna to the "supply ellipse" on earth. After coarse orientation is completed, automatic transfer to the RF-sensor system assures fine antenna orientation.

The thermal control system includes heat radiating areas, reflecting cells (OSR: Optical Surface Reflector), thermal blankets (SSM: Second Surface Mirror; MLI: Multi-Layer Insulation), thermal paints and heater elements.

Tx- and Rx-antenna systems use focal point fed offset paraboloid reflector antennas. By carefully illuminating the reflector symmetrically, the offset antennas achieve very high crosspolarized signal suppression in accordance with WARC requirements.

The Tx-antenna system includes a paraboloid reflector, an elliptical tracking feedhorn with circular polarizer and an RF-sensor. The antenna transmits both the useful down-link signals supplied by the output multiplexer of the transponder and the telemetry signals while simultaneously receiving beacon signals from the ground control facility.

The Rx-antenna system includes a paraboloid reflector of identical size as for the Tx-system and an identical feedhorn appropriately scaled for operation at the receive frequency. The antenna system receives the useful up-link signals of the ground station and transmits them to the satellite transponder for appropriate frequency translation and amplification. The Rx-antenna also receives telecommand signals.

The TM/TC-antenna system consists of a circular waveguide horn antenna and provides for reception and transmission of telemetry and telecommand data during launch and transfer phase of the satellite. When in orbit, after deployment of the Tx- and Rx-reflectors, these tasks are performed by the Tx- and Rx-antenna systems, while the TM/TC-antenna acts as redundant system.

MAJOR SYSTEM COMPONENTS

Antenna Tower

The antenna tower, required for positioning the feedhorns in the focus of the paraboloid re-

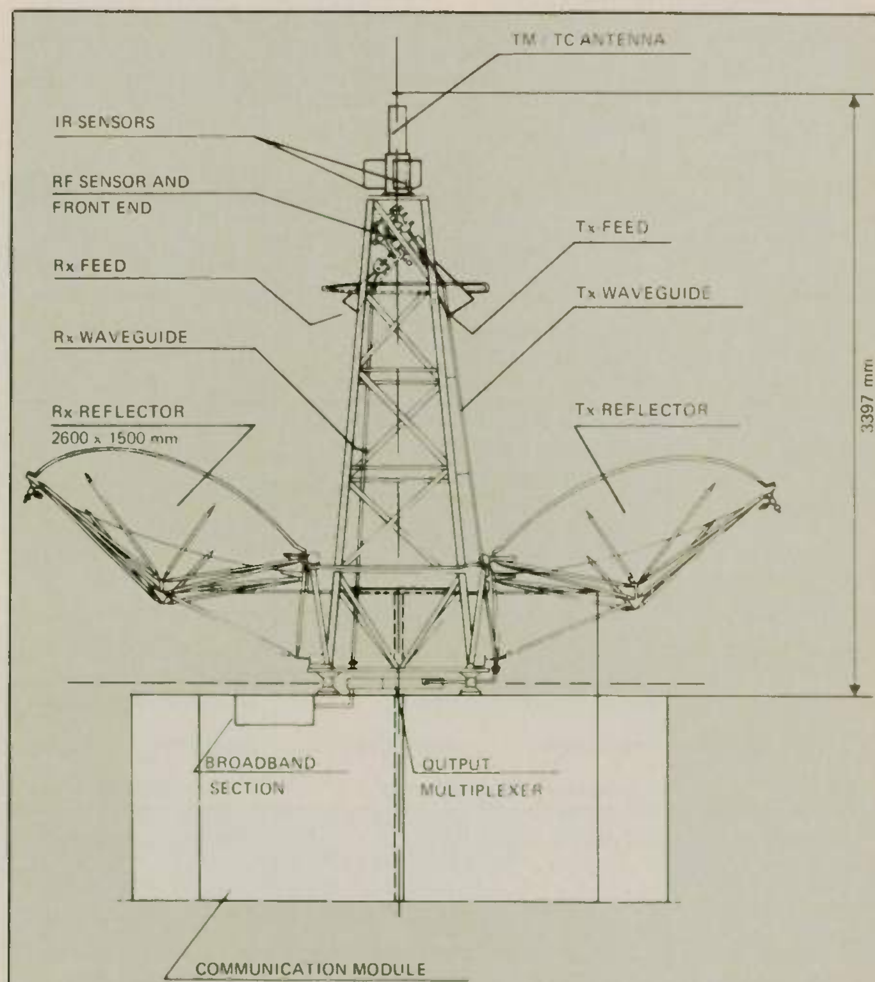

Fig. 2 Antenna system.

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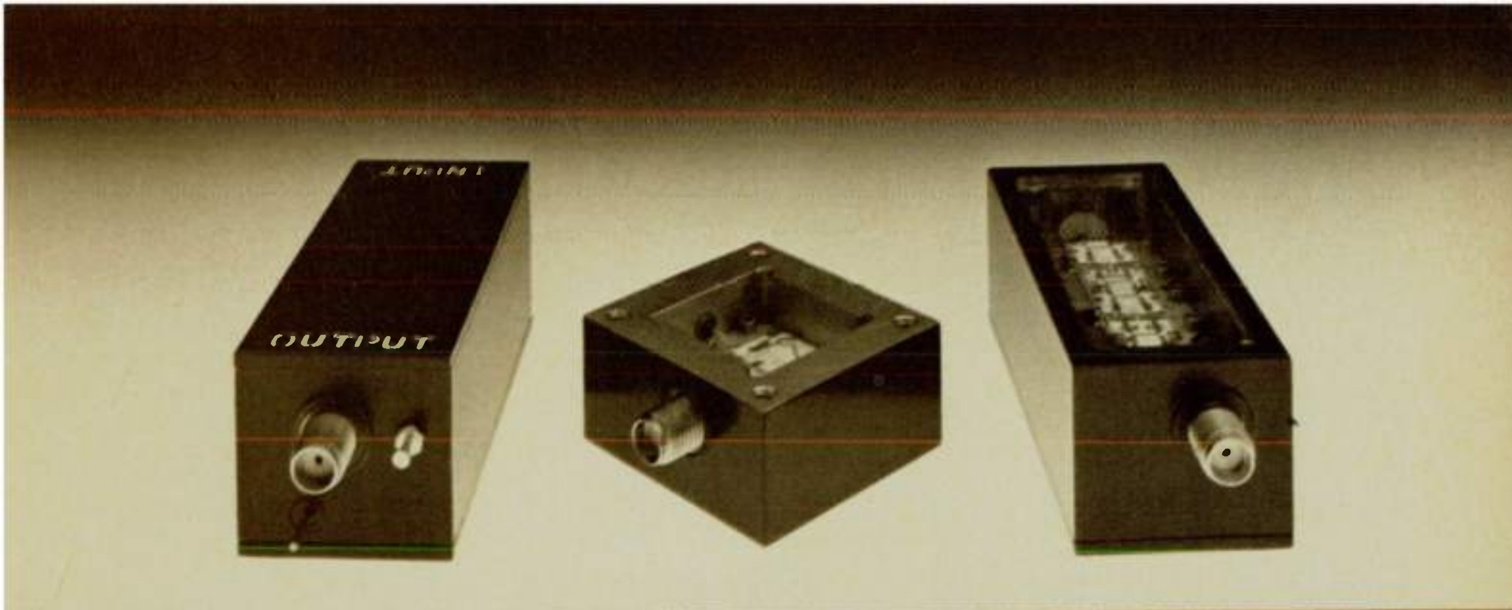


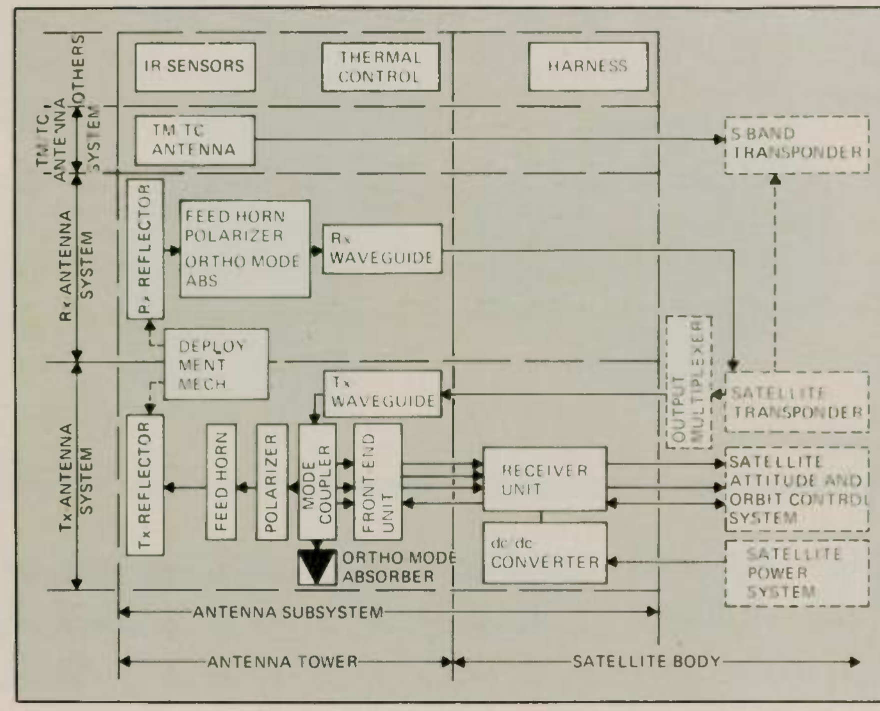


Fig. 3 Block diagram of the antenna system.

flector dishes, bears all components of the antenna subsystem, except for the RF-sensor system tracking receiver. The tower, which has an overall height of 2800 mm and a weight of 24 kg, is composed of four external tubes arranged in a square cross section and joined together by diagonal braces and sandwich plates for fixing individual components of the antenna system. To obtain a small mass while simultaneously maintaining high

Fig. 4 Reflector with feedhorn (test set-up).

stiffness and thermal control deformation resistance, carbon fiber reinforced plastics (CFRP) are used throughout. The individual CFRP components of the tower as mentioned above are joined by appropriate cement bonds.

Reflectors

The antenna reflectors are sections of a paraboloid surface with a quasi-elliptical aperture (2600 x 1500 mm) and focal lengths of approximately 1500 mm. The reflector rim was determined such that the measured radiation pattern (copolarized signals) of an available feedhorn resulted in a -25 dB edge illumination relative to the peak of the illumination pattern.

The reflectors (**Figure 4**) are fabricated with aluminium honeycomb structure and CFRP surfaces. A three-dimensional support structure made of CFRP tubes and titanium nodes strengthens the antenna dishes. Antenna mounting pads are an integral part of the support structure.

Overall weight of a reflector including support structure is approximately 12.8 kg. The CFRP surfaces, that provide the reflectors with a great stiffness and a high thermal deformation resistance in the operational temperature range of -150°C to +100°C, consist of four resin-impregnated, pressed unidirectional carbon fiber layers with a total thickness of 0.35 mm. The reflector surface tolerance is less than 0.3 mm RMS (RMS: Mean variation of the real reflector contour from the specified ideal value). For thermal stability the front and back surface fiber layers are made of identical CFRP covers.

The first external fiber layer is orientated in the 0° reference direction, the layers underneath run successively at angles of -45°, +45° and 90° to the reference direction. In this way a loss due to imperfect reflection is of less than 0.1 dB (equal to 97.5% reflectivity) for circularly polarized signals at frequencies around 12 GHz. Crosspolarized signals due to the reflector components are suppressed by more than 40 dB and the side lobes are increased by less than 1 dB, as compared with performance achieved with solid metal reflecting surface

Feedhorns

The feed systems design is the principal reason for the extremely good crosspolar decoupling, especially for the Tx-antenna system, and they are manufactured using galvanoplastics from

Fig. 5 Elliptical corrugated feedhorn (Electrical model)

a nickel alloy and are made structurally stiff through the use of CFRP bands. The transmit antenna feedhorn (**Figure 5**)

- is composed of a truncated cone with an elliptical basis and interal corrugations made up of elliptical rings with a separation approximately equal to the disc thickness;
- has a length from the horn aperture to the rectangular

waveguide flange of ≈ 400 mm and is excited by a square waveguide 20 mm on a side;

- has external elliptical horn aperture dimensions of ≈ 50 x 150 mm;
- has a weight of ≈ 1.1 kg made by lightweight construction;
- has a transmit port, a port for transmitting telemetry signals and three ports for receiving beacon signals. The latter provide sum and two error signals to the RF-sensor system for antenna pointing purposes;
- has a boresight gain of 18.7 dBi;
- has a beamwidth at 3.10 and 25 dB below boresight amplitude of 17, 31 and 45° for the broad and 7, 12.5 and 23° for the small main axis;
- has a crosspolar decoupling of 32.2 or 31 dB for the orthogonal main axes. The overall performance for the crosspolarized signals was carried out by optimization of the feedhorn within the complete antenna reflector system;
- has an insertion loss of less than 0.05 dB;
- has a reflection coefficient (SWR) at the input flange of 1.1;
- handles a total RF-power of 2 kW without performance degradation; and
- is succeeded by a polarizer (**Figure 6**) consisting of a square section of waveguide with a fixed differential phase shift and a correction section. In the fixed phase shift section, a 90° differential phase shift between orthogonally polarized waves is achieved by the well-known principle of inserting a dielectric plate in the 45° plane of the waveguide. The correction section consists of a 25 mm long square section loaded with small dielectric plates in the symmetry and 45° plane, thus providing for an adjustable differential phase shift of up to ± 10°, dependent on the arrangement of the dielectric plates. An adjustable amplitude variation of as much as ± 0.3 dB is achieved by changing the coupling factor between the two orthogonal waves.

Due to fabrication inaccuracies, the feedhorn does not radiate a circular polarized field even when orthogonal field components of equal amplitude and a 90° relative phase excite it; i.e., there is a crosspolarized interfering radiation component. The correction section of the polarizer compensates the resulting differential amplitude and phase differences of the orthogonal field components such that, together with the feedhorn, the radiated field is almost circularly polarized. The receive antenna feedhorn:

- has a length from the horn aperture to the circular waveguide flange of ≈ 275 mm with a circular excitation section 14 mm in diameter;
- has an elliptical horn aperture ≈ 47 x 118 mm;
- has a weight of ≈ 0.9 kg;
- has an insertion loss of less than 0.05 dB;
- has a reflection coefficient (SWR) at the input flange of less than 1.12; and
- has an integrated polarizer in the horn's throat.

RF-SENSOR SYSTEM

The infrared sensors available today are no longer capable of fulfilling the high WARC requirement for the pointing accuracy of the Tx-antenna which is 0.1° in any direction. This function must be performed by RF or monopulse sensors which are directly integrated in the Tx-antenna feed system. The RF-sensor system consists of an RF-sensor and a front-end unit at the high-frequency end and the receiver unit at the low-frequency end.

RF-Sensor

The RF sensor has to assure:

- Transmission of high transmit power (up to 2 kW) at low attenuation and minimum degradation of the transmit signals;
- Generation of largely decoupled error signals of the antenna main axes; and
- Generation of a sum signal required for tracking signal production.

From a functional view, the RF-sensor together with the Tx feedhorn represents a monopulse system. A terrestrial beacon station, located in the Tx-antenna boresight, generates signals which are received by the feedhorn of the satellite Tx-antenna. If the Tx-antenna boresight does not point exactly in the direction of the beacon station, two error signals are generated in the orthogonal principal feedhorn planes. The values of these error signals are proportional to the error angles. By phase comparison of the error signals with a sum signal, simultaneously produced in the feedhorn, the sign of the error angle can be determined, because the error signals change in phase around boresight while the sum signal remains phase constant.

The RF-sensor (**Figure 6**) is a highly sophisticated waveguide

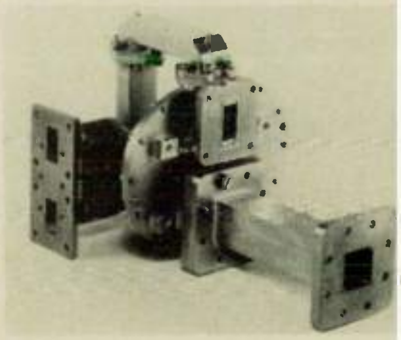


Fig. 6 RF-sensor and rectangular waveguide polarizer (Electrical model).

system and a detailed description of its function would go beyond the scope of this paper. Therefore, only its basic set-up and the major parameters will be presented. The complete RF-sensor includes a mode coupler, a correction coupler and a diplexer with ortho-mode-absorber. The mode coupler basically is a multimode waveguide junction for selecting the energy components of different waveguide modes.

A central rectangular waveguide is designed such that, with respect to the propagation capability of waveguide modes, in o direction only the useful Tx-signals can pass, while in the opposite direction only the sum and error signals from the Tx-feedhorn are allowed to pass. The correction coupler generates largely decoupled error signals from the strongly intercoupled error signals supplied by the

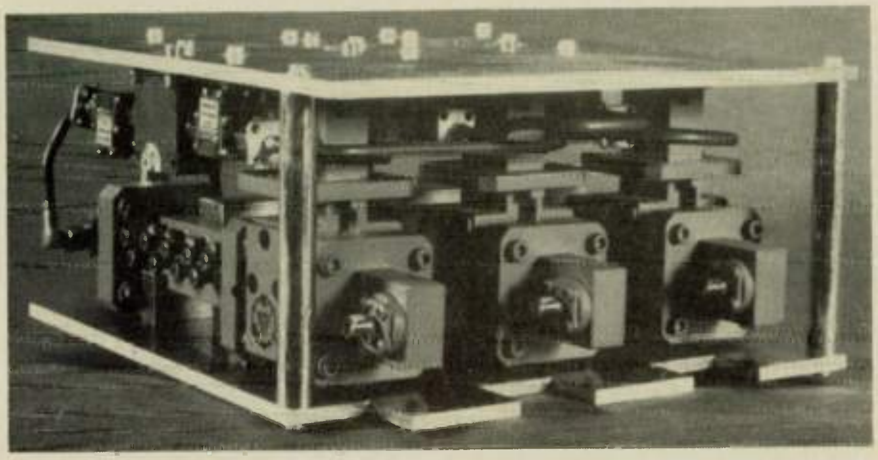


Fig. 7 Front-end unit of the tracking receiver. (Electrical model).

mode coupler. A diplexer, consisting of a 10 dB waveguide coupler, separates the sum signal from the transmit power, cross-coupled by reflections. An orthomode-absorber suppresses this reflected transmit power.

The error signals and the sum signal, separated by the RF-sensor, are supplied to the front-end unit of the tracking receiver. The Tx-signal input port is connected to the output multiplexer of the satellite transponder. Most important features of the RF-sensor are:

- The insertion loss for the transmit signal path is less than 0.06 dB, for the sum signal path less than 0.1 dB without diplexer and for the error signal paths 0.6 dB each;
- The reflection coefficient (SWR) for the transmit signal input port is less than 1.06, for the sum and less than 1.2 at the error signal ports;
- The decoupling between sum and transmit signal port is greater than 56 dB, between the error signal ports and the transmit signal port greater than 35 dB each, between the error signal ports and the sum signal port greater than 56 dB each, and between the two error signal ports greater than 30 dB;
- The phase shift between the error signals and the sum signal is less than 2° each; and
- The complete RF-sensor has dimensions of 136 x 130 x 136.5 mm and a total weight of 1.36 kg. To minimize phase shift variations between the tracking channels, copper beryllium (CuBe), with a high thermal deformation resistance, is used as material for the RF-sensor.

Tracking Receiver

The tracking receiver has the task of processing the high-frequency sum and error signals supplied by the RF-sensor and delivering at the output two dc error voltages to the satellite's attitude control system for Tx-antenna pointing purposes.

The receiver is of complete three-channel design, corresponding to the tracking signals supplied by the RF-sensor, and is composed of a front-end unit (**Figure 7**) and a receiver unit (**Figure 8**). The front-end unit consists of one waveguide isolator for each channel to achieve a (SWR) less than 1.1. An integral rectangular waveguide bandpass filter with a center frequency of 17.3 GHz and a 3 dB bandwidth of 900 MHz suppresses cross-coupled transmit signal power by more than 60 dB. A succeeding frequency downconverter shifts the high frequency signals to an intermediate frequency of 70 MHz. The 70 MHz signals are passed to the receiver unit by coaxial cables for further processing. The receiver unit contains all functional groups for extracting the pointing error information with respect to the two principal planes of the Tx-antenna. As the receiver unit is a highly complex electronic device, this paper will only describe its basic set-up and present the most important parameters. The three tracking signals supplied by the front-end unit are converted to a second intermediate frequency of 2.5 MHz through amplifier, filter and mixer units. The amplification synchronization of the 2.5 MHz-amplifiers is ensured through automatic gain control (AGC) circuits. An automatic frequency control (AFC) unit assures the frequency stability of the first 70 MHz-frequency conversion in the front-end unit. The receiver output supplies two error voltages on dc-level. The amplitude of each voltage indicates the amount and the sign the direction of the Tx-antenna pointing error.

Fig. 8 Receiver unit of the tracking receiver (Electrical model).

Most important features of the tracking receiver are:

- Input sensitivity for the sum channel is -85 dBm and for the two error channels -110 dBm each;
- Resolution accuracy is less than 0.015° for less than 0.01° Tx-antenna deviation from nominal boresight;
- Input SWR at the front-end unit is less than 1.2;
- Noise figure of each error channel between front-end in-

put and error voltage output is less than 14 dB;

Receiver output bandwidth is 8 Hz;

For an angular region of 0.3° around boresight of the Tx antenna, the receiver output error voltages are directly proportional to the antenna pointing error (linear range);

At angles greater than 0.3° up to 1° only the error direction is indicated, not the absolute value (limiter range); and

At angles greater than 1°, the error voltages at the receiver output are undefined. In this case, coarse orientation through four infrared sensors is required in order to return into the defined control range of the RF-sensor system of less than 1° around Tx-antenna boresight.

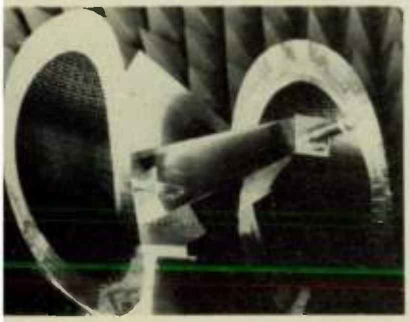


Fig. 9 TM/TC antenna on top of the antenna tower with deployed reflectors (Electrical model).

TM/TC Antenna System

The antenna consists of a tubular aluminium waveguide section with a 110 mm diameter and a total length of 658 mm (Figure 9). On one side of the tubular waveguide antenna the TE_{11} mode is excited with a coaxial feed. The second open side is provided with a metallic cone, fixed at a distance of 87.5 mm across the antenna aperture, and a reflecting rim with a 167.5 mm diameter, mounted at a distance of 62.5 mm below the open antenna aperture. With this construction a quasi-omnidirectional radiation pattern is achieved which is rotation symmetrical to the axis connecting satellite and ground station (yaw axis), with a coverage of 0° to 120° related to the above mentioned axis.

Orthogonal to the coaxial feed for the 50 Ω coaxial cabling, a septum consisting of absorbing material is inserted into the wave guide serving as an orthogonal mode absorber. An integrated circular polarizer comprises five couples of bolts arranged opposite to each other and set up at 45° angles to the electric field vector thus producing a differential phase shift of 90° between two orthogonal electric field vectors entering the polarizer section in phase.

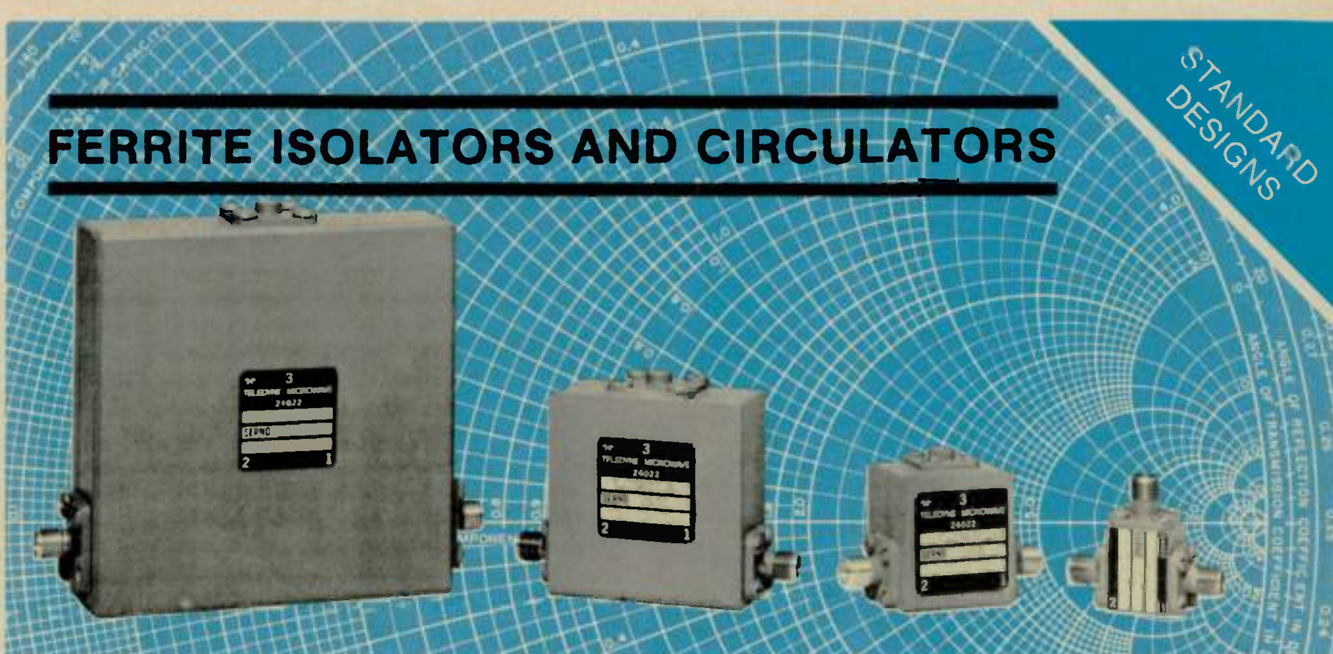
Most important features of the TM/TC antenna system are:

- Gain in the range of 0° to 30° related to the yaw axis is 10 dBi for TM and TC, in the range of 30° to 60°, about 15 dBi for TM and TC, and in the range of 60° to 120°, about 10 dBi for TM and 12 dBi for TC;
- Reflection coefficient (SWR) at the coaxial input is less than 1.6, and
- Weight is less than 0.85 kg.

REFERENCES

1. International Telecommunication Union, Final Acts of World Administrative Radio Conference (WARC). Broadcasting Satellite Conference, Geneva 77.
2. Magele, M., "Direkte Rundfunkversorgung uber Satelliten im 12 GHz-Bereich *Nachrichten-Elektronik* Vol. 2, Feb 19[illegible] pp. 41-45.
3. Fasold, D., "Rechnergestutzte Optimierung und Realisierung einer Offset Reflektorantenne fur Satelliten," *NTG-Fachberichte* No. 57, 1977, pp. 124-12[illegible]
4. Marz, G; E., Nuding, "Die Ausnutzung der Sende-Antenne eines Hochleistungs Satelliten als Monopuls-Lagesensor fur die Dreiachsen-Stabilisierung," *NTG-Fachberichte* No. 57, 1977, pp. 102 10[illegible]
5. Fasold, D.; Pecher, H., "Gain of Rectangular Horn," *Microwave Journal* No. 3, Vol. 22, pp. 76-79.
6. Fasold, D.; H. Pecher and G. Saulich, "Elliptische Offset Reflektor-antennen mit Einfach- und Mehrfachspeisesystemen," *Kleinheubacher Berichte* No. 23 1980, pp. 155-163.

Rolf Rosenberg was born in Lauenburg, Germany, on September 7, 1947. He received his Diplo. in Electrical Engineering at the "Rheinisch Westfalische Technische Hochschule" of Aachen in 1974. In 1975 he joined AEG-Telefunken, Ulm, as a system engineer for radar applications. Since April 1978 he has been with the research company "Deutsche Forschungs- und Versuchsanstalt fur Luft- und Raumfahrt e.V. (DFVLR)" in Cologne as a project engineer providing support on all system and circuit aspects of satellite payloads. In 1979 he became member of the project management staff for a direct broadcasting German TV Satellite, responsible for the antenna subsystem.



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

Frequency (GHz)	Model No.	Isolation (dB min.)	Insertion Loss (dB max.)	VSWR (max.)	Height	Size Width	Thickness
0.5 - 1.0	T-0S63T	17	0.8	1.35:1	5.78	5.59	1.35
1.0 - 2.0	T-1S63T-18	18	0.5	1.30:1	2.75	2.75	0.88
2.0 - 4.0	T-2S63T-6	17	0.5	1.35:1	1.63	1.63	0.75
2.6 - 5.2	T-2S63T-44	17	0.5	1.35:1	1.25	1.25	0.70
4.0 - 8.0	T-4S63T-10	17	0.4	1.35:1	1.06	1.00	0.76
4.5 - 9.0	T-4S63T-13	17	0.5	1.35:1	1.13	0.95	0.76
5.2 - 10.4	T-5S63T	17	0.5	1.35:1	1.06	1.00	0.76
8.0 - 16.0	T-8S63T-18	17	0.5	1.35:1	0.75	0.63	0.40
10.0 - 20.0	T-10S63T-5	17	0.7	1.35:1	0.68	0.51	0.56

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

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

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

POPULAR NARROW BAND — STANDARD DESIGNS

Frequency (GHz)	Model No.	Isolation (dB min.)	Insertion Loss (dB max.)	VSWR (max.)	Height	Size Width	Thickness
.95 - 1.225	T-0S23T-2	20	0.5	1.25:1	1.20	1.20	0.75
1.2 - 1.6	T-1S23T-7	17	0.5	1.35:1	1.25	1.25	0.70
1.9 - 2.3	T-1S13T-2	20	0.4	1.30:1	1.25	1.25	0.75
2.2 - 2.3	T-2S03T-11	20	0.4	1.35:1	1.05	1.00	0.58
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	0.50
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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INTRODUCTION

Hughes Aircraft Company is currently building over 100 RF terminals (RFT) for Satellite Business Systems (SBS) to provide voice, data, facsimile, and teleconferencing services to private networks in the United States.[1] The high power amplifiers for these terminals use traveling-wave tubes to obtain the final stage amplification and transmitter power. In each RFT, two tubes are paralleled to achieve either a phase combined high power mode with a fail-soft feature, or a conventional switched redundant low power mode. Design considerations and performance data on the 881H, a 250 watt CW, 14 GHz TWT are presented.*

Key design goals were to achieve excellent communication characteristics, reliable operation, long life, together with ease of maintenance. The PPM focused tube uses a uniform pitch helix and a long attenuator to achieve the desired communication characteristics. A modulating anode gun with low cathode loading and an integral ion pump contribute to long tube life. A single-stage depressed collector is used to achieve approximately 25% overall efficiency. The EPC which provides the voltages to the TWT also incorporates many protective features for the tube.

* Paper presented at INTELCOM '80 Los Angeles, CA. on Nov. 12th, Components Symposia, Tubes for Communications Systems.

TUBE DESIGN

Beam Optics and Focusing

The electron gun for this tube is a modulating anode type with 0.3 microperveance. The cathode nominal voltage is 8.6 kV and the anode normally operates at +200 volts with ability to switch to cathode potential in the beam-off mode. In order to achieve long life, a low cathode loading of 0.75 A/cm^2 was selected for the dispenser cathode. This required a 50:1 area compression gun. Another important factor in achieving long operating life is excellent beam optics. Careful selection of circuit-to-beam diameter ratio, a PPM focusing design using samarium-cobalt magnets with conservative plasma wavelength-to-magnetic period ratio resulted in excellent beam transmission where typically less than one percent of the beam is intercepted by the helix at full power output. To protect the helix from excessive electron bombardment during abnormal conditions or power supply malfunction, a beam scraper was incorporated between the electron gun and the input helix as well as between the output helix and collector.

Circuit and RF Couplers

The RF circuit is a two-section-conventional helix supported by four shaped beryllia rods. Various shapes were evaluated for dielectric loading effects, circuit impedance, thermal loading and ease of manufacturing. The helices have uniform pitch with slightly different pitch between the input and output section to optimize RF performance. Internal reflections of the RF signal between the internal attenuator and input and output couplers result in gain and power variation across the frequency band. Special long attenuators with tapered loss consisting of thin carbon films on the support rods have resulted in extremely smooth gain and power curves. Stability from oscillations is also achieved by proper placement and design of the attenuator. Short circuit stability of the tube input and output was achieved under pulse condition over a wide range of cathode voltage.

TABLE I

TYPICAL OPERATING PARAMETERS

Cathode voltage	−8.6 kV
Cathode current	270 mA
Anode voltage	+200 volts
Body current	2 mA
Collector voltage	−4.5 kV
Heater voltage	6.3 volts
Heater current	1.7 amps
Vac-ion voltage	+3.4 kV

RF input and output to the tube are through coax lines which transition to WR-75 waveguides. Initially arcing problems were encountered at the output transition at high power but were later eliminated by changing to a cylindrical window design.

Collector and Body Cooling

The single-stage depressed collector used for the tube is a simple and rugged design incorporating a cylindrical isolation ceramic. The high voltage depressed electrode is attached to the I.D. of the ceramic while cooling fins operating at ground potential are attached to the O.D. of the ceramic. The fins provide 1600 square cm (250 sq. in.) of cooling surface. Cooling air is directed transverse to the tube and with 100 CFM of flow, the collector can dissipate 1.4 kilowatts of collector power. A thermal switch is attached to the collector which shuts off the power supply when the temperature exceeds a certain value.

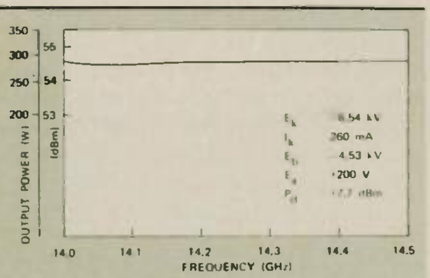

Fig. 2 Saturated output power.

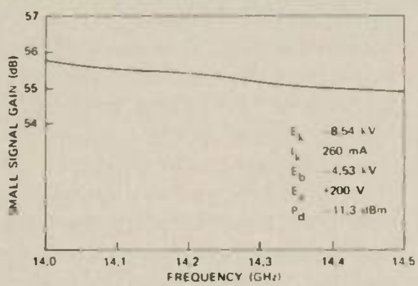

Fig. 3 Small signal gain.

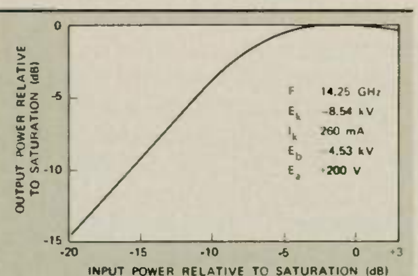

Fig. 4 Phase shift and AM-to-PM.

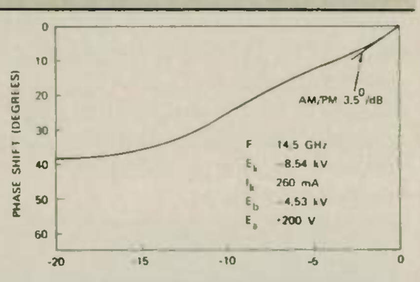

Fig. 5 Output power versus input power.

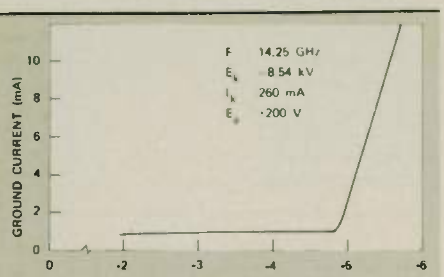

Fig. 6 Ground current versus collector depression.

Body cooling is accomplished by conduction to a finned extrusion attached to the baseplate. Part of the cooling air is channeled to cool the body. Packaging of the tube consists of anchoring the collector to the baseplate, tying the waveguides through rigid waveguide supports to the baseplate, attaching the wiring harness, and covering the assembly with three sheet metal covers. A photograph of the 881H is shown in **Figure 1**. Physical dimensions of the tube are approximately 55 cm (21.6 in.) in length, 13 cm (5.2 in.) width at collector end, 7.6 cm (3.0 in.) at gun end, and 6.2 cm (2.4 in.) high exclusive of the handles. TWT weight is 5.0 kg (11 lbs).

TUBE PERFORMANCE

RF Characteristics

Over 100 tubes have been built to date and typical RF performance data are shown in **Figures 2** through **8**. Saturated output power and small-signal gain (10 dB backoff) plotted in **Figures 2** and **3** respectively show the extremely smooth characteristics as a function of frequency. Typical saturated output power is 270 watts with 46 dB gain. Small-signal gain is about 55 dB with gain variation of 1 dB over the band and gain slope of less than 0.25 dB per 100 MHz.

Phase shift from small signal to saturation is typically 40° as shown in **Figure 4** AM-to-PM at saturation is 3.5° per dB. The transfer curve with drive relative to saturation is shown in **Figure 5**.

Typical operating parameters of the 881H are listed in Table I and phase and amplitude sensitivity figures are given in Table II.

TABLE II

PHASE AND AMPLITUDE SENSITIVITY

Phase sensitivity	
Beam voltage	0.8 degree/V
Anode voltage	0.1 degree/V
Collector voltage	0.06 degree/V
Amplitude Sensitivity	
Beam voltage	0.007 dB/V
Anode voltage	0.002 dB/V
Collector voltage	0.001 dB/V

Ground current as a function of collector voltage shown in **Figure 6** indicates the relative insensitivity over a wide range of collector voltages. The collector supply is unregulated and can vary over 1000 volts about its nominal value of 4.5 kV. Intermodulation characteristics are presented in **Figure 7** and group delay in **Figure 8**.

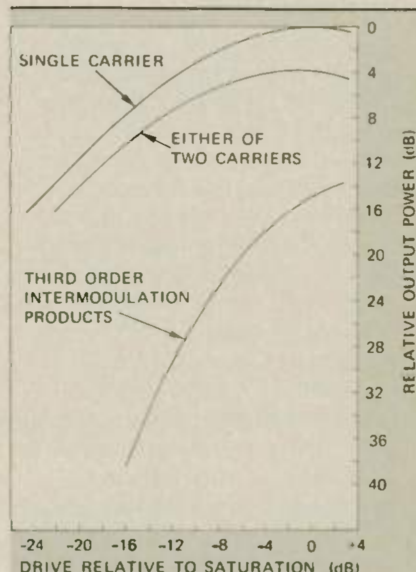

Fig. 7 Intermodulation.

Life Considerations

The cathode is the only element in the tube that has a wearout mechanism. In order to achieve long life, a low cathode loading has to be selected. The minimum four-year life requirement dictated the selection of a conservative cathode loading of 0.75 amperes per square centimeter with cathode operating temperature of 1020°C. Estimat-

(continued on page 62)

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ed minimum life and average life for a 10% cathode emission degradation was based upon a number of control triodes tested at Hughes. Based upon this data, the minimum and average life expectancy is 25,000 and 36,000 hours respectively. The saturated power and gain degradation at the end of this period is estimated to about 0.7 dB and 3.0 dB, respectively. In a redundant system, tube life is further extended when heater voltage of the tube in standby is reduced from the operating point. In the SBS system the heater voltage is reduced by 0.6 volts during standby corresponding to a 50°C temperature reduction.

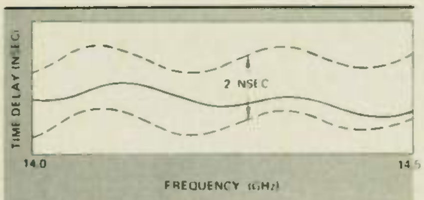


Fig. 8 Group delay.

An appendage 0.2 liter per second ion pump is permanently attached to the tube which aids in extending tube life. Special procedures are exercised during the manufacturing process to outgas and thermally stress the various components beyond the level expected during its life time. The collector is outgassed at 30% above its normal power level, and the gun is high potted at a higher potential to prevent flash over and microdischarges between cathode and anode.

TUBE PROTECTION AND MAINTENANCE

Electronic Power Conditioner and TWT Protection

In addition to supplying all the voltages required by the TWT, the Electronic Power Conditioner (EPC) has protective features to maintain safe operation under abnormal and fault conditions. Three types of fault reaction are as follows:

- State A – Beam off
- State B – High voltage off, except heater voltage
- State C – All voltages off

A State A fault causes the TWT anode to switch to cathode potential thereby shutting off the beam. The EPC will automatically recycle after one second. If the fault still exists, or if a second fault occurs within ten seconds, the EPC goes to State B shutting off high voltages except the heater. In case of low line voltage, reset is automatic once normal line voltage is restored. State B fault can be reset manually or from a remote site. State C fault causes all voltages to be off including the heater.

Abnormal and fault conditions which cause the EPC to switch to various protective states are shown in Table III.

TABLE III

FAULT CONDITIONS AND PROTECTIVE STATES

State A	– TWT high helix current – High voltage faults
State B	– TWT temperature high – EPC temperature high – Interlock open
State C	– TWT heater voltage abnormal – Line voltage abnormal

Other special features include a three-minute time delay from cold start to full on and less than 0.5-second delay between standby and full output power. For a primary power failure of less than three seconds, the HPA can return to its previous state within 1.5 seconds after power is restored.

Ease of Installation and Maintenance

One of the attractive features of the 881H is the ease with which it is installed in the system. Six captivated screws hold the tube vertically in position to a transmitter plate. The input and output waveguides are then connected. Mating two connectors, a high voltage and a low voltage connector, completes the installation. To avoid time consuming voltage adjustments, the cathode, anode, and heater voltages are automatically set at one of several discreet values specified on the nameplate. Prior to tube installation, the EPC can be checked out with a portable light weight "diagnostic load," to verify proper operation.

CONCLUSION

The demand for high-power communication systems at K_u-band has created the need for a development of the 881H, a 250 watt CW, 14 GHz helix TWT. Design considerations directed towards achieving excellent communication characteristics, reliable operation, long life, and ease of maintenance, together with performance data which demonstrate some of these goals were presented. It is hoped that the 881H will also fulfill other communication systems needs of the future.

ACKNOWLEDGEMENT

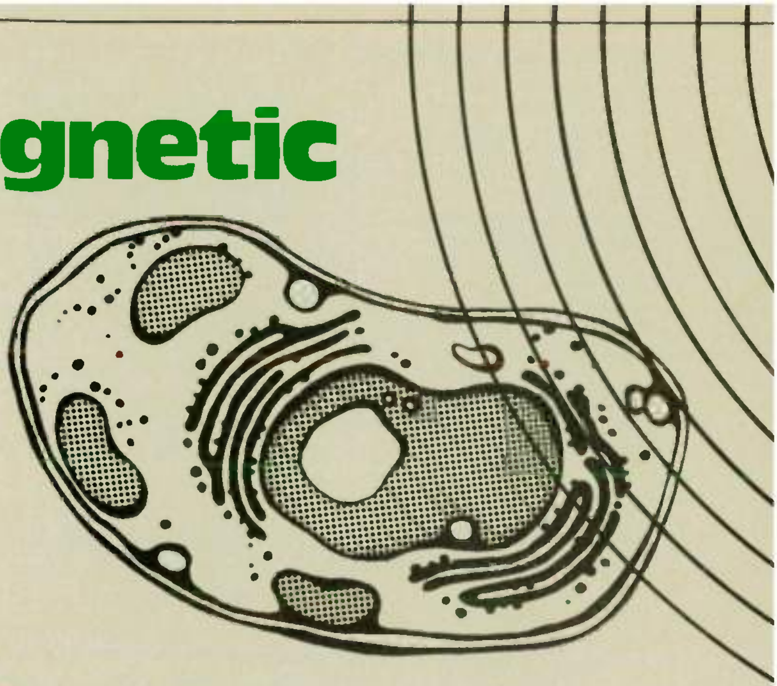
The author would like to acknowledge the contributions made by team members: J. T. Benton, F. Hansen, J. W. Huber.

REFERENCE

1. Weischadle, G. M., and A. Koury, "SBS Terminals Demand Advanced Design," *Microwave Systems News*, April 1979, pp. 70-79.

Richard Ohtomo received his B.S.E.E. degree from Purdue University in 1956 and his M.S.E.E. in 1958 from the University of Michigan. From 1956 to 1959 he was employed as a research assistant in the Electron Physics Laboratory of the University of Michigan where he was engaged in research and development on traveling wave tubes. In 1959, he joined Varian Associates, Palo Alto, to work on various TWT's and BWO's. Mr. Ohtomo joined Hughes Aircraft Company, Electron Dynamics Division in 1966 and has been engaged in the development and production of high power helix ECM TWT's. He is presently a Project Manager in the Helix Tube Department where he is responsible for commercial instrumentation TWT's, as well as high power communication TWT's. He has been awarded several patents in the field of microwave tubes.

Electromagnetic Waves and Biology–



International Symposium Report

F. E. GARDIOL
École Polytechnique Fédérale de Lausanne
Lausanne, Switzerland

The small village of Jouy-en-Josas, better known for a particular cloth printing technique, played host to an International Symposium from June 30 - July 4, 1980 which was organized by A. J. Berteaud and B. Servantie under the sponsorship of URSI Commission A and the French organizations CNFRS and CNRS.

This symposium presented material of particular interest in the microwave community, since most of the papers dealt with effects observed in the microwave range — most often in the vicinity of the ISM frequency at 2.45 GHz.

The opening address by Professor Latarjet, of the Academy of Sciences, covered considerable ground, considering first the subtle self-balancing processes which govern our environment — which are often hard-pressed to take care of human interventions. He remarked that nowadays people require increasingly severe safety standards, and then questioned whether the discrepancies observed in microwave biological experiments might not be due to inhomogeneous heating of the cell material, causing migration of metal ions.

Mr. Rechen, of the Bureau of Radiological Health discussed the outstanding paradox: how is it possible that, while based on similar scientific experiments, the tolerated radiation levels in different countries would vary over a range of roughly 1000 to 1? The selection of a safety level depends not only on scientific findings, but also on administrative and sociopolitical criteria, and very different approaches can be chosen to set up a safety standard.

The first session considered cellular physiology, and nine papers described the survival and growth of various kinds of isolated cells, in the presence of a number of chemical substances, with and without microwave radiation. Most of the experiments appeared to be rather involved and most results were not readily understood, by non-biologists. Generally, microwave irradiation produces effects similar to those of a temperature increase, however there are subtle differences. The growth of certain yeasts is very strongly frequency-dependent; sharp resonance lines were observed.

Physiology and reproduction of rats, mice, rabbits and frogs were the subjects of the second session. Studies carried out in Kiev (USSR) show an "inhibition" of the nervous system anc a decrease of the *capacity for work* of rats at power levels as low as 50 $\mu W/cm^2$. Such results would be most significant, if on could trust them. Unfortunatel the English text, read by a French speaker, did not contain sufficient details on the experimentation procedure and answe to questions were rather noncommittal. Quite on the contrary, most of the other papers presented at this session as well as at the whole symposium were very thoroughly documented, specifying the number of animals tested, the measurement procedures, the comparison witl sham-exposed animals and the statistical significance, if any, of the results obtained. At 5 mW/cm^2, the only significant results reported were a smaller food intake for the same growth rate o rabbits (interesting for breeders and some decrease in heart frequency for rats. Rats exposed *a birth* to power levels of 5 to 10 mW/cm^2 exhibited growth anomalies.

The third session considered biochemistry and mechanisms.

(continued on page 6

(from page 63) ELECTROMAGNETIC

Several odd results were reported, most of them for irradiations at several mW/cm². In several instances, microwaves were applied together with chemicals almost at the lethal dose. Unfortunately, the practical significance of the presented data was not readily obvious for the non-biologist.

Physiopathology was at the center of the fourth session. Dr. Szmigielski, of Warsaw, clearly and accurately presented measurements carried out on mice and rabbits inoculated with *Staphylococcus aureus*. Exposition to microwaves at 5 mW/cm² did not change the death rate; at 15 mW/cm², on the contrary, the death rate increased significantly. Several other papers were in close agreement. In same cases, however, the humoral immunity was stimulated by microwave irradiation.

The study of behaviour was considered during the fifth session, covering experiments with trained monkeys, mice and rats. Monkeys consistently reduced their ambient temperature by a few degrees while microwaves (6-8 mW/cm²) were on. Irradiated rats made ***fewer mistakes*** when requesting food than non-irradiated ones! A statistical study on a large group of Polish workers showed that irradiation between 7 and 30 MHz is much more damaging than between 3 and 7 GHz. The conditions of test were not outlined and there was no control group to compare with the experimental group.

The positive effects of microwaves were taken up on the last day of the conference, under an American flag celebrating the Fourth of July. By then, some of the participants had already left. Mr. Gautherie presented a thorough review of the status of microwave thermography in France, considering both contact and antenna probes. Hot spots deep inside the body can be detected with a radiometer, the only microwave source being the patient himself. It was thus possible to determine whether some breast tumors were malignant or not; in the cases considered, infrared thermography consistently gave wrong answers.

Brain tumors can also be investigated in this way. Thermography was also used together with hyperthermia: the internal heating produced can then be accurately controlled. Hyperthermia is increasingly used in cancer treatment; after considerable investigations on animals, limited applications in actual cancer patients are taking place, generally in conjunction with X-ray irradiation and chemotherapy. In several instances, malignant tumors did actually decrease or even vanish.

What conclusion can be drawn from the many papers presented at the symposium? For the biological effects of microwave exposure, the new results add to the rather large data base already available, roughly confirming what is already known: no or little effects below 1 mW/cm²; some effects, generally harmless between 1 and 10 mW/cm²; more pronounced effects which can become harmful beyond 10 mW/cm². Present tendencies in several countries to reduce safety standards from 10 down to 1 mW/cm² seem to be at least partially justified.

The East-West disagreement is not over: Soviet scientists still claim to have observed effects at much lower levels. Unfortunately, as before, their results could not be corroborated by similar research in Western countries (which is much better documented).

Some rather vague ideas are still coming up concerning the absorption process at the cellular level; a lot of research remains to be done to better understand the phenomena.

Finally, it is quite doubtless that microwaves have a large part to play in medical applications, for the detection and treatment of cancer. The few cases described certainly show great promise. It is now necessary to build up a larger data base in order to draw statistically significant conclusions.

For the complete papers of the symposium, contact Dr. Berteaud, CNRS, 2 rue H. Dunand 94320 Thiais, France.

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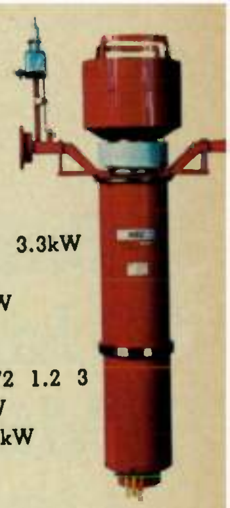

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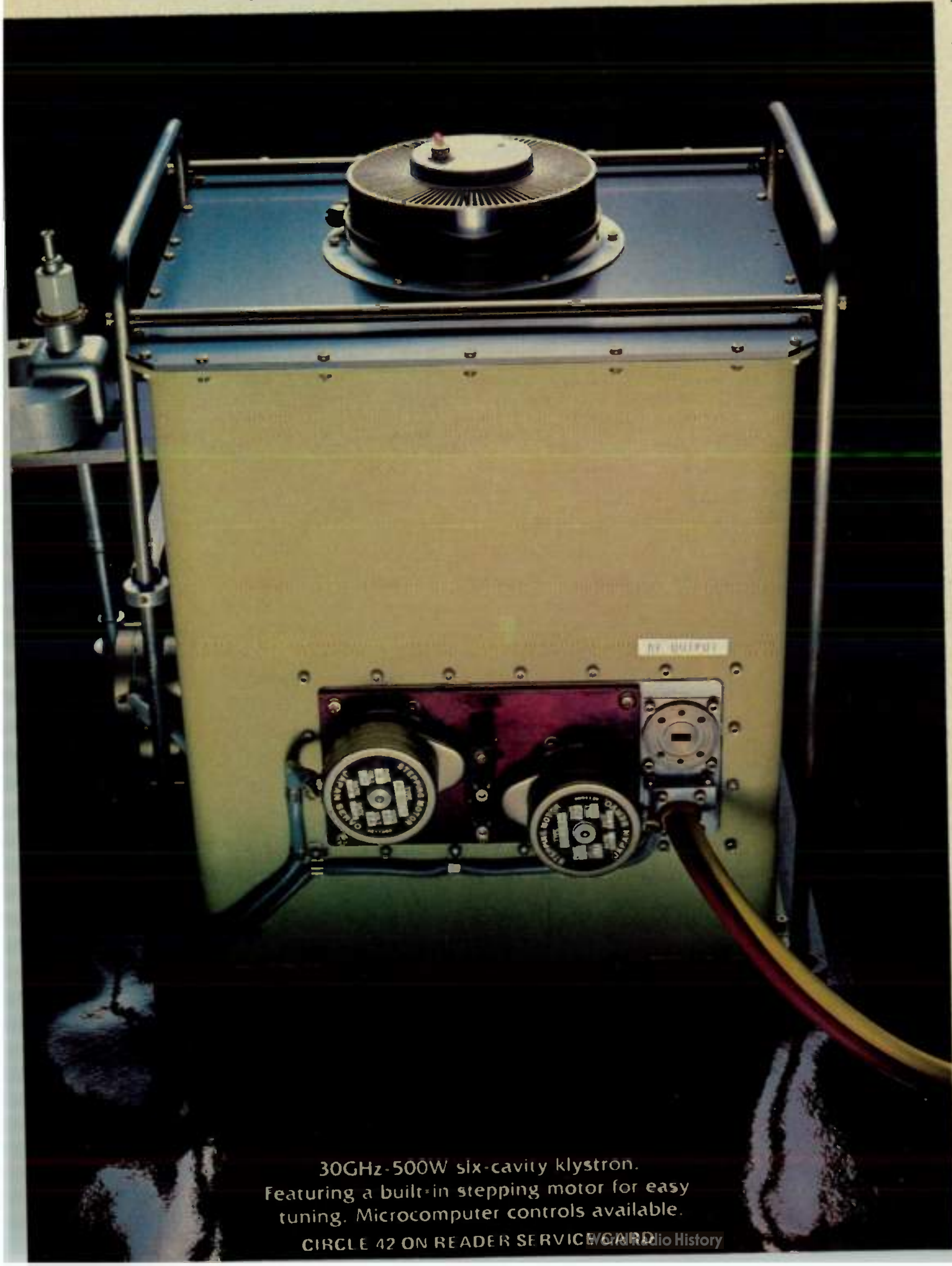
34.77 – 34.89GHz: 0.6kW



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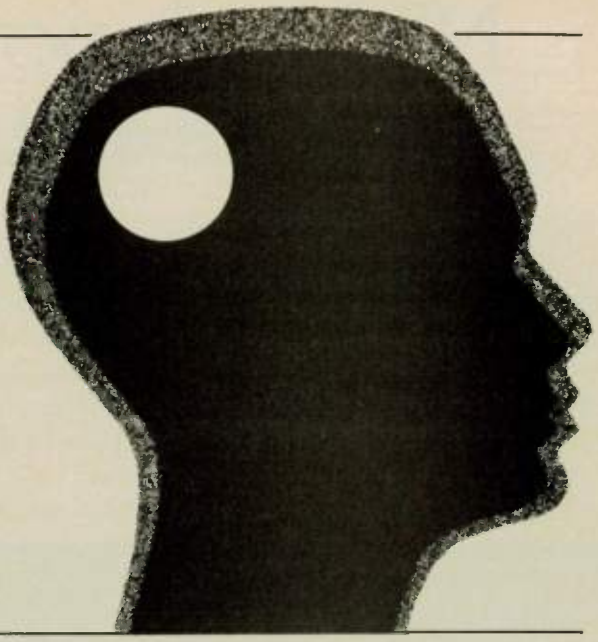

Brain Cancer Therapy Using an Implanted Microwave Radiator

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INTRODUCTION

A historic innovation in the medical application of micro wave frequencies occurred at the University of Maryland Hospital, on June 12, 1980 when a S-band microwave radiator was surgically implanted in the brain of a human patient, a young man with a brain tumor which had resisted other forms of treatment. Several watts of microwave energy at 2450 MHz were injected to raise the temperature of the volume of tissue around the radiator to 45°C; a non-interfering temperature sensor, mounted on the antenna, monitored the temperature of the tissue during the thermotherapy.

Microwave hyperthermia treatment of cancer is now being used at more than two dozen institutions in the United States, principally in the treatment of tumors close to the body surface. The application of microwaves through an implanted radiator to cancers in solid interior organs, the brain in this case, was conceived by the author in 1976.[1,2] The completion of the first patient treatment using a microwave syringe device is a milestone in the treatment of internal tumors.

The patient had been diagnosed as having a brain tumor two years ago and despite surgery, chemotherapy and ionizing radiation, the tumor had apparently continued to grow. In the hyperthermia treatment at the University of Maryland Hospital, the neuro-surgeon first surgically removed about one-half the lesion, which had grown to a tangerine-sized mass; the remaining portion was not surgically accessible without destruction of vital brain tissue. The radiating element, a simple coaxial needle antenna, was implanted in this portion, about three inches into the brain, and the tissues temperature elevated to 45°C using 2450 MHz microwave power for one-half hour. Another hour-long treatment followed later the same day, and again two days later before removal of the radiator. The patient was conscious during the thermotherapy and was released from the hospital a few days later to return home. Two other brain cancer patients have since received similar therapy. It will be many months before the success of these procedures can be determined since establishment of a cancer cure depends on the absence of recurrence, but test results so far are encouraging.

HISTORY

Heat has been used as a cauterizer and as a therapeutic agent for a variety of diseases since the beginnings of recorded history. Hippocrates wrote, "Give me power to produce fever and I will cure all disease." However, the therapeutic effects of relatively gentle heating in the treatment of cancer were not recognized until the latter half of the nineteenth century when physicians in Europe and the United States became aware of the fact that skin cancers sometimes disappeared when the patient also suffered a fever due to some unrelated disease such as malaria. The American physician, William Coley, was a pioneer in this field in the 1890s. Coley injected his cancer patients with erysipelas toxin to cause fever and inflammation and thus achieved cancer cures in a number of cases. Coley, however, dismissed the idea that heat was the therapeutic agent and held to the belief that some bacterial by-product was the cause. His work seems to have had little impact and to have gone without notice in Europe, and it was not until 1911 that a remarkable German physician, Christian Muller, became the first to successfully treat large numbers of cancer patients using thermotherapy. Muller pioneered the application of electromagnetic fields (long-wavelength diathermy) combined with X-ray therapy in the treatment of a wide variety of malignancies and wrote extensively about his theories, which involved the efficiency of heat in increasing the circulation of blood and lymphatic fluid to tumors, but there were few successors. A 1958 survey of the literature revealed over 500 reported instances of cancer hermotherapy during the preceding decades, but interest in his form of cancer therapy seems to have tapered off although it never disappeared completely. For example, in 1936 Denier became the first to use microwaves (80 cm diathermy) combined with X-rays to treat tumors, but in general there was a loss of interest in this application of thermotherapy. The cause may have been the uncertain nature of the amount of heating required, the poor follow-up on the patients treated, the interest in other new techniques provided by nuclear medicine, or simply the intervention of the wars in Europe. Whatever the reason, physicians also began to fear, without evidence, that the application of heat to cancer patients would metastisize the disease to distant parts of the body. Thus, it was not until the 1960s, when research workers began to scientifically establish the radiobiological principles involved, that interest in this "fourth modality" of cancer therapy began to spread again. It is now known that in some situations hyperthermia can destroy tumor cells with negligible damage to normal cells, and can be particularly potent against hypoxic cells in the tumor core which are a principal problem in tumor control because they are the most radiation and chemoresistant. It is also now generally accepted by hyperthermia researchers that a) there is a marked increase in sensitization to ionizing radiation with increasing temperatures above a temperature threshold which is at about 40-41°C; the sensitivity approximately doubles for each degree increase and b) the sensitization is probably greater for malignant cells than for normal tissue. There is considerable evidence that a mechanism of hyperthermia sensitization may be the denature or inactivation of enzymes and other proteins which are involved in the repair processes of radiation-induced DNA strand breaks. Hyperthermic exposure above the critical temperature produces prolonged inactivation of enzyme systems so that the time interval between hyperthermic exposure and irradiation is not critical. It is also known that in hyperthermia the poorly vascularized central tumor regions undergo a relative temperature rise with respect to normal tissue with consequent effects on cell membrane permeability, tumor biochemistry, pH, immunogenicity and inflammatory response, which all appear to enhance tumor cell killings.

MICROWAVE HYPERTHERMIA

A number of methods of creating controlled local hyperthermic fields in patients are possible despite the body's cooling mechanisms. All have been used with some success. Indeed, because of the great variation of types of malignancies, it must be expected that each method may eventually find its place in clinical procedures. Electromagnetic fields within the spectral range of kilohertz to gigahertz frequencies may be used to produce hyperthermia and have indeed been used medically since the beginning of this century to treat other conditions which respond to mild heating. At the low-frequency (10^5-10^7 Hz) range, the depth of heating is large, but there is excessive heating of fat in some geometries and the field cannot be well localized or shaped. At the high-frequency end of the microwave spectrum, because of the relatively high loss tangent of tissue, the depth of penetration into tissues is so small that the use of frequencies in C and X bands does not appear promising. Thus, interest in microwave hyperthermia has centered in S and L bands, particularly at 2450 and 915 MHz, where the energy is deposited in relatively larger volumes. These particular frequencies have also long been available for medical use in diathermy. However, although selective heating of fat is not troublesome at these frequencies, the depth of penetration of plane waves into tissue (the "skin" depth at which the energy deposition is reduced by a factor of e^{-1}) is still quite limited, varying from about 0.8 cm to 1.2 cm at 2450 MHz and 915 MHz, respectively, for high water content tissue such as muscle, brain and organs. (Application of 915 MHz rather than 2450 MHz generally requires correspondingly large radiating elements.) Also, the problem of standing waves produced in fat layers surrounding muscle and organ tissue appears. Nevertheless, microwave hyperthermia treatment of cancer patients using external microwave applicators is underway at a number of clinics and records of satisfactory results have been widely reported for tumors accessible to such treatment.

IMPLANTABLE RADIATORS

The basic difficulty in the hyperthermia of deep lying tissues by external microwave radiators is that the field is attenuated by the intervening tissue which is heated to a high temperature. This problem can be reduced to only a limited extent by simultaneously concentrating the energy of several radiators from differing angles or by cooling the surface. Some tumors can be reached by passing the radiator through a body orifice to the proximity of the malignancy. There is long-standing medical precedence for this procedure; conventional diathermy (0.4-3.0 MHz) using metallic orificial electrodes applied directly to the vagina, cervix, rectum and prostate has been used in the treatment of a variety of conditions in which the increase of blood and lymph flow due to heating has therapeutic value. Microwave hyperthermia treatment of a number of cases of cancer of the prostate have been carried out in this way by Mendecki[3] and his associates, for example. To meet the problem of cancers deep in solid organs, the writer designed a simple coaxial needle antenna. A coaxial guide or cable is useful, of course, since it has no low-frequency cutoff. The radiator is obtained, simply by open-ending the outer conductor and having the inner conductor extend out beyond it for the proper length for matching. This microwave syringe can be made from commercial coaxial

Fig. 1 Microwave syringe (needle antenna) constructed in semi-rigid coaxial waveguide.

teflon-filled waveguide (**Figure 1**) connected by standard connectors and cable to the microwave generator. Subminiature semi-rigid coax is a spin-off of the computer industry; it is available in a variety of materials, including copper and stainless steel, down to 0.2 mm diameters; standard OSSM connectors can be used down to the 0.5 mm diameter guide. Thus injection of microwave energy into tissue at any depth is feasible. The smaller diameter coax is small enough to pass through standard hypodermic needles which can be used to facilitate entry if necessary. Miniature coaxial cable can also be employed when a flexible radiator is required. To prevent damage to the soft tissue of the brain by motion of the radiator, a flexible cable is desirable, and the writer constructed a syringe in UG/178BU, (**Figure 2**) a minia-

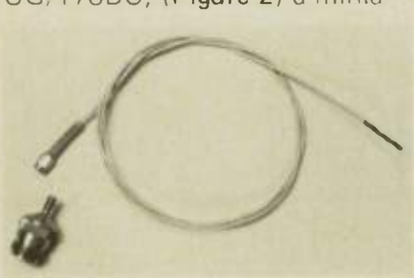

Fig. 2 Microwave needle antenna (coaxial cable form) used in brain cancer therapy.

ture coaxial teflon-filled line with a 1.8 mm diameter, for brain cancer therapy. This was the antenna used in the patient treatment at the University of Maryland Hospital. Typically in these applications, power levels of less than ten watts are required and only short lengths necessary so that the relatively limited power transmission capability and high attenuation of these waveguide and cable types are not a problem. It is also noteworthy that the needle antenna devices are well-matched (and broadband) when inserted in tissue; SWR's of less than 1.1 are readily obtained by adjusting the length of exposed inner conductor.

The energy deposition pattern of the needle radiator can be understood on the basis of the work of Wait,[4] King[5] and others on the propagation of waves along buried insulated wires and the radiation o f monopoles in lossy media. The needle may be regarded as a short open-circuited insulated section of transmission line, with complex propagation constant whose value is determined by the physical parameters of the needle, insulator and surrounding tissue medium. The standing current wave on the needle is one source of radiation. An attenuating traveling wave is also excited which propagates back towards the generator on the coaxial outer conductor; it is assumed that the needle depth in tissue is large enough (a few centimeters) so that reflection from the surface, which would result in standing-wave hot spots, is negligible. The current wave on the bare outer conductor also contributes to the radiation into the tissue. The thermographically observed heating patterns agree with the calculated parameters. The fact that the radiation is from a distributed current source is quite important. Consider the radiation pattern of an elementary dipole: in the near field, the energy disposition pattern is proportional to $(\sin^2\theta + 4\cos^2\theta)$, where θ is the angle with respect to the dipole axis. Consequently, the heating pattern (surfaces of constant energy deposition) is an ellipsoid with major axis in the forward direction. (In the far field the absorbed energy pattern is proportional to $\sin^2\theta$, with a null in the forward direction; the far-field radiation pattern of an antenna is generally quite different from the near-field absorption pattern in a lossy medium.) The heating pattern of the needle antenna does show an ellipsoidal pattern of this type in thermographic studies (ignoring the slight attenuated tail progressing back towards the generator), as may be seen from **Figure 3**. However, for the elementary dipole the energy deposition per unit volume decreases radially first as $r^{-6}\exp[-2k_0 r \mathrm{Re}\,\epsilon^{1/2}]$ and only achieves the slower rate of decrease, $r^{-2}\exp[-2k_0 r \mathrm{Re}\,\epsilon^{1/2}]$, more like a plane wave, as we enter the far field at radial distances greater than $\lambda_0/\pi \mathrm{Re}\,\epsilon^{1/2}$ (about 0.5 cm in tissues at 2450 MHz.)

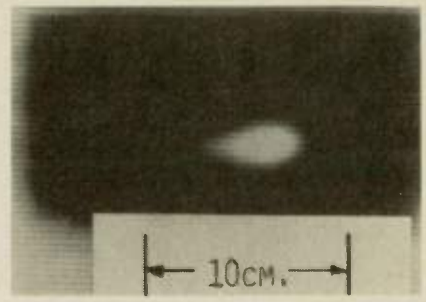

Fig. 3 Energy deposition pattern (infra-red photograph) of needle antenna in phantom material. The antenna coaxial outer conductor terminates at the center of the ellipsoidal pattern.

This pattern would not deposit the energy into appreciable depths in the tissue, and only conduction and blood perfusion would be available to distribute the energy, as in the case of a simple heated needle. The distributed current, however, produces a lower rate of energy deposition than the elementary dipole and the needle radiators do experimentally display energy deposition patterns with significant amounts of power being delivered once a one centimeter diameter in good agreement with theory. It should be emphasized, however, that *in vitro* studies cannot accurately predict the heating pattern which will be obtained *in vivo*, where blood perfusion will be the dominant mechanism in removing thermal energy, and affecting the temperature profile. It can be argued, however, that the thermal scale length associated with blood perfusion is of the same order of magnitude as the attenuation distances associated with microwave absorption. Consequently blood perfusion cannot have an order of magnitude effect upon the volume of heated tissue, although it will smooth out the pattern. This expectation is confirmed by *in vivo* animal experiments.

(continued on page 71)

ig. 4 Photograph of the needle antenna inserted in a human brain.[7] A Vitek temperature probe, used for thermal field mapping, is seen inserted to the right of the antenna cable.

IEATING PATTERN EVALUATION

The most convenient method if *in vitro* heating pattern evalua ion involves the use of semi-solid rtificial materials called "phan oms" which have the same di lectric properties as tissue. In he *split phantom* technique, the adiator is placed between the ialves of a large styrofoam mold illed with phantom material. After a short period (~ 30 s) of iigh power (~ 50 W) of CW ir adiation, one half of the mold is quickly removed, and a thermo raphic analysis of the tempera ure distribution across the other nold face is rapidly accom lished. Commercially available nfra-red systems provide an in rared picture of the mold face s well as continuous tempera ure profiles over the entire area. Because the procedure is carried out during a brief period, com pared to times required for ap preciable thermal conduction, he observed pattern is the en rgy deposition pattern. In the bsence of thermographic cam ras, a liquid crystal sheet placed n contact with the phantom can e used as an inexpensive substi ute, and a photograph will pro ide a permanent record of the heating pattern. In our work we have been fortunate to enjoy the cooperation of the Bureau of Radiological Health, which has permitted us the use of its thermographic facility.

CONCLUSION

The cytological and architectural variation of malignant diseases is extensive. Thus, the design of devices which can produce controlled hyperthermal fields for the wide variation of malignant structures has become a principal problem affecting the potential of hyperthermia treatment. The successes achieved over the last few years using microwave-induced hyperthermia indicate great promise for this modality. Of course, patient treatment by invasive applicators is a medical decision complicated by numerous physiological considerations and the fear of injury to nearby vital structures; the danger of burns due to microwave hotspots is real, and adequate thermal monitoring is essential. Nevertheless, hyperthermia may be the only viable alternative, for many patients. The patients involved in the program[7] at the University of Maryland were diagnosed as afflicted with glioblastoma multiforme, the most common form of brain tumor. Glioblastoma is an invasive lesion, typically found in the deep central white matter and often inaccessible to surgery. It has no effective treatment at present and represents one per cent of all cancers in the US. Other malignancies which have shown very low patient survival rates with conventional radiation or chemotherapy are now also being considered for treatment by thermotherapy at the University of Maryland Hospital.

ACKNOWLEDGMENT

Carrying through this project required an interdisciplinary effort which involved the efforts of Professor A. Y. Cheung, who assisted in designing the microwave power system, Professor G. M. Samaras, the physiologist who designed the thermoregulatory control system and who carried out a lengthy series of animal experiments in coordination with Dr. M. Salcman, the operating surgeon, as well the work of several other medical specialists at the University of Maryland Hospital. The many allied contributions of researchers at other institutions, described in a review paper,[6] is also acknowledged. The author also acknowledges support by the National Science Foundation Grant ECS-7910028

REFERENCES

1. Taylor, L. S., "Electromagnetic Syringe, *IEEE Trans. Biomed. Eng.*, Vol. BME-2 May 1978, pp. 308-309.
2. Taylor, L. S., "Devices for Microwave Hyperthermia," In *Proc. 2nd Int. Symp Cancer Therapy by Hyperthermia and Radiation*, 1977, pp. 115-117.
3. Sterzer, F., R. Paglione, M. Nowogrodzki, E. Beck, J. Mendecki, E. Friedenthal and C. Botstein, "Microwave Apparatus for the Treatment of Cancer," *Microwa Journal*, Vol. 23, No. 1, (1980), pp. 39-44.
4. Wait, J. R., "Electromagnetic Wave Propagation along a Buried Insulated Wire," *Can. J. Phys.*, Vol. 50, December 1972, pp. 2402-2409.
5. King, R.W.P., S. R. Mishra, K. M. Lee, and G. S. Smith, "The Insulated Monopole: Admittance and Junction Effects IEEE Trans. AP-23, March 1975, pp. 172-177.
6. Taylor, L. S., "Implantable Radiators for Cancer Therapy by Microwave Hyperthermia," *Proc. IEEE*, Vol. 68, (198 pp. 142-149.
7. Samaras, G. M., M. Salcman, A. Y. Cheung, H. S. Abdo and R. S. Schepp, "Microwave-induced Hyperthermia: An Experimental Adjunct for Brain Tumor Therapy," *Journal Nat'l Cancer Inst. Monography Series* (In press).

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Product Feature

35 GHz, 30 kW TWT

VARIAN ASSOCIATES
Palo Alto, CA

Close-up of top section of VTA-5700 TWT within its beam-focusing electro-magnet.

The new Varian VTA-5700 is a coupled-cavity TWT rated at 30 kW peak, 3 kW average power at 34.5-35.5 GHz. An early model has been operated at 9 kW average and a 30% duty cycle. Developed under contract to the US Army Ballistic Missile Defense Advanced Technology Center at Huntsville, Alabama for initial application in a radar under design at MIT Lincoln Laboratory, the tube offers power levels far beyond that previously available in the 35 GHz band and its anoucement culminates an 18-month development effort.

The tube performance is derived principally from two major features. First, it employs an electron beam with a current density of 1000 amperes/cm^2 and a power density of 50 megawatts/cm^2 with a transmission efficiency of 99%. Secondly, its coupled-cavity structure is a radical departure from the classical stacked disc approach. The mechanical design of the new structure substantially relieves requirements for extreme dimensional precision in its parts and enhances the tube's produceability. It also facilitates RF matching of the sections, minimizing phase and gain variations over the tube's 1 GHz bandwidth.

Over the 34.5-35.5 GHz bandwidth, the tube has a minimum gain of 50 dB at a rated saturated output of 30 kW peak at a 10% duty cycle. Typical operating conditions and power and gain characteristics are shown.

The Lincoln Laboratory radar will be installed at the Kwajalein National Missile Range. While techniques such as pulse compression, frequency agility and coherent signal processing have been readily applicable only at lower frequencies to enhance radar performance, the VTA-5700 affords the opportunity to employ them at 35 GHz.

TYPICAL OPERATING CONDITIONS

Peak Output	30 kW
Drive Power	0.5 W
Gain, at saturation	53 dB
Beam Voltage	47 kV
Cathode Current, peak	4 A
Body Current, peak	0.04 A
Duty Cycle	10%
Load SWR	1.15

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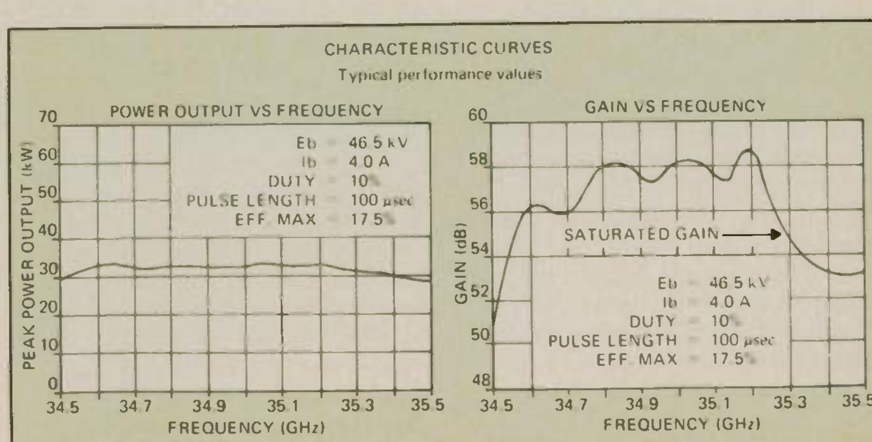

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The most versatile, co effective and reliabl self-contained generato of CW power. Guarantee minimum power-out o 250W from 10 t 2000 MHz. RF oscillato plug-ins are easily inte changeable. Digit readout of power an direct reading o frequency. Capability o increasing output powe from 400 to 600V at specific frequencie for special application

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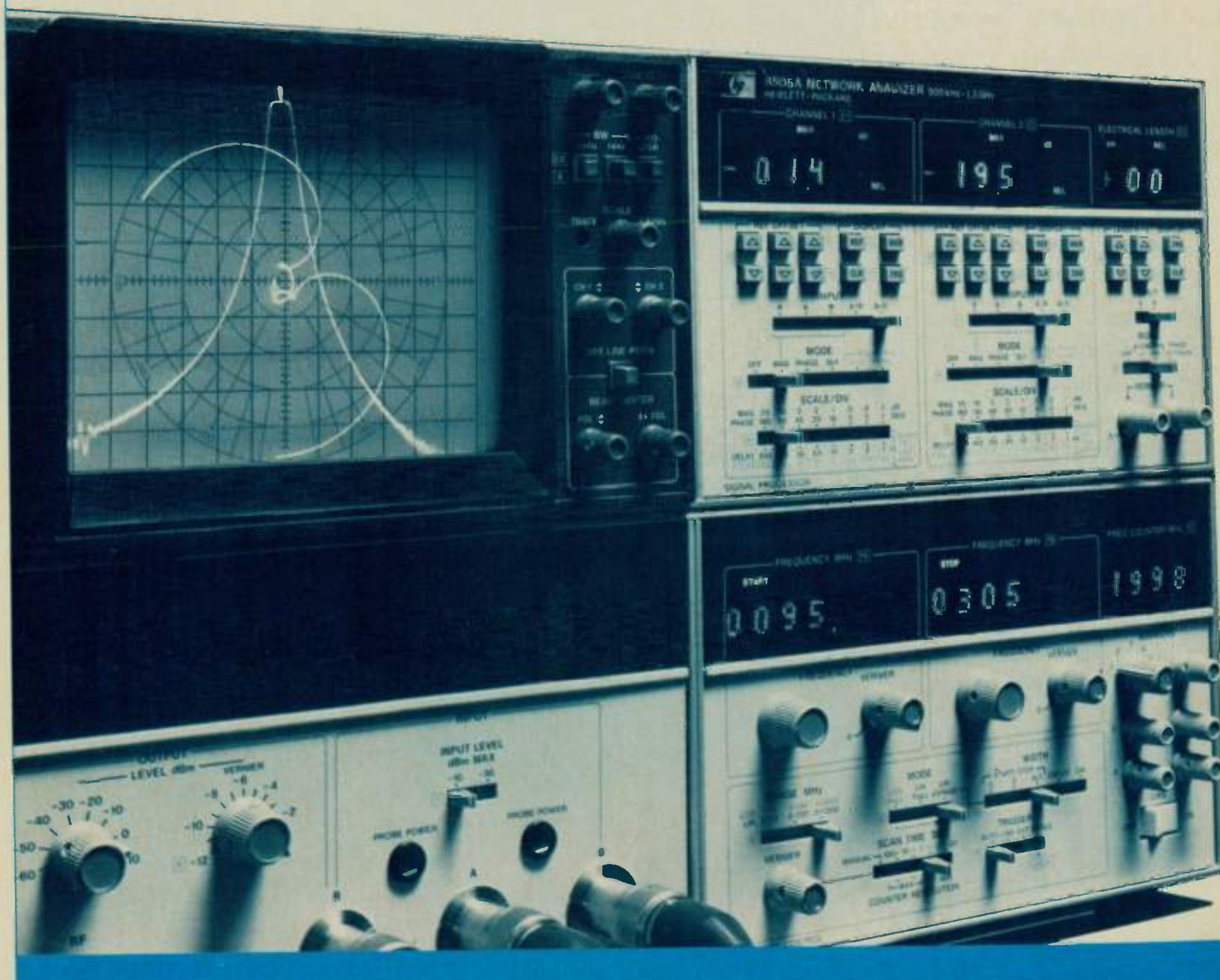

• Over 3 Decades of Swept Frequency Coverage
• 100 dB Dynamic Range
• Direct Measurement of Group Delay

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

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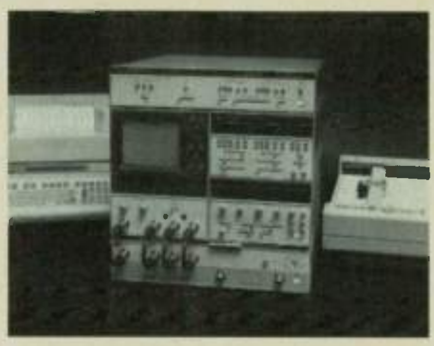
Get the speed, precision and efficiency of automatic measurements.



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

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

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

- *Digital storage* for flicker-free displays.
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- *Magnifier* for up to a tenfold increase in resolution.
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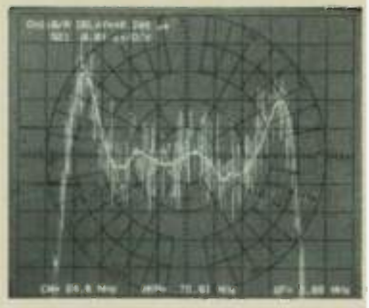
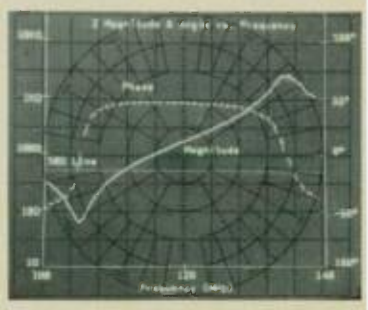
- *Signal Averaging* that raises signal-to-noise ratio, thereby improving narrowband group delay and low signal level measurements.



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

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



Reflection Coefficient data reformatted to impedance magnitude and angle

45906A

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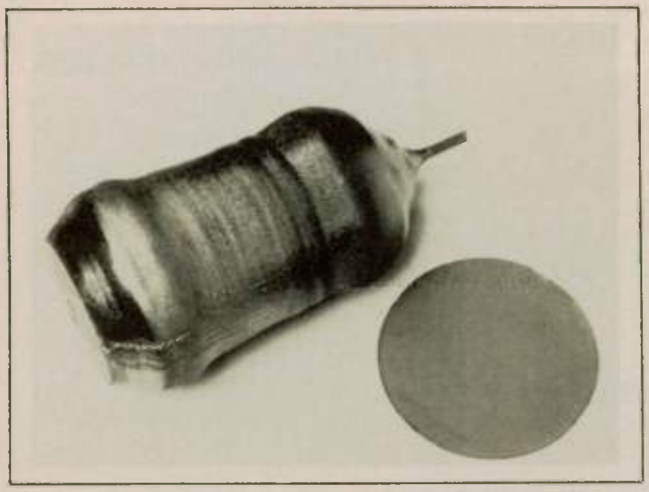

Sole US Source for S.I. GaAs Large Area, Undoped

MICROWAVE ASSOCIATES, INC.
Burlington, MA

Microwave Associates has developed and refined growth techniques for high purity, undoped semi-insulating gallium arsenide using the high pressure liquid encapsulation Czochralski technique. These new techniques eliminate the need for chromium to achieve the semi-insulating (S.I.) properties and, thereby, eliminate the problems associated with chromium outdiffusion during subsequent processing.

Undoped semi-insulating GaAs substrates are used for processing a variety of GaAs devices, such as low noise FET's, power FET's and GaAs integrated circuits. Improved performance or simplified processing can be expected in all these devices due to the elimination of chromium from the substrate. Increased device yields can be expected due to the high degree of uniformity of electrical properties in these substrates.

Resistivities obtained are typically in excess of 10^6 ohm-cm and mobilities are in excess of 4000 cm^2/V-sec over the length of the crystal ingot and across the diameter of an individual substrate, as illustrated in **Figure 1a & b** and **Figure 2a & b.** This high degree of uniformity insures consistent device yields from all substrates from a given crystal. Active device layers can be made in these substrates by direct ion-implantation or by epitaxial growth. No degradation of resistivity is seen in uncapped wafers after annealing at 750°C for 30 minutes or in capped wafers annealed at 850°C for 30 minutes, assuring that the wafers can be utilized for ion-implantation or epitaxial growth.

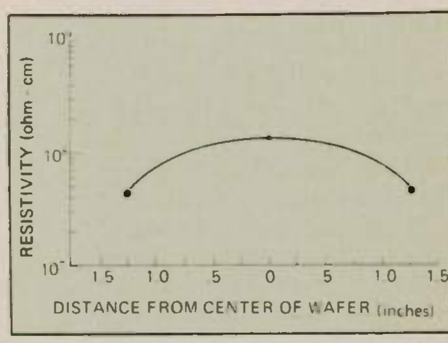

Fig. 1b Resistivity across undoped semi-insulating GaAs wafer.

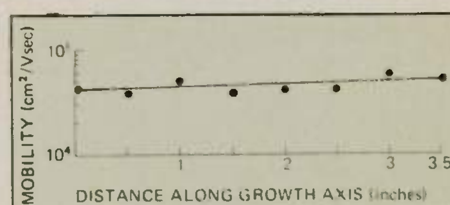

Fig. 2a Mobility along axis of undoped semi-insulating GaAs ingot.

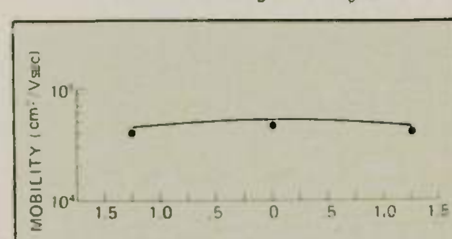

Fig. 2b Mobility across undoped semi-insulating wafer (inches).

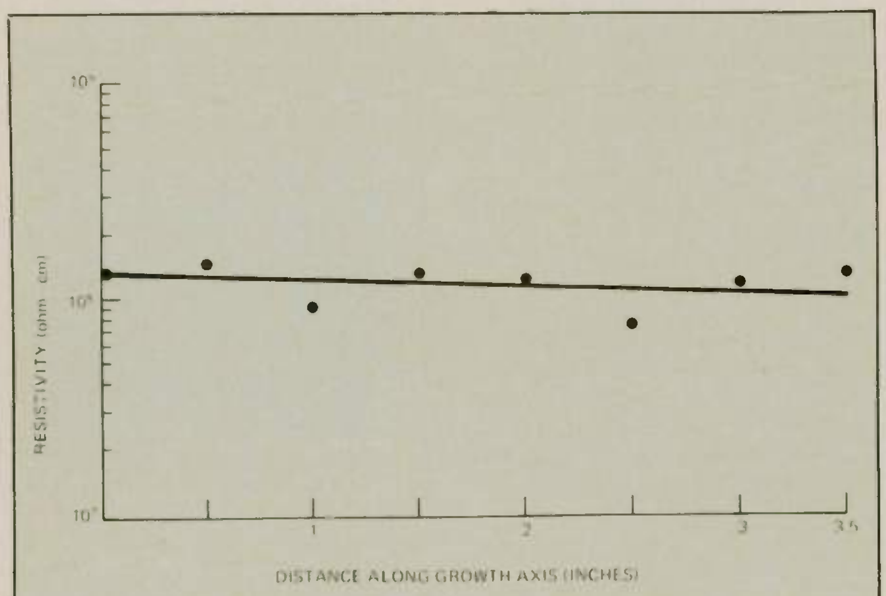

Fig. 1a Resistivity along axis of undoped semi-insulating GaAs ingot.

Crystals have dislocation density profiles typical of Czochralski GaAs. Figure 3 shows a typical profile where the etch pit density ranges from a low of 15000 per cm^2 to a high of > 100,000 per cm^2 at the wafer edge.

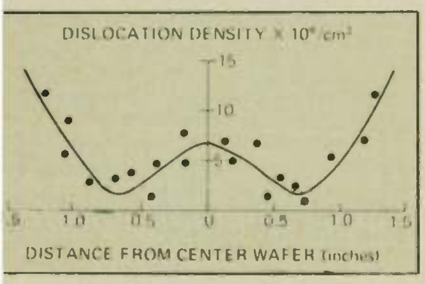

Fig. 3 Etch pit across undoped semi-insulating GaAs wafer.

Substrates are polished to a high degree of surface perfection for uniform and reproducible device processing. Round wafer shapes of up to three-inch diameter permits the economies of large-area processing and automatic wafer handling.

Polished substrates are presently available in orientations of (100) and 2° off (100) from stock.

High substrate quality is maintained by routine measurement of a variety of electrical and crystallographic properties. The electrical resistivity and Hall mobility are determined using the high impedance van der Pauw method. Trap levels are determined through the use of a variety of measurements, including transient spectroscopy, photoluminescence, and resistivity versus temperature measurements. Wafers are qualified for use in epitaxy or ion-implantation by annealing followed by van der Pauw measurement. Dislocation densities are determined by the use of selective etchants and microscopic examination. Only ingots which are fully qualified for FET processing are fabricated as undoped S.I. substrates.

An ongoing development program is focussing on obtaining even higher quality substrates. A substantial effort is directed toward increasing the uniformity of electrical and mechanical properties and toward reducing the level of background impurities of which may lead to device degradation. Significant improvements are expected in levels and distribution of dislocations and other crystallographic defects. New measurements are under development which will give improved correlation with actual device performance. As advances are made in crystal quality and evaluation, they will be incorporated into production substrates. For more information contact: Gerry Porter, Microwave Associates, Inc., 43 South Avenue, Burlington, MA 01803; (617) 272-3000.

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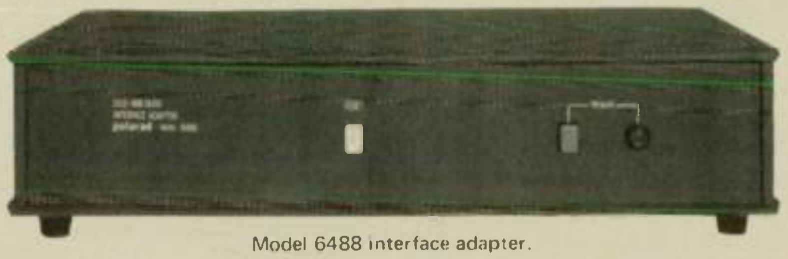
Spectrum Analyzer Accessories

POLARAD ELECTRONICS INC.
Lake Success, NY



Model 6488 interface adapter.

Two accessories for the Polarad 600 Series Spectrum Analyzers significantly expand their capabilities and the range of applications for which these moderately priced analyzers are suited.

DATA INTERFACE ADAPTER

The Model 6488 Data Interface Adapter enables the digital memory of the analyzers to "talk" and "listen" to IEEE-488 Bus compatible accessories such as desk-top computers, data recorders and plotters. With the data interface, spectrum display data in the digital memory may be stored, recalled and processed. The adapter is compatible with the HP Model 9825A computer and Tektronix Models 4051 and 4052 graphic computer systems. An X-Y plotter can be used to produce multi-color hard copy fully calibrated readouts.

With split memory analyzer operation, any stored display may be directly compared to incoming signals for production line or field test purposes. The external controller can be programmed to process a number of signals, i.e., add them, take differences, obtain averages, maxima, minima, etc., and the interface adapter permits the results to be displayed. The Model 6488 has a buffer read/write memory equal in size to that of the spectrum analyzer and handles entire display wave forms.

CASSETTE RECORDER

A second accessory, the Programmable Digital Cassette Recorder, Model 6700, can be used for recording, storing and recalling spectrum displays. It employs a standard (Philips type) C60 tape cassette which can record up to 60 displays on each side. Any of these can be recalled to the analyzer display by key pad entry.

For production and field test applications, remote storage and recall of any number of reference spectrum displays for on-screen comparison to real time signals is facilitated. Simple go, no-go measurements of frequency and/or amplitude are simplified by the comparison method available with the recorder.

The Model 6488 interface adapter is priced at $1,575; the Model 6700 Cassette Recorder at $2,000. Delivery for both is 60-90 days.

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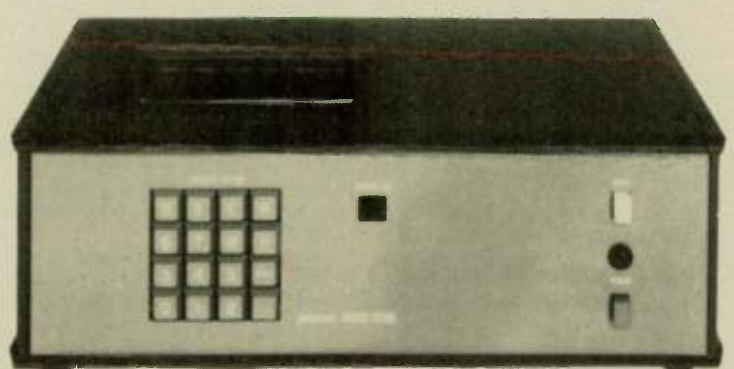


Model 6700 programmable digital cassette recorder.

Microwave Products

Hardware

CABLE TRIMMER

A trimming machine for UG/141 and UG/085 coaxial cable trims to connector specification MIL C 39012B. Two different bushings are included to handle two cable sizes (0.141" and 0.085"). Machine produces a clean cut and is rugged and easy to operate. Trimming takes 15 seconds or less and set up time is minimal. Size: 5 1/3" W x 11 1/2" L x 4" H. Price: $680. Avail: Off the shelf, F.O.B. delivery. **U.Z., Inc. Culver City, CA. Jerry Hoffman, (213) 839-7509. Circle 152.**

Systems

HIGH POWER AMPLIFIER FOR SATCOM SYSTEM

The Model 10517 is a 2.5 kW TWT C-band transmitter with IPA designed to amplify communication and data signals to a power level suited for satellite communication. Unit operates from 5.9-6.4 GHz with a 70 dB gain and offers small size, self diagnostic capability, full panel metering, reliability, fault protection and regulation. Model employs a long life, conservative design. **MCL, Inc., LaGrange, IL. Frank Morgan, (312) 354-4360. Circle 151.**

Tubes

MINI-TWT FOR 7-17.5 GHz BAND

Model F-2169 is a CW miniature traveling wave tube designed for use in multi-tube phased array ECM and radar systems. Unit covers the 7-17.5 GHz frequency range and has over 55 dB small signal gain over the entire band, plus minimum output of 45 W over the 8-13 GHz band. Tube uses a vane loaded helix type slow wave structure and is PPM focused with Sm-Co magnets. Isolated focus electrode is featured for turning power supply on or off. This metal ceramic tube is conduction cooled and may be mounted in any position. Collector is isolated and can be depressed up to 50% of the collector voltage. For multiple tube mounting, tubes can be placed adjacently on .800" centers. **ITT Electron Tube Division, Components Group N. America, Easton, PA. Jack Myers, (215) 252-7331. Circle 180.**

BACKWARD-WAVE OSCILLATOR SPANS 110-170 GHz BAND

Model RWO 170 is a backward-wave oscillator with an electronic tuning range of 110-170 GHz at average power output of 10 mW, minimum 1 MW. BWO is suited for waveguide transmission systems and mm radar systems. Tube and magnet system form a single unit with weight of 2 kg (4.5 lbs). Heater voltage is 6.3 ± 2% Vac, and delay line voltage is 500-2500 Vdc typically, maximum 2700 Vdc while delay line current is up to 15 mAdc maximum. Maximum temperature range of unit may be from -20° to 55°C. **Siemens Corporation, Iselin, NJ. (201) 494-1000. Circle 153.**

75 W TWT FOR EARTH STATIONS

The TH 3641 is a 75 W traveling wave tube which operates in the 5.925-6.425 GHz uplink band. Its principle application is for small 6 GHz earth stations in "domestic" satellite telecommunications systems. Tube offers better than 25% efficiency at saturation, with only one collector stage. Model has average operating life which exceeds 15,000 hrs. Model offers low AM-PM coefficient and broadband helix TWT performance. **Thomson-CSF, Electron Tubes Div., Clifton, NJ. (201) 779-1004. Circle 155.**

15 kW GRID-PULSED TWT

Model VTC-5762A2 is a grid pulsed traveling-wave tube developed for use in either airborne or surface radar systems. Tube delivers a peak power output of 15 kW, min. over the 5.4-5.9 GHz frequency range. Maximum drive power is 250 mW at a 2.2% duty cycle. Weight: 26 lbs. Size: 28" long. The metal-ceramic tube is air-cooled and may be mounted in any position. **Varian Associates, Electron Device Group, Palo Alto, CA. (415) 493-4000. Circle 182.**

Materials

EMI/RFI GASKETING WITH PRESSURE SEAL

A composite EMI/RFI shielding and pressure seal strip, Pola-H™, is designed for H (magnetic) field shielding but also provides E (electric) field and P (plane wave) shielding performance as well. Gasketing consists of continuous solid-copper conductive paths in a solid silicone pressure seal. Protruding tips of the cut copper are plated with tin alloy for low contact resistance at the mating surfaces. Minimal compression characteristics with minimal compression set are featured. Material is rated for use within the -56°C to +240°C temperature range. Tight seal up to 250 psi (17.58 kg cm^{-2}) offered. Size: 18' (548.64 cm) or 9' (274. cm) strip lengths, .25-.625" (3.18-15.88 cm) widths; .125-.500" (3.18-12.70 mm) heights. Material usually used in gaskets larger than 3" (76 mm) sq. **Metex Corporation, Electronic Products Div., Edison, NJ. (201) 287-0800. Circle 183.**

1-40 GHz LOCK BOX FREQUENCY STABILIZERS

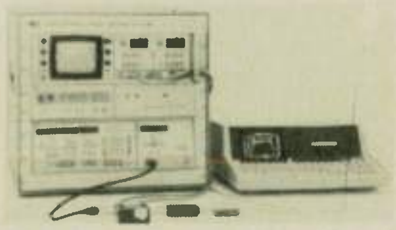
Series MS 150 are frequency stabilizers which cover 1-40 GHz in two input ranges. Sample of the RF to be phased locked is connected to either the Type N rear panel connector for 1-18 GHz or the type UG 595 U waveguide on the front panel for 18-40 GHz. Control functions are TTL implemented so that the instrument may be manually operated or automatically operated from remote intelligence. Frequency stability of various models ranges from $4/10^{8}$/hr to $8/10^{10}$/hr. Price: From $5075. Del: 45-90 days. **Niagara Scientific, Inc., E. Syracuse, NY. (315) 437-0821.** **Circle 149.**

FREQUENCY COUNTER FOR 1.3 GHz BAND

A 1.3 GHz frequency counter, Model DC508A, is designed for communications applications in the 960-1215 MHz band and 1215-1300 MHz band. Frequency resolution is 0.01 Hz in 1 sec. from 10 Hz to 25 kHz. Frequency from 10 Hz to 1.3 GHz is shown on a nine-digit LED display. Prescalar input measures frequency from 100 MHz to 1.3 GHz, and direct input from 10 Hz to 100 MHz. Input SWR is 2.2 or less. Input sensitivity is 20 mV RMS from 100 MHz to 1.1 GHz and 40 mV RMS over the 1.1-1.3 GHz band. Available with oven controlled time base option or time base and tracking generator combination. Price: $1,400 (US). Del: 2 wks. ARO. **Textronix, Inc., Beaverton, OR. (503) 644-0161; 1-800-547-1512.**

Circle 179.

LOW COST, AUTOMATIC SCALAR MEASUREMENT SYSTEM



Model HP 8755P is a low cost, automatic scalar analyzer system which contains a microprocessor-based sweep oscillator RF plug-in and frequency response test set for measurement of insertion loss or gain and return loss (calibrates and measures up to 500 points) of devices, components and networks operating in the 0.04-18 GHz frequency bands. System command is provided by a computing controller and system control is achieved via HP-Interface Bus which implements IEEE-488. Basic performance characteristics are determined by the HP 8755 test set for measurement range (60 dB range for all these detector inputs), and by the 8350A/83592A sweeper for test signal frequency and power level accuracies (less than 20 MHz and less than 1.5 dB at 20 GHz). System offers amplitude resolution of 0.1 dB over full screen range at 10 dB/division sensitivity (100 dB range) which improves to 0.02 dB if the signal falls within ± 2 divisions of screen center (40 dB). With 1 dB/division sensitivity setting, resolutions achieved at 0.01 dB over full 10 dB screen range or 0.002 dB in middle range (4 dB). Price: Automatic Scalar Network Analyzer, $45,930. Reduced performance and cost options are available. Del: 20 wks. **Hewlett-Packard Co., Palo Alto, CA. (415) 857-1501.** **Circle 145.**

 CIRCLE 47 ON READER SERVICE CARD

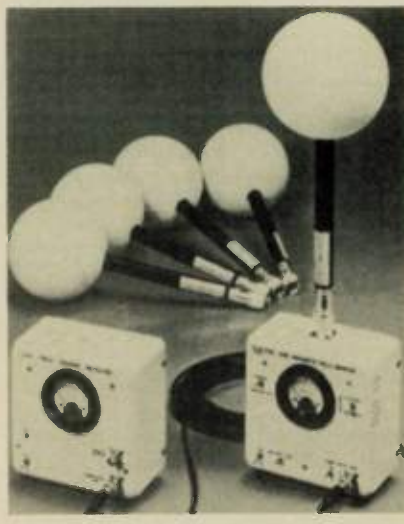
COMPUTER-CONTROLLED PHASE NOISE ANALYZER

An automatic, computer controlled phase noise analyzer, Model 900, is designed for continuous measurement of direct phase noise contributions from various subsystems within a CW or pulsed radar system. This automatically calibrated instrument has a sensitivity of 115 dBc/Hz, typical, X-band, and includes capabilities for full frequency ranges of 1 GHz to 12.4 GHz and 1-18 GHz. Max. residual error is 0.5° for 1-12.4 GHz and 1.0° for 12.4-18 GHz. Unit has 0-55°C operating temperature; -40-65°C non-operating temperature. Completely self-contained, a rack-mounted option is available and model features digital controls. Size: 7" H x 19" W x 24" D. Weight: 80 lbs. **Frequency Engineering Laboratories, Farmingdale, NJ. (201) 938-9000.** Circle 178.

MICROPROCESSOR-CONTROLLED VECTOR ANALYZER

Model ZPV is a microprocessor-controlled vector analyzer for automated test set-ups. Unit features complete GPIB (IEEE-488) control and measures: complex voltage and voltage ratio; S parameters, impedance and group delay. Frequency range is 0.1-2000 MHz. Basic unit consists of a dual-channel vector voltmeter which measures magnitude and phase and a microprocessor-controlled analyzer section to weight, normalize and convert the measured voltage vectors into the desired complex quantity. Options permit intelligence of the set to be matched with the requirements of the specific application. **Polarad Electronics, Lake Success, NY. Gene Kushner, (516) 328-1100.** Circle 148.

RF FIELD SENSOR SYSTEM



Novel RF field sensor system uses balanced, isotropic probes to respond to any incident field, regardless of polarization, and allows true summing of all incident electric or magnetic fields in the 1 MHz to 500 MHz frequency band. System includes a completely shielded metering instrument with separate sensor probes, and a field sensor repeater connected to the metering instrument via a fiber-optic cable. Three sensor probes span electric field strengths from 10-100 V/m full scale and two sensors cover magnetic field of 1 and 10 A/m full scale. System provides true reading of incident radiation. Size: metering instrument and repeater each measure 15 cm x 15 cm x 9 cm. Price: $7,650, including metering instrument, repeater, fiber-optic link and five proves. Del: 69-90 days ARO. **Amplifier Research, Souderton, PA. (215) 723-8181.**

Circle 144.

RF DETECTOR GIVES 75-OHM TESTS FOR SCALAR NETWORK ANALYZER

Model 560 Scalar Network Analyzer offers an RF detector (560-71N75) which measures transmission loss or gain and power of 75-ohm test devices. Instrument operates over the 1-2000 MHz range and has a frequency response of ± 0.5 dB maximum and -50 dBm sensitivity. Measurement accuracy is enhanced by network analyzer which automatically subtracts from test data residuals stored in memory during calibration. Hard copy output curves provide permanent record of test results. Detector has type N male connector and may be used interchangeably on A, B, or R channels of network analyzer. Unit includes field replaceable Schottky diode module. Price: $270, Model 560-71N75. Del: 90 days. Wiltron Company, Mountain View, CA. Walt Baxter, (415) 969-6500.
Circle 146.

SYNTHESIZED FREQUENCY SOURCE

Model PLS-4853-10 is a synthesized frequency source designed to operate over the 48.8-53.2 GHz frequency band in 10 MHz frequency steps. Frequency selection is via a thumbwheel switch. Power output is + 13 dBm minimum and options for 5, 10, or 100 MHz input reference are featured. Price: $1500, 1-4 qty. Del: 90 days ARO. **Miteq Inc., Hauppauge, NY. (516) 543-8873.** Circle 181.

Components

FLEXIBLE COAXIAL ASSEMBLIES FOR TEST EQUIPMENT

A ruggedized .190" O.D. Gore-Tex microwave cable assembly is designed for use with microwave test equipment in labs, production areas and in the field. Assemblies have impedance of 50 ohms ± 1 ohm, shielding effectiveness of greater than 100 dB down at 1 GHz plus a capacitance of 26 pf/ft and time delay of 1.2 nsec/ft, maximum and dielectric withstanding voltage of 1000 V, RMS. Crush resistance is in excess of 300 lbs/linear ft, plus excellent flexibility (minimum bend radius of 1") and long flex life. Performance tested over 2" D mandrel with no significant changes in SWR (1.25 maximum, through 18 GHz) or insertion loss (from .08 dB/ft at 1 GHz to .60 dB/ft at 26.5 GHz). Constructed with polyurethane jacket 15 mils thick over cadmium plated steel spring, with patented Gore-Tex PTFE dielectric and molded, tapered PVC strain-relief boots at the connectors. Weight: 28 gm/ft cable, plus 15 gm per pair of SMA connectors. **W.L. Gore & Associates, Inc., Electronic Assembly Div., Newark, DE. (302) 368-3700.** Circle 163.

SERIES OF DUAL-IN-LINE BROADBAND NOISE GENERATORS

NZG series of Noizeg™ models are dual-in-line broadband noise generators with frequencies from 100 Hz to 2 MHz. Component features white Gaussian noise; 14-PIN DIP; qualified peak factor of 5:1 (minimum) and frequency flatness of ± 0.5 dB. Temperature coefficient is -0.05 dB/C (nominal); load impedance is 600 Ω and operating voltage for the model is +15 V. Unit conforms to MIL STD 202 and is hermetically sealed. Size: 0.870" × 0.50" W × 0.240" H. Weight: 10 gm (maximum). Price: $90 and up for 1-9 qty. Del: Stock to 6 wks ARO. **Micronetics, Inc., Norwood, NJ. Gary Simonyan, (201) 767-1320.**
Circle 164.

50 W STUD-MOUNTED TERMINATIONS & RESISTORS

A series of 50 W stud mounted terminations and resistors, PMS 500, are power components operating at 100 C ambient temperature. Terminations are 50 ohms ± 2%, and resistors are offered from 10-500 ohms. Terminations have a SWR of less than 1.10:1 at 500 MHz. Studs are nickel plated per specification QQ-N-290, Class 1, Grade D. Price: $24.25 each, 100 pieces. Avail: From stock. **KDI Pyrofilm Corp., Whippany, NJ. (201) 887-8100. Circle 158.**

YIG MULTIPLIER

Model YM1134 is a multioctave, YIG multiplier. Unit may be used as a local oscillator, with output signal having all harmonics and spurious down to 60 dB. Model accepts input of 1-2 GHz at 1 W, output range is 2-8 GHz with RF power output at +10 dBm. Size: 1.7" cube. Weight: 16 oz. Analog driver or 12-bit TTL also available.

Omniyig, Inc., Santa Clara, CA. William Capogeannis, (408) 988-0843. Circle 167.

MULTICOUPLERS COVER 1 MHz TO 4 GHz RANGE

A line of multicouplers designed for antenna distribution and communication systems cover the 1 MHz to 4 GHz frequency range. Models have up to 32 output ports and offer one octave to two decade bandwidths. Units feature low noise (6 dB at 470 MHz) with spurious-free wide dynamic range and excellent isolation between outputs, plus high reliability. Modular design permits incorporation of input limiters and channel filters (HP, LP, or BP). Del: 60-90 days. **North Hills Electronics, Inc., Glen Cove, NY. Herb Marx, (516) 671-5700. Circle 174.**

LOWER PARASITIC REACTANCE THIN FILM CHIP RESISTORS

A line of thin film alloy chip resistors features a wide sheet resistivity range and minimum parasitic reactance. Resistor element sheet resistivities range from 10 to 3000 ohms/sq with minimum parasitic reactance at frequencies from dc to 2 GHz. Produced on alumina or beryllia substrates, these resistors provide ground edges for improved part-to-part uniformity. Power transfer rating is 1-150 W. Contacts are high adhesion, solder-over-nickel, with gold available also. Size: from 0.040" x 0.020" x 0.010" to 0.375" x 0.250" x 0.063". Price: From $1.50 each. **Piconics, Inc., Tyngsboro, MA. Irving Kadesh, (617) 649-7501. Circle 175.**

VHF TUNABLE BANDPASS FILTER

Model HP5BT-30/76-N is a VHF tunable bandpass filter which covers a greater than octave band from 30-76 MHz with a power handling capability of 50 W CW when terminated in a load of 3 to 1. Model has a passband which is only 3% of the tuned frequency and its 40 dB rejection bandwidth is limited to 6% maximum. Selectivity is achieved via five High Q, gang tuned resonators. When operated in a 50-ohm system, SWR is less than 1.3, typical, at center frequency, (1.5, maximum). Price: $2,675, single qty. Avail: 8 wks. **K & L Microwave, Inc., Salisbury, MD. Charles Schaub, (301) 749-2424. Circle 159.**

VOLTAGE CONTROLLED BANDPASS FILTER

A voltage controlled bandpass filter, #VTF-1450, is tunable from 1425-1525 MHz. Unit uses a tuning voltage of 2-15 Vdc and tuning rate of 1 μsec. The 3 dB points above midband loss are at ± 20 MHz maximum; the 40 dB points are at ± 75 MHz maximum. Insertion loss for the model is 9.0 dB maximum at ± 10 MHz and filter has SMA Female connectors. Size: 2.6" x 1.4" x 1.0". Price: $1,200, small qty. Avail: 6-8 wks. **Triangle Microwave, Inc., East Hanover, NJ. James Beard, (201) 884-1423. Circle 168.**

UNABLE, DUAL-CHANNEL BANDPASS FILTER

he 501800 is a tunable, dual channel andpass filter with a 7.8-8.5 GHz tuning ange. Tracking accuracy between is 2 MHz between filters at any frequency n range. A 10 turn shaft tunes the unit cross its entire range. 3 dBbw is 16 ± 1 MHz and 25 dBbw is ± 60 MHz maximum. nsertion loss of filter is 1.5 dB at fo ± 2 MHz minimum and SWR is 1.4 maximum. Comes with SMA female connectors and is onstructed of aluminum with temperature ompensation. Price: $1560, small qty. Avail: 6-8 wks., ARO. **Coleman Microwave Co., Edinburg, VI. (703) 984-8848.**

Circle 170.

UHF DUAL ISO-FILTER

An ultra high frequency dual iso-filter, Model 103600027, uses a sharp cutoff omb-line filter plus two high performance errite isolators integrated on a common round plane structure. Model covers the 494-554 MHz band with an insertion loss of 1.3 dB, max. Rejection at 614 and 438 MHz is greater than 40 dB. Both input and output SWR remain below 1.3 for all load onditions. Single and dual iso-filters covering bandwidths as wide as 70% from 500 MHz to 18 GHz are available. Price: (Model 103600027) $1,395, small qtys. Del: 8-12 wks, ARO. **Eaton Corp., Communication Products Div., Sunnyvale, CA 94086. Jim Moore, (408) 738-4940**

Circle 171.

POWER UPCONVERTER FOR SAT COM EARTH STATION

Model UC7041 is a S to Q-band power upconverter with power output of 10 mW (min.). at a frequency in the 35-45 GHz frequency range. Outputs up to 100 mW are available as options. Unit has an instantaneous bandwidth of 2 GHz and broadband 2-4 GHz signals are translated to the higher Q-band frequencies with a conversion loss of 7 dB to drive the TWT transmit chain. Configuration includes an optional high-power C band phase-locked local oscillator. **LNR Communications, Inc., Hauppauge, NY. Jeannie Piotrowski, (516) 273-7111.**

Circle 172.

HYBRID RF AMPLIFIER SPANS 5-300 MHz

Model QBH-103 is a 15 Vdc, RF amplifier with 11.5 dB gain, 7.0 dB noise figure at 25 C. Amplifier exhibits a gain flatness of ± .5 dB, maximum, ± .25 dB, typical and gain vs temperature of ± .5 dB from −54 C to 71 C. Unit has high reverse isolation (greater than 25 dB). SWR in/out for the unit is less than 1.5:1 for 50 ohm system. Amplifier includes an internal decoupling choke in series with the power supply and is housed in a TO-8 can. Finish for header is gold plated Kovar and cap is nickel. Weight: 2.3 gm. **Q-bit Corporation, Palm Bay, FL. (305) 727-1838.**

Circle 166.

LOW FREQUENCY VARIABLE ATTENUATOR

A low frequency, continuously variable attenuator, Model 0682-40F, operates over the dc to 60 MHz frequency range with a minimum attenuation range of 40 dB and it is equipped with a direct reading dial in 1 dB increments. Insertion loss is less than 0.5 dB and SWR is 1.5 maximum. Connectors are SMA, Type N or TNC, also available with 75 ohm impedance. Size: 2.5" x 1.54" x 1.5". Price: $175, small qty. Avail: stock to 4 wks. ARO. **ARRA, Inc., Bay Shore, NY. Mike Geraci, (516) 231-8400.**

Circle 173.

TTL COMPATIBLE PROGRAMMABLE ATTENUATORS

A line (of TTL) compatible attenuators is available in the dc to 1300 MHz frequency range. Attenuators are supplied in 4, 6 or 8-cell configurations and provide incremental attenuation in .1 or 1 dB steps to a maximum of 127 dB. Attenuators can be specified for 50 or 75 ohm applications and operate from 24-28 Vdc. Price: $4.50 per cell, with TTL option. Del: 4-6 wks. **Texscan Corporation, Indianapolis, IN. Raleigh B. Stelle, III, (317) 357-3781.**

Circle 165

CIRCLE 53 ON READER SERVICE CARD

FUNDAMENTAL-OUTPUT, YIG-TUNED TRANSISTOR OSCILLATOR

A fundamental-output, YIG-tuned transistor, Model AV-7248, oscillator with GaAs FET buffer amplifier and integral tracking YIG filter offers a low - 40 dBc maximum harmonic content over the 2-8 GHz tuning range as well as + 14.8 dBm (30 mW) minimum output power with ± 30.0 dB maximum variation, and ± 0.1% tuning linearity. Unit exhibits a maximum 20 MHz frequency drift over the 0° to +65° C case temperature range. Model suited for use as signal source in lab sweep generators as well as a local oscillator for spectrum analyzers and microwave receivers. Size: 2" D. x 1.4" L hybrid construction package with gold, thin-film and includes low-inductance FM coil. Weights: 17 oz. **Avantek, Inc., Santa Clara, CA. John Hyde, (408) 727-0700.**

Circle 156.

MIXER-PREAMPLIFIERS COVER 3.7-4.2 GHz BAND

Models MPA4200A and MPA4201A are mixer-preamplifiers designed for the 3.7 to 4.2 GHz communications band. The units feature double-balanced mixers which provide isolation greater than 20 dB. IF bandwidth for the former is 880 ± 20 MHz and 1112.5 ± 20 MHz for the latter model. Noise figure for both models is 12 dB max. and RF-IF gain of both is 18 ± 0.75 dB. The MPA4201A has an integral isolator on the RF port to provide input SWR of less than 1.25:1; MPA4200A input SWR is 1.5:1 (max.). **Aertech Industries, Sunnyvale, CA. W.S. Patton, (408) 732-0880.**

Circle 169.

TERMINATIONS FROM dc TO 18 GHz

Models T180M and Model T130M are two versions of a dc to 18 GHz 50-ohm termination. The T180M unit is a SMA male, 1 W CW, 1 kW peak load. Its maximum SWR over the dc to 18 GHz frequency band is 1.15, and the SMA stainless steel connector complies with requirements of MIL-C-39012. Model T130M operates to same performance specifications, but it is provided with a beaded chain and #6 eyelet for front panel mounting. Price: $15, T180M; $20, T130M. Del: Stock to 30 days. **Engelmann Microwave Co., Montville, N.J. Carl Schraufnagl, (201) 334-5700.**

Circle 157.

MIXER SERIES IN COMMUNICATIONS BAND

A series of mixers designed for communications band applications, include Models M63T-1 and M66T-1 mixers, which operate in the 1.7-2.3 GHz band. Typical conversion loss for M63T-1, which has a LO drive level of +7 dBm, is 7 dB; for M66T, typical conversion loss is 6.5 dB at LO drive level of +13 dBm. Typical isolation is L-R, 25 dB; L-I, 28 dB for the units. Mixers are hermetically sealed in a TO-8 package and can be mounted on printed circuit board. Avail: From stock, immediate delivery. **Magnum Microwave Corporation, Sunnyvale, CA. David Fealkoff, (408) 738-0600.**

Circle 160.

HIGH AVERAGE POWER, DUAL CHANNEL ROTARY JOINT

Model 2255 is a high average power, dual-channel rotary joint in WR-284, offered for use in azimuth axis of AF ground terminal surveillance radar. Both channels operate in the 3.1-3.7 GHz frequency band with 15 kW average power and 170 kW peak power. Size: 25" L x 5" D. **Kevlin Manufacturing Co., Woburn, Mass. Ernest Lattanzi, (617) 935-4800.**

Circle 162.

Advertising Index

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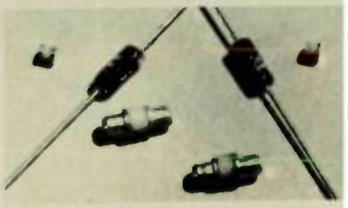


New Literature

INT'L PUBLICATION ON MEASUREMENT METHODS

Publication 510-1-3 contains standard methods of measurement for radio equipment used in satellite earth stations as well as measurements common to subsystems and combinations of subsystems plus measurements in the IF range. This standard is a further refinement of a previously published 510-1 standard dealing with measurements common to subsystems in the intermediate frequency range. It sets conditions for measurement of return loss, input and output levels, amplitude/frequency characteristics, static automatic gain control characteristics, dynamic characteristics and group-delay/frequency characteristics. **International Electrotechnical Commission, Geneva, Switzerland. 34 01 50, TLX 28872.** Circle 137.

BOOKLET ON GYROTRONS

A 14-page booklet provides an "Introduction to Gyrotrons." Literature provides a description and test results of gyro-devices, including gyrotron oscillator, gyroklystron amplifier and gyro-TWT. Booklet has introductory section, plus sections on basic characteristics, programs and results for each type of gyro-device, gyrotron operation and future projects. Performance characteristics, schematic drawings and photographs are included in each section. **Varian Associates, Electron Device Group, Palo Alto, CA. (415) 493-4000.** Circle 143.

DOUBLE BALANCED MIXER CATALOG

A line of double-balanced mixers is described in a catalog which includes comprehensive data sheets on expanded line of low frequency mixer products from dc to 2300 MHz and microwave mixers up to 18 GHz. Information on satellite communications band mixer line is included. **Magnum Microwave Corp., Sunnyvale, CA. David Fealkoff, (408) 738-0600.** Circle 140.

DATA SHEET FOR FUSED FEEDTHROUGH ADAPTOR

This two-page bulletin contains information on electrical, mechanical and environmental characteristics of fused feedthrough adaptors. Applications and mounting instructions also included. **Cablewave Systems, Inc., North Haven, CT. Steven Raucci, Jr., (203) 239-3311.** Circle 136.

VARIABLE CAPACITOR CATALOG

A 16-page manual on variable capacitor design includes seven sections covering variety of capacitor types, styles and characteristics. Format incorporates design concept which tabulates capacitors by part number, product photo and characteristics. Provides detailed dimensional drawings and electrical characteristics for line. **Johanson Manufacturing Corp., Boonton, NJ. Eric Fagerlund, (201) 334-2676.** Circle 139.

APPLICATION BROCHURE ON CONDUCTIVE COATING

A full color, four-page brochure details applications for EMI conductive coatings on plastics used in electronic enclosures. Literature includes "how to" information, with pointers on surface preparation, thinning formulas, spraying procedure and electrical testing for acrylic finish application to plastic substrates. Brochure contains recommendations on selection of equipment and list of plastic substrates compatible to spray conductive coating procedure. **Tecknit, Cranford, NJ. R. Bilby, (201) 272-5500.** Circle 141.

CATALOG OF SMALL SIGNAL, LOW NOISE TRANSISTORS

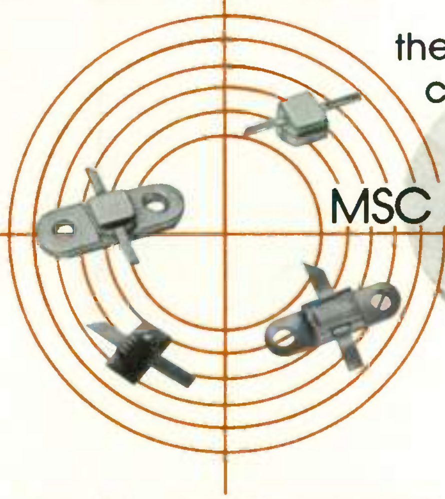
A large format, 52-page booklet describes a family of 15 small signal, low noise transistors. This 1980 four-color catalog contains specifications, performance graphs, photographs and circuit diagrams, plus package drawings and dimensions. Also provides description of gold metallization and ballast resistor features. **TRW RF Semiconductors, Lawndale, CA. Bernie Lindgren, (213) 679-4561.** Circle 142.

CATALOG OF MICROWAVE COMPONENTS AND ASSEMBLIES

An 80-page catalog describes microwave components and assembly product line. This 1980 catalog highlights continuously variable attenuators, fixed attenuators, and coaxial components such as directional couplers, power dividers and waveguide products. A removable chart is included which lists all waveguide sizes and flanges as well as electrical specifications and mechanical dimensions. **ARRA, Inc., Bay Shore, NY. Mike Geraci, (516) 231-8400.** Circle 135.

MSC

Revised Power GaAs FETs



the highest power devices commercially available, and made in America

MSC 88000 SERIES

Features

- Broadband Linear Gain
- Lowest Thermal Resistance
- S-Parameters Compact™ Databank
- Metal-Ceramic Packaging
- Gold Metallization

Electrical Characteristics (@ 25°C)

MODEL NUMBER	TEST FREQ (MHz)	POUT(1) TYP (W)	POUT(1) MIN (W)	PIN (mW)	Vds NOM (V)	Idss NOM (mA)	θcc(2) TYP (°C/W)	PACKAGE TYPE
C-BAND SERIES								
MSC 88000	6000	0.060	0.050	8	8	90	45	FLIP-CHIP HERMETIC
MSC 88001	6000	0.200	0.175	40	8	150	35	FLIP-CHIP HERMETIC
MSC 88002	6000	0.400	0.350	90	9	300	25	FLIP-CHIP HERMETIC
MSC 88004	6000	1.000	0.800	200	9	700	20	FLIP-CHIP HERMETIC
MSC 88012	6000	3.700	3.500	800	10	2000	7	FLIP-CHIP HERMETIC
X-BAND SERIES								
MSC 88100	12000	0.060	0.050	16	8	90	45	FLIP-CHIP CARRIER
MSC 88101	12000	0.200	0.175	56	8	150	35	FLIP-CHIP CARRIER
MSC 88102	12000	0.400	0.350	125	9	300	25	FLIP-CHIP CARRIER
MSC 88104	12000	1.000	0.800	280	9	700	20	FLIP-CHIP CARRIER
Ku-BAND SERIES								
MSC 88199	15000	0.030	0.025	6	8	70	40	FLIP-CHIP CARRIER
MSC 88200	15000	0.110	0.100	25	8	120	35	FLIP-CHIP CARRIER
MSC 88201	15000	0.250	0.200	70	8	160	29	FLIP-CHIP CARRIER
MSC 88202	15000	0.450	0.400	140	9	325	23	FLIP-CHIP CARRIER
MSC 88204	15000	0.900	0.800	316	9	675	15	FLIP-CHIP CARRIER

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

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

YOUR TOTAL MICROWAVE RESOURCE

The MSC series of GaAs FETs are designed for linear power amplifiers and for oscillator applications from 2-14 GHz. Higher frequency state-of-the-art devices are also available. Please call or write for a complete GaAs FET Product Data Packet, and the MSC 24-Page Product Guide.

MSC MICROWAVE SEMICONDUCTOR INC.
an affiliate of SIEMENS
100 School House Road
Somerset, New Jersey 08873, U.S.A.
(201) 469-3311 TWX (710) 480-4730 TELEX 833473

CIRCLE 2 ON READER SERVICE CARD

Now Available...

1W AMPLIFIERS

0.05-1200 MHz from $199

- Broadband ... each model multi-octave (see table)
- High linear output ... up to 30 dBm (1 W)
- Gain ... available from 16 dB to 27 dB
- Very flat gain response ... ±1 dB
- Connectors ... BNC Std; SMA, TNC, N available
- Compact ... 3.75" × 2.60" × 1.92" (ZHL-A Models)
  4.75" × 2.60" × 2.22" (ZHL Models)
- Self-contained heat sink
- One-week delivery

ZHL-2-8

If your application requires up to 1 watt for intermodulation testing of components ... broadband isolation ... flat gain over a wide bandwidth ... or much higher output from your frequency synthesizer or signal/sweep generator ... MiniCircuits' ZHL power amplifiers will meet your needs, at surprisingly low prices. Five models are available, offering a selection of bandwidth and gain.

Using an ultra-linear Class A design, the ZHL is unconditionally stable and can be connected to any load impedance without amplifier damage or oscillation. The ZHL is housed in a rugged ⅛ inch thick aluminum case, with a self-contained hefty heat sink. BNC connectors are supplied; however, SMA, TNC and Type N connectors are also available. Of course, our one-year guarantee applies to each amplifier.

So from the table below, select the ZHL model for your particular application now ... we'll ship within one week!

ZHL-1A

MODEL NO.	FREQ. MHz	GAIN dB	GAIN FLATNESS dB	MAX. POWER OUTPUT dBm 1-dB COMPRESSION	NOISE FIGURE dB	INTERCEPT POINT 3rd ORDER dBm	DC POWER VOLTAGE	DC POWER CURRENT	PRICE $ EA.	PRICE QTY.
ZHL-32A	0.05-130	25 Min.	±1.0 Max.	+29 Min.	10 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-3A	0.4-150	24 Min.	±1.0 Max.	+29.5 Min.	11 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-1A	2-500	16 Min.	±1.0 Max.	+28 Min.	11 Typ.	+38 Typ.	+24V	0.6A	199.00	(1-9)
ZHL-2	10-1000	15 Min.	± 1.0Max.	+29 Min.	18 Typ.	+38 Typ.	+24V	0.6A	349.00	(1-9)
ZHL-2-8	10-1000	27 Min.	±1.0 Max.	+29 Min.	10 Typ.	+38 Typ.	+24V	0.65A	449.00	(1-9)
ZHL-2-12	10-1200	24 Min.	±1.0 Max.	+29 Min.*	10 Typ.	+38 Typ.	+24V	0.75A	524.00	(1-9)

Total safe input power +20 dBm, operating temperature 0° C to +60° C, storage temperature −55° C to +100° C, 50 ohm impedance, input and output VSWR 2:1 max.
*+28.5 dBm from 1000-1200 MHz
For detailed specs and curves, refer to 1980/81 MicroWaves Product Data Directory, Gold Book, or EEM

World's largest manufacturer of Double Balanced Mixers

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