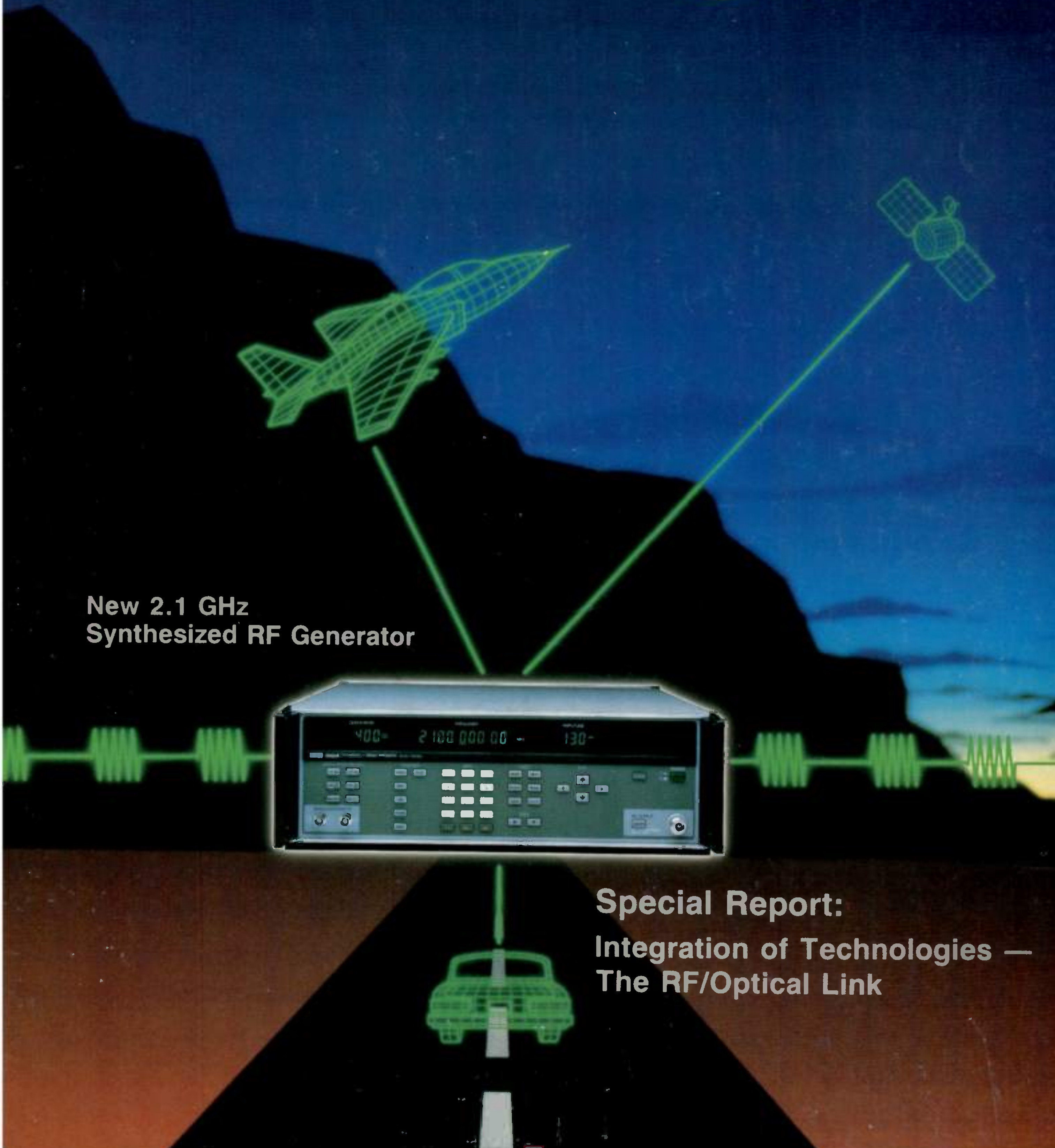
rf design

ideas for engineers

April 1987



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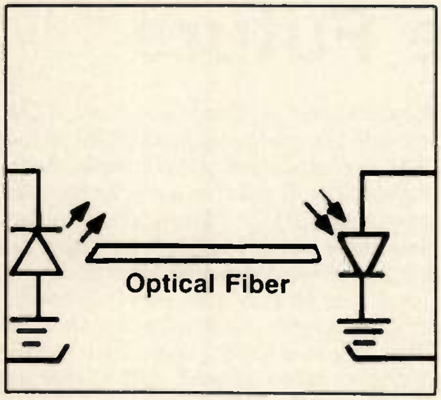
INFO/CARD 3

rf design

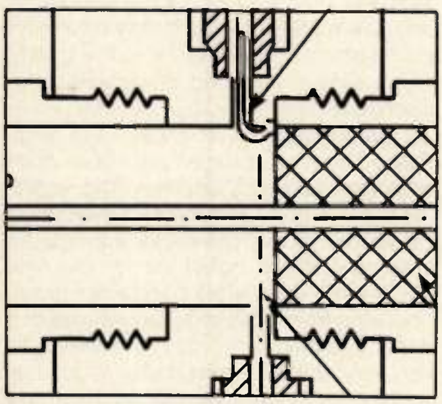
April 1987

Cover Story



Page 31 — *Analog Fiber Optic Links*

Features



Page 44 — *Measuring Dielectric Constant*

Page 48 — *RF Radiation Monitoring*

Departments

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Waves of the Future

By Gary A. Breed
Editor

The fastest growing use of the electromagnetic spectrum isn't at kHz, MHz or GHz frequencies. . . it's at hundreds of THz (Terahertz): light waves. Light is rapidly becoming an integral part of communications, instrumentation, industrial, medical and military systems. The technology of light even has a new name: *photonics.* Directly and indirectly, the development of light technology will have a major impact on the RF industry; a *positive* impact.

For a start, RF techniques are integrated with optical techniques in fiber optic communications, where signal processing and modulation techniques operate below a couple GHz. Laser-based instruments have signal processing circuits operating into the MHz range, similar to radar video processing. Even "star wars" laser weapons are pumped with high power RF. There is more information on these direct connections between light and RF in our Special Report on page 28.

The Fiber Optic Revolution

Of all the applications of light technology, fiber optic communications systems will have the greatest impact on our professional and personal lives. First, there is the technical challenge to utilize all the available bandwidth of an optical system. A glass fiber as small as a human hair can pass many GHz of information, if we can find a way to impress that information on a light beam. Gigabit per second digital circuits are already here, with both optical and electronic modulation techniques soon to follow. Exotic ideas, such as RF/optical mixers using RF and a laser as signal and local oscillator, are being explored.

These technical challenges will easily keep the interest of RF, digital and optical engineers. However, there may be a more subtle area of impact as a result of growth in photonics: *reduced demand for RF spectrum.*

I agree with the scientists and engineers who predict the end of our reliance on communications satellites. The restricted bandwidth of wireline and microwave transmission was the major impetus for communications satellites in the first place. With even more bandwidth possible using fiber optic systems, why launch expensive and risky satellites when we can bury an inexpensive cable in good ol' *terra firma*? We can dismantle a few microwave systems, too. Of course, we'll keep a few systems intact to serve remote locations, and as a backup.

Just as wires replaced hand-carried messages, radio links replaced wires, and satellites replaced multi-hop microwave systems, optical transmission will take its place as the next step in the progression. RF engineering will continue to play a major role in the development of the new communications infrastructure, and we will get back some valuable spectrum space to use for the next generation of RF applications.

Gary A. Breed

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More About The New RF Engineers

By Keith Aldrich
Publisher

In January, just a few weeks before RF Technology Expo 87 was held in Anaheim, I visited a number of major RF engineering groups in Southern California to determine the extent of their knowledge of and involvement with the Expo. They worked at Hughes, Rockwell, TRW, General Dynamics, in clusters of half a dozen up to forty or fifty. The majority do know about the Expo and many have been to at least one. And as I talked with them I was able to confirm the truth of something which had started to emerge in reader research and in other ways over the past two or three years. . .

There is definitely a new breed and body of RF engineers, forty and under, baby boomers who differ in several significant respects from older RF engineers. To begin with they are not just younger, they are actually separated by an age gap. There were ten to fifteen years when few new graduate EEs were going into RF work, so today the RF engineering population tends to be either younger or older, with not much in between.

Secondly, the older RF generation is less likely than the younger to be attracted to computer-aided design techniques. Its members are justifiably proud of instincts and insights developed over long years of experience which make CAD less imperative to them than it is to the relative newcomers. When they do use computers it is more likely to be with a program developed for a very specific design routine, rather than one of the general purpose programs.

The new RF engineers outnumber the older ones. That is because the field is growing and, of course, the more recent recruits tend to be younger. It is possible that a higher percentage of the new RF engineers have EE degrees, and especially graduate degrees. On the other hand, the proportion of the new RF engineers who are ham radio operators is probably smaller than the percentage of older RF people who are hams. Among the older group, many became RF engineers as a result of being youthful hams, and received their training in such on-the-job situations as the armed services. The younger crowd tends to see itself as electronics circuit designers first, and radio specialists second.

I don't see the viewpoint of either of the groups as being necessarily superior to the other — and certainly we will not allow the magazine to become identified with one viewpoint as opposed to the other. I do see that in the tug of war, the slight tension that exists between the polarities, we have the potential for truly creative solutions to engineering problems. One more reason to predict. . .we are on the verge of a golden age of RF technology.

Keith Aldrich

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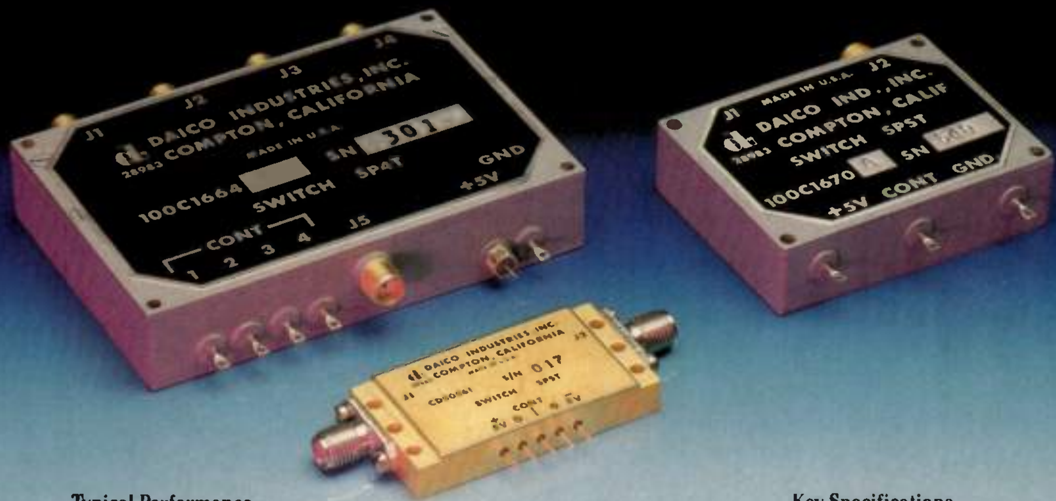

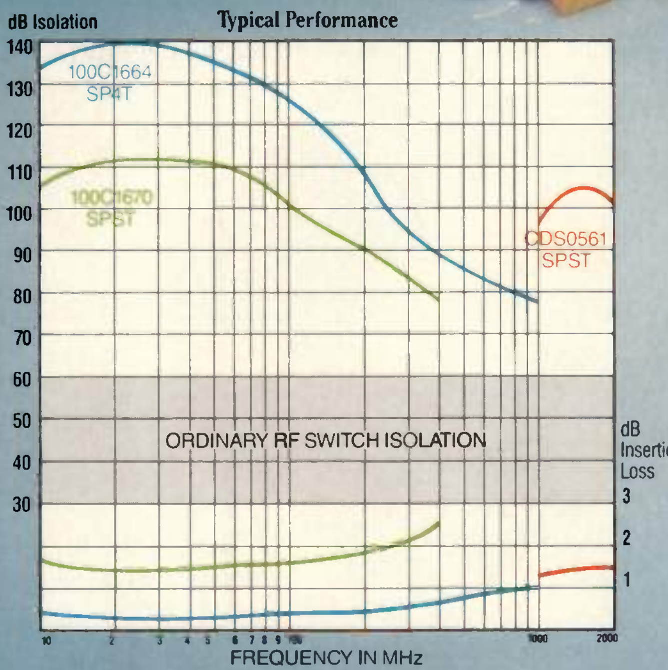

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Transition Time	4	2	—	ns	90%/10% or 10%/90% RF
Switching Speed	17	33	400	ns	50% TTL to 10%/90% RF
Insertion Loss	1.5	1.5	—	dB	—
	—	—	0.7	dB	20 - 350MHz
	—	—	1.0	dB	350 - 600MHz
Isolation	106	100	—	dB	—
	—	—	105	dB	20 - 200MHz
	—	—	85	dB	200 - 600MHz
VSWR	1.15 / 1	1.2 / 1	1.1 / 1	—	—
Termination VSWR	1.5 / 1	1.2 / 1	1.1 / 1	—	—
RF Power,	+13.5	+12	+24	dBm	0.1 dB Compression
Operate Max.	—	—	+30	dBm	No Damage
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INFO/CARD 6

Letters should be addressed to: Editor, *RF Design*, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111.

Hybrid Splitter/Mixer IMD Comments

Editor:

With regards to Daniel Marz article "Hybrid Splitter Improves Mixer IMD Performance" (Jan. 87) I wonder how much of the improvement in IMD is due to the 3 dB padding effect of the hybrid. Virtually the same performance can be achieved by terminating the mixer wiith a 3 dB resistive attenuator. This would properly terminate the filter as well. The resultant circuit would be less costly and easier to implement.

Better performance can be obtained by using an LC diplexer at the output of the mixer to terminate the LO, but this would add to the circuit complexity and therefore its cost.

Stephan E. Sykes
Harris/RF Communications
Rochester, NY

Editor:

The author of the article "Hybrid Splitter Improves Mixer IMD Performance," January 1987, p. 62, implies that all energy reflected from the filter is absorbed by the isolating resistor in the power divider, thus accounting for the mixer IM improvement. This is not true; the reflected energy is equally divided between the isolating resistor and the mixer. A 3 dB pad would have the same effect.

David E. Norton
Adams-Russell, Anzac Division
Burlington, MA

The Author's Response

Editor:

Both the 3 dB pad and the splitter will give similar results, although at high frequencies, where a splitter can be easily constructed using microstrip techniques, the splitter will need only two resistors against the three required by the 3 dB pad.

Daniel Marz
General Instrument, Jerrold Div.
Hatboro, PA

Errata

Editor:

I especially enjoyed my old colleague Dick Bain's article "The Engineer's Toolkit," but unfortunately it suffered from having received less than your usual grade of editing. I suggest a contest: a prize for finding the most errors on page 134!

William B. Lurie
Boca Raton, FL

Figure 1, page 134 of the February 1987 RF Design *should have rho (ϱ) in place of p. — Editor*

Editor: Feb. issue, page 41 — center — part of paragraph one appears below Figure 5. Was something of importance left out? Where is Fig. 10? I hope this is not standard procedure.

C.B. Shuttle
Belmont, CA

No, it's not standard procedure! Disregard the repeated text just below Fig. 5. On page 43, the references to Figures 10 and 9 in the center paragraphs should be changed to Figures 8 and 7. — Editor

rf courses

The George Washington University

Introduction to Digital and Analog Modulators and Transmitters
April 20-21, 1987, Washington, DC

Wind Shear Radar
April 20-22, 1987, Washington, DC

Digital and Analog Modulation, Modulators and Transmitters
April 22-24, 1987, Washington, DC

Introduction to Receivers
May 4-5, 1987, Washington, DC

Modern Receiver Design
May 6-8, 1987, Washington, DC

Global Positioning System: Principles and Practice
May 18-20, 1987, Washington, DC

Fiber Optics Technology for Communications
May 19-21, 1987, Washington, DC

Electromagnetic Pulse and its Effect on Systems
June 15-17, 1987, Washington, DC

Information: Shirley Forlenzo, Continuing Education Program, George Washington University, Washington, DC 20052; Tel: (800) 424-9773; (202) 994-8530

UCLA Extension

Modern Microwave Measurements and Applications
April 21-24, 1987, Westwood, California

Modern Telecommunications Networking: Local/Metropolitan Area and Satellite Communication Networks
May 11-14, 1987, Westwood, California

The Techniques and Technology of the Application of Kalman Filters and Nonlinear Filters
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Microwave Circuit Design I
June 1-5, 1987, Westwood, California

Navstar Global Positioning System (GPS)
June 15-19, 1987, El Segundo, California

Pave Pillar Avionic Systems and Related Technologies
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June 2-5, 1987, Ottawa, Canada
July 14-17, 1987, Denver, Colorado

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Digital EMC
April 21-24, 1987, San Diego, California

Grounding and Shielding
May 5-8, 1987, Atlanta, Georgia
June 9-12, 1987, San Jose, California
July 21-24, 1987, Myrtle Beach, South Carolina

ESD Control
May 18-19, 1987, San Jose, California

Intro to EMI/RFI/EMC
May 20-22, 1987, San Diego, California

TEMPEST Design
June 16-19, 1987, Mountain View, California

TEMPEST Facilities
July 28-31, 1987, Mountain View, California

Information: Interference Control Technologies, Inc., State Route 625, P.O. Box D, Gainesville, VA 22056; Tel: (703) 347-0300

Integrated Computer Systems

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May 5-8, 1987, Palo Alto, California
June 9-12, 1987, Ottawa, Canada
June 23-26, 1987, San Diego, California
July 21-24, 1987, Los Angeles, California

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April 28-May 1, 1987, Toronto, Canada
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April 27-28, 1987, Baltimore, Maryland
April 30-May 1, 1987, Valley Forge, Pennsylvania

Microwave Circuit Design
June 1-5, 1987, Los Angeles, California

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IEEE Instrumentation and Measurement Technology Conference
Sheraton-Boston Hotel, Boston, Massachusetts
Information: Robert Myers, Myers/Smith, Inc., 1700 Westwood Blvd., Los Angeles, CA 90024; Tel: (213) 475-4571

April 28, 1987
1987 Long Island Microwave Theory and Techniques Society Symposium
Crest Hollow Country Club, Woodbury, New York
Information: Bob Koelzer, Narda Microwave, 413 Moreland Road, Hauppauge, NY; Tel: (516) 231-1700

May 11-13, 1987
37th Electronics Components Conference
Boston Park Plaza Hotel and Towers, Boston, Massachusetts
Information: Tom Pilcher, Electronic Industries Association, 2001 Eye St. N.W., Washington, DC 20006; Tel: (317) 261-1306

May 18-22, 1987
National Aerospace and Electronics Conference (NAECON) Set
Dayton Convention Center, Dayton, Ohio
Information: Cathy Joyce, SAE Headquarters, Dept. 935, 400 Commonwealth Drive, Warrendale PA 15096; Tel: (412) 776-4841

May 19-21, 1987
EMC Expo 1987
Town and Country Hotel, San Diego, California
Information: Sandra Hamilton, EMC Expo 87, P.O. Box D, Gainesville, VA 22065; Tel: (703) 347-0030

May 27-29, 1987
41st Annual Frequency Control Symposium
Dunfey City Line Hotel, Philadelphia, Pennsylvania
Information: Dr. R.L. Filler, U.S. Army Electronics Technology and Devices Laboratory, SLCET-EQ, Fort Monmouth, N.J. 07703-5000; Tel: (201) 544-2467

June 1-5, 1987
EFOC/LAN-87, Fifth European Fibre Optic Communications and Local Area Networks Exposition
European World Trade and Convention Center, Basel, Switzerland
Information: Renne Farrington, Information Gatekeepers, Inc., 214 Harvard Avenue, Boston, MA 02134; Tel: (617) 232-3111

June 9-11, 1987
IEEE MTT-S International Microwave Symposium
Bally's Grand Hotel, Las Vegas, Nevada
Information: Steve March, Maury Microwave Corporation, 8610 Helms Ave., Cucamonga, CA 91730; Tel: (714) 987-4715

June 9-11, 1987
NEPCON East '87
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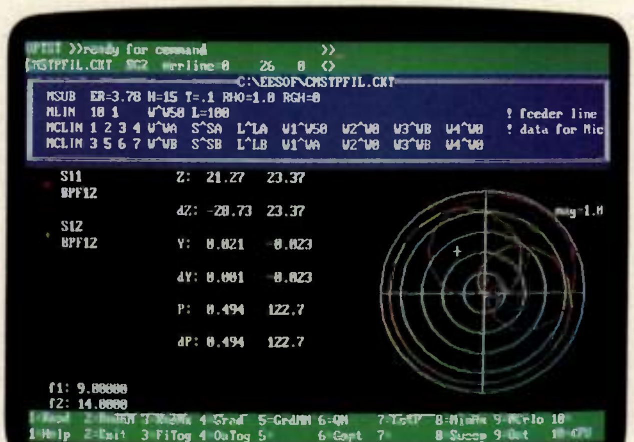

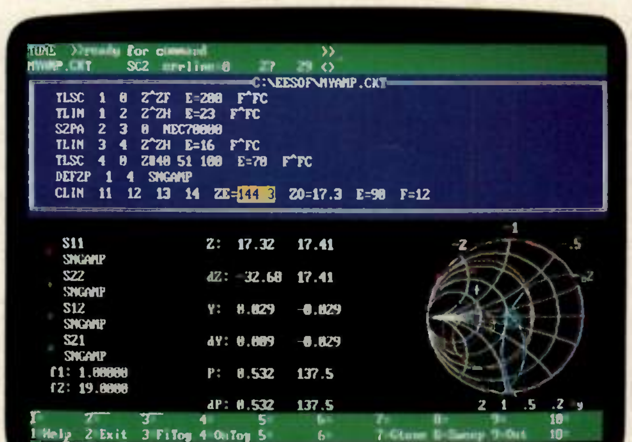

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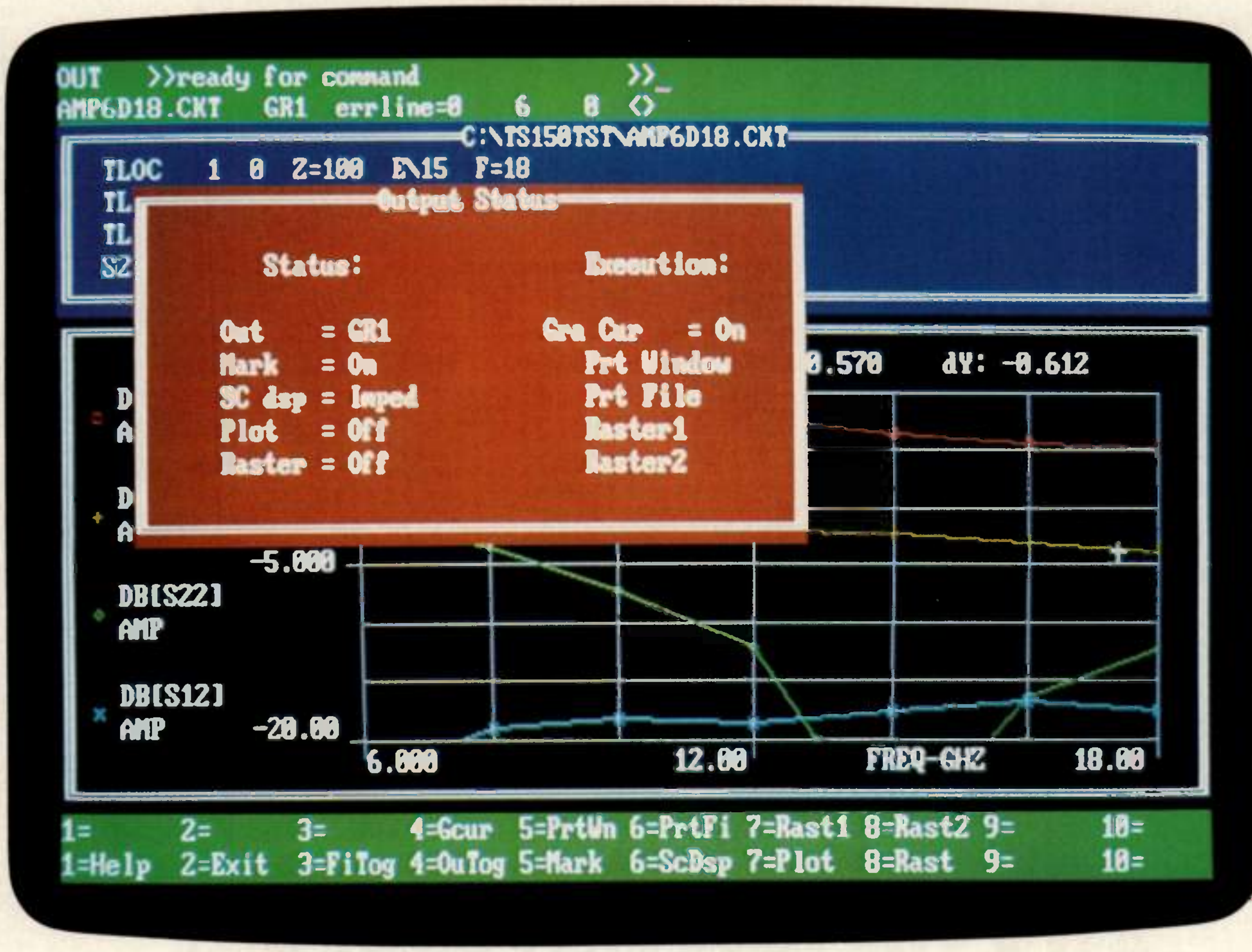

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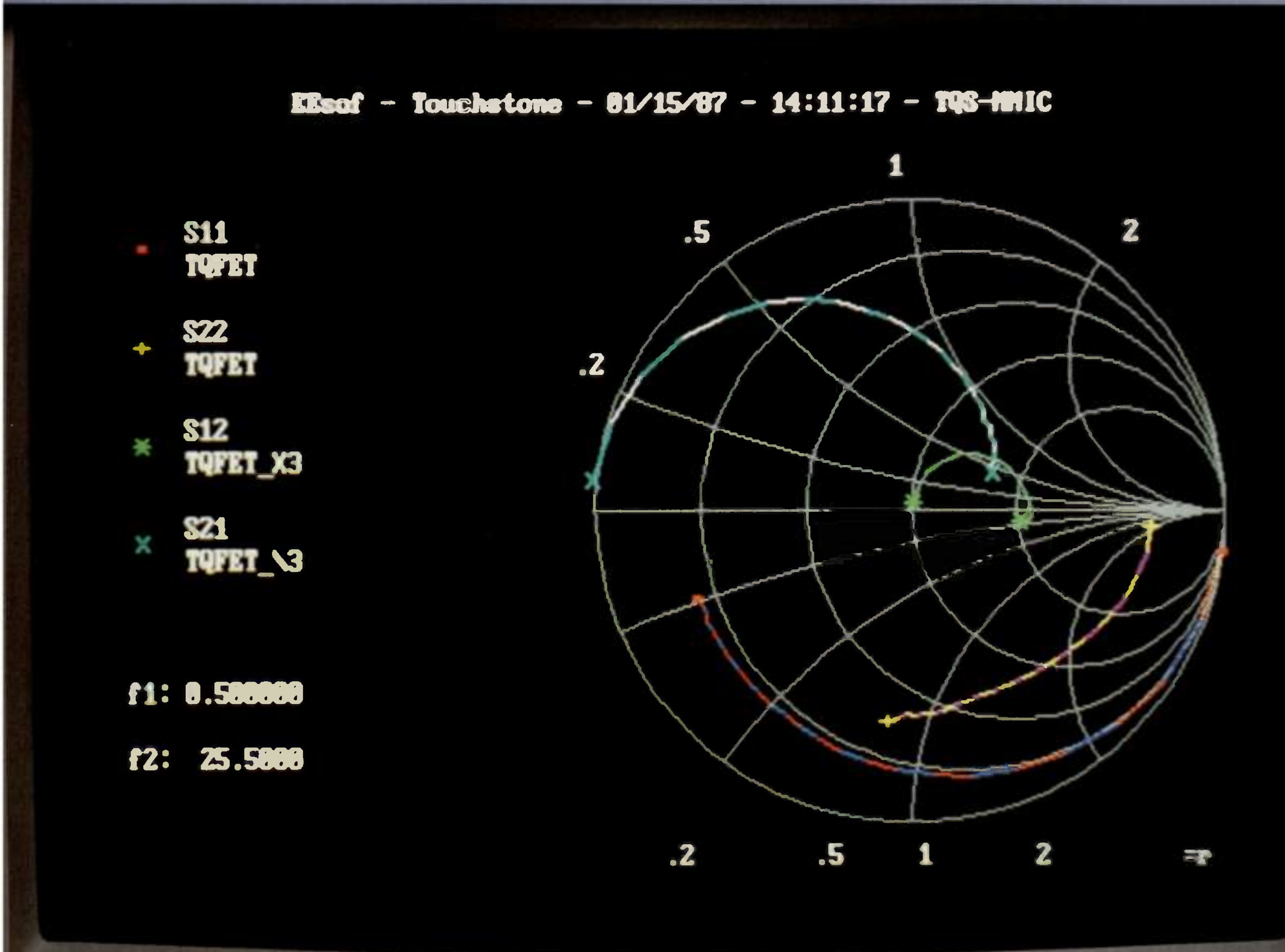

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INFO/CARD 14

TQ587-1

Hypres, Inc. Uses Superconducting Josephson Junction Circuits in First Commercial Application

In 1983, when IBM abandoned its efforts to develop ultra-high-speed computer ICs using superconducting Josephson Junction (JJ) technology, several of the IBM researchers founded Hypres, Inc. Armed with license agreements for IBM-developed technology, plus new ideas of their own, the company set out to develop the technology in a more step-by-step manner. With the introduction of Hypres' PSP-1000 Picosecond Signal Processor, the first product using JJ technology is on the market.

The instrument is an oscilloscope with rise-time capability of 5 ps. Its 50 ohm, DC coupled inputs accept signals in ±10 mV to ±1 V ranges. Waveform storage, display options, measurement parameters and waveform computations include just about every possible need in a high performance measurement situation.

Hypres' PSP-1000, a 70 GHz oscilloscope.

Applications include measurement of GaAs digital and RF circuits with sub-nanosecond rise and fall times, as well as other microwave or millimeter wave measurements. Future development of the instrument is directed toward DC-100 GHz applications requiring high resolution in the time domain.

More important than the instrument itself is the introduction of the technology in a "real" product. The rather disappointing history of the Josephson Junction principle includes both U.S. (IBM) and Japanese efforts to develop the technology into supercomputers. The possibility of an immediate 10-fold or greater increase in speed was the driving force behind these efforts. When the difficulties of implementation became known, the large-scale development came to a halt.

Hypres, Inc. is the result of confidence in the JJ principles held by its president, Dr. Sadeg M. Faris, and the other ex-IBM researchers who joined him. They were prepared to develop the Josephson Junction into small-scale products, learning about the difficulties in cooling, fabrication and performance along the way. The PSP-1000, with its 70 GHz bandwidth and 50 uV sensitivity represents only the introduction of JJ technology to the world outside the laboratory.

Hypres intends to continue work on the instrumentation applications of the JJ, while developing the digital logic capabilities. Long-range plans include the same type of supercomputer applications that started JJ development in the 1960s. Conventional fabrication techniques, combined with the materials and low-temperature developments already established by

Hypres could result in commercially available products with 0.01 ps switching speeds. The current 1 ps times have been achieved with only 3 micron lithography.

Beyond all of the publicity and media attention that the company has received over the past few weeks, is the fact that Hypres has introduced the first working Josephson Junction products to the electronics marketplace.

Raytheon/Texas Instruments Joint Venture Wins MIMIC Program Award

Raytheon Company and Texas Instruments Inc. head a team that has been selected by the Department of Defense to develop gallium arsenide microcircuits under the tri-service Microwave/Millimeter Wave Monolithic Integrated Circuit (MIMIC) program. Raytheon and Texas Instruments have formed a joint venture to develop the technology that will enable the production of large quantities of affordable, reliable, high performance MIMIC components.

GaAs wafer processing capability keys MIMIC program.

The contract from the Naval Air Systems Command provides funding of approximately $1 million to the Raytheon/TI joint venture under the concept definition phase, or phase zero. MIMIC program funds will be awarded in four phases, extending from 1987 to 1992. Funding in excess of $135 million is expected for the program.

The partnership proposes to develop and produce affordable gallium arsenide devices for use ir radar, communications, smart weapons, and electronic warfare systems. Additional support comes from a team consisting of additional systems applications contractors General Dynamics (Fort Worth), Aerojet, Magnavox, and Norden Systems. CAD/CAT/CAM contractors Compact Software and Consilium; and technology contractors Airtron, a division of Litton Industries, and Teledyne.

MIMIC program objectives complement the Very High Speed Integrated Circuit (VHSIC) program objectives set forth by the Department of Defense. Both programs are designed to make available affordable, high performance devices while promoting new system solutions previously precluded by reliability and cost considerations.

Harris Microwave Semiconductor Announces MIMIC Team Affiliations

The Microwave division of Harris Semiconductor is participating in Phase 0 of the Department of Defense MIMIC program through teamings with prime contractors Hughes Aircraft, Harris Corp. Government Systems Sector, and Hittite Co., Woburn, Mass. Harris Microwave also expects to serve as a gallium arsenide monolithic microwave integrated circuit foundry for other Phase 0 and Phase 1 teams.

Rogers Corp. Adds Woven Glass Substrates to Product Line

Rogers Corporation, maker or RT/duroid® microwave materials, has announced that it will manufacture woven glass-reinforced PTFE materials for microwave circuit applications, responding to a growing number of customer requests.

Rogers' first production material, to be announced soon, combines excellent surface quality, high bond strength, dielectric constant tolerance of ±0.02, and low moisture absorption (0.02%). Certification to MIL-P-13949 is expected in late April or early May, though the material can be used for commercial as well as military applications. Commercial availability of Rogers' first woven glass product is expected to be announced before or at MTT-S.

Amador Corp. Certified for Japanese Interference Testing

Th Amador Corporation of Taylors Falls, Minn., announced an important new addition to its electromagnetic compatibility (EMC) testing services. The company has been registered as a Measurement Facility to do Japanese Voluntary Control Council for Interference (VCCI) testing. Amador is the first non-Japanese EMC testing laboratory to receive a Certificate of Acceptance for testing compliance with these newly implemented Japanese standards. Amador notes that U.S. electronic equipment manufacturers are finding that compliance with the VCCI standards enables them to compete more effectively with the Japanese electronics industry.

Amador adds this Japanese testing capability to its present relationship with West Germany's Institute of Electrical Engineers (VDE), and accreditation by the U.S. National Bureau of Standards National Voluntary Laboratory Accreditation Program (NVLAP).

JFW Industries Opens Hybrid Facility

JFW has entered the world of microelectronics with a new design and fabrication facility equipped with an "EEsof" CAD system with rubylith cutting capability for fast accurate designs. For fabrication it has a thick film screening, firing and trimming capability, as well as die attach and wire bonding capability. It will soon be adding hermetic package sealing capability.

This capability will allow JFW to develop miniature devices, such as RF switches, attenuators and other RF assemblies in the frequency range covered by existing products. It will also allow JFW to increase the frequency range it covers to 18 GHz and to increase the power handling capability of certain products. The products developed will also be more capable of adhering to military environmental specifications.

Micro-Coax Adds Cable Assembly Facility

Micro-Coax™ Components, Inc. has opened an automated custom cable assembly and fabrication facility that enables the company to reduce set-up time during the cable assembly process. The result is efficient, cost-effective production and quicker deliveries. The new facility includes a programmable automatic bender, as well as complementary equipment dedicated solely to production of custom assemblies. Most connector installations are induction soldered, further reducing total assembly time and enhancing repeatability.

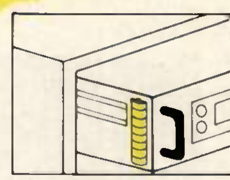
Pirelli to Provide Fiber Optic Television Supertrunk

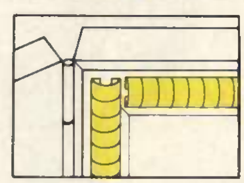
Pirelli Optronic Systems Corp. has been awarded a contract to provide a fiber optic supertrunk for CNN in Atlanta. The instal-

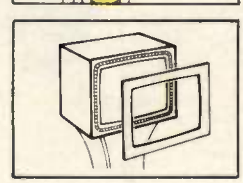
Want to save $10,000?

Heat is on computer manufacturers to comply with FCC emission standards. At stake are amounts of electromagnetic radiation that disrupt communications. Recent FCC test showed that half of 29 models examined failed to meet limits. Agency plans to ask Justice to crack down on offenders with fines of $10,000 for those who fail to comply, and that includes fixing machines already sold.

— as reported by Research Institute of America







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INFO/CARD 16

lation will link CNN Center Headquarters (formerly the OMNI) with their current studios at 1050 Techwood Drive. Pirelli's optical transmission System 1301 will initially carry 50 channels of video and stereo audio between the two sites. Techwood will transmit 38 channels to CNN headquarters, and on a separate path CNN will transmit 12 channels to Techwood. The single mode fiber optic system is expandable to 80 channels providing RS250B quality service. Southern Bell is providing the fiber cable, installation and the supertrunk maintenance service for CNN.

Anixter Bros. Acquires Delphi Electronics, Inc.

Anixter Bros., Inc. announced that it has acquired Delphi Electronics, Inc., an electronic wire and cable specialist of Folcroft, Pa.

Delphi will continue to operate under its own name and will become part of Anixter's network of distribution centers. Delphi is equipped with value-added services including dying, striping, and twisting equipment, as well as connectorized assembly and patch panel interconnect wiring services.

Watkins-Johnson Wins $8.8M

Watkins-Johnson Company announced that during the fourth quarter of 1986 it received and booked an order valued at approximately $8.8 million from the Hughes Aircraft Company Missile Systems Group in Tucson, Ariz.

The contract calls for the production of radio-frequency processors for use in the AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM). Deliveries are expected through late 1988.

ARRL to Oppose FCC's 220 MHz Reallocation Proposal

The American Radio Relay League (ARRL) has announced its opposition to the Federal Communications Commission's proposal to reallocate the 220-222 MHz band, now part of an amateur band, to commercial land mobile services. The Notice of Proposed Rulemaking was released February 12, FCC General Docket No. 87-14.

The 220-225 amateur band has been threatened with commercial reallocation for 15 years, severely discouraging commercial development of amateur equipment, thereby hampering ham operators' ability to utilize the band. Despite these difficulties, 220 MHz operation has been growing rapidly in the past few years.

Repeater operations, including digital "packet" radio relay systems, are well established in the 222-225 MHz segment. 220-222 MHz amateur operations include moonbounce, meteor scatter and long-distance troposphere communications, in addition to non-repeater communications.

Foremost in the ARRL criticism is the FCC's recent authorization of the band for Novice Class operators which will certainly create rapid and sizeable growth in band usage. ARRL president Larry Price, W4RA, observes that "after 12 years, the FCC has finally granted the League's long-standing request that the band be opened to Novice operators. It makes no sense at all for the commission, on the heels of that action, to say that the band it 'lightly loaded.' I'm confident that an objective comparison of our needs with those of commercial land mobile will show that the public interest lies with maintaining the amateur allocation."

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Selected MSA & MSF Components

(Performance @ 1.0 GHz)

Model	Max Usable Frequency (GHz)	Gain (dB, typ.)	Noise Figure (db,typ.)	P_{1dB} (dBm, typ.)	Package Type	1000 Piece Price $$$
MSA-0185	4.5	15.5	5.5	1.5	A	1.60
MSA-0204	4.0	11.0	6.5	4.0	B	1.90
MSA-0370	4.5	12.5	5.5	10.0	C	16.10
MSA-0420	3.5	8.5	7.0	15.0	D	18.45
MSA-0635	4.0	16.5	3.0	1.5	E	4.85
MSA-0835	6.0	23.5	3.0	12.5	E	7.80
MSF-8870	8.0	20.0	NA	9.0	C	29.75

A) 85 mil plastic B) 145 mil plastic C) 70 mil stripline
D) 200 mil BeO E) 100 mil ceramic

Avantek is a recognized leader in advanced, high-performance microwave semiconductors and MMICs for space and military applications. And, we deliver in quantity . . . last year Avantek shipped more than 1,000,000 MMICs and built over 800,000 complex microwave components for more than 3,000 customers. So, when you need high performance low-cost MMICs — whether your system listens, watches or talks — you know Avantek can deliver . . . *in volume*. Contact your nearest Avantek Distributor for additional information.

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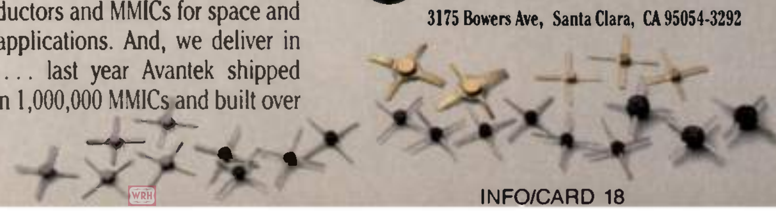

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• Programmable dividers
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Low Cost Signal Generator Features 2.1 GHz Range and Pulse Modulation

With the introduction of the Model 6062A Synthesized Frequency Generator, John Fluke Mfg. Co., Inc. adds greater frequency range and high performance pulse modulation to their product line. The $10,750 price tag will be attractive to many potential users with applications in communications, avionics and navigation from 100 kHz through 2.1 GHz.

Like its companions in the 6060 line, the 6062A has under 100 ms switching speed; AM, FM and PM modulation; low harmonic and spurious levels; plus IEEE-488 bus programming. However, behind the nearly identical front panel is an instrument with significant improvements over the 6060B and 6061A. Most obvious is the increased frequency range to 2.1 GHz (vs. 1050 MHz for the others).

The unit also adds pulse modulation, not included in earlier products. The modulator uses GaAs switch technology to achieve rise and fall times of 15 ns and on/off ratios of 80 dB. Many of the L-band applications for which the instrument is intended require pulse modulation. The pulse modulation input accepts TTL compatible waveforms via a 50 ohm port with integral pull-up.

Another feature not found in the rest of the Fluke line is phase modulation capability. Maximum deviation ranges from 10 to 20 radians, depending on output frequency, with a −3 dB bandwidth of 20 Hz to 30 kHz. Distortion (THD) is less than 1 percent, measured at 1 kHz modulation frequency and deviation greater than 0.01 radian.

Although the 6062A can be considered a frequency-doubled version of the 6061A, many performance specifications are better than the 1050 MHz units. Fluke engineers have improved the basic synthesizer circuitry to achieve equal or better spurious, harmonic and residual FM performance. Even in the 1050-2100 MHz range where doubling is performed, subharmonics are −45 dBc. Major 6062A specifications are listed in the accompanying table.

6062A Specifications

Frequency Range:	0.1 to 2100 MHz
Switching Speed:	<100 ms to ±100 Hz
Amplitude Range:	−127 to +16 dBm (to 1050 MHz) −127 to +13 dBm (above 1050 MHz)
Amplitude Resolution:	0.1 dB
Absolute Accuracy:	±1.5 dB
Harmonics (<+13 dBm):	−30 dBc (>500 kHz) −25 dBc (100-500 kHz)
Non-Harmonic Spurious:	−60 dBc (<1050 MHz) −54 dBc (>1050 MHz)
Residual FM (Hz RMS in 0.3 to 3 kHz BW):	8 (typ., <1050 MHz) 16 (typ., >1050 MHz)
(in 0.5 to 15 kHz BW):	12 (typ., <1050 MHz) 24 (typ., >1050 MHz)
Residual AM (0.05 to 15 kHz BW):	<0.1% RMS (−60 dBc)
Pulse Modulation	
On/Off Ratio:	80 dB
Rise and Fall Time:	15 ns
Aberrations:	<10%
Internal Modulation:	400 Hz & 1000 Hz, 50% duty cycle
External Input:	50 ohms, TTL compatible

The Model 6062A represents Fluke's efforts to improve their position as a synthesized signal generator supplier. It also reflects an industry-wide effort to respond to the RF engineers' needs for maximum performance at lowest cost.

John Fluke Mfg. Co., Inc., Everett, Wash. For more information, circle INFO/CARD #220.

The RF/Optical Interface

Part One in a Series: The Integration of RF and Other Technologies.

By Gary A. Breed
Editor

With this Special Report, we begin a three-part series highlighting the cooperation that is taking place between RF, optical, digital and aerospace technologies. Much of the growth in the business of RF is happening as a direct result of such interrelationships.

Optical technology was chosen for examination because of its rapid development and its reliance on RF techniques. The most publicly visible aspect is fiber optic communications, but there are other significant areas as well. Laser instrumentation, "star wars" laser weapons, and millimeter-wave microwaves all require a joint application of optical and RF techniques.

Fiber optics is easily the largest single application of the technology of light. The capability of fiber optics is enormous, with wide bandwidths, small size, no interference (inward or outward), and mechanical simplicity. Glass fibers are an excellent means of transmitting information — the same information that has been transmitted via wireline, coaxial cable, microwave links and satellites.

The current development challenge is to utilize all the available bandwidth of an optical link. Previous electronic communications have dealt with the "stacking" of maybe 100 voice channels on a "twisted pair" of wires (300 kHz bandwidth), proceeding to 24 video channels on a satellite transponder (500 MHz). Fiber optics has to deal with the goal of putting information into several GHz of available bandwidth.

Transmitters and Receivers

Just like traditional RF systems, fiber optics incorporates transmitters and receivers. With GHz-range bandwidths, these circuits are truly RF circuits before the laser diode and after the detector photodiode.

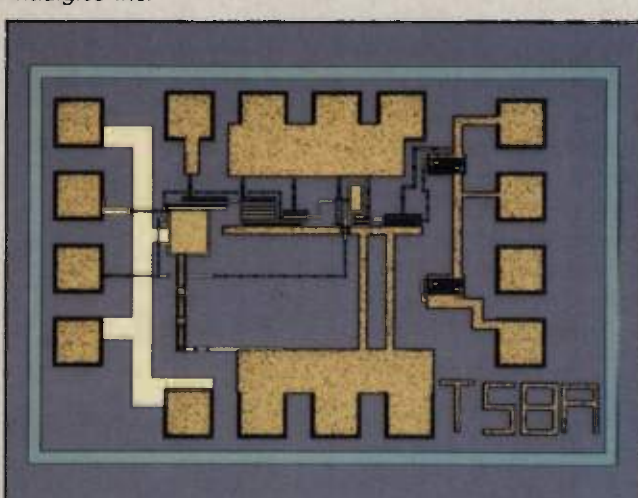
Fiber optic transmitters are very similar to RF transmitters, with the exception that the laser diodes require more closely managed drive parameters than most "antennas." AGC is a necessity for optical drivers to keep the light sources operating within design specifications. In addition, the laser diodes are temperature sensitive, requiring compensation techniques or even temperature control by thermionic means.

At the present level of development, laser diodes of InGaAsP composition can achieve greater than 1 GHz modulation rates with sufficient power for long-haul links. The limitation on transmitter performance is the light source at this time, but RF driver design must keep pace with future developments.

Optical receivers are just as critical as

A Transimpedance Amplifier for High Speed Fiber Optic Data Links

by J.I. Smith
Anadigics Inc.



High rate digital fiber optic links are finding increasing use in serial bus and short distance data transport, including time multiplexed links between large computer mainframes and upgraded interoffice trunking in telephone systems. Bus applications require high rates over short distances using high signal levels, while the trunking applications have lower rates but greater sensitivity requirements.

System Uses

System calculations for FET preamps of either integrating or transimpedance type can be made based on calculated frequency response and a noise model, but more satisfactory results can be achieved if actual measurements are made available for an existing device.

Performance measurements have just been completed on the Anadigics ATA 30010 transimpedance amplifier (see photo), a device designed with high data rate multiplexed serial interconnect systems in mind. The measurements show two broad areas of potential use: As a photodetector amplifier in high level receivers at NRZ data rates up to 3 Gbits/second; and as a post amplifier (possibly as a preradio receivers in terms of noise floor, linearity, stability and impedance matching. The PIN photodiodes used as detectors provide a current output, unlike the voltage levels common to most RF designs. The optical receiver needs a "transimpedance" amplifier to amplify the current from the detector and present a voltage output to the signal processing circuitry. The transfer function of a transimpedance amplifier is a ratio of output voltage to input current, with dimensions in ohms.

Manufacturing an integrated circuit transimpedance amplifier requires linear RF expertise, so it is no surprise that recognized RF component makers are involved in optical driver and receiver components. For example, Signetics designed the NE5212 transimpedance amplifier using proven silicon RF techniques. The device provides 150 MHz bandwidth with ECL-compatible outputs. The NE5212 has a trans-resistance (Rt) of 14.5 kohms from input to its differential outputs, with a noise performance of 3 pA/Hz.

The greater bandwidths required for GHz-speed transmission are being addressed by GaAs devices. One company with a committment to fiber optic technology is Anadigics, Inc., specializing in GaAs integrated circuits. Two of their previously released products with applications in fiber optic systems are a 350 MHz bandwidth operational amplifier and a 2.5 GHz amplifier. The 2.5 GHz device will soon have AGC capability added. A new device, the ATA 30010 transimpedance amplifier, has just been introduced and is described in the sidebar accompanying this report.

Microwave Semicoductor Corp. has recently added GaAs capability to their long experience in RF components. Among the recent GaAs products introduced by MSC is a fiber optics receiver/transmitter chip set. They join many other companies who are including fiber optics in their high speed analog and digital product planning.

Other Applications

High power lasers, whether for weapons or research, often use RF excitation to pump them to a lasing energy state. As an example of the frequency and power of these RF drivers, Microwave Modules and Devices has been supplying 1 kW power amplifier modules operating around 400 MHz. These modules are combined in groups of 25, with the 25 kW groups further combined. SDI-related Laser weapons research at Los Alamos and other facilities will be using RF pulses of as much as 1 megawatt to drive their anti-missile lasers.

Many of the fiber optic techniques can be used in lower-power laser communications. The optical modulation schemes are somewhat more complex than fiber optics, but the driver and receiver systems are quite similar. The military is either using or planning laser systems for anti-jamming and anti-monitoring communications between naval vessels, aircraft, and from satellite-to-satellite.

Instrumentation using lasers for distance and speed measurement uses analog signal processing as well as the expected digital data manipulation. Doppler measurements or differential phase measurements may require MHz range analog amplifiers and detectors.

To sum things up, there is plenty of room for RF techniques in the realm of optics and other light-related technologies. As our human capabilities increase, the need for cooperation between the various scientific and engineering desciplines will only become greater. Next month, we will examine another area of inter-disciplinary cooperation: The RF/Digital Connnection.

amplifier) in lower signal level applications at rates below 1 Gbit/second.

The ATA 30010 was designed with large internal negative feedback to minimize hysteresis effects in GaAs and to cancel out DC drift. The gain stages have a total forward gain of 100, with a feedback resistance of 2.5 kohms applied around these stages. A source follower buffer provides a 50 ohm output impedance.

The large forward gain with feedback allows for burst mode applications in DC coupled optical transceiver systems at up to 3 Gbit/second NRZ data rates. The sensitivity of the device is high enough to provide margin at these higher bit rates. Figures 1 and 2 show the analog bandwidth and sensitivity of the ATA 30010. The sensitivity curve was determined from measured output noise data and the assumption of a photodetector with 0.8 mA/mW responsivity and 0.7 pF capacitance. This curve, along with transmitter power and fiber loss, can be used to estimate the margin available in a given system at a given bit rate.

Future members of Anadigics' optical receiver family include transimpedance amplifiers with higher trans-resistance and sensitivity for lower bandwidth applications, and higher bandwidth devices for 5 Gbit/second and higher data rates. Additional devices will include "hysteresis-free" decision circuits and demultiplexers. Transmitter ICs will include laser drivers and multiplexers with similar capabilities, providing complete fiber optic system chip sets. **Anadigics Inc., Warren, N.J. For more information, circle INFO/CARD #171.**

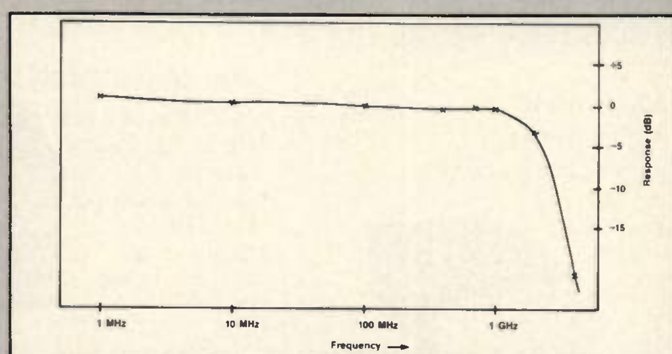


Figure 1. ATA 30010 analog bandwidth.

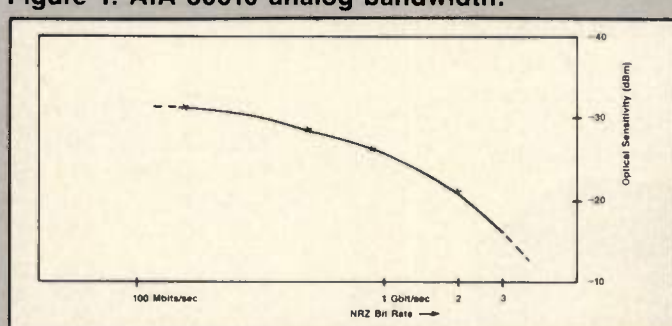


Figure 2. Sensitivity curve.

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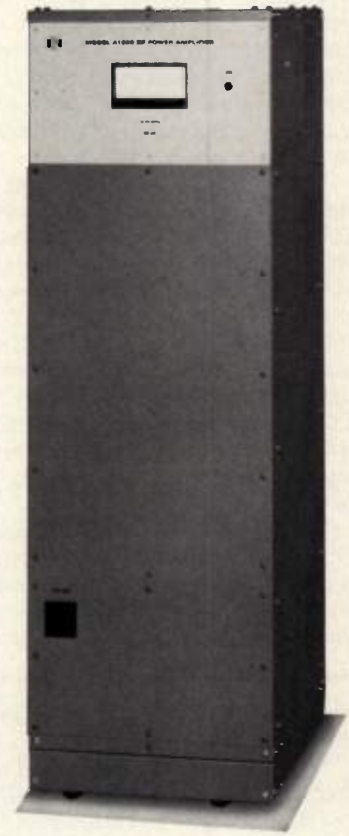

500 Watts/A-500
- 300 kHz to 35 MHz
- Up to 1000 watts pulse and CW
- No bandswitching
- Works into any load impedance

100 Watts/2100L
- 10 kHz to 12 MHz coverage
- 100 watts linear Class A power
- Up to 250 watts saturated

200 Watts/3200L
- 250 kHz to 150 MHz
- 200 watts linear power to 120 MHz
- 175 watts to 150 MHz
- Operates from 115/230V receptacle

3 Watts/603L
- 0.8 to 1000 MHz
- 3 watts of linear power
- Flat 37 dB gain
- Up to 5 watts saturated

400 Watts/1040L
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INFO/CARD 20

Transmission of Analog FDM Signals on Fiber Optic Links

By Jack Koscinski
General Optronics

Fiber optic systems have been finding more and more applications where they provide the most cost effective solution. The majority of these applications pertain to digital communications. However, there are a large number of analog system applications for which fiber optic links are also being selected. The most common requirement for analog transmission on a fiber link is transportation of video signals. In many point-to-point applications, where repeaters are not required, fiber optic analog (FO) transmission systems can prove to be a very cost effective approach.

This article focuses on FO analog transmission applications for carrying multiple video signals over a fiber link. Cable television supertrunks and campus networks would be typical examples where these multichannel analog transmission systems are being utilized.

The key performance parameters used to characterize FO analog system performance are: 1) carrier/noise, 2) bandwidth, and 3) distortion. These parameters will be reviewed in light of how they are affected by the respective FO system components.

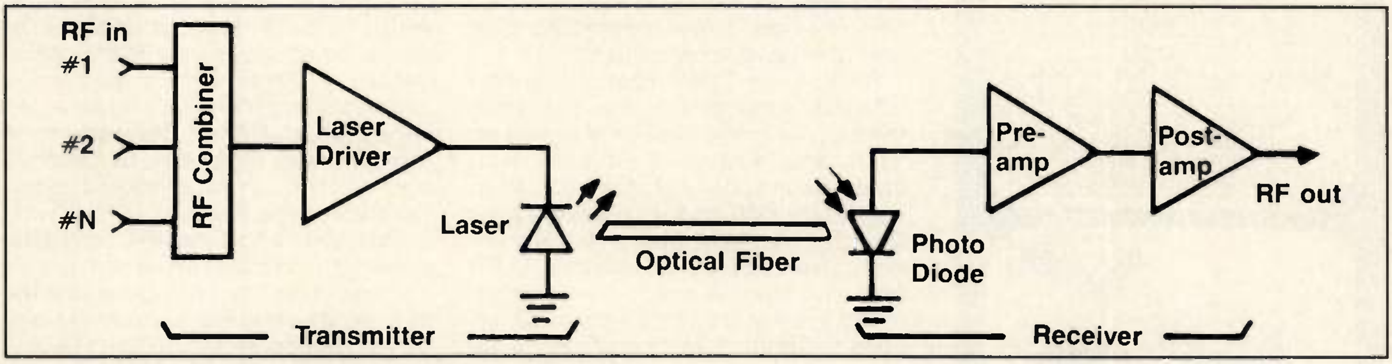

Figure 1. FDM analog transmission fiber optic link.

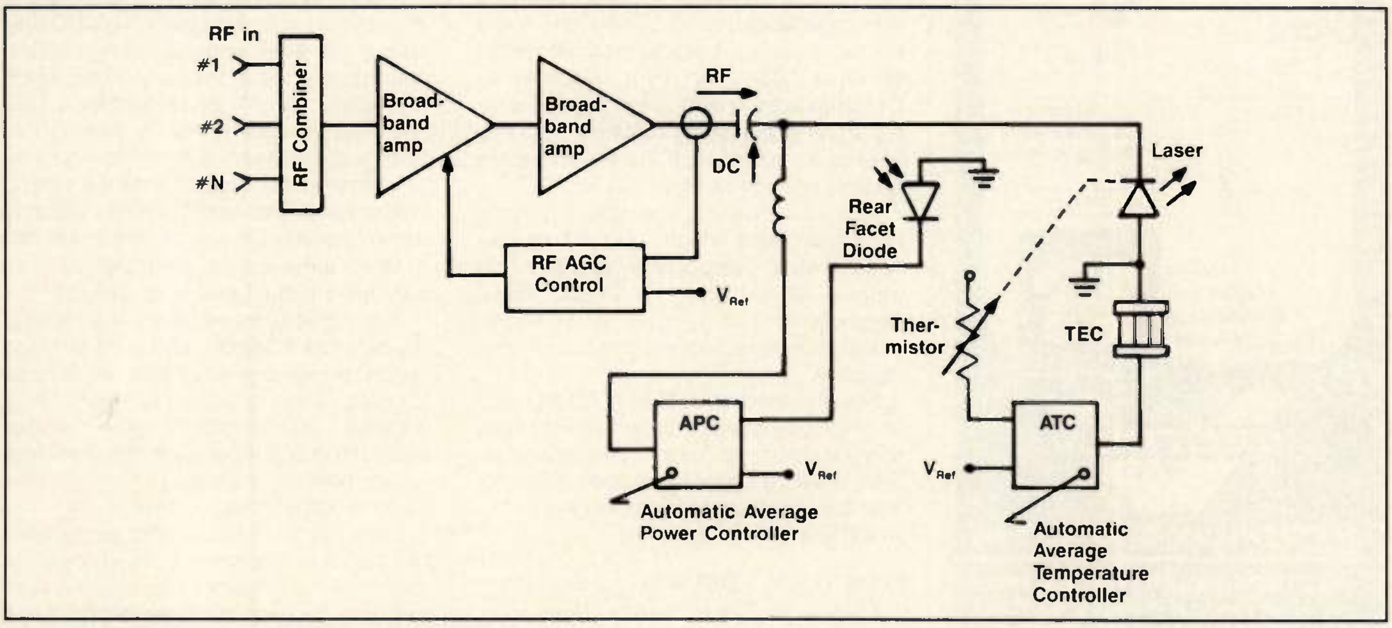

Figure 2. RF analog optical transmitter.

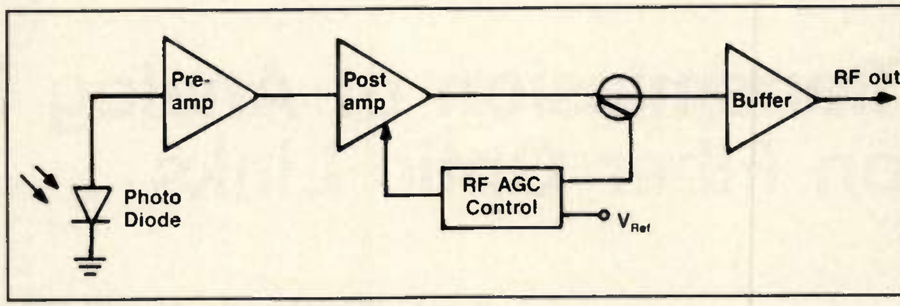

Figure 3. RF analog optical receiver.

Although there are several types of lasers and fiber available, this discussion will deal exclusively with 1300 nm single mode lasers and single mode fibers. These selections are becoming de facto standards for optimum multichannel FO analog systems since they provide low loss links, which are immune from multimode noise phenomena (modal noise).

Fiber Optic Links

FO links are gaining in popularity because they offer several major advantages over alternative approaches:

Performance. Optical fiber is a low loss conductor which minimizes or eliminates the need for reamplification of signals in short and medium haul (<30 km) transmission systems. Single mode, long wavelength 1300 nm fiber losses are typically under 1 dB/km. Optical fiber also offers increased bandwidth operation. However, multichannel analog transmission (FDM) systems may be limited by either noise or distortion, which may restrict the full utilization of bandwidth.

Electrical Immunity. Optical fiber is a non-metallic conductor. Therefore, it will not pick up or emit electromagnetic (EMI) or radio frequency (RFI) interference. Crosstalk is thus eliminated, there are no electrical grounding problems, and if a fiber cable is broken, there are no sparks and no chance of electrical shock.

Small Size/Weight. A single conductor fiber optic cable weighs about 9 lbs. per 1,000 feet. A comparable coaxial cable weighs 80 lbs. per 1,000 feet. Thus, weight-conscious designs can save precious pounds without a sacrifice in signal capacity.

Security. Electronics "bugging" depends on electromagnetic monitoring. Fiber optic systems are immune to this technique. They must be physically tapped to extract information which decreases signal levels which are readily detected.

Fiber Optic FDM Analog System

A block diagram for an FDM (frequency division multiplexed) analog transmission fiber optic link is illustrated in Figure 1. The major system components are: 1) the optical transmitter, 2) fiber optic cable, and 3) the optical receiver.

An optical transmitter accepts the individual RF FDM analog inputs and provides the signal conditioning necessary to drive the semiconductor laser diode. Figure 2 shows the major optical transmitter functional components.

First, an RF combiner sums the multiple analog inputs which are to be transmitted. The RF levels for each carrier should be equalized prior to the optical transmitter. Otherwise, optimum noise and distortion performance for each carrier will not be achieved. However, a slope compensation stage may be provided after the combiner stage to adjust for normal cable slope effects.

Broadband amplifiers, AGC controlled, provide the necessary signal level to drive the laser-diode. The RF drive level to the laser must be precisely controlled to realize the optimum system noise and distortion performance.

A DC bias is applied to the laser to provide a linear operating point. This DC bias current will determine the average optical output power out of the laser diode, which is typically 0.5 mW for single mode 1300 nm lasers. Laser power is sensitive to changes in temperature and laser aging. To preserve a constant average optical output power, two control circuits are commonly provided in the laser transmitter: a laser temperature controller and an automatic optical power controller.

A photodiode monitors the rear facet of the laser as a sample of the transmitted optical power and uses this information to control the laser DC bias current. Thus, if a laser average optical power changes due to time or temperature, the laser bias is automatically adjusted to maintain constant average optical power.

Laser life is adversely affected by operating at higher temperatures. Temperature control is accomplished by using a thermistor to monitor the laser temperature. A control circuit then drives a TEC (ther-

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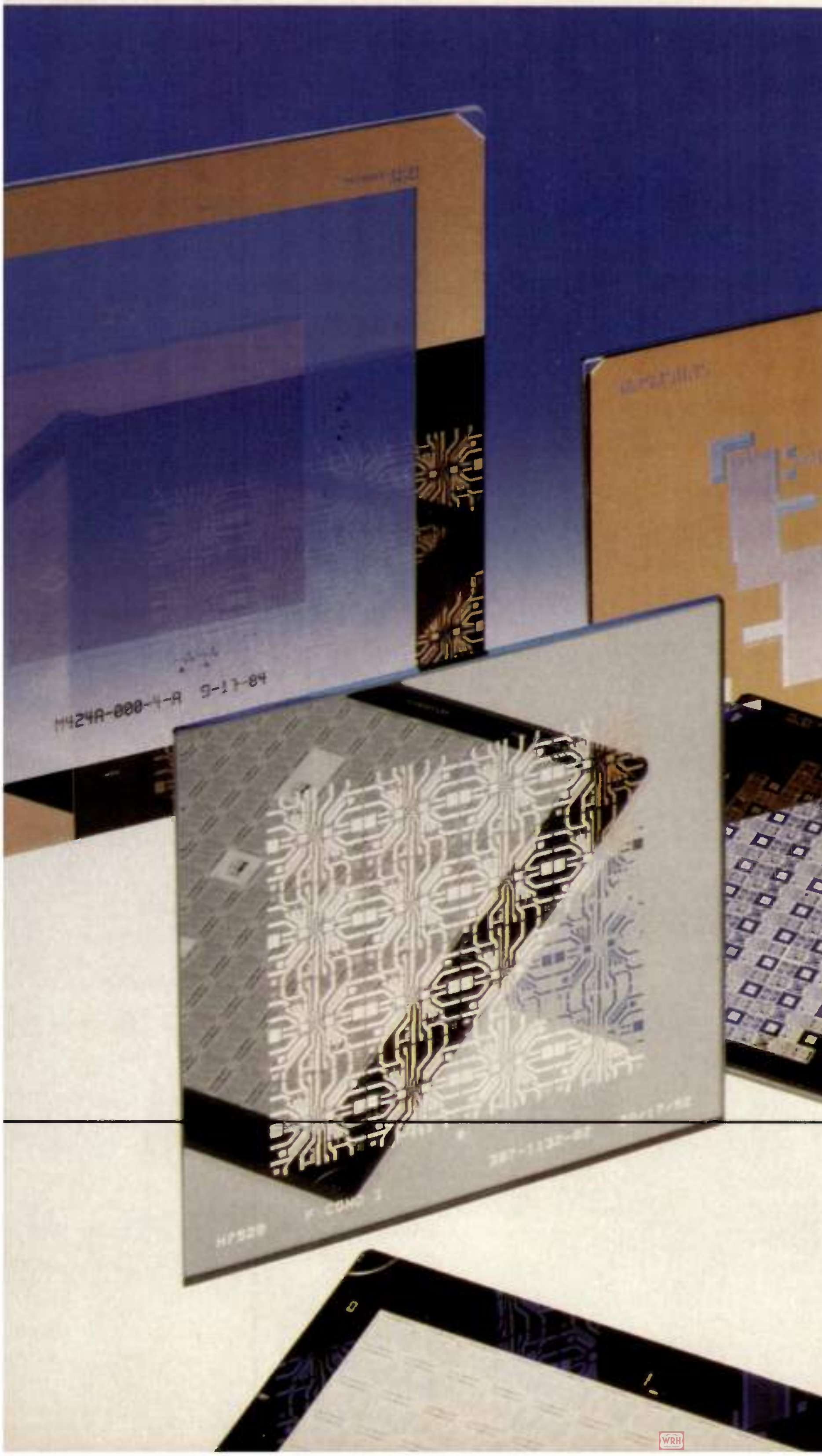

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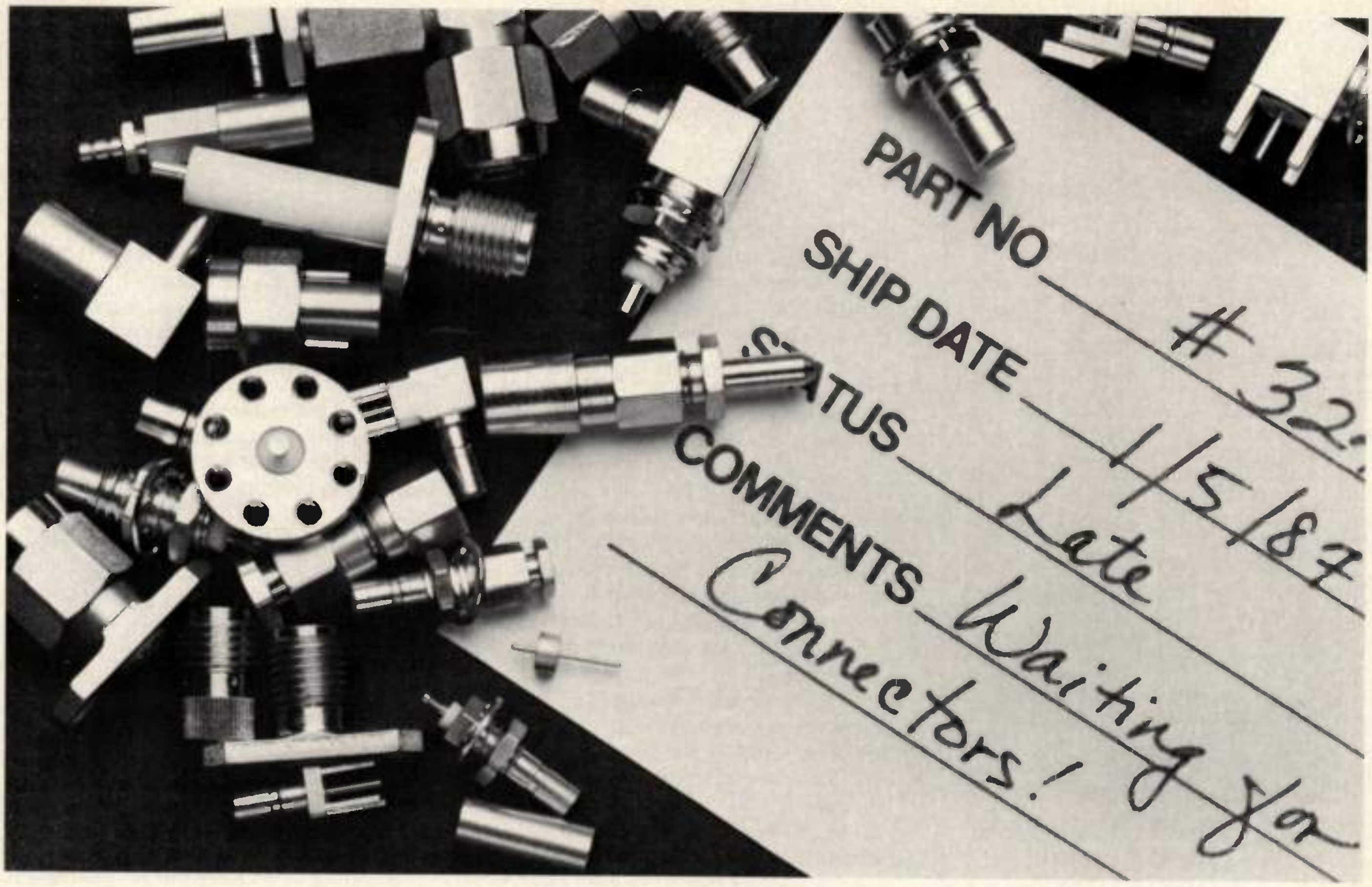

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INFO/CARD 24

mal electric cooler) to which the laser heatsink is mounted to maintain the laser at a constant temperature, typically 20°C.

Single mode, 1300 nm fiber cable is preferred for multichannel analog systems. This fiber has a core diameter of only 9 um with an overall cladding/buffer diameter of 950 um (typical). These fibers may be assembled into various cable assemblies, which provide multiple fibers, strain relief and jacket options.

Fiber cable is available in lengths up to several kilometers per reel. For distances greater than several kilometers, the fibers are typically fusion spliced to minimize path insertion losses. Single mode fusion splices have typical optical losses of only a few tenths of a dB. Single mode connectors have typical losses of 0.5 dB. The optical transmitter and receiver are normally connectorized for convenience in servicing equipment.

The primary function of an analog optical receiver is to reconvert the light power into an RF signal with a minimum contribution of noise and distortion. An analog optical receiver block diagram is shown in Figure 3. The optical detector commonly employed for 1300 nm analog applications is either a InGaAs PIN diode or a Ge avalanche photodiode. The major distinction between them is that the avalanche diode has gain available (approximately 10), whereas the PIN diode does not.

The photodiode current drives a transimpedance preamp which provides high input sensitivity and transforms the diode current into a voltage at its output. These preamps are available as DIP packaged devices with fiber pigtails attached.

A post amplifier with AGC follows the preamp to provide sufficient gain to obtain unity system gain for the entire FO link. AGC is utilized to maintain a constant output level independent of optical input power, which may change due to fiber resplicing, fiber loss versus temperature, etc.

Key System Performance Parameters

Now that a general description of an analog fiber optic system has been provided, this section will discuss how several key system parameters are affected by the respective fiber optic system components. The key parameters, which will be considered, are carrier/noise, bandwidth and distortion.

Carrier/noise obtained at the end of the FO system will ultimately determine the

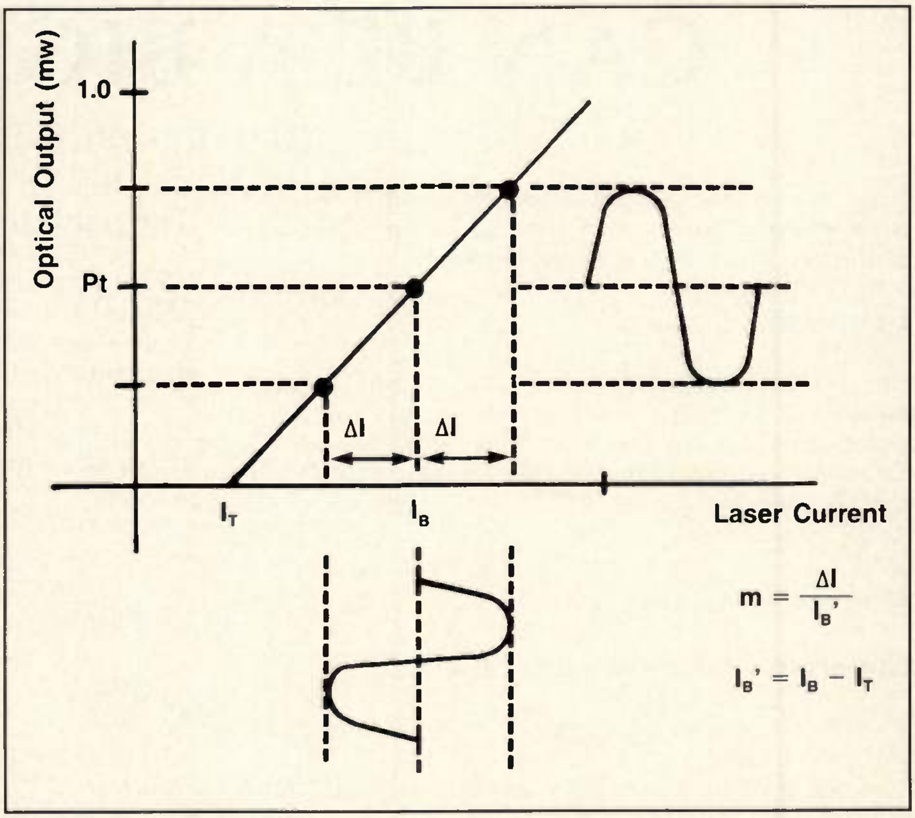


Figure 4. Laser L1 curve.

baseband (video) signal to noise performance. Carrier/noise is preferred over system signal/noise is a FO link parameter since the output of an optical receiver is an RF carrier. Also, analog video may be transmitted via VSB-AM, FM, or other modulation techniques. For a given carrier/noise ratio, the resultant video signal/noise ratio will be a function of the modulation approach. Wideband FM provides higher signal-to-noise ratios at the sacrifice of greater channel bandwidths.

The optical transmitter will have an impact on carrier/noise in two ways: 1) setting of a particular modulation depth and 2) inherent laser source noise.

For an analog system, a time varying signal S(t) is used to directly modulate the optical source about to bias current point IB as shown in the laser LI curve (Figure 4). With no signal input the optical power is Pt. When the signal S(t) is applied, the optical output power P(t) is:

$$P(t) = Pt\,[1 + m\,S(t)] \qquad (1)$$

Here, m is the modulation depth defined by:

$$m = \frac{\Delta I}{IB'} \qquad (2)$$

where, $IB' = IB - IT$

IT = Laser Threshold current

The parameter ΔI is the RF variation in current about the bias point. To prevent distortions in the output signal, the modulation must be confined to the linear region of the curve. Furthermore, if ΔI is greater than IB', the lower portion of the signal gets cutoff and severe distortion will result. Typical m values for analog applications are .25 to .50.

A higher modulation index (m) will provide a higher RF carrier/noise ratio since the received RF carrier is proportional to (m). Thus, a direct tradeoff exists between system distortion and noise performance as contributed by the optical transmitter.

Inherent laser source noise defines the maximum achievable carrier to noise obtainable from a laser transmitter. Minute fluctuations in optical emission are exhibited when biased above threshold. This noise phenomena is referred to as relative intensity noise (RIN). The intensity noise is neither thermal nor strictly shotnoise in nature. It is the response of the laser to modulation by intrinsic shotnoise, which results from the granular nature of light and electricity. Typical values of laser carrier/noise due to RIN are −120 to −140 dB/Hz.

Fiber/Receiver C/N Contribution

The optical loss budget analysis is the conventional approach used for determining the maximum optical path loss. A loss budget compares the optical power transmitted with the minimum optical power at the receiver to provide the required carrier to noise ratio out of the receiver. The difference between these two quantities is the optical loss budget allowable for the total path loss. A typical loss budget

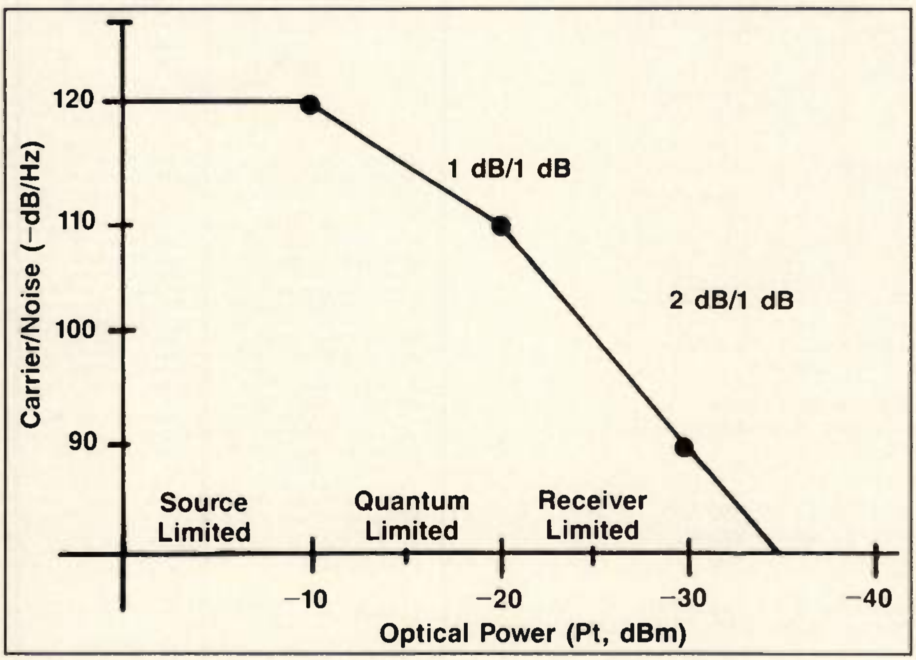


Figure 5. Carrier/noise versus received optical power.

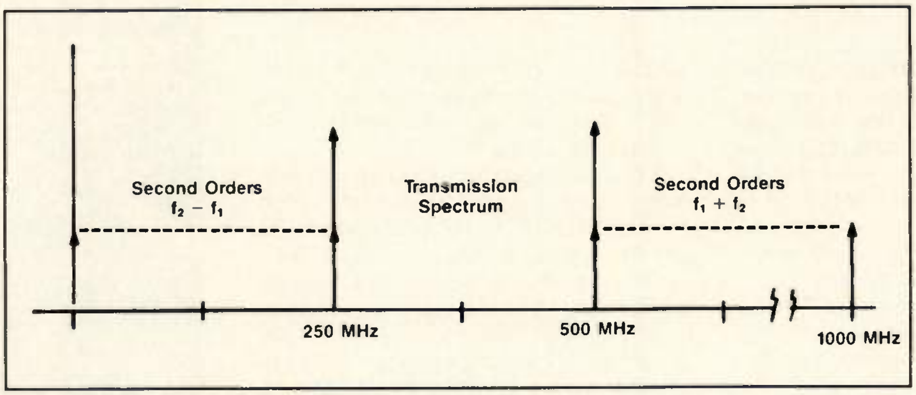


Figure 6. Spectrum plan to avoid second orders.

analysis is shown below.

Power launched (Tx)	−3.0 dBm
Fiber loss	20.0 dB
Splice loss	2.0 dB
Connector loss	1.0 dB
Received Optical Power (Rx)	−26 dBm
Receiver sensitivity (Rx) (min. power allowable to provide required C/N	−30 dBm
System Margin	4 dB

One might ask how the carrier-to-noise performance of the system will change as a function of optical input power. The answer depends on whether the system noise performance is receiver limited, quantum noise limited, or laser source noise limited.

The carrier/noise present at the output of an optical receiver employing a PIN diode is:

$$\frac{C}{N} = \frac{(1/2N^2)\,(m \times Ro \times Pt)^2}{(RIN\ Ro^2\ Pt^2\ B) + 2q(Ro\ Pt + Id)B + (4Kb\ TB/Req)Ft} \qquad (3)$$

(source + quantum + receiver)

Ro = diode responsivity
m = modulation depth
Pt = average optical power received
q = electron charge
K = Boltzmann's constant
Id = diode dark current
B = bandwidth of receiver
T = temperature (K)
Req = equivalent resistance of photodiode load and amplifier
Ft = Noise factor of preamplifier
RIN = Source relative intensity noise
N = number of FDM channels

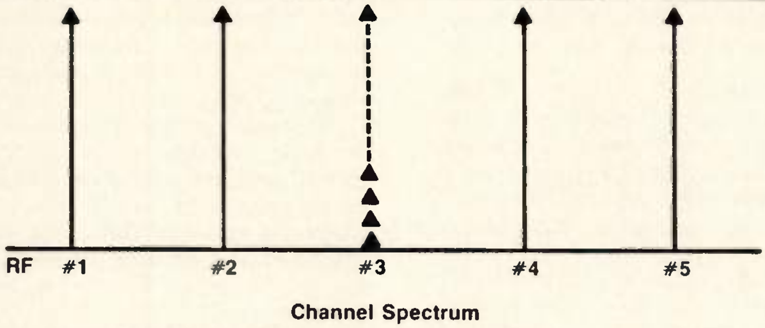


Figure 7. Beat stacking (for 5-channel system).

When the optical power incident on the photodiode is low, the receiver circuit noise term dominates the system noise, so that:

$$\frac{C}{N} = \frac{(1/2N^2)\,(m \times Ro \times Pt)^2}{(4Kb\ TB/Req)Ft} \qquad (4)$$

Here, carrier/noise is directly proportional to the square of the average received optical power. Thus, for each 1 dB change in optical power received, the carrier/noise ratio will change by 2 dB.

For larger optical signals incident on the photodiode, the quantum noise associated with the signal detection process dominates (assuming Id negligible), so that:

$$\frac{C}{N} = \frac{(1/2N^2)\,(m^2 \times Ro\ Pt)}{(2qB)} \qquad (5)$$

Since the carrier/noise ratio in this case is independent of circuit noise, it represents the fundamental or quantum limit for analog receiver sensitivity. In this optical power range the carrier/noise ratio will change 1 dB for each 1 dB change in received optical power.

For very high optical power levels the carrier/noise ratio may be limited by the laser source.

$$\frac{C}{N} = \frac{(1/2N^2)\,(m^2)}{(RIN \times B)} \qquad (6)$$

Thus, the carrier/noise ratio is constant at the maximum obtainable from the laser transmitter.

Figure 5 illustrates an example of carrier/noise obtainable at the receiver output as a function of optical input power when these noise sources are present.

Bandwidth Limitations

Laser transmitters have available modulation bandwidths of at least several GHz. Typically the transmitter circuitry will limit the upper bandwidth rather than the semiconductor laser diode. However, linearity constraints will tend to limit full utilization of the available bandwidth in analog FDM systems.

Single mode 1300 nm fiber has bandwidths above 10 GHz/km available. The electrical 3 dB bandwidth for a single mode fiber is:

$$f(3\ \text{dB}) = (.35)/(M \times \Delta\lambda \times L) \quad (7)$$

M = material dispersion (ps/nm × km)
$\Delta\lambda$ = optical spectral width (nm)
L = fiber length (km)

For 1300 nm single mode fiber:

$$M = 3.5\ (\text{ps/nm} \times \text{km})$$

Thus, for a 10 km path with a single mode laser ($\Delta\lambda = 1$ nm):

$$f(3\ \text{dB}) = 10\ \text{GHz}$$

High sensitivity receivers require that bandwidths be limited. As seen from the expression for carrier/noise ratio (3), all the noise terms are directly proportional to bandwidth. For this reason the optical receiver will intentionally limit the bandwidth to only that required for the particular transmission requirement.

High sensitivity receivers also require high input resistances as can be seen by the carrier/noise expression (3). Higher bandwidths are difficult to maintain at higher resistance levels due to real and parasitic capacitances present in the optical receiver circuitry. Very wide band (>1 GHz) receivers typically utilize 50 ohm photodiode, preamp and postamp stages, which will provide lower receiver sensitivities due to the 50 ohm thermal noise source at the preamp unit.

Distortion

The limiting distortions in an analog FDM system are 2nd and 3rd order intermods. Second order intermods are defined as (f1 ± f2) products. Third order intermods are defined as (f1 ± f2 ± f3) products.

The laser diode will normally be the distortion limiting component in a fiber optic link. Typical values of distortion for a single mode laser operating at a 50 percent modulation depth are:

2nd order: 30-45 dB
3rd order: 45-60 dB

The spread in values indicates that not all lasers have good linearity. Some lasers may even have abrupt discontinuities (kinks) in their LI curves, which disqualify them completely for use in analog systems.

Circuit linearization techniques for lasers have not proven successful to date. A scheme that measures the nonlinearity and corrects it in real time, such as feedback or feedforward, would be helpful here. However, at this time, careful specification criteria and selection of lasers for linear analog performance is an absolute requirement to obtain high performance analog FO links.

The linearity of fiber optic receivers are generally quite good, since they operate at relatively low signal levels. PIN-photodiodes have good linearity over several orders of magnitude. Well-designed preamps and post amplifier electronics will not contribute significantly to system distortions.

With very high optical powers at the receiver input, it may be necessary to utilize an optical and/or electrical AGC. Fixed optical attenuators may also be used at the receiver input when the high levels are a permanent condition.

With prior knowledge of the distortion performance available in a FO link, a system designer can minimize some of the possible limitations. For example, since second orders are the strongest distortions, a frequency transmission spectrum can be selected, which eliminates second orders from falling in desired channels. Limiting the transmission bandwidth to the highest octave region will cause all the second orders to fall above or below the desired transmission spectrum (Figure 6).

Without the second order limitation, third order products will be the limiting distortion mechanism. As the number of channels increase above 3, and are equally spaced, it is important to realize that there will be intermod or beat stacking. That is, several individual beats will exist at or near the same frequency. This is commonly referred to as composite triple beats (CTB). The result of beat stacking tends to be additive on a power basis (assuming the individual carriers are not phase locked). Figure 7 illustrates this situation for 5 RF carriers. The cumulative effect of stacking can be estimated using the expression below.

$$CTB = -d3 + 10 \log (N)$$

where $-d3$ = distortion level of a single 3rd order intermod (three tone)

N = number of stacked beats (equal levels)

The largest number of beats will fall in the center channel for a symmetrically spaced spectrum. For the 5-channel spectrum shown in Figure 7, there will be 4 (3 tone) third order beats stacked in the center of the channel spectrum. Thus, the worst case 3rd order distortion would be 6 dB worse than that contributed by a single 3rd order distortion. Two-tone, 3rd order distortions will also be present with multiple carriers. However, they will have individual distortions, which are 6 dB below a 3-tone 3rd order product and thus tend to be a negligible contribution as the number of channels increase. These extrapolations are useful since many linearity tests are performed using a limited number of carriers.

Systems Applications

Analog FDM fiber optic transmission systems have been used successfully to carry up to 16 channels of video on a fiber link with performance approaching RS-250B (short haul). The most common modulation technique employed is wideband FM (>7 MHz deviation). Wideband FM modulation provides a signal/noise ratio improvement of over 20 dB compared to standard AM transmission. FM signals also have a high tolerance to intermod distortion. AM channels require channel distortion levels greater than −57 dB below the RF carrier; FM will operate with distortion levels of −40 dB.

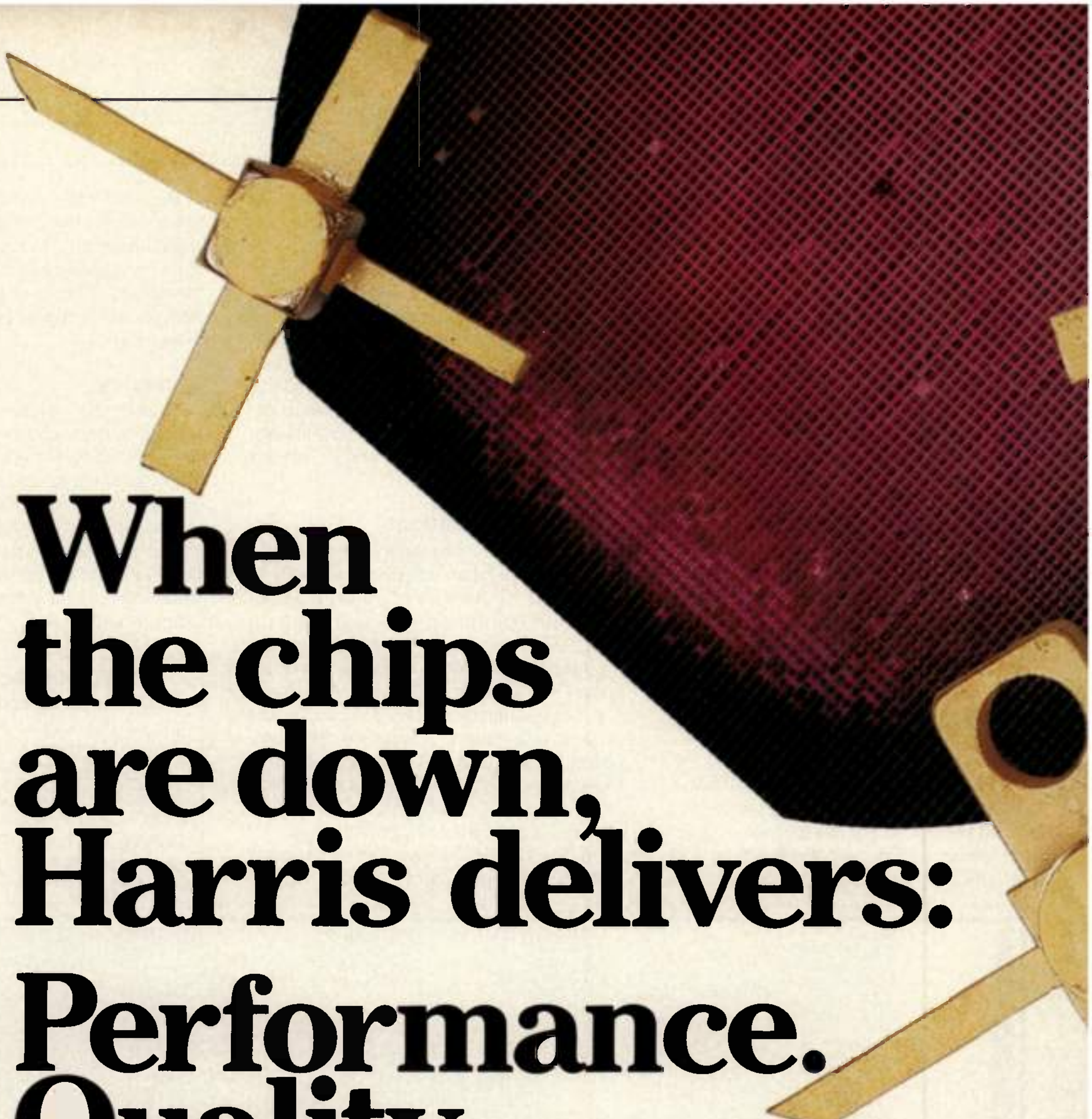
VSB-AM fiber optic transmission systems have successfully carried four to eight channels of video up to 12 km. Performance levels are comparable to CATV standards. The cost per channel for an AM system is significantly lower than for video FM.

Summary

Successful system design for FO analog transmission systems requires an understanding of the key system performance parameters and how they are affected by the various link elements. The intent of this article has been to identify these key performance parameters and provide some background on the performance impact of the respective optical link components. rf

About the Author

Jack Koscinski is engineering manager of the Laser Systems group at General Optronics Corp., 2 Olsen Avenue, Edison, NJ 08820. He received BSEE and MSEE degrees from Monmouth College and an MBA from Rider College. Jack can be reached by telephone at (201) 549-9000.



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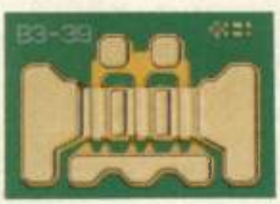

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INFO/CARD 32

Measurement of Dielectric Constant at RF and Microwave Frequencies

By John Ayer
National Research Council

The accurate measurement and characterization of complex permittivity (dielectric constant or relative permittivity) and loss tangent of materials at RF and microwave frequencies is important in the design of efficient industrial heating (lossy dielectric) systems and electromagnetic hyperthermia systems for cancer therapy. Knowlege of dielectric properties can also be used to determine quality factors of the material, such as moisture content.

Experimental techniques for measuring complex permittivity of various materials in solid, liquid and gaseous forms at limited RF and microwave frequency bands have been originally demonstrated by various researchers including Von Hippel — 1954 (33), Grant, et al — 1978 (34), and Chelkowski — 1980 (35) (standing wave method). This study is based on selected papers dating from 1953 to 1985 in an attempt to determine a test system to meet the target specifications for measuring the relative permittivity and loss tangent of solids and liquids at different temperatures at a frequency range from approximately 1 MHz to 3 GHz.

This article attempts to determine a most suitable technique for the measurement of dielectric constant and loss tangent within the following specifications: dielectric constant ~200.0 solid or liquid, loss tangent (tan ∂) ~.01, frequency range approximately 1 MHz to 3 GHz or greater, temperature range of 0°C to 100°C and overall measurement accuracy ±2.0 percent.

The accurate measurement of dielectric constant of solids and liquids from low to high values at RF to microwave frequencies requires an integrally connected computer data processor with the test system together with a well designed test or sample holder cell. If the test temperatures are controlled and recorded at the same time, the computer is absolutely essential due to the large number of data points and processing requirements. At present, no universal method exists to accurately measure the dielectric constant of solid, liquid or gaseous materials from DC to microwave frequencies (5).

The essential factors that affect the measurement range and accuracy of any method are the nature of the sample material, its dimensions, the cell or sample holder design characteristics, the frequency of interest (3), the test temperature, the configuration of the measuring system and its systematic errors.

Comparison of Methods

1. Frequency or length tuned cavity (1): Although the TE_{01} resonator is a simple design which affords a measurement precision of $\Delta\varepsilon'/\varepsilon' \leqslant 7 \times 10^{-4}$ for the real part ε' of the permittivity, there are certain conditions. The size of the cavity and the sample size is about 49.8 mm dia/50 mm thick, the resolution requirement for the frequency counter is of the order of $\Delta f/f \leqslant 10^{-7}$ or better. The undertainty in calculated values of ε' are all based on these measurements.

Some of these uncertainties can be avoided by a modified technique shown in an earlier paper (26), using the ratio of frequency shifts due to two samples of same diameter but different thickness. The maximum error claimed by this technique is ±15 percent for a dielectric constant of the order of 2 to 3. Due to this required precision, size and shape of the sample dielectric, this method will not be suitable to the target specifications.

2. Waveguide transmission method (2): In the 1-2 and 4-6 GHz bands the instrumentation is set up to measure amplitude and phase of the TE_{10} mode transmission coefficient for a dielectric sample of known length. Comparison readings are taken with and without the sample. The measurement errors $\Delta\varepsilon'/\varepsilon'$ and $\Delta\varepsilon''/\varepsilon''$ depend on test system component accuracy and resolution e.g. network analyzer/phase gain indicator. Values as given are $\Delta\varepsilon' \leqslant 0.15$ and $\Delta\varepsilon'' \leqslant 0.17$ for all samples tested (2). $\Delta\varepsilon'/\varepsilon' \leqslant .9$ percent at 1.4 GHz and $\leqslant .7$ percent at 5 GHz for all samples tested, $\Delta\varepsilon''/\varepsilon''$ decreases from 37 percent to 6 percent for volumetric moisture difference in the material under test from a moisture content of approximately six parts to 330 parts per thousand at 1.4 GHz.

3. Guided microwaves in a waveguide (24): The relative dielectric permittivity is obtained by measuring the reflection coefficient in amplitude and phase of a cylindrical sample of the material under test contained in a quartz tube which pierces the transversal section of the waveguide centrally and perpendicularly. This method could also permit the estimation of temperature gradient in the material. The ranges claimed for measurement are ε' and ε'' = 1 to 120. This method can be used for solids or liquids. However, it is not suitable for frequencies in the MHz band.

4. Experimental/theoretical curve fitting of reflection coefficients (13): Although relatively simple in equipment, it has limitations, i.e., the thickness of the dielectric has to be optimized experimentally for minimum error. At micro-

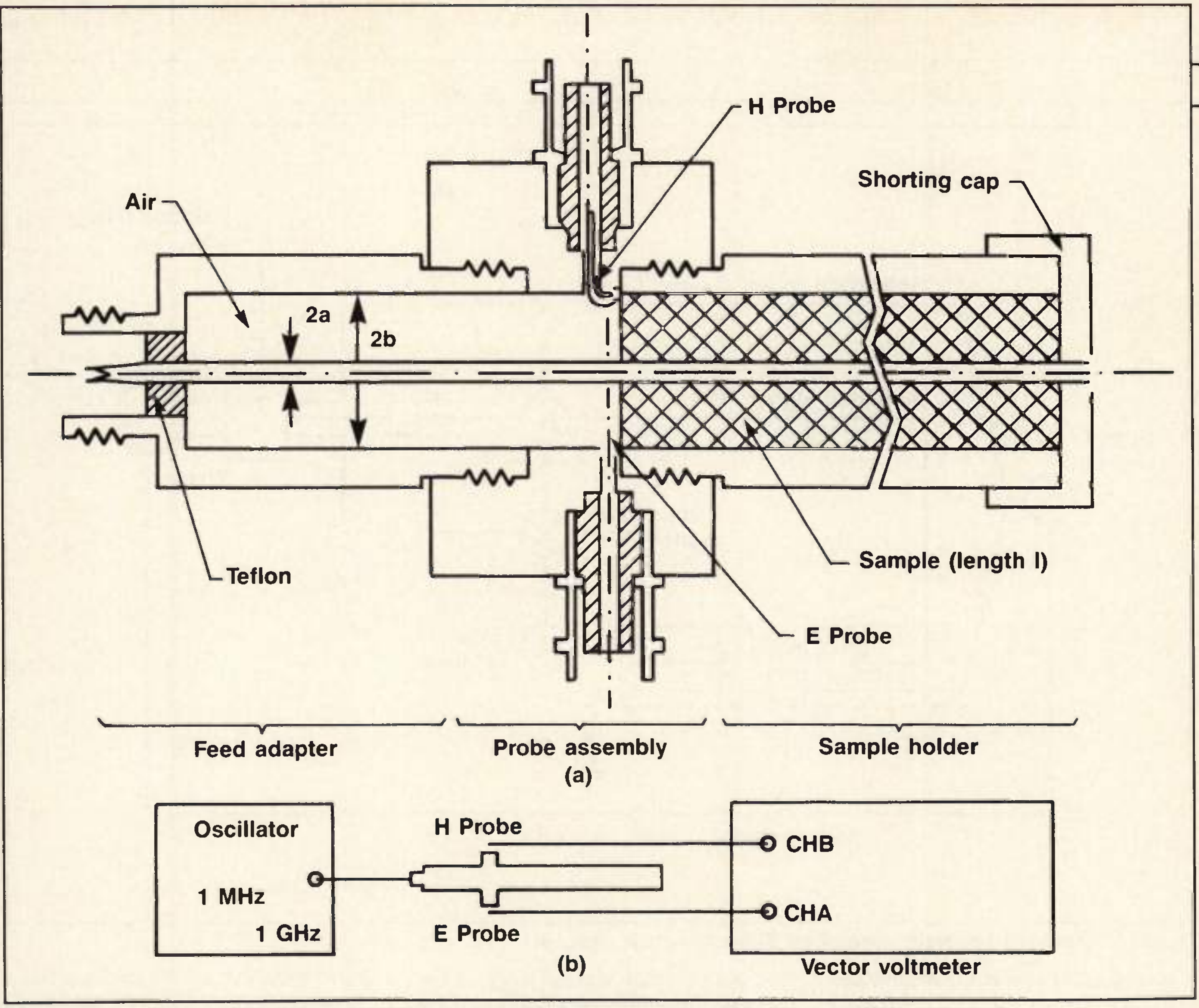

Figure 1. (a) E-H probe assembly. (b) High frequency measurement set- up. Ref. 27.

wave frequencies this method relies on the determination of the lowest amplitude of the reflection coefficient with frequency for various thicknesses of the dielectric under test. It is not suitable in the MHz frequency.

5. Lumped capacitance element/reflection coefficient (28, 29, 32):

This is based on the principle that a small capacitor terminating a coaxial line is filled with the element under test whose permittivity is calculated from the input reflection coefficients of the sample and holder measured in frequency or time domain. Due to the fringing field effect, the lumped equivalent circuit with only capacitance is not a truly equivalent circuit. This is indicated by higher values of ε' than the actual values due to the value of the ratio C_f/C_p inherent in the fringe and parallel plate capacitances. However, the ε'' values are not affected by the fringe field. The fringe effect is evident if the method is analyzed using the series capacitor method.

This method has the advantage that the measurements can be performed at any temperature, with certain limitations. The capacitance of the sample holder is limited between 0.1 to 20 pF, with large uncertainties outside this range. In order to select the optimum value of capacitance of the sample holder the conductivity of the material under test must be known accurately. Further, the frequency range of this test method is limited from 1 MHz to 1 GHz.

6. Computer controlled broadband sampling oscilloscope with an RF pulse generator (31):

The scattering parameters of the broadband microwave component are measured by obtaining the reflected and transmitted transcient responses of the component to an incident subnanosecond risetime pulse. Discrete Fourier transforms are then carried out on the three waveforms. The unknown dielectric is placed in a microwave TEM-mode cell or fixture. This test method has a range of 0.4 to 10 GHz with 0.4 GHz resolution.

The forward and backward scattered energy S_{21} (t) and S_{11} (t) respectively provide time-domain "signatures" uniquely related to the intrinsic properties of the sample i.e. ε and μ. The real and imaginary parts of ε and μ can then be processed as a function of frequency. Errors due to truncation, sampling ratio digitization, low spectral intensity of subnanosecond pulses from generators and timing shifts in reflected waveforms are some of the serious problems associated with this method. Hence it cannot be adapted to the present specifications.

7. Vector voltmeter/RF generator (15, 27):

It seems to be one of the best and simplest techniques for the measurement of complex permittivity of solids and liquids due to its relatively broad frequency band, good accuracy and short measurement time. The method has a relatively high sensitivity in the measurement of complex permittivity since the

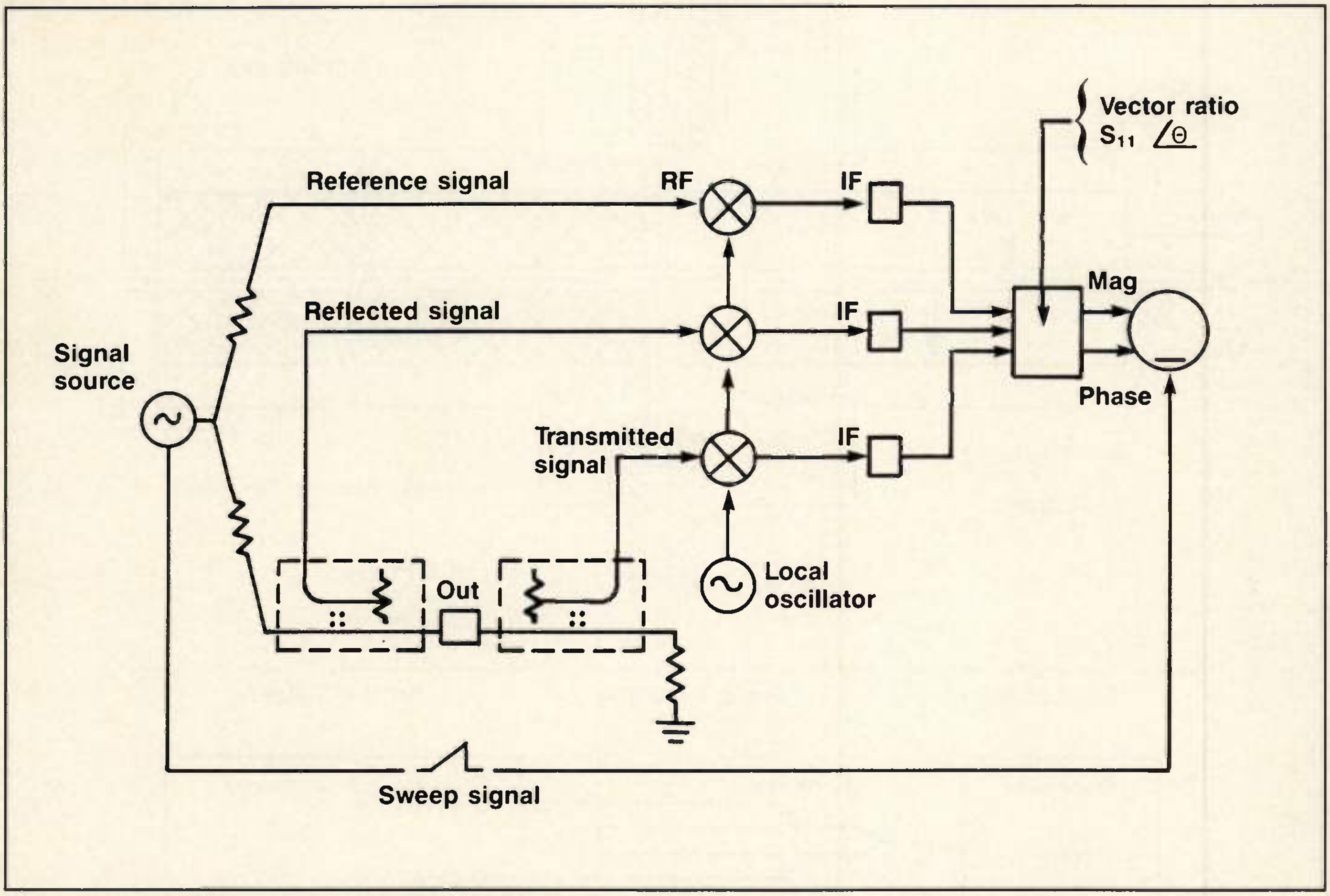

Figure 2. Network analyzer simplified block diagram. Ref. 6.

scattering parameter of the sample cell which acts as a coaxial line (transmission coefficient S_{21}) is directly proportional to its permittivity. The test system consists of a signal generator, a vector voltmeter and the sample holder. The sample holder and the system block diagram is shown in Figures 1a, b.

Calibration is simple and effected by measuring the sample holder or cells' capacitance with and without at least two standard liquid (or solid) dielectrics of different permittivities (i.e. hexadecane, or water) (15).

This method, as shown in Figure 1a, measures the conductivity and dielectric constant of large sample size rapidly and accurately (27). In principle it consists of a coaxial sample holder fitted with electric and magnetic field probes which, when excited as a section of a transmission line, produce an induced voltage which is directly related to the electrical properties of the sample. The cell can operate from 1-1000 MHz with a cell length of 15 to 30 cm and 2-4 cm in diameter. From the values of the characteristic impedance (Z_O), the coupled propagation constant (γ) of the coaxial line formed in the sample holder and the length of the sample, the relative permittivity ε_r of the sample can be calculated.

Due to the simplicity of the instrumentation, the large volume sample holder and good accuracy of broad band measurement, this method will be selected for further experimental study.

8. Non-resonant attentuation/Phase measurement with a computer controlled network analyzer (5, 6, 16, 18, 20, 25, 30): This method has most of the features essential for a reliable test system: good accuracy, repeatability (precision) and broadband either in waveguide or coaxial mode, with computer controlled data and graphic generation. However, this method is more suitable for the measurement of ε_r and μ_r of materials which have relatively high loss tan ∂ ($\leqslant$0.1).

The system can be made semi or fully automatic and can measure solids or liquids over a frequency range (45 MHz-26 GHz). In its full configuration (Figure 2) it is popular in various research/test laboratories. Using a network analyzer with appropriate attachments and a computer as shown in Figure 2, the real and imaginary values of ε and μ are determined and computed from the normalized scattering parameters (S_{21} and S_{11}) of the transmission line section containing the sample element under test. The values can also be listed and plotted automatically The measurement error in the ε_r and μ_r data is of the same order as the error in the measurement in the length of the sample dielectric (7).

Two Selected Test Systems

The vector voltmeter and RF generator method (No. 7) was cited as relatively simple in instrumentation. This method, though limited to a range of 1 MHz to 1 GHz, can be used to measure the dielectric constant of solids or liquids. Further, the relatively large sample holder (Figure 1) used with this method can be easily adapted to temperature control and measurement. However, there are certain shortcomings in this method. The loss tangent (tan ∂) cannot be measured directly and the frequency limit is $\sim$ 1 GHz. This method may be suitable in practice mainly due to its cost and speed in test times.

The second method, a computer controlled network analyzer (Figure 2), appears to be one of the most viable dielectric constant and loss tangent measuring systems. It has features such as accuracy, bandwidth (45 MHz to 26 GHz) coax or waveguide cell holder adaptable for varying temperature control of the material under test, liquid or solid dielectric measurement, computer interface for fast frequency scanning, some error reduction techniques, printed data and graphics. Other advantages associated with programmable measurements include better accuracy, precision, reliability, updating and system expansion. A main drawback of this test method is that its measurement uncertainty of low loss tan ∂ materials ($\leqslant 0.01$) is relatively high.

Summary and Acknowledgements

From this review of methodology in dielectric measurements at RF and microwave frequencies, it seems that the presently available computer controlled RF vector network analyzer system can provide most of the characteristics of the state-of-the-art dielectric measuring system. As this system configuration for dielectric measurements appears to be popular, it can further provide a base for better information exchange and progess.

Two areas where further work is required are the development of sample cells or holders, both coaxial and waveguide for different materials in solid, liquid and gaseous forms; and error correcting techniques required to overcome system uncertainties of measurement. Errors can be essentially divided into (23): instrument errors, such as noise, frequency unstability/conversion, crosstalk, non-linearities, drift; and test set and connection errors as caused by directional couplers, cables, connectors and adapters.

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Environmental Monitoring for Human Safety Part II: Radiation Monitors

By John Coppola and David Krautheimer
Narda Microwave Corporation

A series of broadband isotropic radiation monitor systems are available to fulfill the need for accurate strength measurement of near and far field equivalent power densities from 10 kHz to 40 GHz exist today. All of the available instruments provide measurements, which are independent of polarization and direction of any incident wave. Pulse or CW equivalent power densities are integrated to provide an average equivalent power density measurement.

Electric field probes are available to cover the 10 to 200 kHz, 300 kHz to 1 GHz, and 300 MHz to 40 GHz ranges. For near field measurements, where the magnetic field must also be measured, H field probes cover the 300 kHz to 10 MHz and 10 MHz to 300 MHz ranges. Electric field probes are also available with a frequency response conforming to the ANSI C95.1-1982 standard and reading out directly in percentage of the Radio Frequency Protection Guide.

This photograph demonstrates the size and use of a radiating monitor.

The ANSI Conformal Probe

The .3 MHz to 40 GHz electromagnetic radiation probe provides a frequency sensitivity characteristic that is the inverse of the C95.1-1982 ANSI Standard Radio Frequency Protection Guide, thus providing for metering in percent of RFPG. The shaping and broadband range is accomplished using three modes of detection.

In the frequency region below 1500 MHz, where the sensitivity varies by 20 dB, a dipole with diode detector and both distributed and discrete components are used (Figure 1). The probe employs three mutually orthogonal sensing elements. The diodes are maintained in their square law operating region, the sum of the outputs from the three elements is directly proportional to the true RMS power density or mean square field strength independent of polarization, modulation, direction or propagation, or multiplicity of signals characteristic of the incident RF energy.

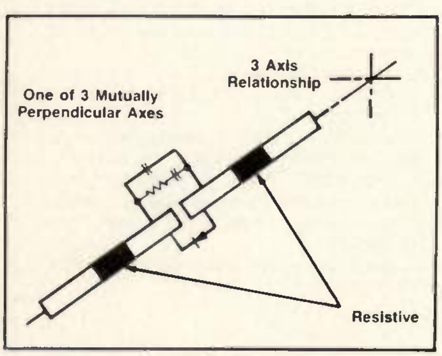

Figure 1. Pictorial view of dipole.

A resistive transmission line carries the modified signals to the metering circuits. These metering circuits include a preamplifier to condition the signals prior to transmission over the flexible cable for display on the metering instrument. The preamplifier contains the controls for calibration. The conditioning amplifier lowers the impedance of the signals, preventing cable modulation by the flexible cable. The preamplifier is a true differential amplifier contributing good common mode rejection thereby reducing the susceptibility to static charges. To further enhance this characteristic, a high resistance film covers the probe surface. The resistance is sufficiently high so as to appear transparent to the radio frequency signals while providing a discharge path for static charges.

A lumped equivalent circuit of a dipole-diode sensor is shown in Figure 2, and pictorially represented in Figure 3. The segments illustrated separately as Ca_1, Ca_2, La_1, La_2 represent the dipole equivalent capacitance and inductance. The frequency response of a typical unit is illustrated in Figure 4. (A ± 2 dB margin that conforms to the ANSI Standard is also drawn on the graph.)

Calibration factors are provided at multiple points over all frequency intervals making more precise measurements possible when the source frequency is known.

The element which is used in the higher frequency region functions in two modes. Between 1500 MHz and approximately 18 GHz, it is a resistive dipole. Above 12 GHz it utilizes the phase delay of a traveling wave to produce additional output. Each probe contains three mutually perpendicular resistive dipole elements.

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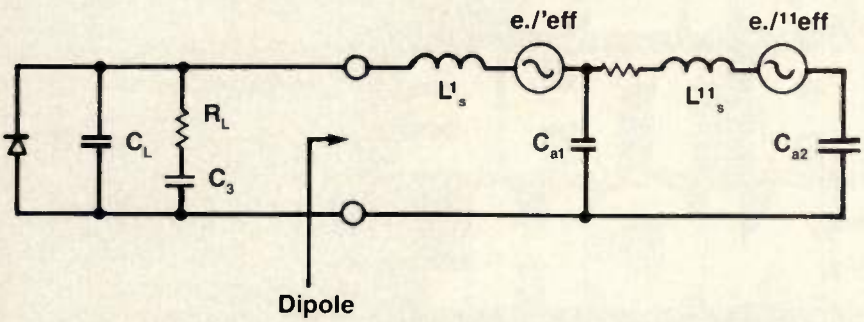

Figure 2. Lumped equivalent circuit of dipole-diode sensors.

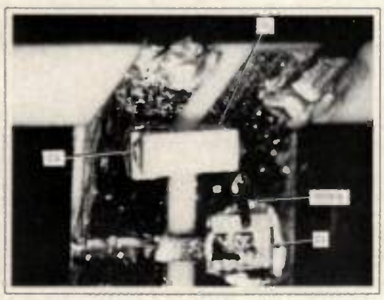

Figure 3. Pictorial presentation of probe.

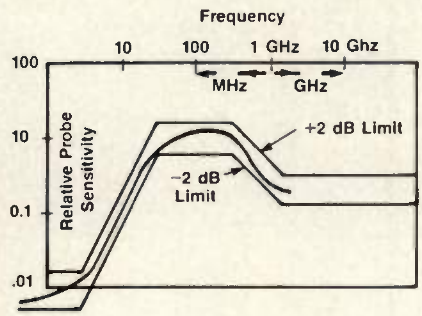

Figure 4. Frequency response of probe with ±2 dB margins.

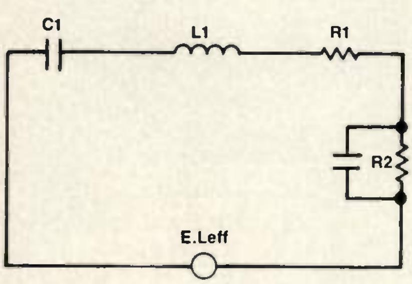

Figure 5. Lumped equivalent circuit of the probe.

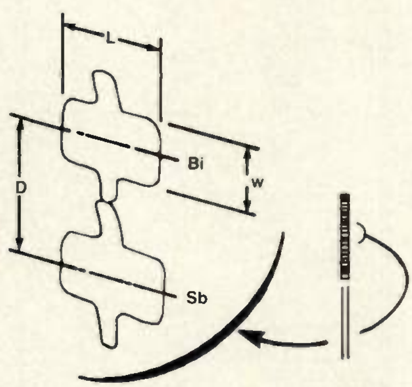

Figure 6. Antenna probe element with distributed thermocouple film elements.

provides a measure of the total energy or equivalent power density, independent of direction or polarization of the RF signals. The detectors for the DC signal generation are thin-film thermocouples or diodes (operated at low signal levels to provide true square-law outputs). The DC signal is proportional to the power dissipated in the square law elements and to the average energy density in the volume in which the elements are contained.

The broadband characteristics of the high frequency probes are obtained by distributing resistive thermocouple dipoles along the length of the element at spacings that will permit no resonant lengths over the range of frequencies within which the probe operates. The spacing is less than 1/4 of the highest frequency to be measured. The probe may be viewed as a group of series-connected, small resistive dipoles or as a very low Q resonant circuit.

A lumped equivalent schematic representation of a high frequency probe element is shown in Figure 5. The three orthogonal probe elements use resistive thin-film elements that are folded back or paralleled upon themselves with the output terminals at one end (see Figure 6). These probe elements are specifically composed of thin-films of overlapping antimony and bismuth deposited upon a thin plastic substrate. The geometry creates alternate cold and hot junctions (see Figures 6 and 7). The hot junctions are formed at the center of the narrow strips having relatively high resistance, thereby allowing for the dissipation of energy and the resultant increase in temperature. The wider sections have low resistance and thus function as cold junctions. The low resistance allows little energy to be dissipated within these sections. In addition, the broad area distributes the energy and conducts heat rapidly into the substrate so that very little temperature rise occurs. The resultant DC output voltage is directly proportional to the energy dissipated in the resistive portion of the thermocouple.

The spacing between the cold junctions is a small fraction of a millimeter. The close spacing permits little zero drift due to ambient temperature since a very small temperature gradient will occur due to variation in ambient temperature. Variation in the ambient temperature will cause variation in sensitivity that is less than 0.05 percent per °C and does not degrade the basic accuracy over wide temperature ranges.

Leads used to carry the DC outputs from the probe elements to the metering instrumentation are of high-resistance films. The total effect is to approximate the condition of the probe elements being suspended in space.

Because of the extremely light coupling into the field, very little perturbation due to scattering is caused. As an indication of the degree of coupling to the field, a term "effective volume" may be applied. This can be defined in a manner similar to that of effective area. The ratio of the power in the terminating impedance to the power density of the field, is defined as effective volume. Based upon knowledge of the efficiency of the thermocouple elements, the effective volume of the probe is approximately 1 cm³. The probe elements are contained within an actual volume of 44 cm^3. The probe is a relatively inefficient device. However, its inefficiency is an indication of its ability to measure a field without causing perturbations to the field. One series of probes are E-field instruments. The probe elements couple very lightly into the field causing extremely small perturbation to the field and may be used in the near field to make accurate measurements of equivalent plane wave power density.

The dipole, when oriented tangential to the electric field, will have an induced current proportional to the electric field in the region where the distributed resistance of the dipole is greater than its reactance. This current will heat the dissimilar resistive deposited films producing a thermoelectric output voltage proportional to the square of the electric field. As the reactance of the dipole increases above the dipole resistance, the induced current is proportionately reduced, resulting in lowered sensitivity. This occurs above 12 GHz and below 1.5 GHz.

Above 12 GHz, as the element sensitivity decreases, another mode of operation becomes manifest. In this mode, the dipole is aligned along the Poynting Vector with the cold junctions oriented tangential to the electric field. Each of the three mutually orthogonal elements contains four resistive dipoles with the cold junctions oriented at right angles. This provides for the independence of probe orientation relative to the polarization of the field.

The instantaneous charge distribution on adjacent cold junction elements produces a potential difference across the thin film resistive thermocouples and a resultant dissipation of energy in these films. As the frequency increases, the phase difference between the potentials developed in adjacent elements also increases the open circuit voltage resulting in the combined functions of the high frequency element producing a flat response from 1500 MHz to greater than 40 GHz. This makes the probes and metering circuitry a necessity in the electronic environment in which we live. Part I of the article was published in March, p. 87. rf

About the Author

John Coppola is the vice president of marketing and sales and Dave Krautheimer is a regional sales manager. Both the authors have over 20 years RF experience. They can be contacted at Narda Microwave Corporation, 435 Moreland Rd., Hauppauge, N.Y. 11788, Tel: (516) 231-1700.

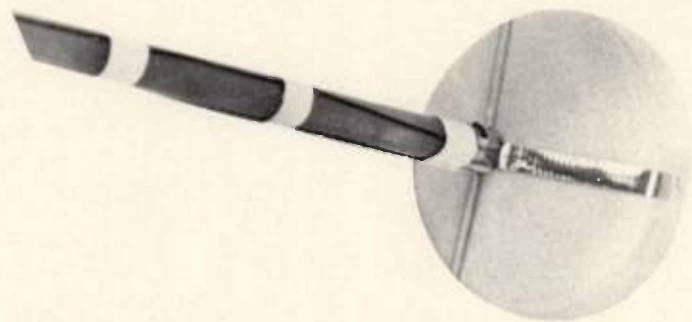

Figure 7. Probe geometry.

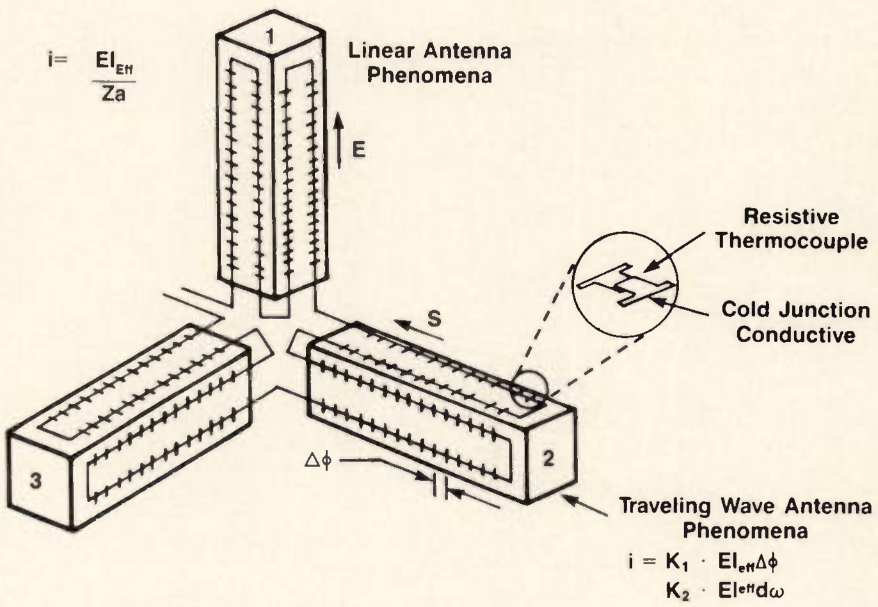

Figure 8. High frequency elements.

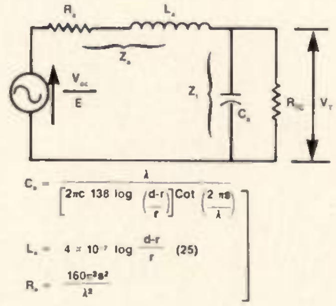

Figure 9. Traveling wave mode equivalent circuit.

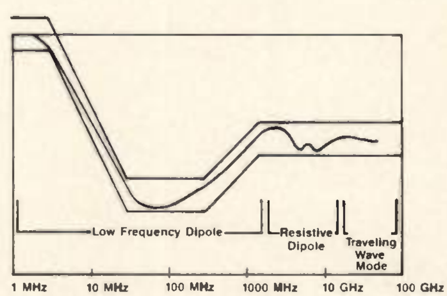

Figure 10. Combined frequency sensitivity and ±2 dB of ANSI.

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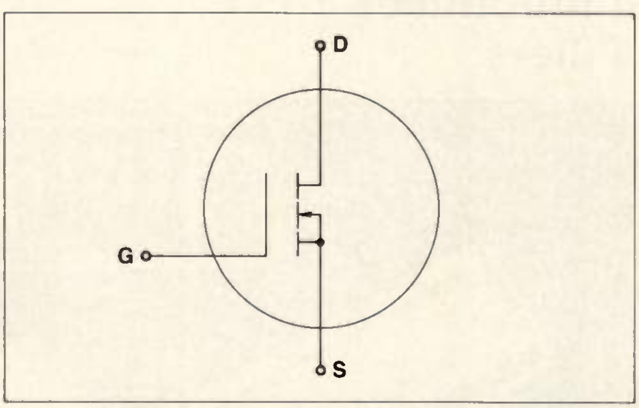

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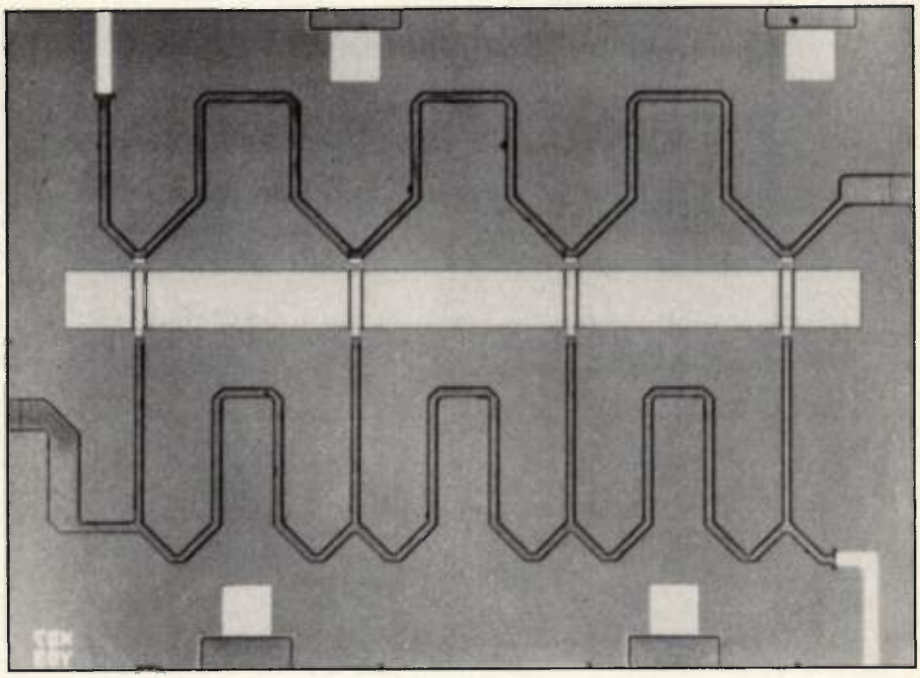
In addition to RF and microwave transistors, Thomson-Mostek manufactures MOS and bipolar devices for both commercial and military applications microcomponents, memories and linear circuits as well as Discrete, passive components and ASIC

MSC Unveils the D Amp 110

The D Amp 110 is a broadband MMIC GaAs amplifier. The applications for this device include broadband signal sources, EW, instrumentation and other wideband applications. The broad width is achieved by combining input and output capacitances of the FETs with inductors to form lumped element artificial transmission lines. The input transmission line is coupled to the output transmission line by the transconductance of the FETs to give the overall gain.

The features of the 110 include a bandwidth of greater than a decade, advanced via hole process for easy and repeatable ground connections, distributed design for stability and cascadability, passivated gates for reliability and ease of handling. It is available as a chip device for direct bonding into microstrip or in standard or custom packages.

The frequency range for this device is from 500 MHz to 10 GHz. The minimum small signal gain is 5.0 dB, while the typical small signal gain is 6.5 dB. Gain flatness is rated at ±1 dB and the power output is ±1 dBm/20 dBm. The maximum input power is rated at 16 dbm. The input VSWR is rated at 2:5:1, whereas the output VSWR is 2:0:1.



Saturated drain current I_{DDS} is typically 100 mA when V_{DS} = 3 V and V_{GS} = 0 V. The maximum pinch off voltage is 3 V with I_{DS} = 0.12 mA.

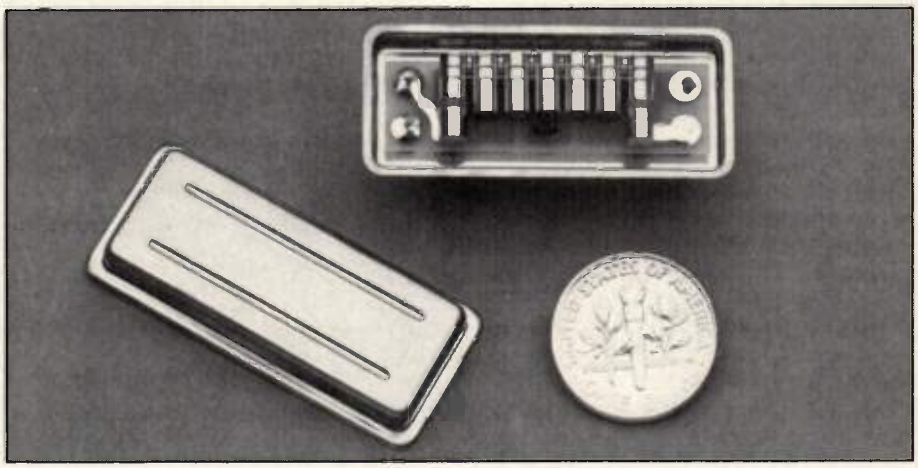
In chip form the device measures 8 mils by 107 mils. In the Matchpac 1 packaging the outer dimensions are 0.2" by 0.410". Case style 106 is a hermetically sealed metal ceramic package measuring 0.509" by 0.83". **Microwave Semiconductor Corp., Somerset, NJ. INFO/CARD #172.**

Rockwell International Introduces Torsional Mechanical Filters

A new product line, Collins Torsional Filters, has been announced by Rockwell International. A key feature of these bandpass filters is their small size resulting from the use of torsional mode resonators and a coil-less transducer design.

The elimination of coils has resulted in a high reliability component with insertion loss of less than 2 dB and low in-band intermodulation distortion reflected by a third order intercept point that is greater than 55 dB.

The torsional mechanical filter center frequency range is 125 kHz to 525 kHz. The bandwidth range is from 0.05 percent to 5 percent of the center frequency value. The bandwidth can be increased through the use of tuning coils. The frequency response characteristics range from equal ripple passband to round top Gaussian shapes. The filters are packaged in hermetically sealed metal enclosures. The cases are designed for PC board assembly. Dimensions of the cases are 1.6" × 0.73" × 0.34" (up to eight resonators) and 2.1" × 0.76" × 0.37" (up to 12 resonators).



Additional features of these filters are low spurious response levels and rugged construction resulting from each resonator being individually supported. In addition, the torsional configuration lends itself to automated assembly processes resulting in consistent performance characteristics. The 100-piece price typically varies from $65 to $175 depending on the complexity of the user's specifications. **Rockwell International, Dallas, TX. Please circle INFO/CARD #219.**

RF Generator is Portable

Texscan unveils the PSG 1000 Direct Synthesis RF Generator with a 10 kHz to 1 GHz range and 13 dBm output. The unit is portable and operates off either standard AC or +12 VDC. The resolution is 10 Hz when the frequency is less than 128 MHz and 100 Hz with frequencies greater than 128 MHz. The features of the PSG 1000 include AM, FM and PM, IEEE-488, digital step sweep and 100 non-volatile memories. **Texscan Instruments Division, Indianapolis, IN. Please circle INFO/CARD #218.**

100 kW Tetrode

The Electron Tube Division of Thomson-CSF announces a new member in the line of tetrodes and associated cavities for FM broadcast, the TH 546. With

this tube, it is possible to design 100 kW FM transmitters using a single tube in the output stage amplifier. The characteristics of this tube include efficiency of 80 percent, high gain of 18 dB and 50 kW of power handling capability in a compact package (32 cm high and 14 cm in diameter). **Thomson Electron Tubes and Devices Corp., Dover, NJ. Please circle INFO/CARD #217.**

Frequency Synthesizer Requires only External Crystals

The FS30 is a complete frequency synthesizer with TTL or CMOS square wave output in a 1.6" × 2.25" shielded package. Components of a wide range frequency phase lock frequency synthesizer, such as loop filters, VCOs and divider registers, are integrated in the FS30. The only exter-

nal part required is a crystal or clock oscillator. The features include a range from 30 Hz to 30 MHz, resolution to 0.13 percent, CMOS inputs with TTL or CMOS square wave output and tristate output for automatic test capabilities. The FS30 is available from stock at $195 (1-9). **Analytic Instruments Corp., Dallas, TX. Please circle INFO/CARD #216.**

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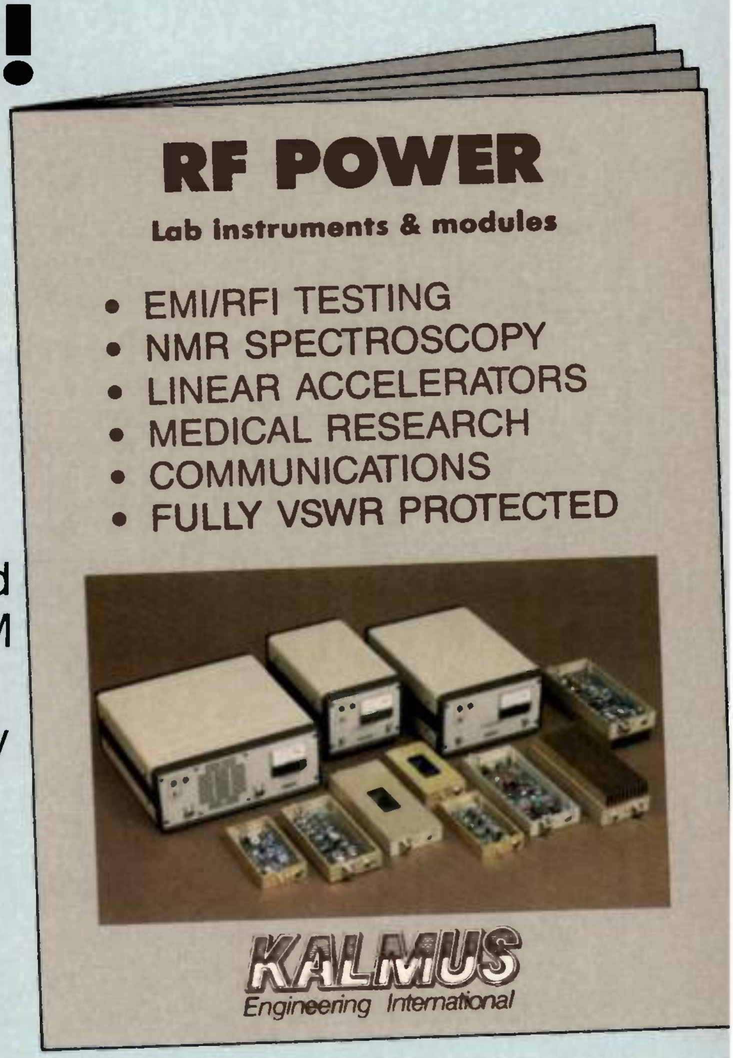

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RA-200 System

The highly modular RA-200 system is a radar/signal simulator capable of emulating an RF environment of radar signals. The RA-200 system software generates and controls all parameters, including a dynamic frequency range of 0.5 to 18 GHz, PRF/PRI stagger and jitter, and antenna and scan patterns for up to 10 separate RF signals. **S.T. Research Corp., Newington, VA. INFO/CARD #215.**

Digital Frequency Synthesizer

This 1 Hz resolution digital frequency synthesizer is introduced by A&A Engineering. It provides an output of 1/2 V peak to peak into a 75 ohm load with almost no phase noise and has a usable output from 1 Hz to 6.5 MHz. Since it uses digital synthesis techniques there is no VCO or PLL. The unit requires a 24 bit binary word to set the output frequency. The system can be used as a programmable frequency generator when connected to a computer. Under software control FSK, FM, scanning and other variations are possible. Changing frequencies is as simple as transferring in a different 24-bit word. The output is phase continuous so sidebands generated by change are minimized. **A&A Engineering, Anaheim, CA. INFO/CARD #214.**

Wideband RMS to DC Voltage Converter

Linear Technology Corporation introduces the LT1088 Wideband RMS to DC converter, capable of converting RMS voltages up to 9.5 V at frequencies up to 300 MHz to their DC equivalents. It is a monolithic thermally-based converter intended to replace thermal converters used for wideband applications with crest factors up to 50:1. Applications for the LT1008 include wideband RMS voltmeters, RF leveling loops, wideband automatic gain controls and SCR power monitoring. The LT1008 is priced at $28.65. **Linear Technology Corp., Milpitas, CA. Please circle INFO/CARD #213.**

Laboratory Spectrum Analyzer

The 2756P programmable spectrum analyzer offers frequency coverage from 10 kHz to 325 GHz with −134 dBm sensitivity and 10 kHz to 3 MHz resolution. It is optimized for use in baseband through millimeterwave measurements. A built-in signal converter with 144 dB dynamic range enables the user to determine the exact frequency of marked signals only 10 Hz apart or count the exact delta frequency between two marked signals. Macro programming capability enables the user

to download frequently used measurement programs into non-volatile memory of the instrument. The features include a 90 dB display dynamic range, preselection and multiband sweep coverage from 1.7 GHz to 21 GHz, Mate/CIIL language option and data plotting without a controller. The 2756P is priced at $42,245. **Tektronix, Inc., Beaverton, OR. Please circle INFO/CARD #212.**

Low Noise Amplifier

Anzac's AM153 amplifier provides low noise figures along with third order intercept points. Noise figures are typically less than 2 dB to 1 GHz and less than 2.8 dB from 1.0 GHz to 1.8 GHz; third order are typically greater than +17 dBm. Other specificatons include nominal gain of 12 dB and low power consumption of less than 1/4 W. **Anzac Division, Adams Russell, Burlington, MA. Please circle INFO/CARD #211.**

Low Power FM Receiver IC

The S422 superheterodyne FM receiver IC includes an IF preamplifier and amplifier, discriminator, filter amplifier, data out buffer and regulated bias supply. The supply voltage range of 1 to 6 V allows single battery cell operation. Supply current is typically 1.2 mA. The IF amplifier section has 100 dB of voltage gain at 455 kHz. The signal path from the discriminator output through the filter amp to the data out buffer can be DC or AC coupled with any desired time constant, enabling the receiver designer to optimize the tradeoff between frequency and transient responses. The S422 in SO-16 package is priced at $3.20 at 1,000 unit quantity. **Siltronics Ltd., Kanata, Ontario, Canada. INFO/CARD #210.**

Vector Analyzer and Vector Generator

HP introduces the HP8780A vector generator and the HP8980A vector modulation analyzer. The 8780A covers 10 to 3000 MHz and features digital BPSK, 8QAM and 16 QAM modulation directly along with pulse bursts at clock rates to 150 MHz. The 8980A is a dual channel sampling oscilloscope with matched X-Y inputs each capable of DC to 350 MHz bandwidth. The analyser displays vector, constellation and time domain. **Hewlett Packard, Palo Alto, CA. Please circle INFO/CARD #209.**

Textiles for EMI Shielding

Devex metalized textiles provide an alternative to traditional shielding methods. These textiles are offered in a wide selection of fabric bases ranging from transparently sheer to opaque. The textiles have a continuous metallic coating of nickel, which covers all the crossing points of the fiber. The material can be used for cable wrappings, computer windows, waveguide gaskets, structural composites and Faraday cages. **Devex, Inc., Dallas, TX. INFO/CARD #208.**

Surface Mounted Trimmer Capacitors

Sprague-Goodman Electronics introduces a new line of surface mounted trimmer capacitors. Designed for vapor phase reflow soldering, the Surftrim line is available in unsealed and sealed models. The membrane seal provides protection against contaminants, such as flux and solvents, during production. **Sprague-Goodman Electronics, Inc., Garden City Park, NY. INFO/CARD #207.**

RF Amplifier is Modular

RF Power Labs introduces the first member of a series of lab and general purpose wideband amplifiers, Model 2002 with a ±1 dB gain flatness response from 1.0 to 500 MHz, 35 dB gain and 2 W of class A linear power output. The amplifier design utilizes MOSFET technology and surface mount components. The construction is totally modularized and includes a visual fault detection system. Other features include LCD power meter, fast RF gating control and built-in RF power test source. The amplifier section, Model 1002 is available in modular form for OEM applications. The 2002 is priced at $1,495. **RF Power Labs, Inc., Bothell, WA. INFO/CARD #205.**

VCO is Oven Stabilized

General Services Engineering introduces an oven stabilized VCO for a −55°C to +70°C temperature range. It features built-in modulation signal processing, digital divider network and VCO supply regulation. **General Services Engineering, Inc., Baltimore, MD. INFO/CARD #204.**

Substrates for SAW Devices

Piezoquartz substrates with Al, Au or chrome metallization are being introduced by Balzers Optical Corporation. Balzers SAW devices feature 15 micron etched lines and spacing with ±5 micron tolerance on piezoquartz substrates metallized with Al, Au or chrome. **Balzers Optical Corp., Marlborough, MA. Please circle INFO/CARD #206.**

Gaussian Noise Generator

The Calnet CNM-1000 noise generator module produces Gaussian random noise over the frequency range of 25 Hz to 1 MHz. The unit has provision for an interstage output level control, which allows constant output impedances of 600 Ω and 50 Ω to be maintained. The unit can provide up to 2 V RMS in a 10 Hz to 10 MHz noise bandwidth. **Calnet Electronics, Inc., Kanata, Ontario, Canada. Please circle INFO/CARD #203.**

Emission Measuring System

Eaton Corporation introduces the Eaton series 3000 emission measuring system for FCC, VDE and CISPR measurements. Designed for manual or programmable operation, the series 3000 assists manufacturers in meeting CISPR, FCC and VDE requirements for the measurements of radio interference voltages and currents. Making up the series 3000 system are two emission measuring receivers; the 3018 and 3038. The 3018 covers from 9 kHz to 30 MHz, while the 3038 operates from 25 MHz to 1 GHz. Both units feature synthesized frequency accuracy, full preselection and an internal GPIB bus. Triple shielding and modular construction ensure shielding effectiveness for emission measurements in the presence of RF fields. **Eaton Corp., Los Angeles, CA. INFO/CARD #202.**

rf software

EMC Problem Solver

Interference Control Technologies introduces three software programs for EMC. Program 5220 is called Box to Box Radiated EMI Susceptibility and Control. The program evaluates designs to eliminate radiated susceptibility problems due to cable pickup between interconnected equipment, predicts interference levels, etc. The 5300 is also known as Box Level Radiated Emission Control and its features include determining for prototype designs to meet various regulatory standards. Program 5500 (Design of Shielded Boxes) is to help solve designing, integrating, installing or retrofitting problems of shielded boxes. **Interference Control Technologies, Inc., Gainsville, VA. INFO/CARD #177.**

Active Filter Design

RLM Research announces a revision to the Active Filter Design software package for the IBM family. This version (2.10) adds a filter selection capability, as well as several other enhancements to the program. The program designs Butterworth, elliptic, Chebyshev and Bessel low pass, high pass, band pass and band stop active filters. It also allows the direct entry of pole and zero locations or transfer functions and can convert low pass prototype poles and zeros to the desired filter configuration. Also new is a companion program that takes a file created by the active filter design program and compiles it into a Spice-compatible net list. The use of this utility allows the user to obtain a more detailed analysis of the actual filter circuits. The price of the Active Filter Design program is $525 and the Spice utility program is $125. **RLM Research, Boulder, CO. INFO/CARD #176.**

Combline Filter Program

Combline designs microwave combline filters by exact synthesis. When the passband and stop band requirements are entered, the program designs and supplies the physical filter dimensions for constant diameter rods with end capacitive loadings. The program has the capability to generate circuit files for each realization for programs like Analop, Touchstone and Super-Compact. It is priced at $950. **Analop Engineering, Milpitas, CA. INFO/CARD #175.**

RF Notes No. 1

RF Notes No. 1 Version 3.0 aids in the design of resonant circuits, filters, basic stripline and microstrip, as well as cross product and VSWR analysis. This version incorporates improved schematic and graphics, in addition to allowing on screen "What if" calculations. The program is fully menu driven and includes tutorial sections. Version 3.0 sells for $85. **Etron RF Enterprises, Diamond Bar, CA. Please circle INFO/CARD #174.**

Technical Database

Test Quality Company introduces Tekbase, a technical database for the HP 9000 series 200 and 300 computers. It allows direct programmatic access to Basic, Fortran and Pascal application programs. The database also supports multiuser access on HP's SRM network. The import/export capabilities let users enter data from outside the database and send processed data to other systems. It can transfer information to ASCII, Pascal and Bdat files through RS-232 and DataComm interfaces or over HPIB. Large (3200 element) arrays, complex numbers, standard real, integer, string and Boolean data types can be handled. The output includes scatter diagrams, line drawings, bar charts, and pie charts. All HP plotters and printers are supported. Tekbase is priced at $3,500. **Test Quality Company, Santa Clara, CA. INFO/CARD #173.**

SYSCAD 3.0 Features Full Screen Editing

Webb Laboratories introduces Version 3.0 of the Syscad RF/Microwave system engineering work station. Link analysis, architecture characterization and optimization, receive and transmit spurious analysis and frequency source phase noise analysis are performed via a single screen editor. SYSCAD 3.0 requires 512K RAM and utilizes but does not require 8087/80287 math coprocessor. It is tailored for IBMs and is priced at $995. **Webb Laboratories, North Lake, WI INFO/CARD #171.**

Touchstone Ported to DEC VAX™

Touchstone is now fully implemented on Digital Equipment Corporation's VAX series of computers. The program provides the full capabilities of Touchstone 1.5 including new optimization techniques, linear circuit analysis capabilities, interactive tuning and Monte Carlo yield prediction. A user interface system called General User Interface™ offers advanced graphics capabilities which include Smith chart displays. The VAX processes CPU-intensive calculations, while Touchstone provides the simulation modes. The price for the Touchstone on the VAX starts at $13,500. **EEsof, Inc., Westlake Village, CA. Please circle INFO/CARD #170.**

rf literature

Ceramic Trimmer Capacitor Catalog

Catalog 500, detailing a line of ceramic trimmer capacitors is released by Tusonix. Featured are Tusonix Vari-Thin series 513, 100 WVDC ceramic trimmers. Other ceramic trimmers include voltage ratings from 100 to 500 WVDC and capacitance ranges from 1 pF to 110 pF. **Tusonix, Tucson, AZ. INFO/CARD #187.**

1987 Publications Catalog

This catalog lists books, conference publications and journals published by the Institute of Electrical Engineers and Peter Peregrinus Ltd. Titles are grouped by subject area and may be located by either the author or the title index. **IEE/PPL, Piscataway, NJ. INFO/CARD #186.**

Coaxial Products Catalog

Catalog #387 features a full line of coaxial adapters, coaxial connectors, coaxial attenuators, coaxial terminators and coaxial cable assemblies. Coaxial connectors and adapters include BNC, SMA, TNC, N SMB, SMC, MHV, UHF, SHV, SSMA and HN. Cable assemblies featured are both flexible and semi-rigid. Also featured are twinax connectors, adapters and twinax cable assemblies. In addition, a line of coaxial cable and hex crimp tools are now available. **Pasternack Enterprises, Irving, CA. Please circle INFO/CARD #185.**

Microwave Materials Catalog

Alpha Industries Trans Tech subsidiary introduces a microwave materials catalog. The catalog includes electrical characteristics and specifications for microwave ferrites, garnets, dielectrics, non-microwave ferrites and technical ceramic powders. **Alpha Industries, Inc., Woburn, MA. INFO/CARD #184.**

Ferrite Core Catalog

Krystinel Corporation introduces a condensed catalog covering ferrite products, such as toroids, E-cores, coil forms, bobbins, sleeves, baluns, cup cores, beads, threaded cores, EMI and RFI suppressors, and design kits. It contains magnetic and electrical characteristics of Krystinel's complete line of ferrite materials and listings of all the stock sizes of the various shapes. **Krystinel Corp., Paterson, NJ. INFO/CARD #183.**

Passive Microwave Devices Catalog

An eight-page catalog describes 55 examples of passive microwave devices developed and manufactured by the Wavecom Division of the Loral Corporation. Products pictured include high performance filters, diplexers and multiplexers covering sub-octave and extended octave bandwidths in the HF through Ku band frequency ranges. Power ranges handled go up to 20 kW CW and 100 kW peak. The catalog also covers a line of precision RF switches and presents examples of integrated assemblies and other Wavecom developments such as 64 channel filters and coaxial power dividers. **Wavecom Division, Loral Corporation, Northridge, Calif. INFO/CARD #182.**

TWT Amplifier Catalog

A short form catalog of high power microwave amplifiers is available from Varian Microwave Equipment Division (MED). It features a selection guide and descriptive information. The catalog includes salient specifications and options for the division's 6900K series low power TWTAs, 6900G series medium power TWTAs, 6900H series broadband TWTAs, 6900L series MM TWTA and 5900P series pulse TWTAs. The product line provides a broad range of coverage from 10 to over 200 W, 1 to 40 GHz and octave bandwidths. **Varian Microwave Equipment Division, Santa Clara, CA. INFO/CARD #181.**

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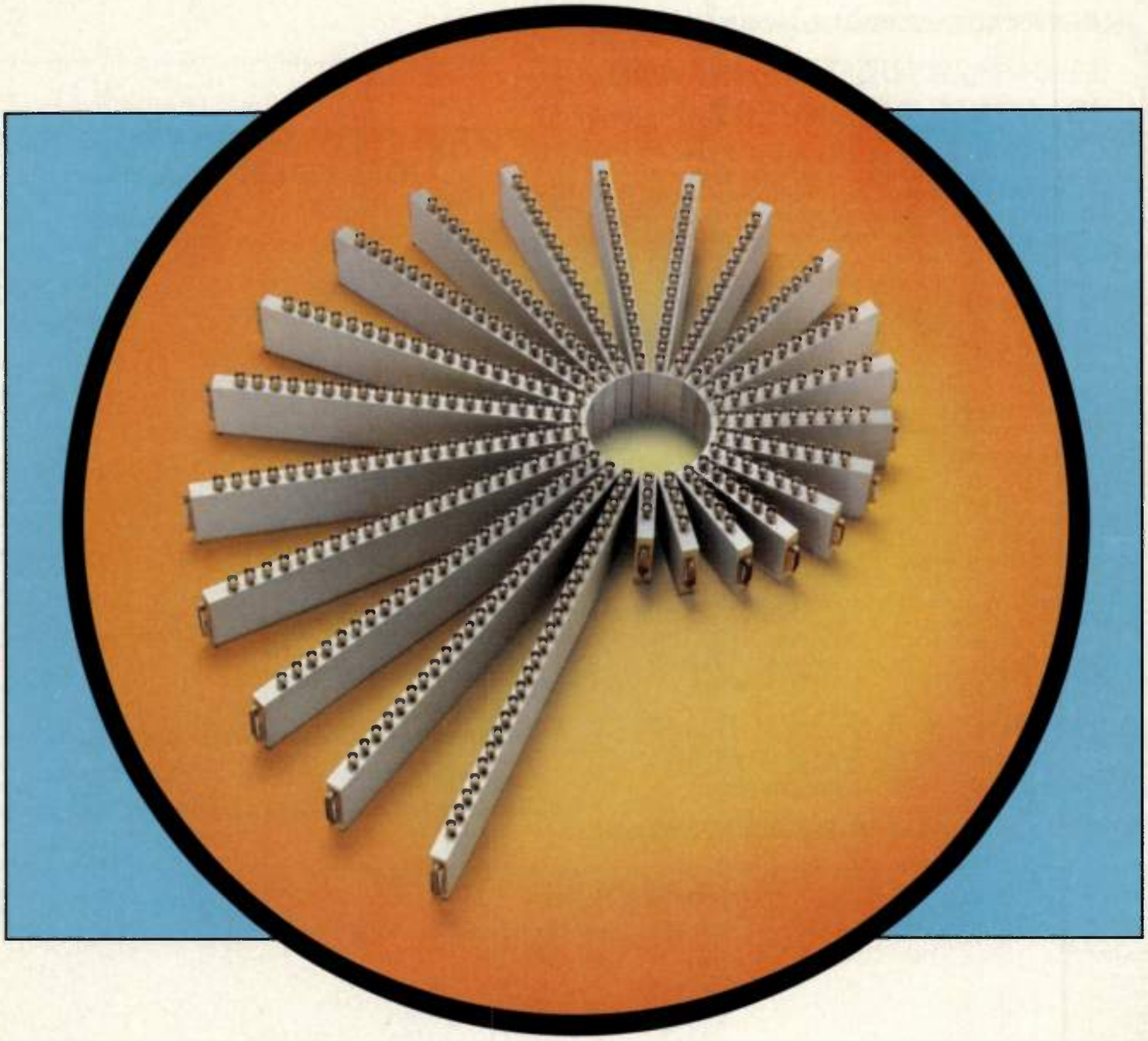

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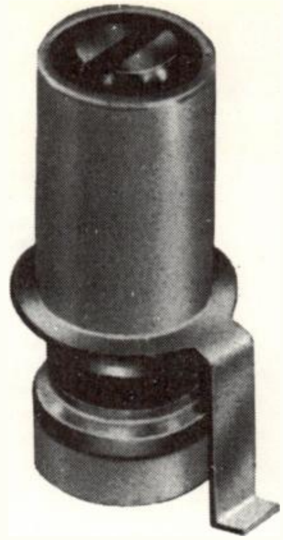

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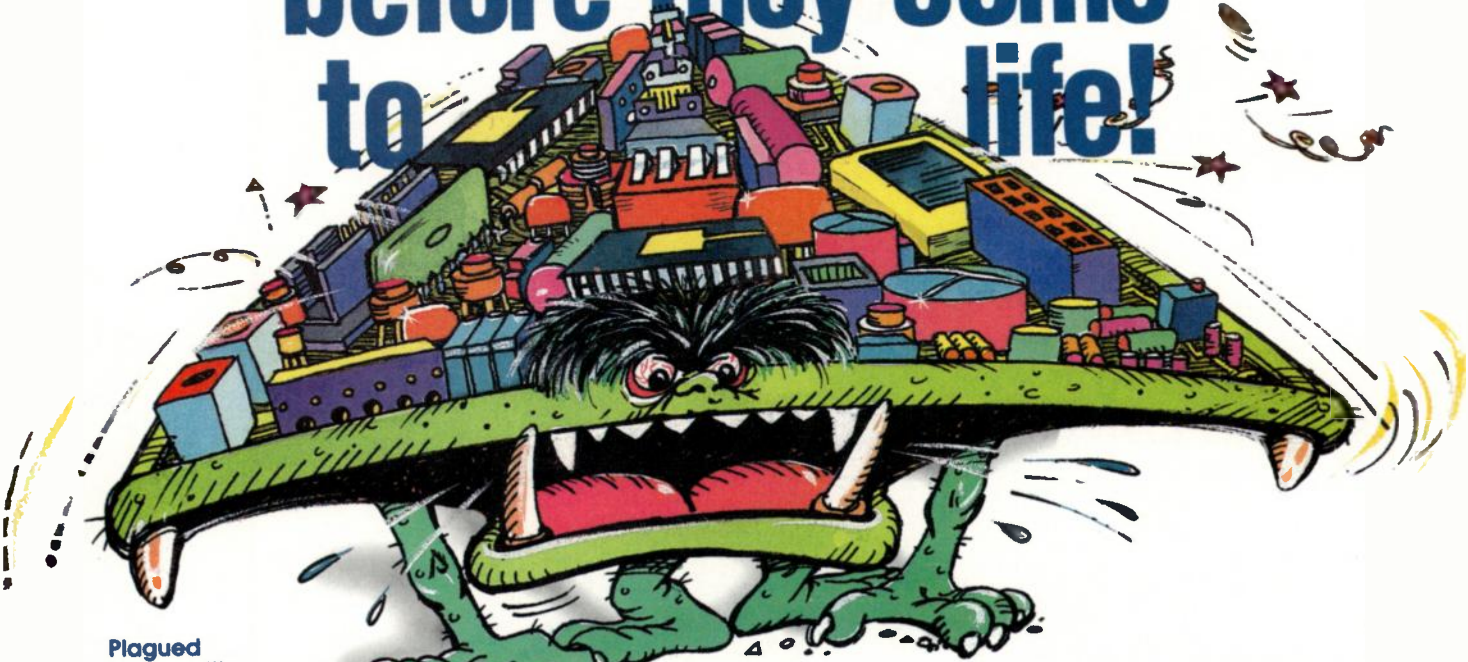
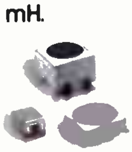
Toko coils and filters attack RF design problems before they come to life!



Plagued by parasitic oscillations, spurs, harmonics and feedback? The problem may not be your design, but the coils and filters you selected. Toko is the world's largest manufacturer of quality small coils and filters, with a selection so large, you're sure to find the right components to neutralize your rf design problems.

SUBMINIATURE ADJUSTABLE AND FIXED

Toko has what you need, so you won't need to compromise... subminiature adjustable coils and transformers, molded coils, radial fixed coils and fixed coils with axial leads. Toko high-Q coils are engineered in sizes from 5mm to 15mm, and inductance ranges from .02 µH to 500 mH.

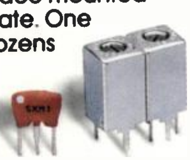


CHIP AND ADJUSTABLE SMD

Need to reduce the size of your products or automate production? Toko solves these problems with a wide range of surface mountable coils and LC, ceramic and helical filters in fixed and adjustable configurations. Packaged for automatic insertion and available for reflow or solder dipping.

CUSTOM MODULES

Toko hybrid modules are a great way to simplify design and production tasks. With short lead time, Toko can develop compact custom modules utilizing a variety of components, surface mounted on a ceramic substrate. One module replaces dozens of components.



FILTERS

For i-f or tuned rf circuitry, Toko filters simplify attenuation of out-of-band signals, while cleanly passing your desired signal. Ultra-miniature ceramic and LC filters at popular i-f frequencies fit tight spaces and tight budgets. With frequencies up to 1.2 GHz Toko helical filters are the right choice for communications transceivers.

ACTIVE FILTERS

If you're advancing the state-of-the-art in digital audio or PCM products you'll appreciate Toko active filters. Especially designed for small size and low distortion, they're also very cost-effective.

Isn't it time to tame the design monsters before they bite back...call or write Toko today for a free coil and filter catalog or a quote on your needs. No matter what Toko coils and filters you choose, you can be assured of exceptionally high quality control at economical prices.

Quality and workmanship that add value and performance to your product.

TOKO

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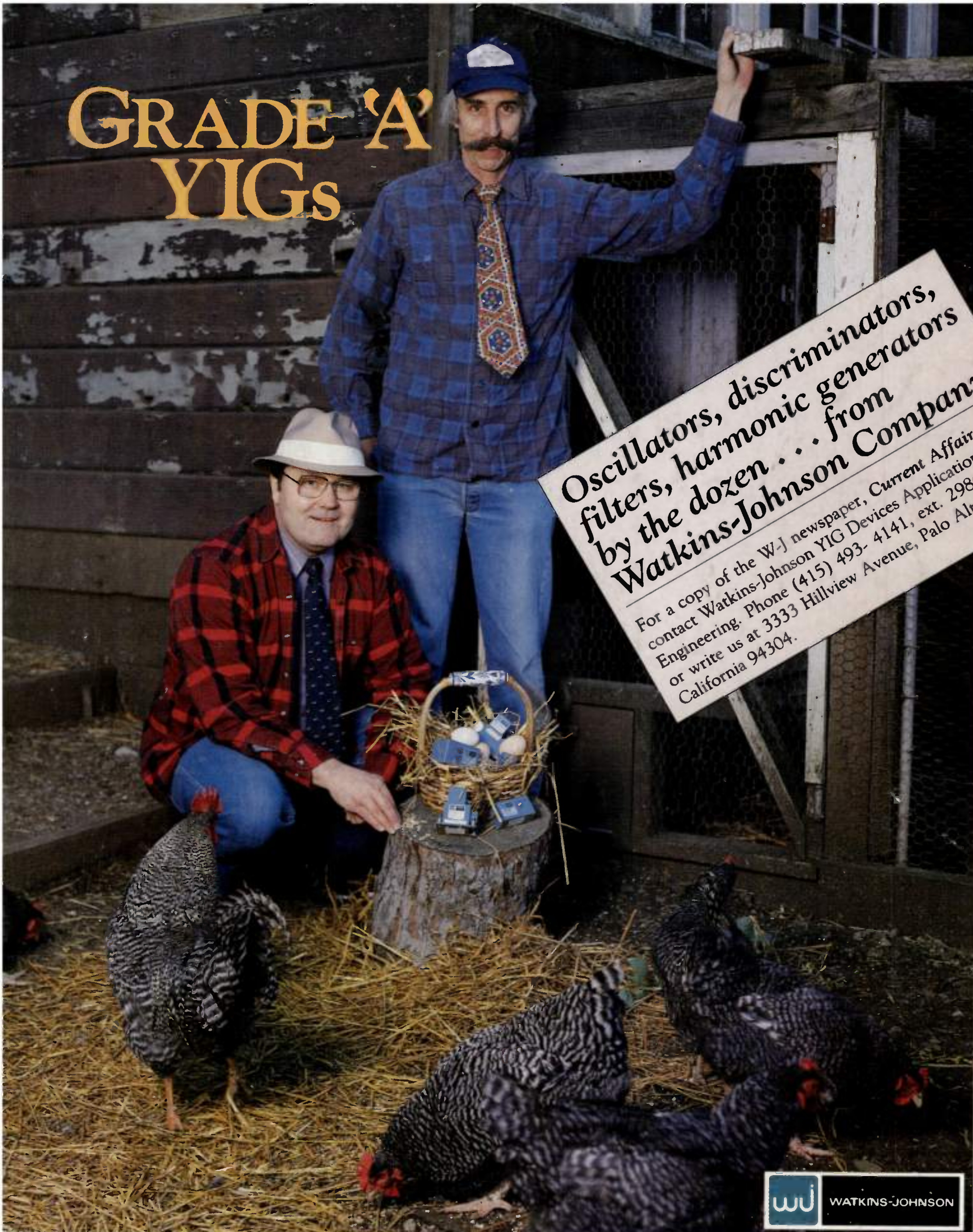
For more information on:
Subminiatures, INFO/CARD 46
Chip/SMD, INFO/CARD 47
Custom Modules, INFO/CARD 48
RF & I-F Filters, INFO/CARD 49
Active Filters, INFO/CARD 50


GRADE 'A' YIGs
Oscillators, discriminators, filters, harmonic generators by the dozen . . . from Watkins-Johnson Company
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