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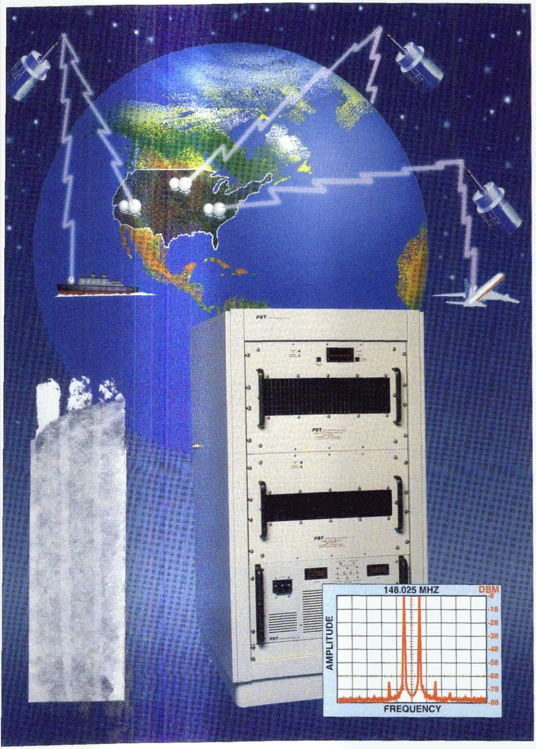

RF COMPONENTS AND SYSTEMS

COMMERCIAL APPLICATIONS SERIES
Mechanisms Governing Wireless Propagation

Noise Parameters of IF Amplifiers

A Superminiaturized SMT DBM-Modulator

CONTENTS, p. 10

horizon house

Everything you expect from a powerful new generation of HP spectrum analyzers.

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If advancing technologies and receding budgets make life difficult, it's time to look at HP's new generation of portable spectrum analyzers.

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The remarkable HP 8560 E-Series delivers the kind of performance that until now was found only on expensive benchtop models. Yet for its extremely affordable price you get lower phase noise, narrower resolution bandwidths, and improved sensitivity. Clearly, this level of performance doesn't exist in any other spectrum analyzer at this price.

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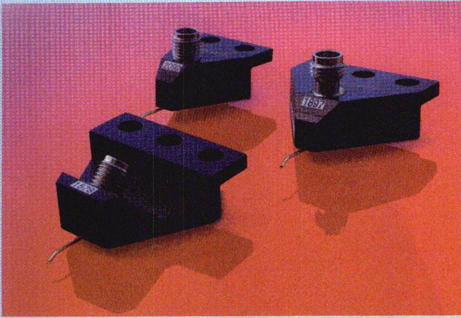
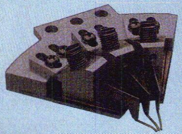


The GGB Industries line of microwave probes sets new standards in microwave performance. Using low loss coaxial techniques, the Model 40A Picoprobe, for example, achieves an insertion loss of less than 1.0 db and a return loss of greater than 18 db through 40 GHz.



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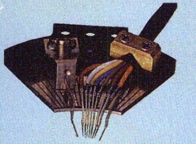
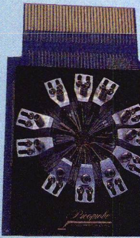


These probes can be mounted in various adaptors for use with standard probe stations or attached to thin blades for use with dc needles on standard 4.5 inch ceramic blade probe cards and our Multi-Contact Wedges.



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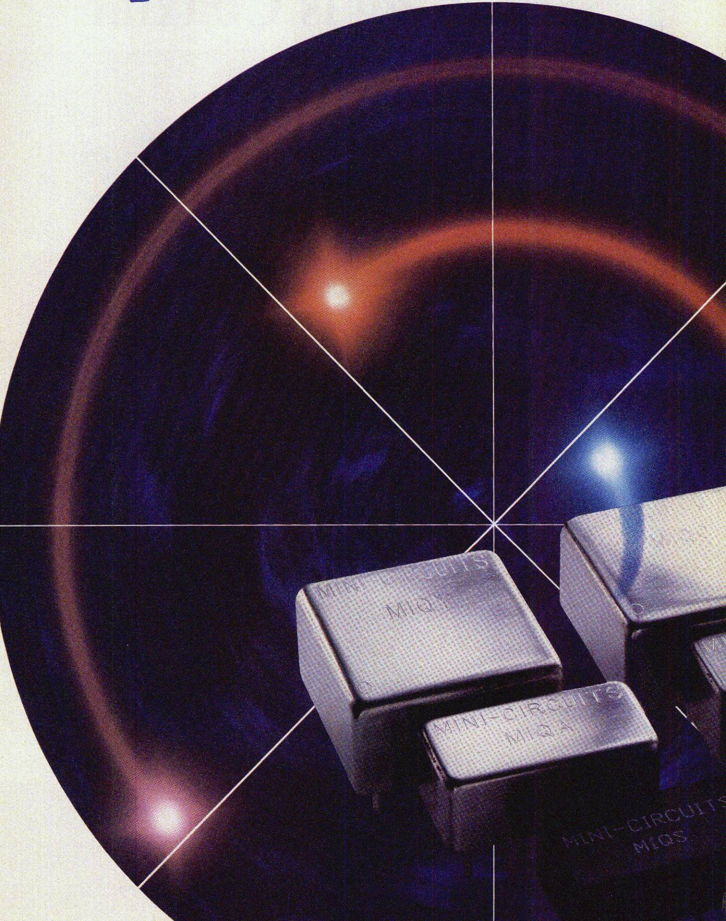
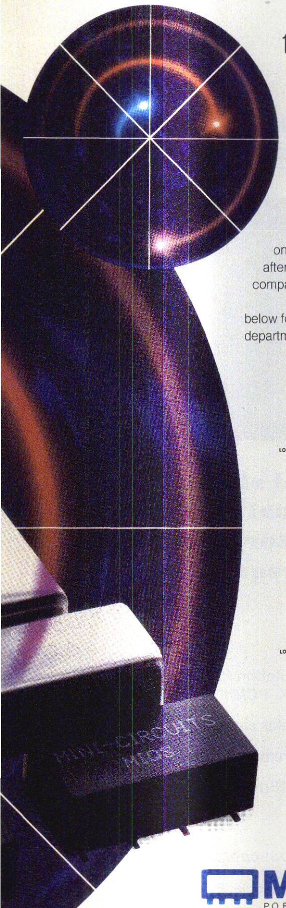


DEMODULATORS



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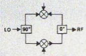
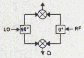


I/Q MODULATORS

MODEL NO.	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) x	σ	CARRIER REJ. (dBc) Typ.	SIDEBAND REJ. (dBc) Typ.	HARM. SUPPRESS (dBc) Typ. 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10M	9	11	5.8	0.20	41	40	58	68	49.95
MIQA-21M	20	23	6.2	0.14	50	40	48	65	39.95
MIQA-70M	66	73	6.2	0.10	38	38	48	58	39.95
MIQA-70ML	66	73	5.7	0.10	38	38	48	58	49.95
MIQA-91M	86	95	5.5	0.10	38	38	48	58	49.95
MIQA-100M	95	105	5.5	0.10	38	38	48	58	49.95
MIQA-108M	103	113	5.5	0.10	38	38	48	58	49.95
MIQA-195M	185	205	5.6	0.10	38	38	48	58	49.95
MIQC-88M	52	88	5.7	0.10	41	34	52	66	49.95
MIQC-176M	104	176	5.5	0.10	38	36	47	70	54.95
MIQC-895M	868	895	8.0	0.10	40	40	52	58	99.95
MIQC-1785M	1710	1785	9.0	0.30	35	35	40	65	99.95
MIQC-1880M	1805	1880	9.0	0.30	35	35	40	65	99.95
☐ MIQY-70M	67	73	5.8	0.20	40	36	47	60	19.95
☐ MIQY-140M	137	143	5.8	0.20	34	36	45	60	19.95



I/Q DEMODULATORS

MODEL NO	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) x	σ	AMP. UNBAL. (dB) Typ.	PHASE UNBAL. (Deg.) Typ.	HARM. SUPPRESS (dBc) Typ. 3xI/Q	5xI/Q	PRICE $ QTY (1-9)
MIQA-10D	9	11	6.0	0.10	0.15	1.0	50	65	49.95
MIQA-21D	20	23	6.1	0.15	0.15	0.7	64	67	49.95
MIQC-895D	868	895	8.0	0.20	0.15	1.5	40	55	99.95
☐ MIQY-1.25D	1.15	1.35	5.0	0.10	0.15	1.0	59	67	29.95
☐ MIQY-70D	67	73	5.5	0.25	0.10	0.5	52	66	19.95
☐ MIQY-140D	137	143	5.5	0.25	0.10	0.5	47	70	19.95

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MIQS case .8 x .4 x .2 in.

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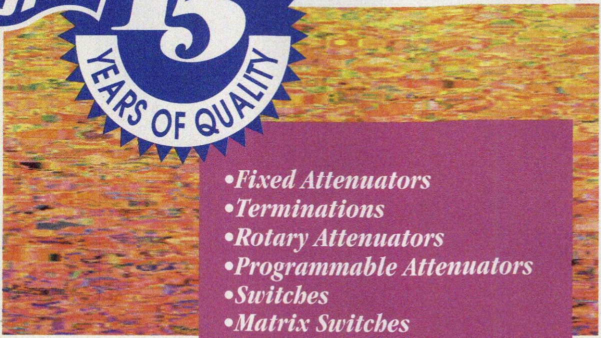

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microwave JOURNAL

FEBRUARY 1994

VOL. 37, NO. 2

COMMERCIAL APPLICATION SERIES

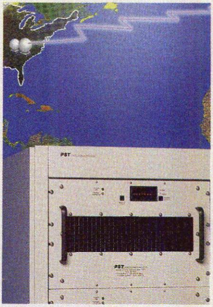
LIGHTWAVE SERIES

FEATURES

[Continued on page 12]

ON THE COVER

On this month cover is a high power feed forward amplifier system that achieves improvements in linearity and maintains high levels of spectral efficiency required for modern communication equipment. Cover art courtesy of PST Inc.; image created by Industrial Marketing Assoc., a division of J.M. Schrier Inc. 128



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Ins. Loss (dB)	1.1	1.4	1.9	0.9	1.3	1.4
Isolation (dB)	42	31	20	50	40	28
1dB Comp. (dBm)	18	20	22.5	20	20	24
RF Input (max dBm)	—	20	—	22	22	26
VSWR "on"	1.25	1.35	1.5	1.4	1.4	1.4
Video Bkthru (mV.p/p)	30	30	30	30	30	30
Sw. Spd. (nsec)	3	3	3	3	3	3
Price, $ (1-9 qty)	YSWA-2-50DR (pin) 23.95 ZYSWA-2-50DR (SMA) 69.95			YSW-2-50DR (pin) $14.95 ZYSW-2-50DR (SMA) 59.95		

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PRODUCT FEATURES

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COMING EVENTS

RF Expo West
March 22-24, 1994
San Jose, CA

Sponsor: *RF Design* magazine. Topics: Wireless communications applications; remote sensing; RF digital data transmission; satellite systems; digital cellular, consumer product, oscillator and filter design; design for manufacturing; personal communications; RF ICs and ASICs; frequency synthesis; analog and digital modulation; power amplifiers; microstrip techniques; EMC/ESD considerations; control systems; and CAD modeling and usage. Contact: RF Expo West, *RF Design* magazine, 6300 S. Syracuse Way, Suite 650, Englewood, CO 80111 (303) 220-0600.

3rd International Conference on MCMs
March 29-31, 1994
Denver, CO

Sponsors: IEPS and ISHM. Topics: Multichip module (MCM) design and test, assembly and interconnections, materials, yield and reliability; processing MCM design and implementation; MCM/printed circuit board interface, structure, electrical and thermal performance; and telephone and cellular applications. Contact: IEPS, 114 North Hale Street, Wheaton, IL 60187-5113 (708) 260-1044; or ISHM, 1850 Centennial Park Drive, Suite 105, Reston, VA 22091 (703) 758-1060.

ATM Developments '94
March 30-31, 1994
Rennes, France

Sponsor: EDICOM, Rennes District and Rennes Atalante. Topics: Asynchronous transfer mode (ATM) technology for broadband, private and virtual networks; ATM compared to competing technologies; evolution of the customer/operator ATM contract; broadcast or cordless applications; tests, projects and development strategies; and migrations toward ATM. Contact: EDICOM, 21 rue Tournefort, 75005 Paris, France +(33 1) 47 07 29 29.

Russian Telecom '94
April 18-22, 1994
St. Petersburg, Russia

Sponsors: Russian Ministry of Communications and St. Petersburg Bronch-Broevich State University of Telecommunications. Topics: Telecommunications policy, technology, applications and implementation plans relating to the needs of Russian and the Commonwealth of Independent States. Contact: Information Gatekeepers Inc., 214 Harvard Avenue, Boston, MA 02134 (617) 232-3111; or Russian Telecom Secretariat, 61 Moika, 191065, St. Petersburg, Russia +(812) 315-118.

1994 GaAs MANTECH
May 2-5, 1994
Las Vegas, NV

Topics: GaAs solutions to the dual-use challenge: substrates to systems, including GaAs manufacturing, processing, materials, advanced devices, testing, applications, and design for yield. Contact: Susan Stulz, conference chair, Watkins-Johnson Co., 3333 Hillview Avenue, Palo Alto, CA 94304-1204.

Tactical Communications Conference '94
May 10-12, 1994
Ft. Wayne, IN

Sponsors: Advanced Research Projects Agency. Topics: Tactical networks, modulation and coding, signal processing, man/machine interface, dual-use technology, simulation and analysis, asset management and RF technology. Contact: Mary Anne Hotham, conference coordinator, Eagle Technology, 320 West Street Road, Warminster, PA 18974 (215) 672-6250.

China Fibercom '94
May 15-18, 1994
Shanghai, China

Sponsors: Shanghai University of Science & Technology. Topics: Fiber-optic communications systems, and fiber-optic applications in China and the Pacific Rim. Contact: Information Gatekeepers Inc., 214 Harvard Ave., Boston, MA 02134 (617) 232-3111; or Prof. Huang Hung-Chia, Shanghai University of Science & Technology, Shanghai, China +86-21-953-2932.

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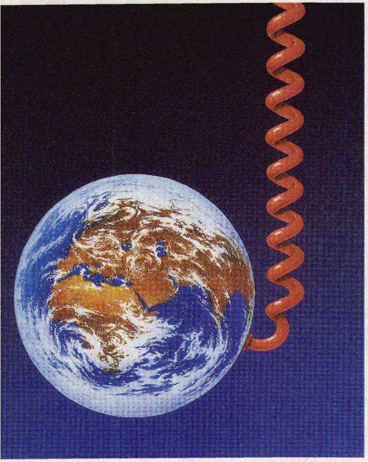

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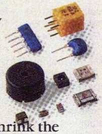

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COMING EVENTS

IEEE MTT-S International Microwave Symposium
May 23-27, 1994
San Diego, CA

Sponsors: MTT-S. Topics: Biological and medical applications; SAW, passive, ferrite and control components; guided waves and propagation characteristics; filters and multiplexers; nonlinear modeling and analysis; transistor power amplification; sources; measurement theory and techniques; high power sources and control; phased arrays; low noise receivers and detectors; manufacturing, production and packaging; MICs; mm- and submm-wave technology; EM analytical and numerical techniques; field theory; monolithic circuits and modules; CAD; microwave and communications systems; active and quasi-optic antennas; lightwave technology and techniques; superconductivity technology; and digital signal processing. Contact: Don Parker, Hughes Aircraft Co., Radar Systems Group, 4500 Park Allegra, Calabasas, CA 92302 (310) 334-8534.

Conference on Lasers and Electro-Optics/Europe
Aug. 28 - Sept. 2, 1994
Amsterdam, The Netherlands

Call for papers. Sponsors: European Physical Society; IEEE/LEOS; Optical Society of America (OSA); and the Institute of Physics. Topics: Laser, quantum physics and electro-optics research for applications including aerospace, environmental monitoring, imaging and manufacturing. Send to: IEEE/LEOS, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08854-1331. Send: an abstract and a summary. **Deadline: March 7, 1994.** Contact: OSA, 2010 Massachusetts Ave., NW, Washington, DC 20036-1023 (202) 416-1950.

24th European Microwave Conference
Sept. 5-8, 1994
Cannes, France

Sponsors: IEE; IEEE Region 8 and MTT-S; and URSI. Topics: Microwave materials and measurements; electromagnetic field, scattering and RCS; radio wave propagation; passive components; antennas and associated circuits; mm- and submm-waves; active devices and circuits; microwave and mm-wave IC and gigabit electronics; simulation, modeling and CAD; electromagnetic compatibility, packaging and interconnections; fixed and mobile terrestrial and satellite communications; radar, remote sensing and environmental applications; microwave technology in industry, transport, medicine, radio astronomy and scientific research; optics and microwaves; and modern microwave education. Contact: A. Papiernik, EuMC chairman, CNRS, Bâtiment 4, Laboratoire d'Electronique, 250 rue Albert Einstein, 06560 Valbonne, France +33 92 94 28 02; or 24th EuMc Conference, Nexus Business Communications Ltd., Warwick House, Azalea Drive, Swanley, Kent BR8 8HY, UK +44 (0)322 660-070.

Third International Conference on Plastic Optical Fibres and Applications (POF '94)
Oct. 26-28, 1994
Yokohama, Japan

Call for papers. Sponsor: Information Gatekeepers Inc. Topics: Polymer optical fibers and waveguides; materials, fiber and cable technology; special plastic fibers; fiber measurements, passive and active components, and testing; communication systems; and communication, industrial and medical applications. Conference is held concurrently with International Symposium on Fiber Science. Send to: POF '94 Secretariat, IGI Europe Inc., c/o AKM AG, Clarastrasse 57, PO Box 6, CH-4005 Basel, Switzerland (US and Europe); or Prof. Yasuhiro Koike, Keio University, Faculty of Science and Technology, 3-14-1, Hiyoshi, Kohoku-ku, Yokohama 223, Japan. Send: an abstract or a full-length paper. **Deadline: May 16, 1994.** Contact: Information Gatekeepers Inc., 214 Harvard Ave., Boston, MA 02134 (800) 323-1088 or (617) 232-3111; or IGI Japan Inc., New State Manor Bldg. #1067, 2-23-1 Yoyogi, Shibuya-ku, Tokyo 151, Japan +81-3-3299-3935.

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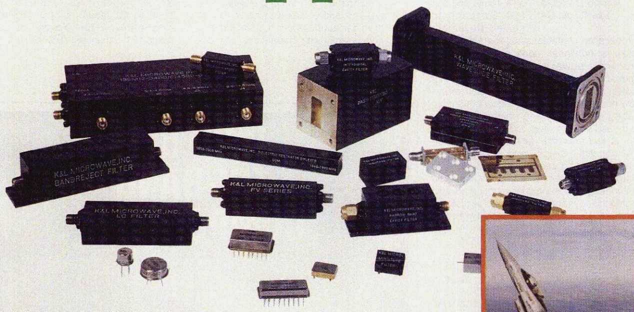

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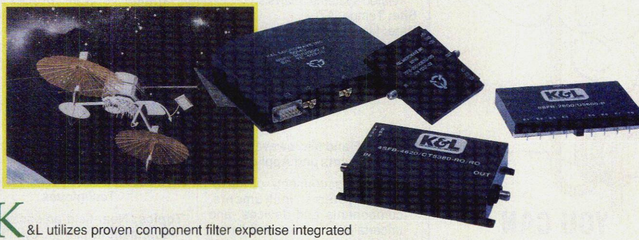
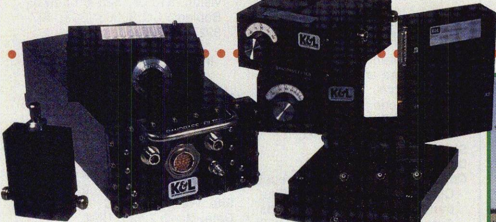
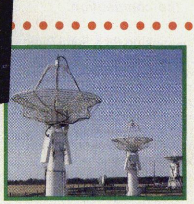
The Right Decision



K&L utilizes proven component filter expertise integrated with our RF switch technology to produce a wide variety of switched filter banks ranging from 2 to 50 channels and covering frequencies from 10MHz to 26GHz. Overall performance is optimized by integrating and tuning filter/switch components as composite assemblies. In addition to switched filter banks, a select product line of "filter based" multi-function assemblies is available. Devices now in production include both commercial and military applications.





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WORKSHOPS & COURSES

Fiber-Optic Communications

Topics: Fiber-optic communications system components and related systems analysis.
Site: Tempe, AZ
Date: March 2-4, 1994
Contact: Arizona State University, Center for Professional Development, Box 877506, Tempe, AZ 85287-7506 (602) 965-1740.

RF and Microwave Measurements and Applications

Topics: Measurements of microwave systems, instruments, components and devices; and uncertainties, errors and limitations of equipment and measuring techniques. Fee: $1195.
Site: San Diego, CA
Date: March 7-10, 1994
Contact: University Consortium for Continuing Education, 16161 Ventura Blvd., M/S 752, Encino, CA 91436 (818) 994-6335.

Antennas: Principles, Design and Measurements

Topics: Antenna fundamentals; arrays; wire and broadband antennas; horns; reflectors; numerical methods; antennas in systems; RCS of antennas; and measurements. Fee: $985.
Site: St. Cloud, FL
Date: March 9-12, 1994
Contact: Kelly Brown, Northeast Consortium for Engineering Education, 1101 Massachusetts Ave., St. Cloud, FL 34769 (407) 892-6146.

Understanding ATM

Topics: Asynchronous transfer mode (ATM) services, applications and broadband technologies. Fee: $895.
Sites: Washington, DC & Chicago, IL
Dates: March 16-17 and 28-29, 1994
Contact: Data-Tech Institute, PO Box 2429, Clifton, NJ 07015 (201) 478-5400.

Aspects of Modern Military and Commercial Radar

Topics: Radar basics; digital and analog signal processing; monopulse principles and techniques; target cross section prediction and reduction; and commercial radar applications.
Site: Davosdorf, Switzerland
Date: March 21-25, 1994
Contact: CEI-Europe, Box 910, S-61225 Finspong, Sweden +46 122-175 70.

Antenna Parameter Measurement by Near-Field Techniques

Topics: Near-field antenna measurement in planar, cylindrical and spherical coordinates, including measurement theory, probe antennas calibration, backward transform techniques and probe position error correction.
Site: Boulder, CO
Date: March 21-25, 1994
Contact: Carl F. Stubenrauch, NIST, Electromagnetic Fields Division, 813.08, 325 Broadway, Boulder, CO 80303 (303) 497-3927.

Introduction to Radar ECM and ECCM Systems

Topics: Microwave-radar electronic countermeasures and electronic counter-countermeasures (ECCM) systems; noise jammers; repeater jammers; chaff and stealth; and answering ECCM technology. Fee: $1125.
Site: Washington, DC
Date: March 22-25, 1994
Contact: Dick White, George Washington University, Washington, DC 20052 (800) 424-9773.

Radar Cross Section Reduction

Topics: Principles and basic concepts of radar cross section reduction. Fee: $995.
Site: Atlanta, GA
Date: March 22-25, 1994
Contact: Georgia Institute of Technology, Continuing Education, Atlanta, GA 30332-0385 (404) 894-2547.

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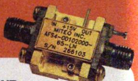
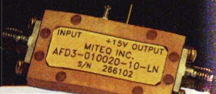


Model Number	Frequency (GHz)	Gain (Min.) (dB)	Gain Var. (Max.) (±dB)	Noise Figure (Max.) (dB)	Dynamic Range 1 dB Gain Comp. Output (Min., dBm)	VSWR (Max.) Input/Output	Domestic Price
OCTAVE AND MULTIOCTAVE							
AFS2-00100050-13-LN	.1-.5	25	1.00	~~1.4~~ **1.3**	+10	2:1	$ 750
AFS2-00500100-12-LN	.5-.1	23	1.00	~~1.3~~ **1.2**	+10	2:1	$ 750
AFS3-01000200-10-LN	1-2	34	1.00	1.0	+10	2:1	$ 950
AFS3-02000400-13-LN	2-4	28	1.00	~~1.5~~ **1.3**	+10	2:1	$ 750
AFS3-02000600-15-LN	2-6	24	1.00	~~1.6~~ **1.5**	+10	2:1	$ 750
AFS3-04000800-16-LN	4-8	24	1.00	~~1.8~~ **1.6**	+10	2:1	$ 750
AFS3-08001200-22-LN	8-12	22	1.00	~~2.5~~ **2.2**	+10	2:1	$ 950
AFS3-02000800-24-LN	2-8	20	1.50	~~2.5~~ **2.4**	+10	2:1	$ 950
AFS4-12001800-32-LN	12-18	20	1.50	~~3.5~~ **3.2**	+10	2:1	$ 950
AFS4-08001800-35-LN	8-18	20	1.75	~~3.8~~ **3.5**	+10	2:1	$ 950
AFS4-06001800-40-LN	6-18	18	2.00	~~4.5~~ **4.0**	+10	2:1	$ 950
AFS4-02001800-50-LN	2-18	18	2.50	~~5.5~~ **5.0**	+10	2:1	$ 995
ULTRA WIDEBAND							
AFS3-00100200-18-LN	.1-2	36	1.00	~~2.0~~ **1.8**	+10	2:1	$ 750
AFS3-00100400-22-LN	.1-4	28	1.25	~~2.5~~ **2.2**	+10	2:1	$ 750
AFS3-00100600-25-LN	.1-6	24	1.50	~~3.0~~ **2.5**	+10	2:1	$ 750
AFS3-00100800-32-LN	.1-8	24	1.50	~~3.4~~ **3.2**	+10	2:1	$ 750
AFS3-00101000-38-LN	.1-10	20	1.50	~~4.0~~ **3.8**	+10	2:1	$ 750
AFS3-00101200-42-LN	.1-12	20	1.75	~~4.5~~ **4.2**	+10	2:1	$ 750
AFS4-00101800-55-LN	.1-18	18	2.50	~~6.0~~ **5.5** *	+10	2.5:1	$ 900
AFS4-00102000-60-LN	.1-20	16	2.75	~~6.5~~ **6.0** *	+10	2.5:1	$ 995
MEDIUM POWER							
AFS1-00100100-20P-MP	.1-1	14	1.50	~~2.5~~ **2.0**	+20	2:1	$ 750
AFS2-00500200-23P-MP	.5-2	22	1.50	~~3.5~~ **3.0**	+23	2:1	$ 950
AFS3-00100200-25P-MP	.1-2	33	1.50	~~4.0~~ **3.5**	+25	2:1/2.5:1	$ 950
AFS2-00500400-20P-MP	.5-4	18	1.50	~~4.5~~ **4.0**	+20	2:1/2.5:1	$ 750
AFS4-00100600-20P-MP	.1-6	20	1.50	~~4.8~~ **4.6**	+20	2:1	$ 950
AFS4-00100800-20P-MP	.1-8	18	2.00	~~5.0~~ **4.8**	+20	2:1	$ 950
AFS4-00101200-20P-MP	.1-12	18	2.00	~~5.5~~ **5.3**	+20	2:1	$ 950
AFS3-04000800-20P-MP	4-8	25	1.25	~~4.0~~ **3.8**	+20	2:1	$ 750
AFS4-08001200-20P-MP	8-12	20	1.00	~~5.0~~ **4.8**	+20	2:1	$ 750
AFS4-02000800-20P-MP	2-8	22	1.50	~~6.0~~ **5.8**	+20	2:1	$ 750
AFS6-02001800-20P-MP	2-18	22	2.75	~~8.0~~ **7.0**	+20	2.5:1/2:1	$1450
AFS6-02002000-18P-MP	2-20	22	3.00	~~8.0~~ **7.0**	+18	2.5:1	$ 1495

* Noise figures increase below 500 MHz



Model Number	Frequency (GHz)	Gain (Min.) (dB)	Gain Var. (Max.) (±dB)	Noise Figure (Max.) (dB)	Dynamic Range 1 dB Gain Comp. Output (Min., dBm)	VSWR (Max.) Input/output	Domestic Price
MODERATE BANDWIDTH							
AFD3-012014-09-LN	1.2-1.4	34	.25	0.9	15	1.5:1	$ 775
AFD3-014017-09-LN	1.4-1.7	34	.25	0.9	15	1.5:1	$ 775
AFD3-017019-09-LN	1.7-1.9	34	.25	0.9	15	1.5:1	$ 775
AFD3-018022-09-LN	1.8-2.2	34	.50	0.9	15	1.5:1	$ 795
AFD3-022023-10-LN	2.2-2.3	30	.50	1.0	10	1.5:1	$ 650
AFD3-023027-10-LN	2.3-2.7	30	.50	1.0	10	1.5:1	$ 600
AFD3-027031-10-LN	2.7-3.1	30	.50	1.0	10	1.5:1	$ 650
AFD3-031035-10-LN	3.1-3.5	30	.50	1.0	10	1.5:1	$ 650
AFD3-037042-10-LN	3.7-4.2	30	.50	1.0	10	1.5:1	$ 650
OCTAVE AND MULTIOCTAVE							
AFD2-005010-12-LN	.5-1	20	1.0	~~1.3~~ 1.2	10	2:1	$ 750
AFD3-005010-12-LN	.5-1	32	1.0	~~1.3~~ 1.2	10	2:1	$ 650
AFD2-010020-12-LN	1-2	22	1.0	~~1.3~~ 1.2	10	2:1	$ 650
AFD3-010020-12-LN	1-2	32	1.0	~~1.3~~ 1.2	10	2:1	$ 750
AFD3-010020-10-LN	1-2	32	1.0	1.0	10	2:1	$ 950
AFD3-012024-11-LN	1.2-2.4	34	1.0	~~1.2~~ 1.1	10	2:1	$ 995
AFD3-020040-13-LN	2-4	30	1.0	~~1.4~~ 1.3	10	2:1	$ 950
AFD3-040080-28-LN	4-8	25	1.0	~~3.0~~ 2.8	10	2:1	$ 600
AFD3-080120-42-LN	8-12	20	1.0	~~4.5~~ 4.2	10	2:1	$ 650
AFD4-080160-40-LN	8-16	20	1.0	4.0	10	2:1	$ 985
AFD2-004014-12-LN	.4-1.4	25	1.0	1.2	10	2:1	$ 995
AFD3-005020-14-LN	.5-2	34	1.0	~~1.5~~ 1.4	10	2:1	$ 995
AFD3-010040-15-LN	1-4	28	1.0	~~1.7~~ 1.5	10	2:1	$ 985
AFD3-020080-33-LN	2-8	24	1.5	~~3.5~~ 3.3	10	2:1	$ 675
AFD3-040120-47-LN	4-12	19	1.5	~~5.0~~ 4.7	10	2:1	$ 795
AFD4-060180-50-LN	6-18	20	2.0	5.0	15	2:1	$ 985
AFD4-120180-45-LN	12-18	20	1.5	4.5	15	2:1	$ 985
AFD4-080180-45-LN	8-18	20	2.0	4.5	15	2:1	$ 985
MEDIUM POWER							
AFD2-015017-25P-MP	1.5-1.7	24	1.0	3.5	25	2:1	$ 475
AFD2-017019-25P-MP	1.7-1.9	24	1.0	3.5	25	2:1	$ 475
AFD3-020027-25P-MP	2-2.7	22	1.0	4.5	25	2:1	$ 550
AFD3-027031-25P-MP	2.7-3.1	22	1.0	4.5	25	2:1	$ 550
AFD3-031042-25P-MP	3.1-4.2	22	1.0	4.5	25	2:1	$ 550
AFD2-005010-20P-MP	.5-1	24	1.2	~~3.0~~ 2.8	20	2:1	$ 475
AFD2-005010-23P-MP	.5-1	24	1.2	~~3.5~~ 3.0	23	2:1	$ 505
AFD2-005010-25P-MP	.5-1	24	1.2	3.5	25	2:1	$ 525
AFD1-010020-25P-MP	1-2	12	1.0	4.0	25	2:1	$ 425
AFD2-010020-25P-MP	1-2	24	1.25	3.5	25	2:1	$ 525
AFD3-020040-20P-MP	2-4	20	1.0	4.5	20	2:1	$ 595
AFD3-020040-23P-MP	2-4	20	1.0	4.5	23	2:1	$ 650
AFD3-020040-25P-MP	2-4	20	1.0	4.0	25	2:1	$ 750
AFD3-040080-25P-MP	4-8	20	1.0	5.0	25	2:1	$ 650
AFD3-080120-23P-MP	8-12	16	1.25	6.0	23	2:1	$ 725
AFD4-120180-20P-MP	12-18	20	1.0	~~5.0~~ 4.8	20	2:1	$ 950
AFD3-010040-23P-MP	1-4	22	1.5	5.5	23	2:1	$ 650
AFD3-020080-23P-MP	2-8	19	1.5	5.5	23	2:1	$ 750
AFD3-040120-20P-MP	4-12	15	1.5	6.0	20	2:1	$ 750
AFD4-060180-20P-MP	6-18	18	2.0	~~6.5~~ 6.0	20	2:1	$ 975
AFD4-080180-20P-MP	8-18	18	2.0	~~5.5~~ 5.0	20	2:1	$ 975

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Mechanisms Governing Wireless Propagation Between Different Floors in Buildings*

W. Honcharenko and **H.L. Bertoni**
Polytechnic University
Brooklyn, NY
and
J. Dailing
Motorola, Inc.
Fort Lauderdale, FL

The potential implementation of wireless radio local area networks (LAN) and personal communication services (PCS) inside buildings requires a thorough understanding of signal propagation within buildings. This paper develops a theory that explains propagation between a transmitter and receiver located on different floors of a building. Depending on the structure of the building and location of the antennas, either direct ray propagation through floors or diffraction outside the building will determine the propagation characteristics and range dependence of the signal sector average as the number of floors between the transmitter and receiver is increased.

Introduction

Implementation of radio LAN or wireless PCS in the UHF 300 MHz to 3 GHz bands inside buildings has sparked a large interest in understanding the propagation characteristics of radio signals within buildings. Many measurements for both single floor and multiple floor propagation have been made[1-9] for determining the statistical properties of the propagation. However, no accurate theoretical models based on electromagnetic theory are available that can be used to determine the propagation characteristics for an arbitrary building. It has been shown that propagation over single floors of modern buildings can be predicted through the use of ray tracing techniques and diffraction theory.[10] This method of determining the propagation characteristics at any building can be less expensive and less time consuming than performing measurements at each proposed installation site. Similar propagation techniques can be used to determine the propagation characteristics between floors.

Theory of Propagation to Other Floors

In order to examine the propagation characteristics between floors of a building, the possible paths of propagation must be determined. Two paths over which propagation can take place are paths that involve transmission through the floors and paths having segments outside the buildings and involving diffraction at window frames. The paths through the floors include the direct ray path and the rays that are multiply reflected and transmitted at the semi-transparent walls and floors. These ray paths are contained entirely within the building perimeter. The diffracted ray paths involve transmission outside the building through windows, and diffraction into paths that run alongside the face of the building, propagating until they reach another window, at which point the ray re-enters the building at a different floor.

Floors of modern office buildings typically are constructed using either precast concrete slabs, reinforced concrete or concrete poured over corrugated steel panels. UHF signals can propagate through the precast slabs and reinforced concrete with a transmission loss at each floor. Measurements in the 900 MHz band indicate a transmission loss for precast slab floors of 13 dB. Floors constructed over corrugated steel panels seriously limit the propagation through the floor. A transmission loss of 10 dB has been measured for floors constructed of reinforced concrete.[2]

Floors constructed over corrugated steel exhibit isolation of 26 dB between floors.[2] These isolation measurements were made in the corridors of a glass sheathed building. The 26 dB isolation is not a result of transmission through

[Continued on page 26]

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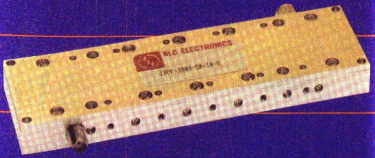

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the floor as previously claimed.[2] Rather, the signal propagates down the corridor and out a window, where it diffracts and propagates along the building face to a different floor. It again diffracts back into the building.

For propagation of the direct ray through semi-transparent floors, the field strength reaching a receiving site is given by

$$|E|^2 = \frac{Z_0 P_e}{4\pi L^2} \prod_m T^2_{Floor(m)} \prod_n T^2_{Wall(n)} \quad (1)$$

where

Z_0 = freespace wave impedance
P_e = effective radiated power
L = direct distance between transmitting and receiving antennas
$T_{Floor(m)}$ = specular transmission at floors crossed by the direct ray
$T_{Wall(n)}$ = specular transmission at walls crossed by the direct ray

Such a direct ray, path T, passing through three floors and two interior walls is shown in Figure 1.

The signal can also reach other floors via paths that involve diffraction. Referring to paths D_1 and D_2 in Figure 1, the signal can propagate horizontally from the source to windows on the outside walls on the right and left sides. Passing through the windows, the fields can then be diffracted through 90° by the window frame, and thereby propagate vertically along the face of the building. At windows on other floors, the field diffracts back into the building, finally reaching the receiver. The field reaching the receiver via one such diffracted path is given by[11, 12]

$$|E|^2 = \frac{Z_0 P_e}{4\pi} \frac{\prod_i D^2(\alpha_i) \prod_j T^2_{Glass(j)} \prod_k T^2_{Wall(k)}}{\sum_n L_{nm} \prod_n L_{nm}} \quad (2)$$

where

L_{nm} = length of the path segments for paths D_1 and D_2
$T_{Glass(m)}$ = transmission coefficient through glass crossed by path segments
$T_{Wall(n)}$ = transmission coefficient through interior walls crossed by the path segments
$D(\alpha_i)$ = diffraction coefficient for a propagating ray bending through angle α_i

Depending on the construction of the building and window frame, different choices may be made for the diffraction coefficient.[11] For simplicity in investigating the relative strength of the fields associated with the direct ray and the diffraction path, the coefficient for an absorbing wedge is used, which is given by

$$D(\alpha_i) = \frac{1}{\sqrt{2\pi k}} \left[\frac{1}{2\pi + \alpha_i} - \frac{1}{\alpha_i} \right] \quad (3)$$

where

$k = \frac{2\pi}{\lambda}$
= the wavenumber

Plotting the variation of the direct ray's signal strength and the

[Continued on page 29]

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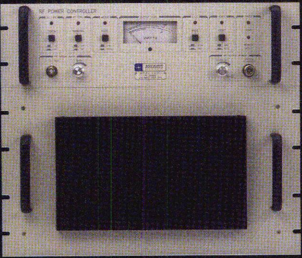

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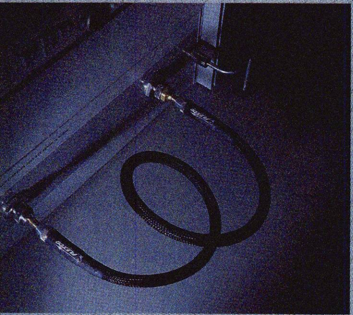
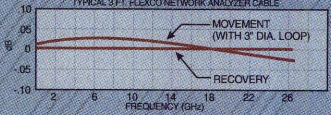


AMPLITUDE STABILITY VS. FREQUENCY

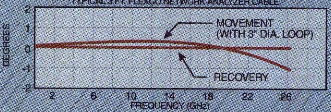
TYPICAL 3 FT. FLEXCO NETWORK ANALYZER CABLE



Change in amplitude measures less than .05 dB when flexed and returns virtually to zero when uncoiled.

PHASE MOVEMENT AND RECOVERY VS. FREQ.

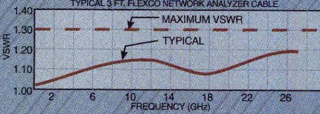
TYPICAL 3 FT. FLEXCO NETWORK ANALYZER CABLE



All Series 40000 test cables exhibit excellent phase stability when flexed permitting truly accurate measurements.

VOLTAGE STANDING-WAVE RATIO VS. FREQ.

TYPICAL 3 FT. FLEXCO NETWORK ANALYZER CABLE



Typical VSWR compared to maximum specification. VSWR remains constant during flexing.

Flexco's new Series 40000 flexible ANA test cable assemblies represent a true breakthrough in test cable performance vs. price.

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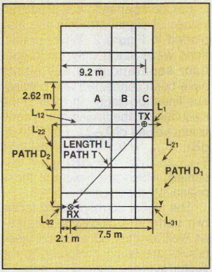


Fig. 1 Cross sectional view of hotel building.

diffraction path vs. the number of floors separating the transmitter and receiver, different characteristics are obtained for the two paths. The direct ray passing through floors decreases by the square of the transmission coefficient (10 dB or more) for each additional floor. This variation with the $1/L^2$ dependence in Equation 1 results in a significant signal decrease from floor-to-floor. For diffracted paths, the diffraction coefficient $D(\alpha_i)$ results in a large path loss even for a single floor separating the transmitter and receiver, but does not change from floor-to-floor. However, the increase in the length of the vertical path segment L_{2m} ($m = 1,2$) in going from floor-to-floor will cause a small decrease in the diffracted path signal. Thus, when propagation takes place through the floors, the signal will decrease rapidly with the number of floors separating the transmitter and receiver. If propagation occurs via diffracted paths, the signal will be small even for separation by a single floor, but will decrease more slowly with increased separation. Hence, in buildings with reinforced or precast concrete floors, the signal will decrease rapidly with floor separation until the signal of the diffracted path is larger than that of the direct ray, after which the signal decreases more slowly. For buildings with only corrugated steel floors, propagation through the floors is not possible and the signal will reach other floors via diffracted paths. In this situation, there is a large between-floor isolation.

Comparison with Measurements

Figure 1 shows a cross-sectional view of a hotel building in which measurements were made. For these measurements, a hand-held portable radio operating at 852 MHz with an EIPR of 1.61 W was used as the transmitter. At each transmitting site, the transmitter was moved around in a two-meter circle, during which time the signal at the fixed receiving site was sampled and averaged. Averaging the signal over a distance of about 18 λ (called a sector) removes the effects of fast-fading observed in such multipath environments. The receiver was located in a room and the transmitting sites were located in the hallways opposite the room and directly above. Room A is the sleeping area, while room B is the bathroom area of the hotel room. Area C is the hallway in which all transmitting sites were located. The transmitting sites were located

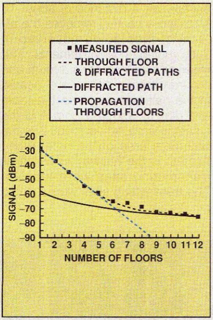


Fig. 2 Propagation to other floors of hotel building.

directly next to large plain glass windows with aluminum frames.

The floors in the building were constructed from precast concrete slabs, which have some reinforcing bars in them, similar to reinforced concrete. Measurements were made for up to 11 floors separating the transmitter and receiver. The theoretical paths of propagation through the floors and diffracted are also shown. Path T is the direct ray that passes through two walls and the floors. Paths D_1 and D_2 are the diffracted ray paths that pass through two walls and two windows, diffracting twice at the frames of the windows. Path D_1 is shorter than D_2, hence it will carry more power to the receiving sites. For both paths, the angle (α_m) through which the ray bends is 90°.

Figure 2 shows the measured signal as a function of the number of floors separating the transmitter and receiver. The values of signal strength were obtained using half-wave dipoles having gain of 2.15 dB and a radiated power of 1.4 W (EIRP = 1.61 W). The measured signal decreases by 12 dB per floor for the first six floors of separation. As the separation between transmitter and receiver increases to more than eight floors, the measured signal decreases more slowly with the number of floors, as is expected.

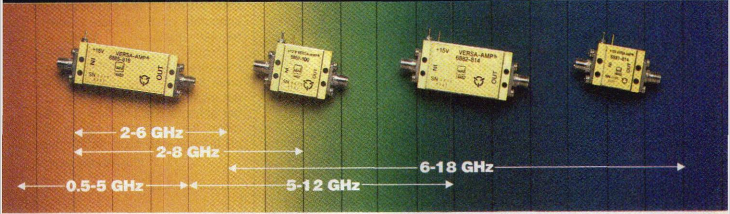
For comparison, the predicted values of signal strength are also plotted in Figure 2. While predictions were made only for integer floor separations, these points have been connected with continuous lines for clarity. In making the calculations, the transmission coefficient values of $T_{Glass} = 0.97$ (0.25 dB), $T_{Wall} = 0.775$ (2.2 dB) and $T_{Floor} = 0.22$ (13 dB) were assumed, which are typical of those previously reported.[13]

The signal corresponding to the two paths are plotted separately, as well as their sum. Since these results are being compared to the sector average measured signal, it is appropriate to add the signals (field squared) of the two paths, rather than the fields themselves. The predictions are in good agreement with the measurements, and show the change in importance of the two paths as a function of the number of floors between transmitter and receiver.

Measurements[14] have also shown similar trends in attenuation characteristics as the number of

[Continued on page 32]

A Hot New Band Member.



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6881-813	25	1.0	4.5	18	55	220
6881-814	35	1.0	4.5	18	65	300
2.0-6.0 GHz						
6882-100	26	1.0	2.5	12	40	120
2.0-8.0 GHz						
6882-812	22	0.8	4.0	20	40	185
6882-813	33	1.0	4.0	20	55	265
6882-814	44	1.0	4.0	20	65	325
6882-824	40	1.0	4.0	24	65	475
5.0-12.0 GHz						
6884-812	16	0.8	4.8	18	35	150
6884-813	25	0.8	4.8	18	50	220
6884-814	34	0.8	4.8	18	65	290
6884-824	30	1.0	4.8	23	65	450
6.0-18.0 GHz						
6885-813	18	1.0	6.0	15	45	210
6885-814	25	1.5	6.0	15	65	250
6885-815	30	1.5	6.0	15	65	310
6885-816	38	1.8	6.0	15	70	360

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floors separating receiver and transmitter is increased. Measurements[14] were performed on a nine-story building with the receiver located on the top floor while the transmitter was moved to all other floors, including an underground floor. For the above ground floors, the attenuation characteristics follow the described trend, but in moving from the last above ground floor to the underground floor, the attenuation increases by 15 dB, which indicates that propagation paths outside the building carry significant power to other floors.

A second comparison was made using the obtained results.[15] The measurements were made in a building of downtown San Francisco. The building's floor plan with the transmitting location for one floor and the receiving sites on higher floors is shown in Figure 3. The floors in the building are constructed of reinforced concrete and the exterior walls are of masonry construction. Metal ducts and cabling are located in the ceiling. Measured signal strength at the receiving site for +37.4 dBm transmitter power at 915 MHz as a function of the number of floors separating the receiver and transmitter is shown in Figure 4. The measured signal exhibits a more irregular variation for eight and more floors, which may be due to different environments on each floor of the building. There were no detailed floor plans available, which has a large bearing on determining the propagation characteristics of the building. Also descriptions of the rooms' contents were not available, so that it is not possible to speculate on the cause of the irregular variation.

Propagation has also been measured through reinforced concrete floors.[13] The attenuation did not increase linearly with the number of floors. For one floor of separation, the propagation loss is 12.9 dB through one floor. As the num-

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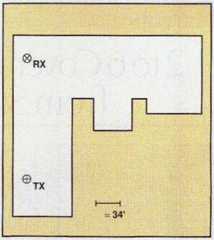

Fig. 3 Outline of a building in downtown in San Francisco.

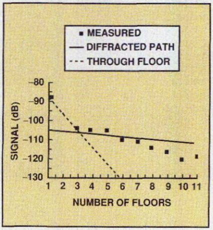

Fig. 4 Propagation to other floors of the building in San Francisco.


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[From page 32]

ber of floors is increased, the attenuation per floors decreases, which is consistent with the propagation mechanism's model.

Conclusion

This study has shown that propagation to different floors of a building can occur via two separate propagation paths. Each path exhibits its own path loss variation with the number of floors. In buildings with steel panels in the floors, propagation to the floors will only occur via diffracted paths. In buildings without steel panels, the propagation will result from transmission through the floors as well. Measurements confirm that significant power is carried by diffracted paths as the number of floors separating the transmitter and receiver is increased.

Acknowledgment

This work was supported by a University Partnership in Research Grant from Motorola Inc. and in part by the New York State Science and Technology Foundation.

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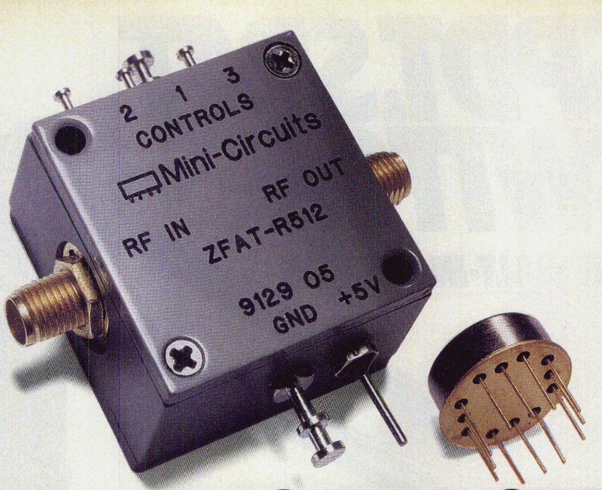
Walter Honcharenko *received his BS and MS degrees in electrical engineering from Polytechnic University, in 1989 and 1991, respectively. In January 1993, he completed the PhD degree in electrophysics at Polytechnic University. From 1988 to 1993, he was affiliated with the Center for Advanced Technology in Telecommunications at Polytechnic University. From 1988 to January 1993, he was affiliated with the Center for Advanced Technology in Telecommunications at Polytechnic University, where he developed models to predict propagation characteristics and signal coverage inside buildings for future use with wireless personal communications systems. Since May of 1993, Honcharenko has been with the Wireless Technologies Laboratory of AT&T Bell Laboratories. He continues to work on issues related to RF propagation for telecommunication systems. Honcharenko is a member of the IEEE APS and the IEEE Vehicular Technologies Society.*

Henry L. Bertoni *received his BS degree in electrical engineering from Northwestern University in 1960, and his MS degree in electrical engineering in 1962, and his PhD degree in electrophysics in 1967, from the Polytechnic Institute of Brooklyn (currently Polytechnic University). After graduation, he joined the faculty of the Polytechnic. He is now head of the Electrical Engineering Department. From 1982 to 1983, he was at University College London as a guest research fellow of the Royal Society. Bertoni was awarded the 1984 Best Paper Award of the IEEE Sonics and Ultrasonics Group for his research. During the summer of 1983, he held a faculty research fellowship at USAF Rome Air Development Center, Hanscom AFB. His research in electromagnetics deals with the theoretical prediction of UHF propagation characteristics in urban environments. Bertoni is an IEEE fellow and is chairman of the technical committee on personal communications of the IEEE Communications Society. He is chairman of the Hoover Medal Board of Award and has served on the ADCOM of the IEEE UFFCS. He is also a member of the International Scientific Radio Union and the New York Academy of Science.*

James L. Dailing *attended Quincy College, and received his BSEE degree from the University of Illinois in 1953. After graduation, he joined Motorola Inc. In 1962, he transferred to Motorola's Applied Research Department. His early research dealt with the theoretical and practical aspects of LC and crystal filters. He has taught courses at Motorola and was an adjunct instructor in electrical engineering at Florida Atlantic University in 1985. His recent interests have been in the field of RF propagation inside buildings. He holds four patents. At the end of 1993, he retired from Motorola after 40 years of service. His hobbies are amateur radio and astronomy.*



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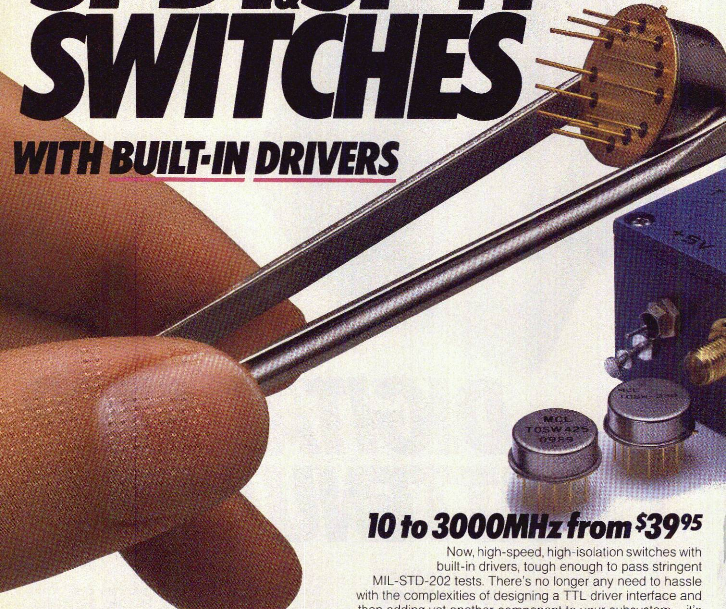

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100-1500MHz	40	28	40	30
1500-3000MHz	35	22	35	22
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100-1500MHz	27	19	27	19
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NEWS FROM WASHINGTON

Gerald Green, *Washington Editor*

Pentagon Selects Foreign Microwave Systems for Evaluation

The Pentagon has selected three microwave-related items for evaluation that have been developed or produced by foreign nations, including the UK, Israel and Denmark. The three items were among 30 items of foreign defense equipment selected under DoD's foreign comparative testing program in FY 1994. Items of interest to the Armed Forces include an automatic target tracker (ATT), an identification friend-or-foe (IFF) tracker and an electronic warfare management system (EWMS).

Of particular interest to the US Army is an ATT developed by the UK and Israel. The ATT is a computer-driven subsystem add-on to the Abrams main battle tank fire control system, but the ATT has potential application to other vehicles. Candidate systems from OCTE Ltd. of the UK, and Elbit and RAFAEL of Israel will be evaluated to determine whether they can satisfy an Army requirement for an ATT that is capable of automatically detecting, tracking, and prioritizing multiple targets.

An IFF tracker developed and manufactured by the UK's Cossor Electronics is of interest to the US Navy and Marine Corps. The system interrogates and tracks up to eight aircraft targets simultaneously. It is being tested to determine whether it satisfies a precision/automatic aiming requirement for the transmit antennas of the Navy's AN/ULQ-13(V)1 countermeasures signal simulator vans, which are employed by the Navy's multielectronic warfare support group for EW training.

An EWMS, manufactured by TERMA of Denmark, is of interest to the US Air Force. The EWMS replaces individual cockpit controls with centralized control of the electronic combat (EC) suite in F-16 aircraft. The system's capabilities include up-front presentation of all EC status, in-flight selection of chaff/flare dispenser programs and full night vision capability.

High Power Communications Satellite to be Built by Hughes and JCSAT

Hughes Aircraft Co. and Japan Satellite Systems Inc. (JCSAT), have signed a multimillion-dollar contract for construction and launch of a high power communications satellite. The spacecraft, known as JCSAT 3, will relay voice, data and television signals to Japan, and have multiple-beam coverage extending west to India, south to Australia and New Zealand, and east to Hawaii. JCSAT 3 will carry four octagonal antennas on its cube-shaped central body. The payload will include 28 transponders for signals in Ku-band and 12 transponders for C-band. Japan's NEC Corp. is a major Hughes subcontractor and will be responsible for a significant part of the payload electronics.

In other news, Hughes Network Systems Inc., Germantown, MD, has been selected by Memphis-based retailer AutoZone Inc. to supply a comprehensive satellite-based data network linking over 800 stores in 21 states. AutoZone, an auto parts chain store, will use the network to implement a variety of new on-line systems that will enhance customer services and improve operating efficiency. The contract calls for Hughes to install a dedicated Personal Earth Station™ (PES) network hub in Memphis and 1 m PES remote antennas atop each of AutoZone's outlets. A PES network allows direct transmission of data, voice and/or video signals from the originating station to a satellite hovering 23,000 miles above Earth. The sites were slated to go on-line by the end of last year.

NEWS FROM WASHINGTON

Greater GPS Role Recommended for DoT

A joint Department of Defense/Department of Transportation (DoT) task force has recommended a more substantive role for the DoT in the management of the US' global positioning system (GPS). The panel recommended that the two departments should manage the GPS system jointly. This action follows last month's DoD announcement that GPS has achieved its initial operational capability.

The task force also recommended that a study of all planned GPS enhancement systems (including differential GPS) be conducted to determine how best to provide GPS services to all civil users. This recommendation surprised many Washington observers, since differential GPS is used by US military services to guard against hostile military use. Several other US government agencies, including the Coast Guard and the Federal Aviation Administration, also are developing differential GPS for their own use.

US Industry Team Studies Sensor and Data Fusion

A US industry team is investigating methods that combine data collected from multiple sensors employed in surveillance operations. The $1.9 M Off-Board Augmented Theater Surveillance Study is being conducted for the US Air Force Rome Laboratory. The team, led by Grumman Corp., includes E-Systems, Westinghouse Electronics Systems and Martin Marietta. Two proven surveillance platforms, Joint STARS and AWACS, are being used to evaluate proposed solutions.

Petroleum Seepage Detected Using Ground-Based Radar

Engineers of the Naval Research Laboratory (NRL) have used ground-based radar to show that relatively simple radars can detect gas seepage from underground petroleum and gas deposits. The study could have important ramifications for locating natural petroleum deposits. The effort was conducted by the Amoco Production Co., under the provision of a cooperative research and development agreement.

The engineers report that use of a ground-based system offers several significant advantages over an airborne system. It is capable of detecting range, amplitude and distinctive spatial variations of received signals. The ground system allows for rapid employment and evaluation of radar returns through the use of both fan-beam and pencil-beam antennas. The ground system also provides superior recording, processing and radar data displays, and easy correlation of radar echoes with surface features.

Several unique radar returns, which NRL believes are associated with gas seepage, were noted. The uniqueness was indicated by the observation that the echoes did not correlate with any distinctive terrain features, such as ground clutter, rocks, earthen depressions or man-made objects.

Clinton Names Perry to Fill Defense Secretary Post

President Clinton has named deputy secretary of defense William Perry as the new defense secretary, pending confirmation by the Senate. Perry, slated to fill the void left by departing secretary Les Aspin, was appointed deputy last year on a unanimous voice vote by the Senate.

Perry said it would be a privilege to serve as Clinton's secretary. Perry's career includes working as professor and codirector of the Center for International Security and Arms Control at Stanford University from 1989 to 1993, as chairman of Technical Strategies and Alliances from 1985 to 1993 and as managing director for Hambrecht and Quist Investment Bankers from 1981 to 1985.

In January, Clinton's first pick for the post, Admiral Bobby Ray Inman, withdrew his nomination for defense secretary. Inman cited unfavorable press reports of his past activities as one of the reasons for his departure. ■

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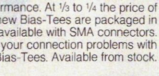

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Model	Freq MHz		Insertion Loss, dB Typ.			Isolation dB (RF)-(DC) (RF+DC)-(DC) Typ.			VSWR Typ.	Price $ ea. Qty
	f_l	f_u	L	M	U	L	M	U		1-9
ZFBT-4R2G	10-	4200	0.15	0.6	0.6	32	40	50	1.3:1	$59.95
ZFBT-6G	10-	6000	0.15	0.6	1.0	32	40	30	1.3:1	79.95
ZFBT-4R2GW	0.1-	4200	0.15	0.6	0.6	25	40	50	1.3:1	79.95
ZFBT-6GW	0.1-	6000	0.15	0.6	1.0	25	40	30	1.3:1	89.95

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Martin Streetly, *International Correspondent*

Ferranti MBO Proposed

Following the appointment of an administrative receiver on 1 December 1993, Ferranti International's director of marketing, Phil Burton, is leading an attempt at a management buyout (MBO) for a major part of the troubled UK electronics conglomerate. Traditionally one of the UK's leading defence electronics, command and control system and communications houses, Ferranti has been brought down by both the discovery of massive fraud in its US subsidiary ISC, which left it with debts totalling some £8 M, and the failure of an agreed take-over by UK contractor GEC.

Burton characterises the bid as beyond the reach of an ordinary MBO due to the level of capitalisation needed, and is structuring the offer as a consortium effort backed by long-term players in its core business areas. Initial discussions with the receiver reportedly have been encouraging, as have contacts with potential partners in the UK and overseas. The MBO team expects to commence formal negotiations this month and is being advised by a member of Coopers & Lybrand's Corporate Finance department.

The alternative to the proposed MBO would appear to be a fire sale of Ferranti's most lucrative business sectors, and closing of the loss-making elements. UK electronics giant GEC is a likely key player in this scenario, since it may be able to acquire businesses for less money than it had offered in its abortive 1993 £10 M bid for the Ferranti Group. Ferranti's close links with France's Thomson group in the area of sonar systems suggests strong interest from this direction. Arthur Andersen, the company's receiver, notes approaches from a large number of UK and overseas companies interested in Ferranti acquisitions.

AMS Launches Low-Power GSM Vocoder

Austrian contractor Austria Mikro Systems (AMS) has launched a low power global mobile system (GSM) standard vocoder that incorporates an analogue front-end and a single chip software-configurable digital signal processor (DSP) for battery-powered handheld mobile telephone applications. The AS3501 vocoder has an on-chip, 13-bit, linear sigma delta codec and a 16-bit DSP core preprogrammed for 13 Kbps speech transcoding functions set out in the GSM single-chip system standard. DSP activity reportedly utilises 25 percent of AS3501's available processing capability, allowing the introduction of special function algorithms such as noise reduction, echo cancellation and voice-activated dialling. The vocoder's programmable functions are controlled by a 16-bit parallel control port.

DE Takes Major Holding in ASICs Group

French contractor Dassault Electronique (DE) has taken a two-thirds holding in the SOREP Group, which specialises in the development and production of hybrid circuits and ASICs for military, civil, space and telecommunications applications. Headquartered near Rennes, France, the SOREP Group incorporates la Société EDGETEK (100 percent ownership) and has a 43 percent stake in ERULEC and a 56 percent holding in the US-based SOREP Inc. (in conjunction with Schlumberger). As a group, SOREP reports an annual turnover figure of FFr 230 M. Under the new arrangement, SOREP will retain its separate identity. The DE buy-in reportedly has the full agreement of the SOREP board and was expected to become effective in January.

Philips Launches Automotive/Industrial ADS

Netherlands-based Philips Semiconductors has launched a contactless angular displacement sensor (ADS) and claims it offers a fully encapsulated, nonwearing and adjustment-free ADS solution for automotive and industrial applications. Developed in cooperation with Germany's AB Electronics, the new model KMA 10/70 unit is a three-terminal device based on Philips' KMZ11B1 magneto-resistive sensor element.

Operating over an 8.1 to 11 V supply voltage range, the system has an integral input shaft, sealed bearing and magnet assembly. The magnet assembly allows the magnet's magnetic field to be rotated over the sensor head. The resultant changes in the sensor's resistance are detected by a thick-film hybrid signal conditioning circuit. The circuit produces a temperature-compensated 4 to 20 mA output signal corresponding to the angular displacement of the input shaft.

Operating temperature ranges from –40° to +100°C, and operating life is 10^8 operating cycles. Maximum angular displacement speed is reportedly 20°/μs, a value that Philips believes will far exceed the inertia of the mechanical systems to which it is likely to be connected. Applications of the model KMA 10/70 sensor include high speed servo control, active suspension systems, servo-controlled actuation and accelerator pedal position sensing. Based on order volume, the KMA 10/70 can be customised to meet specific requirements.

SPS Wins UK Radar Order

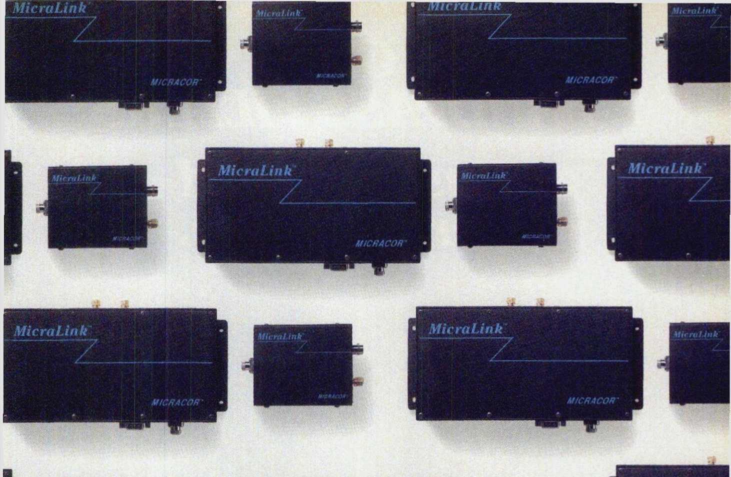
UK-based contractor Siemens Plessey Systems has been awarded a £23 M contract from the UK's Ministry of Defence for three examples of its new AR327 long-range air defence radars and their long term support. Designed specifically for out-of-area operations, this radar is a direct development of the company's AR325 set and is optimised for transportation by C-130 class aircraft or as an underslung helicopter load. The new radar utilises an end-feed planar array, with a reduced number of elements compared to the model AR325. It also employs flexible energy management, including electronically steered pencil beam output and digital pulse compression, to achieve a detection range of up to 400 km in conditions of severe natural clutter and electronic countermeasures pollution. The system's modularity reportedly facilitates upgrading, and it can be deployed by a six-man team within one hour of site delivery. SPS also is actively pursuing export orders for the system.

GEC VOA Broadcast Station Opens in Morocco

The US Information Agency has opened a new 5 million watt Voice of America (VOA) shortwave broadcast station in Tangiers, Morocco. The station is intended to increase the service's audibility in Russia, the Middle East, the Far East and Africa.

The Tangiers station is one of a number of VOA facilities equipped with an RF subsystem designed, supplied, installed and commissioned by UK contractor GEC-Marconi Communications through its US subsidiary, Marconi Communications Inc. The subsystem installed at Tangiers comprises 10, 500 kW B6128 HF transmitters together with a range of ancillaries, including dummy loads, cooling and power equipment, switch matrix gear, coaxial feeders and transmission lines.

The initial VOA broadcast station modernisation contract was awarded to Marconi Communications Inc. in collaboration with Cincinnati Electronics in May 1988. Under this joint venture arrangement, Marconi is responsible for programme management and the procurement and quality control of US-manufactured components. GEC-Marconi Communications in the UK acts as design authority for the RF subsystem. In addition to this latest facility, VOA has taken options on similar provision in Thailand, Botswana and Sri Lanka. The complete programme is valued at more than $150 M. ■



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Stephen Shaw, *Correspondent*

3Com and Pacific Monolithics Agree to Wireless Ethernet Licensing

3Com Corp., Santa Clara, CA, has reached an agreement to license the wireless Ethernet technology of Pacific Monolithics, based in Sunnyvale, CA. The agreement was billed as enabling for the first time wireless LANs to operate at the full 10 Mb/s data transmission capability of Ethernet-based networks.

The agreement gives 3Com exclusive rights to develop, manufacture and sell wireless LAN products based on the radio technology developed by Pacific Monolithics. 3Com expects to combine its EtherLink III parallel tasking technology and Pacific Monolithics' GaAs and microwave communications techniques for a tenfold improvement in performance over other wireless LAN communications techniques. In addition to the technology licensing agreement, a Pacific Monolithics design team will merge with 3Com to continue developmental efforts.

Inmarsat Approves LYNXX Transportable Station

The International Maritime Satellite Organization (Inmarsat) has approved California Microwave's LYNXX transportable earth station for voice service. California Microwave subsidiary ViaSat Technology, which builds the LYNXX, was expected to begin initial shipments of the terminal last month.

The unit is designed to provide global connectivity for telephone, fax, data and digital video services. A 64-kb/s duplex capability is included as a standard feature. The terminal operates through Inmarsat-B service, the all-digital replacement for the original Inmarsat-A service.

Inmarsat reports that the new service's operating costs will be half those of the older technology. Inmarsat provides a simplified on-demand service directly into the public telephone network, eliminating the need for leased channels.

Multi-LYNXX, a high-capacity fixed Inmarsat-B system capable of supporting up to 44 voice channels from remote areas, also was granted Inmarsat approval. Typical LYNXX applications include hotels, oil fields, mining sites and business centers, where the international communications infrastructure is unavailable.

Continental Becomes First Airline to Rely Solely on GPS

Continental Airlines will operate the first scheduled commercial airline flight using a satellite-based global positioning system (GPS) for en route navigation and landing approaches. The initial approaches will be performed in Aspen, CO. The Aspen GPS approach replaces a private microwave landing system (MLS) and follows a more desirable path to the airport than used in the MLS system. Other approaches will be performed in Steamboat Springs, CO and Houston, TX. The GPS equipment was provided by Honeywell, which installed its FMZ-900 flight management systems and dual HG2021 global positioning system on Continental Express' commuter aircraft.

Continental president and CEO Robert Ferguson told a House of Representatives' subcommittee in July that a satellite-based communications, navigation and control system would improve airline safety and save the airline industry $5 B annually by reducing delays and allowing for more direct airline routes. GPS consists of a constellation of 24 satellites, owned by the US government and operated by the Department of Defense, for positioning and other applications.

OKI Semiconductor Unveils New GaAs Device

In December, OKI Semiconductor of Sunnyvale, CA unveiled the first in a series of advanced communications ICs designed for the North American market. The new KGF27101 chip is a GaAs FET MMIC broadband feedback AGC amplifier that specifies well-matched 50 Ω input/output. OKI stated that while the useful signal range of the device actually extends to over 5.4 GHz, flat gain from below 800 MHz to over 4 GHz makes it ideal for narrow- and broad-band IF and RF amplifiers operating in the L-, C- and S-bands.

"Gallium arsenide is one of the most powerful processes we've developed for our internal systems and technology partners," said OKI VP of sales and marketing, Joe Baranowski. "Now we're able to channel the GaAs products already in production to expanding markets, such as cellular and personal communications."

By maximizing the energy coupling, the amplifier minimizes cross-talk and RF radiation without the need for filters or shields in 50 Ω, controlled-impedance systems. With its internal AGC, the system also maintains its impedance matching while changing gain characteristics, without the need for additional components.

Because of its flat frequency characteristic, the model KGF2701 is expected to eliminate the need for system tuning over the broader 600 MHz to 5 GHz frequency range, which includes C-band and TVRO microwave frequencies. The company said that additional GaAs-based ICs were under development for use in low noise microwave amplifiers, high speed digital and logic devices for wireless communications applications, and laser, fiber and infrared products, including laser diodes and optical transceiver modules.

Andrew Selected to Supply Consortium Eyeing Argentine Network

Andrew Corp., Orland Park, IL, has been selected as a supplier to a consortium that is expected to win a contract to provide cellular telephone networks for large portions of Argentina. Argentina's National Telecommunications Board recently announced the selection of the CTI consortium, comprised of GTE, AT&T, TCW, CAI, Clarin and Benito Roggio, as the leading bidder on the product.

If successful, Andrew's participation in the project could result in $50 M in revenues in 1994, said Andrew president and CEO Floyd English. "This is the largest and most challenging project that we have undertaken," English said. Andrew is expected to provide coaxial cable, cellular and terrestrial microwave antennas, towers, installation and program management services.

Finland Selects Ericsson for First DECT-Based PCS

The Helsinki Telephone Company of Finland has chosen Ericsson to provide the switching technology for the first commercial personal communications service (PCS) based on DECT, the new European standard for cordless telephony. The service is expected to start early this year and operate initially in the town of Porvoo, near Helsinki. Targeted initially at business customers, this communications system will allow users to make and receive phone calls throughout the town center using pocket-sized telephones. All transmissions are encrypted to prevent eavesdropping.

The PCS network will include cordless Centrex facilities, which emulate the operation of a normal office telephone system, such as a private branch exchange (PBX). Business users will be able to transfer calls, make internal intercom calls and use all other PBX facilities from their cordless phones without installing a PBX. The PCS network in Porvoo will be controlled by an Ericsson AXE public exchange, located 30 km away in Helsinki and linked to the PCS network by microwave radio. ■

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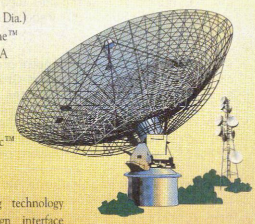

INTERFACE CHART

INTERFACE PRODUCT CAPABILITY	FREQUENCY RANGES COVERED	CATALOG	CUSTOM COMMERCIAL DEFENSE	SPACE QUALIFIED
Electromechanical				
Switches	DC-18 GHz	✓	✓	✓
Phase Shifters	DC-26 GHz	✓	✓	✓
Rotary Joints	DC-40 GHz	✓	✓	✓
Passive Connectorized				
Filters	100 MHz - 26 GHz	✓	✓	✓
Hybrids	60 MHz - 26 GHz	✓	✓	✓
Couplers	60 MHz - 18 GHz	✓	✓	✓
Power Dividers	100 MHz - 18 GHz	✓	✓	✓
Drop-In Caseless				
Wireline Hybrids	25 MHz - 18 GHz	✓	✓	✓
Wirepac Hybrids	25 MHz - 4 GHz	✓	✓	✓
New Technology Products				
Interface Assemblies	DC-26 GHz		✓	✓

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AROUND THE CIRCUIT

INDUSTRY NEWS

Meyer "Mickey" Gilden died on July 4, 1993 of lymphoma. Gilden had been scientist in charge of microwave physics at United Technologies since 1971. Before that, he worked with the General Electric Microwave Laboratory, the Stanford Research Institute, Microwave Associates and Monsanto Co., and taught at the Illinois Institute of Technology and the University of Illinois. Gilden authored a number of publications and was the holder of numerous patents.

Varian Canada Inc., a subsidiary of **Varian Associates Inc.,** has acquired the assets of glass-to-metal hermetic seal manufacturer **Quality Hermetics Co. Inc.** of Toronto, Canada. Terms of the agreement were not disclosed.

Cadence Design Systems Inc. has entered into an agreement to sell its **Automated Systems Inc. (ASI) Division,** Brookfield, WI. The buyer is a corporation owned by several members of the ASI Division management. ASI is a designer and fabricator of complex printed circuit boards.

LBA Technology Inc. of Greenville, NC has entered into an agreement with **Geleco Electronics Ltd.** of Toronto, Canada to acquire Geleco's RF systems and components business.

The Portland, OR office of **LeBlanc Communications Inc.** has moved to new facilities located at 600 SE Maritime Drive, Suite 190, Vancouver, WA 98661 (206) 694-1204.

In an effort to become a key supplier of microelectronic chips, **TRW Space & Electronics Group** has signed an agreement with **RF Micro Devices** of Greensboro, NC. Under the terms of the three-year agreement, TRW will fabricate a majority of the GaAs heterojunction bipolar transistor chips developed by RF Micro Devices for wireless communications products.

Stanford Telecommunications Inc. has joined a team of major international companies, led by **TRW Inc.,** to formulate a joint proposal for submission to prospective investors for TRW's Odyssey™ satellite communications system. Stanford Telecom has been selected to participate in the ground processing electronics segment of the Odyssey program.

Siemens Components Inc.'s Special Products Division has announced expanded production of its self-healing MKT capacitors at its plant in Brazil.

Janco Electronics of Somersworth, NH will expand its capabilities to include fabrication and assembly services for the microwave and RF market. The company is in the process of ISO 9002 certification.

Premier Microwave Corp. has supplied rotary joints, cavity spectrum limiting filters, harmonic filters, arc sensors and four-port differential phase shift circulators to Unisys Corp.'s Systems Development Division. The products are for use in the Advanced Weather Radar WSR-88D (NEXRAD) program.

Microprecision, a division of **136963 Canada Inc.,** recently completed the first phase of its contract with **Raytheon Co.** for the TRC-170 program. Under the contract, the division has supplied more than 300 directional couplers, 200 adapters and 1500 waveguide assemblies to Raytheon.

GaAs integrated circuit manufacturer **Anadigics** has received registration with **SGS Yardley ICS** for ISO 9001 international quality standard certification. In addition, Anadigics reports production of its ten millionth GaAs IC since its founding in 1985.

Belden Wire & Cable Co.'s administrative office, distribution and engineering centers and US manufacturing facilities have been registered to ISO 9000 series standards.

The Marlboro, NJ and Phoenix, AZ facilities of mobile telecommunications system manufacturer **Celwave Inc.** have been certified to ISO 9001 quality management standards.

Robinson Nugent Inc.'s Dallas, TX plant has been registered and its quality management system certified as meeting the requirements of ISO 9002/EN 29002 and BS 5750 Pt 2. The facility is the company's primary US interconnect product manufacturing location.

Short- and medium-haul communication product and system designer and manufacturer **Digital Microwave Corp.** has received ISO 9001 certification for its San Jose, CA facility.

The UK's National Measurement Accreditation Service has accredited the automated calibration system of **Fluke Corp.**'s service center in Watford, UK. The system uses Fluke's MET/CAL calibration software to automate calibration of digital multimeters, oscilloscopes and other instruments.

Raytheon Service Co., a subsidiary of Raytheon Co., has received the US Small Business Administration's Award of Distinction. The national award recognizes prime government contractors that possess exceptional programs for subcontracting to small and minority businesses.

Astrolab Inc. has been selected as a "Partner in Quality" by **Raytheon Co.'s Missile Systems Division.** The award is presented to the Division's top 100 suppliers, and recognizes those who have continuously provided high quality, timely delivery and rapid responsiveness.

[Continued on page 50]

AROUND THE CIRCUIT

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AMP Inc. reports that it has received several supplier awards and certifications, including a certified supplier award from **Siemens Gammasonics,** a Star Achievement Award from **Northern Telecom,** an outstanding performance/vendor partnerhsip program award from **AT&T Denver Works,** and a supplier excellence award and several Quality Leader Awards from AT&T.

JFW Industries Inc. of Indianapolis, IN celebrated its 15th anniversary on January 19th.

FINANCIAL NEWS

Littelfuse Inc. reports sales of $40.7M for the third quarter, ended June 30, compared to $38.8M for the same period last year. Net income was $3.9M (32¢/share), compared to $1.1M (11¢/share) for the same period last year.

Digital Microwave Corp. reports sales of $30.3M for the second quarter, ended September 30, compared to $22.5M for the same period last year. Net income was $1.3M (10¢/share), compared to a net loss of $10.2M (84¢/share) for the same period last year.

Photronics Inc. reports sales of $48.4M for the year, ended October 31, compared to $41.3M last year. Net income was $4.9M (88¢/share), compared to $4.4M (82¢/share) last year. Fourth-quarter sales were $14.8M, compared to $10.1M for the period last year.

Comtech Telecommunications Corp. reports sales of $3.5M for the first quarter, ended October 31, compared to $4.9M for the same period last year. Net loss was $442K (18¢/share), compared to a net income of $232K (18¢/share) for the same period last year.

Kevlin Corp. reports sales of $2.4M for the first quarter, ended November 30, compared to $2.8M for the same period last year. Net loss was $1.9M (68¢/share), compared to a net income of $124K (4¢/share) for the same period last year.

Applied Science and Technology Inc. (ASTeX) reports sales of $2.3M for the first quarter, ended October 2, compared to $1.7M for the same period last year. Net income was $69.3K (3¢/share), compared to $35.1K (1¢/share) for the same period last year.

Illinois Superconductor Corp. reports sales of $69.3K for the third quarter, ended September 30, compared to $85.8K for the same period last year. Net loss was $360.8K (18¢/share), compared to a net loss of $153.4K (10¢/share) for the same period last year.

[Continued on page 52]

AROUND THE CIRCUIT

[From page 50]

CONTRACTS

Raytheon Co. has been awarded a $219.3M US Air Force contract to build 769 advanced medium range air-to-air (AMRAAM) missiles. Contracting agency is the Air-to-Air Joint System Program Office at Eglin AFB, FL. Missile recipients include the US Air Force, US Navy, UK, Turkey and Norway.

California Microwave Inc.'s Airborne Systems Integration Division has received $31.6M in contract options from the US Army for additional airborne reconnaissance low (ARL) systems. The award includes funding to design and integrate two ARL aircraft, spare equipment and continued support of an existing system that California Microwave delivered to the Army in early 1993.

Lam Research Corp. has received a $30M order from Hyundai Electronics Co., and orders totaling $19M from Samsung Electronics Co. Ltd., for its transformer coupled plasma (TCP™) and advanced capability Rainbow™ etch systems. The systems will be used to etch advanced 4- and 16-megabit dynamic random access memory devices.

The US Naval Systems Weapon Center has awarded a $3.6M contract to **Raytheon Co.** for development of an electronic module foundry service. The 18-month effort will provide a service, to include integrated CAD capability, that will enable government contractors to design modules for manufacture at a Raytheon facility. Also, Raytheon has signed a $500K contract with the Naval Avionics Weapons Center to develop a high-density gold connector for use in the next generation of standard electronic modules.

Watkins-Johnson Co. has been awarded contracts from several European customers totaling more than $2.5M. Under the contracts, Watkins-Johnson will deliver microwave receiving systems for signal collection and analysis.

Teradyne Inc.'s Assembly Test Group has been awarded a two-year, $1.5M contract from E-Systems Inc.'s Greenville Division to develop boundary-scan design and test tools for the Defense Department's ARPA application-specific electronic module (ASEM) multichip module (MCM) infrastructure program. The ASEM program promotes a commercial infrastructure that will improve MCM design, manufacturing and test.

Stanford Telecommunications Inc.'s Systems Engineering Division has been awarded a contract from the John A. Volpe National Transportation Systems Center to assist the FAA in "transition and implementation support." Contract value is $950K, with options worth $2.9M over 18 months. Also, Stanford Telecom's **ASIC and Custom Products Division** has received a $500K order from Andrew VSAT Systems to develop 1000 VSAT receiver subsystems for rural telephony applications.

[Continued on page 54]

AROUND THE CIRCUIT

[From page 52]

Superconductor Technologies Inc. has received a $742K small business innovative research contract to build superconducting switches for electronic warfare subsystems. Contracting agency is the US Air Force's EW Division of Wright Laboratory.

Electro-Radiation Inc.'s Government Systems Division has been awarded a Phase I small business innovative research contract by the Naval Air Development Center, Warminster, PA. The project investigates and defines techniques that will counter the effects of electronic countermeasures on noncooperative target identification operation with various radar systems.

Applied Science and Technology Inc. (ASTeX) has been awarded a Phase II contract from the National Science Foundation for microwave plasma diamond depositions at high growth rates. Under the contract, ASTeX will concentrate on gas phase chemistry changes at high power densities, the development of techniques to control film morphology and methods of increasing growth rates.

ITT Aerospace/Communications has received an order from the Moroccan Army for 225 SINCGARS VHF anti-jam tactical communications systems. The radios, part of Morocco's military upgrade program, will be installed in new M60 tanks.

PERSONNEL

R. Gordon Russell, president of Taconic Plastics Ltd., died on September 28, 1993 of cancer. The day before his death, Russell had appointed **Robert Quintus** as his successor. Quintus was GM.

Thomas W. Parker has been appointed president of Litton's Solid State Division. Parker formerly was president and GM of Filcom Inc., a joint venture of M/A-COM Inc. and Filtronic Ltd. He succeeds **Frank A. Olson,** who has joined a new product development team in Litton's Electron Devices Division.

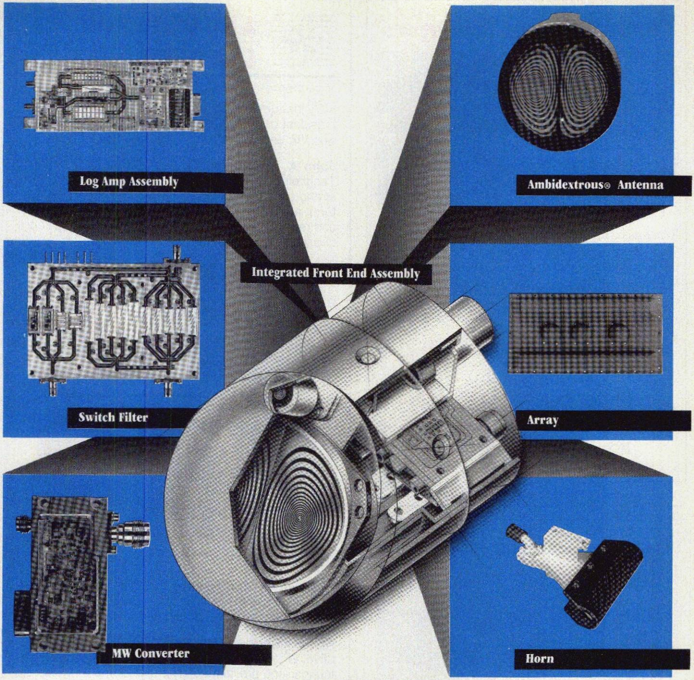
William F. Dinardo has been named president of Tech-Ceram Corp., Amesbury, MA. Previously, Dinardo was VP, sales and marketing with Tech-Ceram.

Tim D'Arcangelis has been named president of Scientific Power Systems Inc. Most recently, D'Arcangelis was president of Instruments for Industry.

CrossCheck Technology Inc. has named **Terry Paullin** president and COO. Most recently, Paullin was VP, sales and marketing for Silvar-Lisco.

Associated Testing Laboratories Inc. of Burlington, MA has named **Donald J. Lewis** president. Previously, Lewis was VP, quality assurance for Fenwal Electronics of Milford, MA.

[Continued on page 56]



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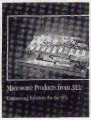

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AROUND THE CIRCUIT

[From page 54]

KLA Instruments Corp. has named **Hee-June Choi** president of its Korean operations. Most recently, Choi was VP, engineering with AG Associates.

John A. Armstrong has been named to Advanced Technology Materials Inc.'s. board of directors. Armstrong currently is the Karl Taylor Compton visiting lecturer at the Massachusetts Institute of Technology, and recently retired from his post as IBM's VP, science and technology.

Donald J. Lewis

Sam Densmore

Robert Hodges

Joe D. Norwood

Michael C. Engle

Malcolm Levy

Cadence Design Systems Inc. has appointed **Raymond J. Lane** to its board of directors. Currently, Lane is president of worldwide operations with Oracle Corp.

RF Monolithics Inc. has named **Sam Densmore** executive VP, COO and CFO. Densmore previously was founder and president of The IBC Group of Dallas, an international business consulting group.

Todd Westerhoff has been named VP, marketing for Compact Software Inc. Most recently, Westerhoff was Racal-Redac's CAE products marketing director.

Rogers Corp. has promoted **Robert Hodges** to VP of its Microwave and Circuit Materials Division. Previously, Hodges was the division's manager.

Joe D. Norwood has been named VP of ITT Cannon and operations and technical director for ITT Cannon in North America. Formerly, Norwood was VP and GM of ITT Cannon Military/Aerospace.

Michael C. Engle has been named VP, marketing for Microwave Networks Inc. Most recently, Engle was manager of advanced marketing with Harris Corp.'s Farinon Division.

Racal Instruments has promoted **Malcolm Levy** to VP, sales and marketing. Levy was director of sales and marketing. Also, Racal Communications Inc. has promoted **Christian B. Hamilton** to VP, finance. Previously, Hamilton was director of finance. In addition, Racal Communications has named **Samuel Kaufman** VP, manufacturing. Most recently, Kaufman was VP, operations with Computer Products Inc.'s Power Conversion America Division.

David E. Kress has been promoted to VP, marketing for Maxtec International Corp. Formerly, Kress was director of marketing for Maxtec's Telemotive Industrial Controls Group.

Rick Germani has been appointed VP, materials for Lam Research Corp. Most recently, Germani was VP, worldwide materials for Dell Computer Corp.

IC Works Inc. has named **Brenda Dohmen** marketing manager. Most recently, Dohmen was director of supplier relations for Quantum Corp.

Jeffrey G. Manni has been appointed manager of Spire Corp.'s biomedical laser product development initiative. Manni is a contributing editor for *Medical Laser Report* newsletter, and is the author of several reports on medical laser products and applications.

LeBlanc Communications Inc. has made several personnel appointments. **Richard E. Elliott Jr.** has been named sales manager, based in Dallas, TX. Most recently, Elliott held sales and marketing positions with Microwave Networks Inc. **Martin de la Rosa** has been named director of engineering at LeBlanc's Sioux City, IA facility. Previously, de la Rosa was with Falcon Steel, Fort Worth, TX. **Carla S. Culley** has been named controller for the Sioux City facility. Formerly, Culley was with Williams & Co., a Sioux City auditing firm. **Steven W. Richards** has been named quality assurance manager for the Sioux City facility. For the past ten years, Richards has served as quality engineer and manager for several California-based electronics companies.

Enthone-OMI Inc. has appointed **Roger H. Landolt** imaging technology product manager. Most recently, Landolt was a program manager with E.I. Dupont de Nemours' Printed Circuit Materials Division.

Bob Morgan has been appointed director of marketing and sales for Applied Engineering Products (AEP). Formerly, Morgan was AEP's western regional sales manager.

Pacific Scientific's Hiac/Royco Division has appointed **Terence Pringle** director of quality and **Dale Richards** customer service manager. Pringle previously was with Martin Marietta and the US Navy's Newport News shipbuilding operation. Most recently, Richards was customer service manager with IBM.

Larus Corp. has appointed **Philip S. Au** engineering manager with its Vista Labs Inc. development subsidiary. Most recently, Au was engineering manager of the PCAD Division of ALTIUM, an IBM company.

[Continued on page 60]

NEWS FROM EUROPE

Cadence Design Systems Inc. of San Jose, CA and **Siemens Semiconductor Group** of Munich, Germany have entered into a five-year, $15M software and services agreement. The contract establishes Cadence's framework-based design environment and integrated circuit design software as the design standard for Siemens' IC design activities worldwide. Siemens also has selected Cadence as a supplier of consulting services and assistance in adapting Siemens' existing databases and tools to the Cadence design environment.

Analogic Corp. of Peabody, MA has created a new European sales centre operated by its subsidiary, **Analogic Ltd.** of Bracknell, Berkshire, UK. The centre will help Analogics to compete more effectively and expand its customer base in the European Community. Product groups served by the new facility include test instrumentation, PC/AT data acquisition boards and component products, and process control instrumentation.

The European manufacturing facility of **Materials Research Corp.'s Advanced Materials Division** has received ISO 9002 certification from the **Association pour l'Assurance de la Qualite (AFAQ)**. The facility, located in Toulouse, France, manufactures high purity metals and alloys for thin films, sputtering targets and vacuum evaporation products.

GEC-Marconi Defence Systems' Electronic Systems Division has won a £2M order for its model PVS1712 radar altimeter. The altimeter is for use in the multirole towed target (MRTT), and currently is in use on the British Army Gazelle helicopter. Also, GEC-Marconi has awarded **Mercury Computer Systems Inc.** of Chelmford, MA a $10M subcontract as part of a $1B Australian Defense Force project for the Jindalee Operational Radar Network (JORN). Under the contract, Mercury will supply multicomputers to perform digital signal processing functions for JORN.

Integrated Optical Components Ltd. (IOC), Witham, Essex, UK, has appointed **Roger Harley** sales manager. Harley will be responsible for sales and distribution of IOC's standard and custom lithium niobate products in Europe.

Applied Science and Technology Inc. (ASTeX) of Woburn, MA has appointed **AIXTRON Semiconductor Technologies GmbH** of Aachen, Germany as exclusive distributor for its line of CVD diamond equipment for production and research.

INTERNATIONAL MARKETPLACE

Tower Top Front End Amplifier

The model LG064 tower top front end amplifier comprises an antenna amplifier and a current injector that feeds the antenna amplifier via an RF cable. Gain is 10 dB, 24 dB or 27 dB (typ.); rejection relative to the passband is > 55 dB at 20 MHz from band-edge; SWR is < 1.5 (input) and < 1.4 (output); and noise figure is < 3.5 dB. A built-in bypass switching function allows the system to remain operational in the event of power or amplifier failure. **LG Products AB, Solna, Sweden +46-8735-8150.**

Circle No. 284

0.1 - 20 GHz Coaxial In-Line Amplifiers

The AFSX series coaxial in-line amplifiers are available either in the frequency range from 0.1 to 20 GHz or optimised in octave and multioctave bands. The units fit into coaxial cable assemblies, receiving antenna systems and test and measurement systems without mounting problems. They can be biased through the output, eliminating wiring problems. The hermetically sealed amplifiers can be used as drivers or gain blocks in test instrumentation, mounted directly behind satellite and radar system antennas, or used as low noise gain equalisers in receiving cables to receiver front ends. **Matech Electronique, Boissy-Saint-Leger, France +(33-1) 45 98 12 12.**

Circle No. 285

1890 MHz Ceramic Microwave Filter

The model CGR 1890 ceramic microwave filter operates at a center frequency of 1890 MHz, and is suitable for use in cordless telephones meeting the European DECT standard. Used as a front-end filter, it gives clear selectivity in the DECT band of 20 MHz, and filters interference out of signals from the transmitter unit. When a second, identical filter is put into the RF stage of a DECT telephone, the two filters produce stopband attenuation of 70 dB at 1680 MHz. Size: 8 × 4 × 3.8 mm. **Siemens AG, Munich, Germany +49-89-4144-8083.**

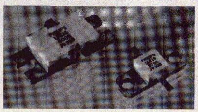
Circle No. 286

Circulators and Isolators

These circulators and isolators are suitable for use in cellular and PCN base stations. For a double isolator, isolation is 60 dB (typ.) and insertion loss is 0.25 dB (typ.). Power handling capability is up to 125 W CW. Options include integrated loads, accurate couplers and detection networks. **Tekelec Components, Montreuil, France, +(33-1) 49-88-49-35.**

Circle No. 287

Microwave Power Transistor



The model LFE15600X silicon npn microwave power transistor is a 60 W device for class AB output stages of transmitters operating over the frequency range from 1.5 to 1.7 GHz. The unit's single-ended base input, high power handling and diffused emitter resistors allow transmitter powers of several hundred watts to be achieved by connecting a number of transistors in parallel, without complex input matching circuitry. Power gain is 8.5 dB (typ.) at 1.5 GHz; and collector efficiency is 50% (typ.). **Philips Semiconductors, Eindhoven, The Netherlands +31 40 724825.**

Circle No. 288

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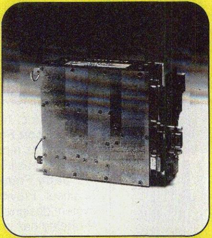
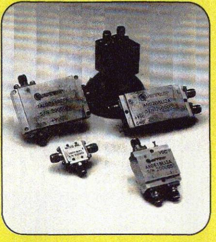


MÉLANGEUR



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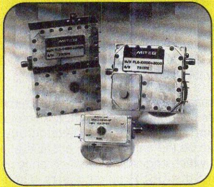
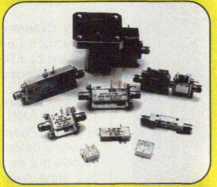
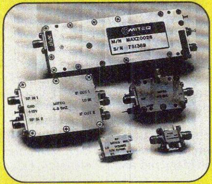


AMPLIFICATEUR

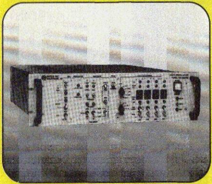


OSCILLATEUR

MULTIPLICATEUR



MODULATEUR TV



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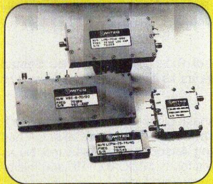
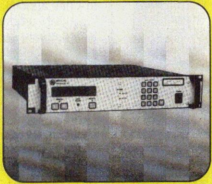


CONVERTISSEUR SYNTHÉTISEUR



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AROUND THE CIRCUIT

[From page 57]

Sierra Microwave Technology has named **Len Doiron** sales engineer and **Ken Nendza** staff scientist. Doiron previously was microwave design engineer for Sierra; and Nendza has more than 20 years of experience working with RF and microwave control components.

Semifab Inc. has made several personnel appointments. **Scott Foster** has been named marketing communications representative. Most recently, Foster held a similar position with Loral/Rolm Mil-Spec. Computers. **Jerry Franklin** has been named electrical design engineer. Previously, Franklin was an electrical control system designer and engineer with CAN-TRON. **Steve Whiteley** has been named customer service manager. Formerly, Whiteley was a product marketing engineer with Applied Materials.

Jerry Graeme of Burr-Brown Corp. has won *EDN Magazine*'s Co-Innovator of the Year award. He was selected by *EDN*'s 161,000 readers from a field of five finalists selected by the magazine's editors.

Eugene Ivanov, head of powder metallurgy research for Tosoh SMD, has been awarded the State Award of Russian Federation in Science and Technology. Ivanov is believed to be the only Russian expatriate to receive this award, which originally was established as the State Award of the USSR to recognize distinguished performance of Soviet scientists.

REP APPOINTMENTS

ITT Cannon/Sealectro of Santa Ana, CA has selected **RF Associates North Inc.** of Mountain View, CA to represent its line of coaxial RF and microwave connectors and cable assemblies in northern California and northern Nevada.

Renaissance Electronics Corp. has appointed **VPI Technical Representatives** of Ellicott City, MD to represent its products in Maryland and Washington, DC.

Quality Microwave Interconnects Inc. of Wilmington, MA has appointed **Penstock Inc.** to distribute its cable assembly product lines, including SEMI-FLEX®, in selected areas.

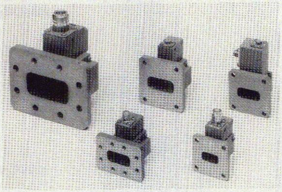
Burr-Brown Corp. of Tucson, AZ has named **Semad** of Toronto, Canada as its first Canadian electronics distributor.

Optotek Ltd. of Kanata, Ontario, Canada has appointed **Electrum Enterprises** of Thousand Oaks, CA and **Technical Marketing Associates** of Roseland, NJ as sales representatives for its MMICAD™ RF and microwave CAD/CAT software products.

A.J. Tuck Co. of Brookfield, CT has appointed **HD Communications** of Holbrook, NY to represent its products overseas.

Iso-Adaptors

WR-284
thru WR-62



Catalog standard Iso-Adaptors cover the spectrum. Most common flanges are available. Optimum performance in rugged, reliable assemblies. Pressurizable. Some popular units are:

W/G Size	Frequency Range	W/G Flanges	Coax
WR 229	3.7 - 4.2 GHz	CMR, CPR-F/G	SMA,N
WR 159	5.8 - 6.5 GHz	CMR, CPR-F/G	SMA,N
WR 137	6.8 - 7.2 GHz	CMR, CPR, U/G	SMA,N
WR 112	7.0 - 8.5 GHz	CMR, CPR, U/G	SMA,N
WR 90	8.5 - 9.6 GHz	CMR, CPR, U/G	SMA
WR 75	10.7 - 12.7 GHz	CPR-F/G, U/G	SMA
WR 62	14.0 - 14.5 GHz	CPR-F/G, U/G	SMA

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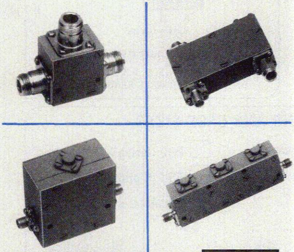
- Communication Bands
- Custom Frequencies
- 250 MHz to 18 GHz
- Single & Multi Junction
- SMA or N Connectors Standard Others as Special
- Compact Sizes
- Low & Higher Power Variations
- Many Available from Stock
- Custom Designs



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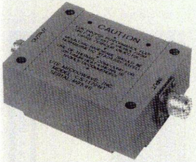

This compact 50 dB Isolator handles 250 watts CW (min.) @ 280 MHz. Size is only 3x4½x1½. Internal terminations will handle up to 75 watts reflected power when unit is properly heat sinked. Loss is typically 0.4 dB.

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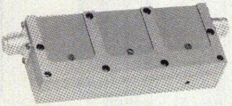
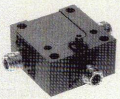
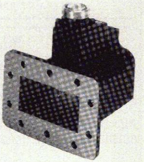


Rugged 250 watts CW triple isolator for cellular base stations gives 68 dB typical isolation with under 0.6 dB loss. An internal 100 watt load absorbs reflected power. Size is $5\frac{7}{8} \times 2\frac{1}{4} \times 1\frac{1}{4}$.



500 watts CW are easily handled by this 2450 MHz circulator which has 0.25 dB max loss and 1.10 max VSWR. Size $2\frac{1}{2} \times 2\frac{1}{2} \times 1\frac{5}{16}$. N connectors. Also available with DIN $^{7}/_{16}$ for higher power levels.

Our 2450 MHz Iso-Adaptor runs cool at 250 watts CW with a water cooled 100 watt load. Isolation is 20 dB (min.) and loss under 0.4 dB. A reverse power monitor is provided to drive protective circuitry.



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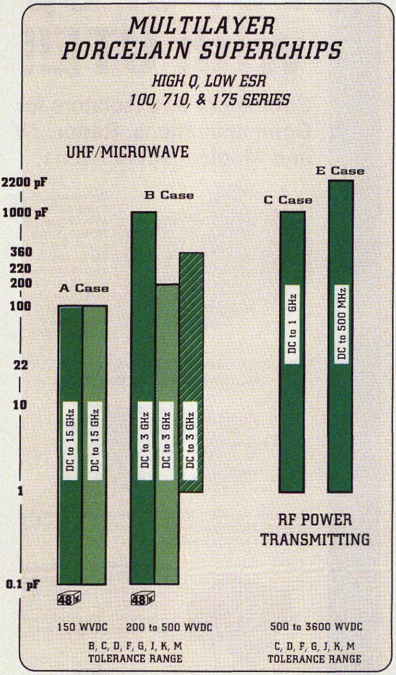

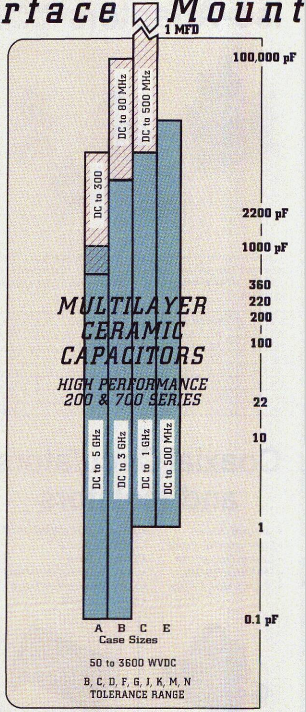

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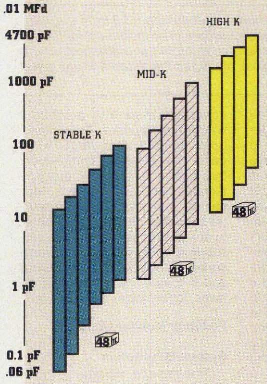

100 WVDC
B, C, D, F, G, J, K, M
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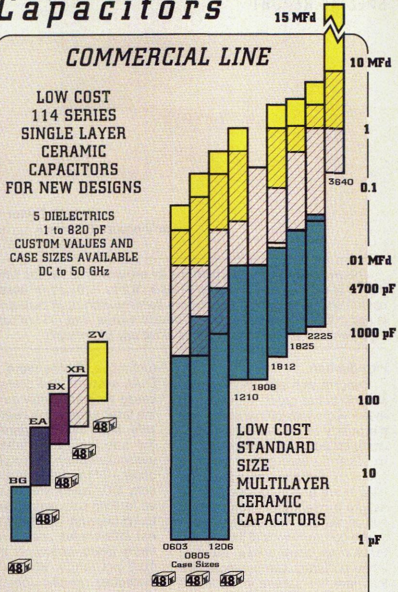
DC to 50 GHz



100 WVDC
B, C, D, J, K, M
TOLERANCE RANGE

25 to 200 WVDC
B, C, D, E, F, G, J, K, M, N, Z, P
TOLERANCE RANGE

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A Concept for Open Path Air Pollution Monitoring

Lyle H. Taylor
Westinghouse Science & Technology Center
Pittsburgh, PA

This monitoring concept combines an acousto-optic tunable filter for emission spectroscopy (3.5 to 14 μm) with a mid-IR (4.6 to 5.4 μm) and a far-IR laser (9.2 to 10.9 μm) for absorption spectroscopy in an instrument for the optical remote measurement of ppb-ppm concentration of air pollutants. It utilizes commercially available components, is fast (~2 minutes for 120 gases), covers a large area (~6 km path lengths), measures the distance to any reflecting object and takes measurements along any line-of-sight.

Introduction

Concern with atmospheric measurements has grown immensely in recent years with the realization that the quality of human life is significantly impacted by the quality of the air. Over 40 toxic gases[1] and 172 specific hazardous air pollutants[2] (HAPs) are of primary concern. To assure a healthy environment for human life, it is necessary to monitor the concentrations of these pollutants over large areas. Most of these pollutants are hydrocarbons that have line spectra in the IR fingerprint region of 8 to 12 μm.

For long open-path remote sensing and quantitative measurements of atmospheric concentrations of trace vapors, differential-absorption lidar (DIAL) is the best technique. Furthermore, infrared DIAL systems are preferred because they are highly sensitive to the laser energy, are relatively eye safe, and more importantly, are in the spectral range where most molecular-specific absorption lines occur.[3] Of the available infrared lasers, CO_2 lasers are the best suited for long path atmospheric monitoring because they have the highest efficiencies and powers, are easily tuned, and cover the 9.2 to 10.9 μm range, which is rich in molecular-specific spectra. Their wavelengths can be extended by harmonic generation to cover the 4.6 to 5.4 μm range.[4]

However, all laser systems have limited wavelength coverage. Thus, a DIAL system should be complemented with a broader wavelength system. An acousto-optic tunable filter (AOTF) is a good choice for the complementary system because it is easily integrated into a DIAL system. Additionally, it monitors emission spectra passively, can be quickly tuned to any desired wavelength, its sensitivity is easily increased by measuring derivatives of spectra lines and it covers two wavelength octaves, for example, 3.5 to 14 μm.[5]

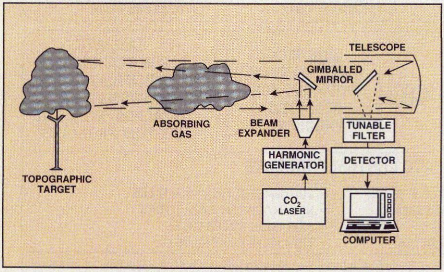


Fig. 1 Basic configuration of remote monitor.

Pollution Monitor Concept

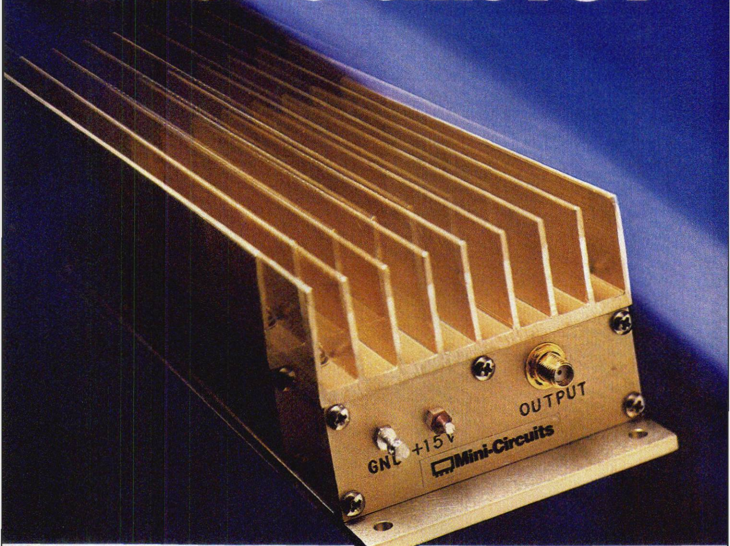
System Description

The remote monitor is comprised of a CO_2 laser, a nonlinear crystal, optics, an AOTF, detectors and a computer, as shown in Figure 1. The CO_2 laser is tunable over 87 lines in the 9.2 to 10.9 μm region where a large multitude of hydrocarbons have absorption spectra. The laser operates at 10 pulses/s, with 1 to 250 mJ/pulse, depending on the line. The pulse width of the linearly polarized beam is 100 ns.

The CO_2 laser frequency is doubled with a Tl_3AsSe_3 (TAS) nonlinear crystal. TAS harmonic generators are completely passive and have produced the highest measured efficiency of 57 percent in the far infrared. This crystal will produce pulse energies from 1 to 15 mJ on 68 lines in the 4.6 to 5.4 μm

[Continued on page 66]

incredible!



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Gain, dB min.	30	40	30	40
Gain Flatness, dB	±1.0	±1.5	±1.5	±1.5
Power Out @ 1 dB CP, dBm min	+29	+29	+29*	+29*
VSWR in/Out, max.	2.5:1	2.5:1	2.5:1	2.5:1
Noise Figure, dB typ	10.0	4.0	8.0**	8.0**
Power Supply, V/ma	+15/690	+15/700	+15/750	+15/850
Third Order Intercept, dBm min.	38	38	38	38
Second Order Intercept, dBm min.	48	48	48	48
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Distribution Centers/NORTH AMERICA 800-654-7949 • 417-335-5935 Fax 417-335-5945 EUROPE 44-252-835094 Fax 44-252-837010 region. The transmitter optics then enlarges the laser beam to a 20 cm diameter to make it eye safe.

The receiver optics collects the reflected beam with a 30 cm mirror and focuses it through the AOTF onto the detectors. The AOTF is fabricated from a TAS crystal. Figure 2 shows the harmonic generator and the AOTF, while Figure 3 shows the operation of the AOTF. The received beam, linearly polarized as indicated by the arrows, enters the crystal and interacts with a periodically varying spatial distribution of indices of refraction set up by an acoustic beam inserted via the transducer. Only a narrow spectral band of 10 cm^{-1} will be phase-matched to the acoustic beam and diffracted out of the main beam, with its plane of polarization rotated 90° since TAS is a birefringement crystal.

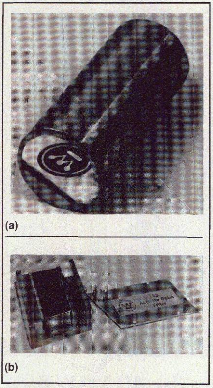

Fig. 2 The (a) harmonic generator and (b) AOTF.

Two detectors are used for improved sensitivity. One detector operates from 7 to 14 μm and one operates from 3.5 to 7 μm. The AOTF directs the received radiation to the two detectors by using one transducer for the 7 to 14 μm portion and a second transducer for the 3.5 to 7 μm portion. The transducers are placed on orthogonal faces of the crystal and diffract the two portions of the beam into two different directions. The detector signals are then analyzed by the computer.

The System Operation

The CO_2 laser wavelengths are switched in a predetermined pattern, typically staying on each wavelength for one second. Electronically activated two-position mirrors direct the CO_2 laser beam through the harmonic generator crystal for short wavelength operation and around the crystal for long wavelength operation. An electronically-controlled gimballed telescope directs the beam to any target in real time. Thus, large areas can be quickly monitored via several beam paths, and the beam paths can quickly change to respond to fugitive releases wherever they may occur.

The AOTF has two functions. During absorption measurements, the AOTF increases the signal-to-noise ratio by restricting radiation from the atmosphere to a narrow spectral range of approximately 10 cm^{-1} around the absorption line. The AOTF is operated from 3.5 to 14 μm during emission measurements. By careful selection of the acoustic frequency, the wavelength of the diffracted beam can be centered on key emission lines

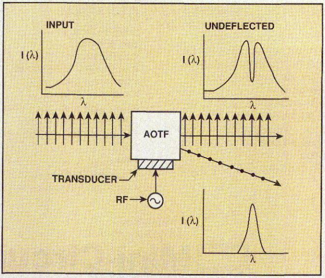

Fig. 3 Operation of the AOTF.

of specific gases, as shown in Figure 4. These key emission lines can be monitored when absorption measurements are not being taken, and if preset thresholds are exceeded, the laser can be can be activated for detailed measurements. Alternatively, the entire wavelength region can be scanned to obtain spectra. An AOTF-generated benzene spectrum is shown in Figure 5.

The detectability of sharp emission lines is enhanced by modulating the acoustic frequency at a fixed frequency of 1 kHz, as shown in Figure 6. This modulation sinu-

[Continued on page 69]

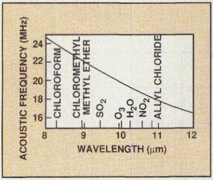

Fig. 4 The AOTF wavelength centered on a line with the acoustic frequency.

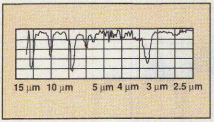

Fig. 5 An AOTF-generated benzene spectrum.

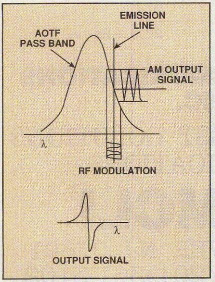

Fig. 6 AOTF derivative detection is sensitive to narrow-line emissions.

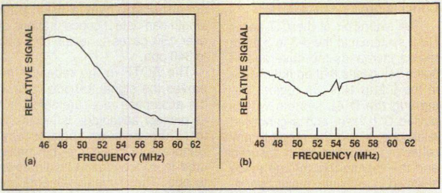

Fig. 7 Measurement of HeNe laser line with 1 percent the radiance of a glow bar and $\lambda = 3.39\ \mu m$; (a) direct and (b) derivative detection.

soidally shifts the AOTF passband. The modulation does not affect the radiation from sources that have relatively constant intensities over the AOTF passband, but modulates the intensity from emission lines narrower than the AOTF passband. A lock-in amplifier tuned to the modulation frequency gives the first derivative of the spectra within the AOTF passband. The second derivative is obtained in a similar manner.[5]

The computer determines concentrations and, with a 10 ns rise time detector, determines the range to the reflecting target to within 2 m. It then stores and displays the results. With associated electronics, it also controls the operation of the monitor.

The System Performance

The laser power is sufficiently large so that signal-to-noise over 6 km path lengths is not a problem. In this mode of operation, the monitor is essentially the same as other CO_2 DIAL systems and has the same sensitivities. In the 9.2 to 10.9 μm region, the monitor has the potential to measure concentrations of 101 HAPs and over 40 other vapors of interest. Detection limits vary from 1 ppb for Freon, 12 to 60 ppb for ethyl-mercaptan to 340 ppb for sulphur dioxide. In the 4.6 to 5.4 μm region, the monitor has the potential to measure 16 HAPs and over 14 other vapors of interest. Detection limits vary from 0.3 ppb for carbonyl sulfide to 21 ppb for nitrous oxide to 187 ppb for carbon monoxide.

In measuring emission spectra, the large wavelength coverage allows the monitoring of literally hundreds of gases. However, the sensitivity is lower because the emitting gas is at or near the same temperature as the atmosphere that is emitting as a blackbody. Fortunately, atmospheric vapors have narrow line widths that allow the modulation of the AOTF to increase the sensitivity by obtaining first and second derivatives of the spectra, as shown in Figure 7 for a laser line with 1 percent of the spectral radiance of a glow bar in the background. The laser line cannot be seen in direct detection, but when the first derivative is taken the laser line is clearly seen.

The technique's concentration sensitivity can be in the ppb range but is wavelength dependent because of the atmospheric blackbody wavelength dependence. The signal (emission line) to background (atmospheric radiation) ratio is increased, by taking the first derivative, by 9 at 10.6 μm, by 36 at 5.3 μm, and by 75 at 3.7 μm. The second derivative gives enhancements of 68 at 10.6 μm, 1100 at 5.3 μm, and 4700 at 3.7 μm.[5]

Conclusion

The extension of the CO_2 laser DIAL system into the 4.6 to 5.4 μm region increases the coverage of some key gases that do not absorb in the 9.2 to 10.9 μm region. Designing the DIAL system with a pulsed CO_2 laser and a gimballed telescope, allows the range to any reflecting target to be measured and the monitoring volume to be selected in real time, major operating conveniences. Absorption spectroscopy over a 6 km path length can detect concentrations of over 150 gases to levels of 1 ppb to 340 ppb.

The AOTF in the receiver improves the signal-to-noise ratio in the absorption measurements, but its primary advantage is in the 3.5 to 14 μm emission spectroscopy. Hundreds of gases can be measured in concentration levels down to ppb. These measurements are possible because of the large enhancements in signal-to-background ratios obtained by taking spectral derivatives, an easy task with an AOTF. ■

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Lyle H. Taylor *received his BS from Iowa State University, his MS from New Mexico State University and his PhD from the University of Kansas, all in physics. He is a fellow scientist at the Westinghouse Science and Technology Center, where he has worked since 1967. He has worked in solid lubrication, gas laser modeling, human behavior to illumination, isotope separation, inertial confinement fusion, nonlinear optics, acousto-optics and infrared imaging systems. Taylor is a member of the American Physical Society and the Air & Waste Management Association.*

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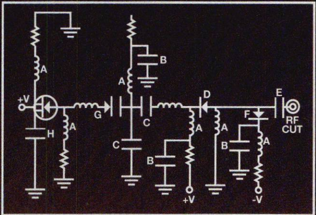

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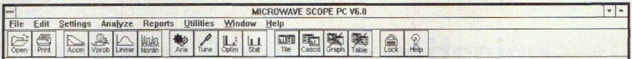

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Determination of Noise Parameters of Low Noise Microwave IF Amplifiers

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Centro Astronómico de Yebes
Guadalajara, Spain

Introduction

It is well known that the noise performance of linear two-port networks can be described in terms of four noise parameters. Designers of low noise amplifiers use these data, which are provided by manufacturers or models, to simulate the noise generated in the devices employed in their designs. System designers are faced with greater challenges since amplifier manufacturers usually provide only the noise figure or noise temperature of their product as part of a matched system. The remaining three noise parameters may be useful. In some cases, for example, these parameters are useful when trying to determine the noise contribution of a microwave amplifier loaded at the input with a poorly matched IF port of a microwave mixer. The use of an isolator may help, but it may also add to the overall noise. When all noise parameters of the amplifier (G_n) are known, it can be determined whether or not to use an isolator. Measured noise parameters are also useful in checking if an amplifier or receiver is performing as designed, giving an indication of the quality of the models used in CAD programs.

Noise parameters are not as easily measured as the widely used S-parameters. Although some commercial equipment exists for their automatic measurement,[1] this kind of equipment is usually not available in many laboratories. This paper presents measured results that are obtained by an easy and accurate method using only a manual tuner, a noise figure meter and a vector network analyzer (VNA). The accuracy of measured noise parameters depends on many factors, and is difficult to calculate in terms of the accuracy of noise and S-parameter data used in noise parameter determination. This calculation can be done by a tedious Monte-Carlo simulation if the accuracy of the measurements is well known. This paper describes a different and simple approach, a confidence test, that checks the validity of the procedure used for noise parameter measurements.

In S-parameter measurements, the VNA is calibrated using a set of standards (short, open, load, through), and the calibrated system can be checked with a different set of verification devices, usually mismatched air lines and attenuators. The impedance of precision coaxial air lines used for verification can be accurately determined if their dimensions are known. In this way, the verification can be performed based only on the geometry of the used standard, which can be measured independently.

A similar approach would be desirable for the verification of noise parameter measurements, but is hindered by the error introduced in correcting for the noise of the second stage when measuring passive gainless devices.[2-5] Ideally, the device used for the verification should show a gain similar to that of the devices to be measured. The standard used for verification in this work is a low noise amplifier preceded by an isolator. Noise parameters of the isolator can be determined by measurements of its physical temperature and S-parameters, as for any reciprocal or nonreciprocal passive two-port network.[6-8] In the case of an ideal isolator[11,12] in front of a receiver, three of the four noise parameters (R_{opt}, X_{opt} and G_n) can be easily calculated, and the other (T_{min}) is directly measured if the isolator is well matched to the noise source used for the measurements.

Procedure

Most of the methods used for noise parameter determination are based on the procedure of measuring noise with a set of input impedances and fitting noise parameters to match experimental data. A variable impedance noise generator should be used for these measurements. Such a generator can be implemented by a standard solid-state diode noise source followed by a low loss microwave tuner. It has been shown[9] that in order to obtain good accuracy in ultra low noise device measurements, the impedance change of the noise source between on and off states should be small. The effect of impedance changes on noise temperature errors has been analyzed.[4] For the present study, a noise diode was used that contains a built-in attenuator to reduce undesirable effects.

[Continued on page 76]

[From page 74] GALLEGO

Selection of the microwave tuner is critical. Ideally, a lossless repeatable tuner, with the capability to adapt any point in the Smith Chart to 50 Ω, should be used. In such a case, the available noise power at the output port of the tuner will be the same as for the noise source, and only the output impedance has to be calibrated. The effect of losses in a real tuner is two-fold. It attenuates noise generated by the source and it contributes additional noise power dependant on the physical temperature of the tuner. The equivalent noise temperature at output can be expressed as

$$T_{out} = \frac{T_{in}}{L} + T_{ph} \bullet \left(1 - \frac{1}{L}\right) \quad (1)$$

where

T_{in} = equivalent output temperature of the noise generator
T_{ph} = physical temperature of the tuner
L = available tuner loss

The excess noise ratio (ENR) and equivalent output temperature in off state of the noise source plus tuner (T_{cold}) must be corrected using Equation 1.

Instead of a frequency dependant correction of ENR and T_{cold}, a totally equivalent and more convenient approach is to take noise measurements for different tuner positions using the uncorrected noise source calibration, and then subtract the tuner noise contribution using Friis' equation given by

$$T_{DUT} = \frac{T_{meas} - (L-1) \bullet T_{ph}}{L} \quad (2)$$

where

T_{DUT} = corrected noise temperature
T_{meas} = uncorrected noise temperature
L = available loss of the tuner
T_{ph} = tuner's physical temperature

The first step in measuring the noise parameter of a DUT as a function of frequency is to calibrate the tuner at several frequency points across the band. The utilized tuner consists of a slab transmission line with two micrometer driven metallic blocks in a sliding carriage, as shown in Figure 1. Carriage position can

[Continued on page 78]

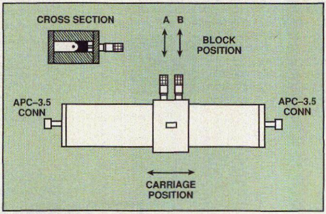

Fig. 1 The slab line tuner used for noise parameter measurement.

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QBH-101	5-500	13.0	7.0	1.5:1	2.4	25.0	20/28	15.0/18	TO-8
QBH-102	5-500	12.3	21.0	1.5:1	7.0	23.0	34/50	15.0/93	TO-8
QBH-103	5-300	11.3	22.0	1.5:1	6.8	22.0	37/51	15.0/91	TO-8
QBH-104	5-500	12.3	10.5	1.5:1	4.5	23.0	25/37	15.0/29	TO-8
QBH-105	5-300	12.2	8.0	1.5:1	3.0	27.0	22/30	15.0/18	TO-8
QBH-108	5-300	11.3	20.0	1.5:1	6.5	21.0	37/50	15.0/71	TO-8
QBH-109	10-500	10.6	12.0	1.5:1	4.5	24.0	28/40	15.0/35	TO-8
QBH-110	5-500	15.0	9.0	1.5:1	3.0	25.0	23/33	15.0/29	TO-8
QBH-115	10-500	12.3	26.0	1.5:1	7.8	25.0	35/42	15.0/165	TO-8
QBH-117	5-100	16.5	4.5	1.5:1	1.5	35.0	17/24	15.0/11	TO-8
QBH-118	3-100	16.3	13.0	1.5:1	1.9	35.0	27/38	15.0/21	TO-8
QBH-119	5-500	15.0	12.0	1.5:1	3.0	25.0	26/36	15.0/33	TO-8
QBH-121	10-500	13.5	12.0	1.5:1	3.5	24.0	27/39	15.0/37	TO-8
QBH-122	10-500	17.0	20.0	1.8:1	4.2	22.0	30/38	15.0/65	TO-8 LP
QBH-124	5-100	19.8	17.0	1.5:1	3.5	32.0	30/40	15.0/60	TO-8
QBH-125	10-100	19.6	23.0	1.5:1	4.5	33.0	38/50	15.0/132	TO-8
QBH-126	5-500	15.0	16.0	1.5:1	3.8	25.0	30/38	15.0/50	TO-8
QBH-131	5-1300	18.0	7.0	1.5:1	5.0	27.0	20/35	15.0/41	TO-8 LP
QBH-132	15-700	14.6	16.0	1.7:1	6.5	27.0	29/39	15.0/44	TO-8
QBH-133	10-500	10.3	16.0	1.5:1	4.5	25.0	29/45	15.0/57	TO-8
QBH-136	10-200	20.0	21.0	1.5:1	4.0	26.0	33/45	15.0/70	TO-8
QBH-137	10-200	12.7	21.0	1.5:1	3.5	26.0	38/48	15.0/94	TO-8
QBH-138	5-150	15.5	21.0	1.6:1	3.2	28.0	37/49	15.0/99	TO-8
QBH-147	20-1100	13.5	10.0	1.5:1	3.5	22.0	23/33	15.0/27	TO-8 LP
QBH-149	10-150	23.0	17.5	1.5:1	2.8	30.0	29/39	15.0/39	TO-8
QBH-150	10-300	20.0	18.0	1.5:1	3.5	25.0	30/41	15.0/46	TO-8
QBH-152	10-300	17.0	18.0	1.5:1	3.5	26.0	33/47	15.0/68	TO-8
QBH-154	200-1200	12.8	8.0	2.0:1	2.6	23.0	21/31	15.0/23	TO-8 LP
QBH-155	5-300	15.0	22.0	1.5:1	5.8	28.0	37/50	15.0/93	TO-8
QBH-171	10-150	13.5	27.0	1.5:1	6.5	27.0	40/50	15.0/105	TO-8
QBH-179	5-200	23.3	9.0	1.5:1	3.0	30.0	23/27	15.0/17	TO-8
QBH-180	5-150	29.0	18.0	1.6:1	3.8	50.0	32/42	15.0/59	TO-8
QBH-181	10-200	24.4	16.0	1.5:1	2.8	31.0	25/36	15.0/33	TO-8
QBH-804	10-100	19.8	24.0	1.5:1	4.0	27.0	38/48	15.0/82	TO-8
QBH-822	10-2000	20.0	11.0	2.0:1	5.0	24.0	24/35	15.0/60	TO-8 LP
QBH-824	10-2000	15.3	12.0	1.6:1	6.5	23.0	21/32	15.0/65	TO-8 LP

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Model Number	Frequency Range	Gain 25°C	P1dB	VSWR In/Out	Noise Figure	Reverse Isolation	3rd/2nd OOIP	DC Power Volts/mA	Housing Style
QB-101	2-70	21.9	31.0	1.5:1	4.5	31.0	56/110	24.0/400	19044
QB-188	0.5-100.0	15.0	21.0	1.5:1	3.0	28.0	37/47	15.0/100	184
QB-300	1-300	24.5	22.0	1.5:1	3.8	36.0	37/52	20.0/154	181/182
QB-538	2-500	34.8	22.0	1.5:1	3.0	45.0	35/52	20.0/187	181/182
QB-761	806-870	23.0	18.0	1.5:1	3.5	42.0	32/0	15.0/140	187-2

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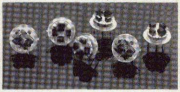
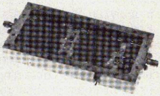
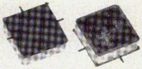
Model Number	Frequency Range	Gain 25°C	P1dB	VSWR In/Out	Noise Figure	Reverse Isolation	3rd/2nd OOIP	DC Power Volts/mA	Housing Style
QBH-5119	10-500	15.0	12.0	1.5:1	3.0	22.0	26/36	15.0/33	F-PACK .450 SQ SMD
QBH-5122	10-500	17.0	20.0	1.8:1	4.2	22.0	30/38	15.0/65	F-PACK .450 SQ SMD
QBH-5237	10-200	12.7	22.0	1.8:1	4.5	15.0	38/50	15.0/97	F-PACK .450 SQ SMD
QBH-5271	10-150	13.2	26.0	1.7:1	6.0	15.0	39/48	15.0/148	F-PACK .450 SQ SMD
QBH-5284	10-100	19.8	22.0	1.5:1	4.0	21.0	38/48	15.0/82	F-PACK .450 SQ SMD







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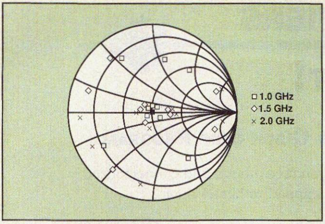


Fig. 2 Impedance points used for noise parameter determination.

be determined with ±0.1 mm accuracy, and micrometer divisions are 0.01 mm. In this experiment, 11 positions were selected to obtain a good coverage of the Smith plane. One point was chosen with the metal blocks in the outermost position (almost matched condition), five points were selected with a moderate effect of the plungers at five different carriage positions, and the last five were chosen with plungers close to the inner line (high reflection) at different carriage positions. Figure 2 shows the 11 impedance points obtained at three frequencies in the band (1, 1.5 and 2 GHz). The extensive coverage of the region close to the center of the chart is intentional, because the optimum noise impedance of DUTs was expected to be close to the matched condition.

Calibration of the tuner at selected positions was accomplished by measurements with a vector network analyzer. S-parameters were read through HPIB by a computer using an in-house program. Data were stored in DOS compatible files for later use. Data files were later processed by the MMICAD program[10] to generate new files containing only output impedance and available gain at each frequency point.

DUT noise was measured for each tuner position at the same frequency points using a noise figure meter. Data was stored in computer files in the same way as before. Then, another computer program was used to reorganize source impedance and noise data files. This step is necessary because data are first stored as a function of frequency, and has to be re-stored in different files, one for each frequency as a function of tuner position. Finally, files are processed, one at the time, by a curve-fitting computer program to find the best set of noise parameters for minimum error.

Noise parameters calculated are T_{min}, G_n, R_{opt} and X_{opt}. Using these parameters, the DUT noise for any input impedance can be expressed as

$$T_{DUT} = T_{min} + \frac{T_0 \bullet G_n}{R} \bullet \left[\left(R - R_{opt}\right)^2 + \left(X - X_{opt}\right)^2 \right] \qquad (3)$$

where

R = real part of the impedance
X = imaginary part of the impedance
T_o = standard temperature (290°K)

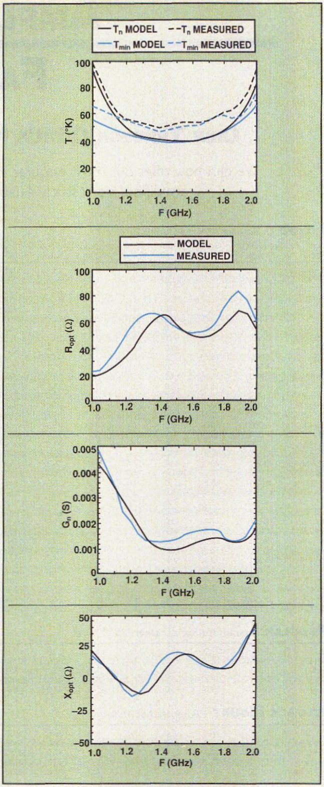
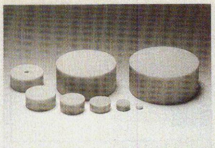


Fig. 3 Measured noise parameters of the L-band amplifier compared with theoretical prediction.

To test this procedure, noise parameters were measured at room temperature in an L-band amplifier.[15] Figure 3 shows measurements compared with the results obtained from a theoretical analysis performed with the aid of MMICAD,[10] using a model[13,14] to represent noise in transistors. There is good agreement between measurement and theory.

[Continued on page 80]



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8600	80.0	−6 to +9 ppm/°C	3.000 @ 3.0 GHz	0.7 to 3.5
8700	29.1	−4 to +4 ppm/°C	10.000 @ 10.0 GHz	5.6 to 32.1
8800	37.5	0 to +4 ppm/°C	6.000 @ 4.5 GHz	0.8 to 5.2
8300	36.0	0 ppm/°C	27.000 @ 850 GHz	0.8 to 1.0

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881.5	13.0	3.0	1.0	2:1	12(f_0+/- 32.5)
915.0	13.0	3.0	1.0	2:1	12(f_0+/- 32.5)
1227.0	5.0	1.2	0.5	2:1	20(f_0 - 140.0) 17(f_0 + 140.0)
1575.0	5.0	1.2	0.5	2:1	20(f_0 - 140.0) 17(f_0 + 140.0)

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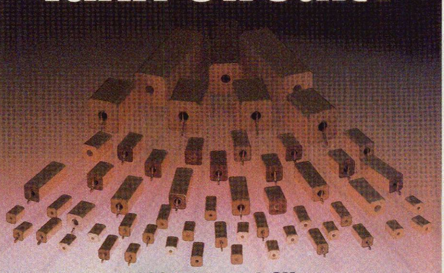

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[From page 78]

Problems, noted by the abnormally high values of standard deviation, were found at some frequencies when fitting the noise parameters. At 1150 MHz, the difficulty was related to a high peak in the tuner loss in some tuner positions, probably due to a spurious resonance, as shown in Figure 4. Three points were eliminated at this frequency. At 1750 MHz, another problem, due to a local interfering signal picked up by the insufficiently shielded tuner, was found. One point was eliminated at this frequency.

Verification

It has been shown[11] that the noise parameters of a receiver preceded by an isolator with no reverse transmision ($S_{12} = 0$) can be expressed as

$$R_{opt} = R_{in}$$

$$X_{opt} = -X_{in}$$

$$G_n = \frac{T_{amb} + T_{min}}{4 \bullet T_o \bullet R_{opt}} \tag{4}$$

where

R_{in} = real part of the impedance looking at the input of the isolator

X_{in} = imaginary part of the impedance looking at the input of the isolator

T_{amb} = isolator's physical temperature

T_{min} = minimum noise temperature of receiver and isolator

T_{min} is needed to compute G_n, and T_{min}'s value is not known a priori. The only way to use Equation 4 for the verification of G_n is to measure first the noise parameters and then use the measured value of T_{min} to generate an approximate value of G_n for verification. For a well matched isolator, the value of T_{min} will be close to the measured value of T_n, noise temperature with input impedance of 50 Ω, and then the accuracy of the value obtained for G_n in Equation 4 will depend on the precision of the noise temperature measurements under nearly matched conditions. On the other hand, the value of G_n obtained by measurements will depend strongly on the accuracy obtained for high reflection positions of the tuner. Thus, the verification of G_n relies on the accuracy of the calibration of the noise source, but helps to check the validity of the fitting procedure and the corrections used for the most sensitive positions of the tuner that occur at higher losses.

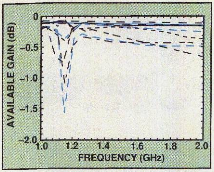

Fig. 4 Available gain of input tuner for all positions used.

The amplifier measured for this study was preceded by an isolator. The input impedance was measured with the VNA. Noise parameters were determined using the previously described method, and

[Continued on page 83]

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Connector Version	ZEL 0812LN	ZEL 1217LN	ZEL 1724LN	ZHL 0812HLN	ZHL 1217HLN	ZHL 1724HLN
Freq. (GHz)	0.8-1.2	1.2-1.7	1.7-2.4	0.8-1.2	1.2-1.7	1.7-2.4
NF, db, max*	1.6 1.5	1.6 1.5	1.6 1.5	1.5	1.5	1.5
Gain dB, min.	20	20	20	30	30	30
Output Pwr., dBm 1dB Comp.	+8	+10	+10	+26	+26	+26
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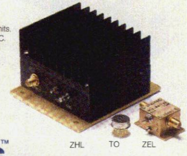
*TO-8 includes test fixture loss.



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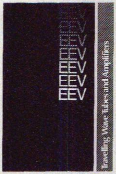

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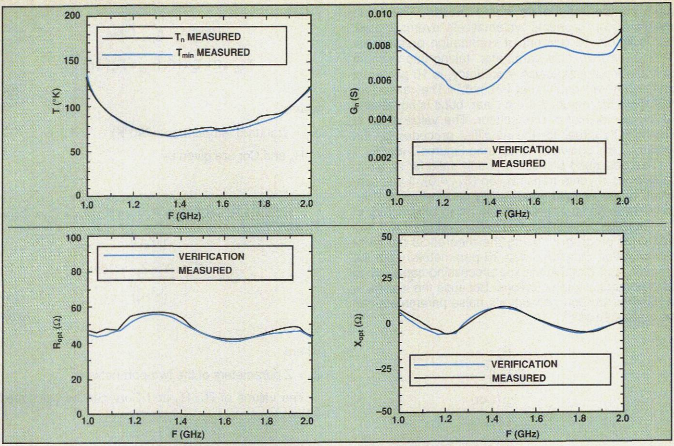

Fig. 5 Verification and measured noise parameters at room temperature.

measured input impedance and T_{min} were used to generate the verification values of R_{opt}, X_{opt} and G_n using Equation 4. Verification and measured data are compared in Figure 5. Good agreement of the optimum source impedance was achieved. The value measured for G_n seems systematically overestimated, but is within 15 percent of verification predictions. Typical error for this parameter, taking into account only the input impedance inaccuracy, is 10 percent if state-of-the-art equipment is used.[16] The reason for this slight discrepancy is not clear, but it is not related to the nonideality of the isolator. The value of G_n is significantly larger for the amplifier preceded by the isolator, as is shown by comparing Figures 3 and 5.

This described procedure is only valid for an isolator with no reverse transmission ($S_{12} = 0$). If this condition does not hold, input noise parameters are dependent to some degree on the noise parameters of the amplifier. This effect has been evaluated with the MMICAD program,[10] using the theoretical model of the amplifier, measured data (S-parameters) from the isolator, and MMICAD in-line processing capability to incorporate custom equations. Because the isolator is a passive two-port network, its noise parameters can be calculated as[6-8]

$$G_n = \frac{R_2}{\left(|Z_{21}|\right)^2}$$

$$X_{opt} = \frac{\mathrm{Im}(Cor)}{G_n}$$

$$R_{opt} = \sqrt{\frac{R_n}{G_n} - X_{opt}^2}$$

$$T_{min} = 2 \bullet T_o \bullet \left(G_n R_{opt} + R_e(Cor)\right) \tag{5}$$

where

T_o = standard temperature (290°K)

R_n and Cor are given by

$$R_n = \frac{\left(|Z_{21}|\right)^2 \bullet R_1 + \left(|Z_{11}|\right)^2 \bullet R_2 - 2 \bullet \mathrm{Re}\left(\overline{Z_{11}} \bullet Z_{21} \bullet \overline{Corv}\right)}{\left(|Z_{21}|\right)^2}$$

$$Cor = \frac{\overline{Z_{11}} \bullet R_2 - \overline{Z_{21}} \bullet Corv}{\left(|Z_{21}|\right)^2} \tag{6}$$

where

Z_{ij} = Z parameters of the two-port network

The values of R_1, R_2 and Corv can be calculated as

$$R_1 = \frac{T_{amb}}{T_o} \bullet R_e(Z_{11})$$

$$R_2 = \frac{T_{amb}}{T_o} \bullet R_e(Z_{22}) \tag{7}$$

$$Corv = \frac{T_{amb}}{T_o} \bullet \frac{Z_{11} + \overline{Z_{12}}}{2}$$

where

T_{amb} = temperature of the device

Noise parameters of the modeled amplifier preceded by a real isolator were computed applying Equations 5 to 7 in a MMICAD procedure block, and compared with data for an ideal ($S_{12} = 0$) isolator from Equation 4. Differences obtained for the isolator used ($S_{12} < -20$ dB) were negligible.

Prediction at Cryogenic Temperatures

The tested L-band amplifier was designed as an IF amplifier for SIS cryogenic radio-astronomy receivers.[15] In practical applications, and due to the difficulties observed in some cases in SIS mixers when loaded with poorly matched loads, a cryogenic isolator is used at the input of the amplifier. Good agreement has been shown between measured and modeled noise parameters. It is believed that the utilized model is equally good at cryogenic temperatures. There is a slight degradation in T_{min} due to losses. There is a large increment in G_n when the isolator is used, which shows that for severe mismatches at the input port, the degradation in noise temperature of the system can be severe even when the isolator is

[Continued on page 86]

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10.7-12.0	D-9408-5
10.95-11.7	D-9408
10.95-12.2	D-9408-1
10.7-11.7	D-9408-2
10.95-12.75	D-9408-3
11.7-12.2	D-9409
11.7-12.75	D-9409-1
11.46-11.96	D-9409-2
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14.0-14.5	D-9411

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3.62-4.2	U-9451
5.845-6.425	U-9453
7.9-8.4	U-9454
11.7-12.2	U-9455
12.2-12.75	U-9455-1
12.75-13.25	U-9455-2
10.95-12.75	U-9455-3
14.0-14.5	U-9456
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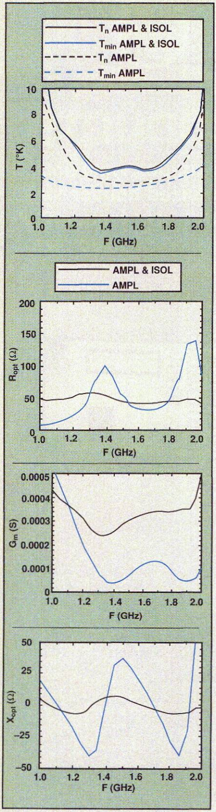

Fig. 6 Theoretical noise parameters at T = 12.5°K.

cooled to cryogenic temperatures. Figure 6 shows noise parameters predicted by models for the amplifier, compared to those for the same amplifier preceded by a typical (hypothetical) cryogenically coolable isolator.

Conclusion

The noise parameters at room temperature are measured in an L-band amplifier. Data obtained are in good agreement with theoretical model prediction. Accuracy of measurements was checked using a confidence test based on measurements of the same amplifier preceded by an isolator. Results show good accuracy in optimum source impedance and a slight overestimation of G_n of unknown origin. The measurements prove the superior noise performance of the amplifier without isolator for nonmatched input. It is believed that this superiority is also maintained at cryogenic temperatures.

Acknowledgment

This work has been partly financed by the CAI CYT project number PB90-408. The hardware and software used for the work described in this paper is a Maury model 8045C tuner; an HP 8510C vector network analyzer and an HP 8970B noise figure meter; the a VECTRA model PC 308 computer, an S/N YL 026 L-band amplifier built at Centro Astronómico de Yebes; and a Thomson CSF model BD 1903 isolator. The noise analysis was based on Pospieszalski's model. ■

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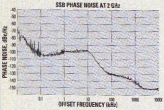

Low phase noise assures you of more accurate narrow-band measurements.

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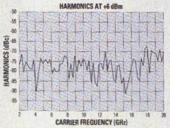
The key to the performance of the GT 9000 is a new single RF module design. This unique design gives you several significant advantages.



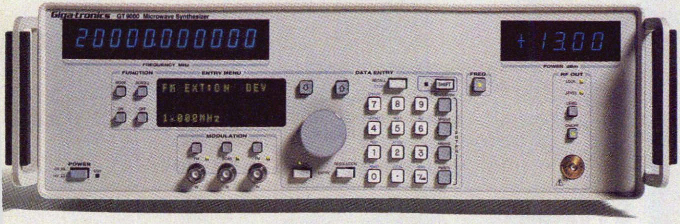
Harmonics are less than -65 dBc at +6 dBm and -55 dBc at +13 dBm for more accurate measurements over a wide bandwidth.

For example.

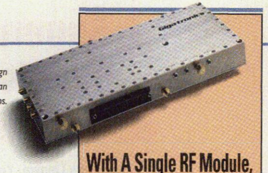
Phase noise at 2 GHz is -120 dBc/Hz at 100 kHz offset, making the GT 9000 ideal for measuring critical narrow-band characteristics such as adjacent channel sensitivity.

Output power is +13 dBm or greater from 10 MHz to 20 GHz. That's enough to overcome most system losses without adding the signal degradation and extra cost of external power amplifiers.

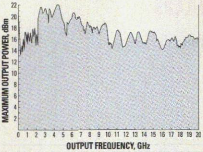
With harmonics less than -65 dBc at +6 dBm and -55 dBc at



The GT 9000 gives you outstanding performance and proven reliability at the lowest price available for a broad-band synthesizer.



The unique single RF module design is more reliable and less costly than multiple module designs.



Output power greater than +13 dBm lets you overcome most system losses without having to add external amplifiers.

With A Single RF Module, Less Is Significantly More

Most broad-band synthesizers use several RF modules for signal generation. The innovative single RF module design of the GT 9000 uses fewer parts and interconnections. This unique design yields higher performance, greater reliability and better serviceability, as well as less expensive manufacturing and testing. So you get significantly more for a lot less money.

+13 dBm, you can accurately test over a wide bandwidth with confidence that the measurements you make are a result of the system under test, and not your synthesizer.

And since more and more test applications require signals below 1 GHz, the GT 9000 starts with standard coverage from 500 MHz to 20 GHz. And if you need even lower frequencies, we've got a model that covers 10 MHz to 20 GHz.

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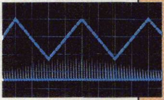

Use the built-in fast scan modulation option to generate complex patterns for simulating dynamic operating conditions.

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A Superminiaturized Double-Balanced SMT Mixer-Modulator

Masataka Osawa, Yukikazu Arai and **Yukihiro Ando**
Tasei Inc.
and
Takeshi Wada and **Michael Alan Stein**
Electro-Science Laboratories Inc.

Introduction

A new manufacturing method for a double-balanced mixer-modulator (DBM) using surface mount technology (SMT) is presented to meet the requirements of miniaturized size and high accuracy. The method is realized with a pair of phase transformers with multilayered coils of thick film. Generally, a computer simulation can give design results for a high frequency circuit and components, but simulation of the multilayered thick-film coil can not be accomplished. However, the optimum width and length of a conductor trace and the thickness and permittivity of insulating layers placed between the conductor traces has been investigated to create a transformer generating values for the DBM. A DBM for SMT application has successfully been developed. The compact size is 4.5 mm × 5 mm × 1.8 mm. Its conversion loss is less than 7 dBm for 0 dBm of the local input level at the 900 MHz band.

Thick-Film Materials

The requirements of this DBM were that the thick-film gold must be bondable, sharp printing, economical, and compatible with the other materials, especially the dielectric layers. The chosen gold thick-film material fires to 8 μm final thickness with a coverage of 90 cm^2/g and has a relatively flat surface for wire bonding. It is compatible with the chosen dense thick-film dielectric layers, which are designed to give a close expansion match to alumina.[1]

Shielding required the highest available conductivity with the lowest possible loss. The resistivity of the chosen silver thick-film material is less than 1.5 mΩ/square. at 12 μm fired thickness. Studies have shown that this material demonstrates very low loss in high frequency applications.[2] The chosen black overglaze protects the silver shielding layer, has an opaque black appearance, and provides acid resistance and a dense, vitreous surface.

The properties of the low dielectric constant insulating layers are critical to the design of the DBM. The fired properties of the utilized low k dielectric constant thick film are listed in Table 1. The dependencies of the dielectric constant and the dissipation factor of the utilized low k dielectric constant thick film are shown in Figures 1 and 2, respectively. The dependencies of dielectric constant and dissipation factor on frequency are shown in Figure 3.

[Continued on page 92]

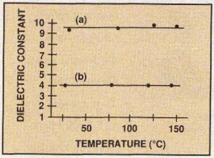

Fig. 1 Effect of temperature of dielectric constant at 1 MHz for (a) low k dielectric constant thick film and (b) the thick film dielectric.

TABLE I
FIRED PROPERTIES OF THE UTILIZED LOW k DIELECTRIC FILM CONSTANT THICK FILM

Dielectric constant at 1 MHz and after 10 refires	4.1 ± 5%
Dissipation Factor at 1 MHz	0.4 %
Insulation resistance at 100 V DC and after pressure cooker (15 min. @ 2 atm steam)	> 10^{12} Ω
Breakdown voltage	1650V/25μm

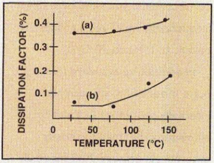

Fig. 2 Effect of temperature on dissipation factor for low k dielectric constant thick film at (a) 1 MHz and (b) 1 kHz.

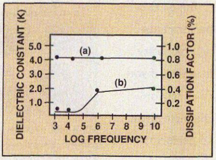

Fig. 3 Influence of frequency on (a) dielectric constant and (b) dissipation factor values for low k dielectric constant thick film.

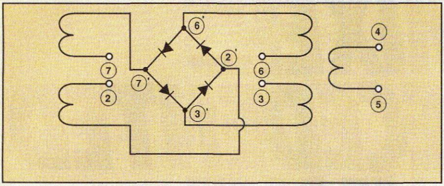

Fig. 4 Equivalent circuit of the double-balanced mixer.

The utilized low k dielectric constant thick film maintains a dielectric constant of near 4 over the frequency range from 1 KHz to nearly 10 GHz. The dissipation factor shows an increase from 0.05 percent to 0.4 percent at 1 MHz and remains essentially unchanged to 10 GHz.[3]

Phase Transformer Patterns

An equivalent circuit of the DBM is shown in Figure 4. It is designed to minimize the conversion loss in order to realize the best transmission and reflection characteristics of a pair of transformers in the desired frequency band. The phase transformer is fabricated with multilayered coils, which are insulated with dielectric layers on an alumina substrate by thick-film technology. Figure 5 shows the multilayer coils as well as a cross section of the printed and fired phase transformer.

First, the gold thick-film paste is printed and fired on the alumina substrate to form the pair of coils of 2 2' and 3 3', followed by printing and firing of the dielectric layer. The process is repeated, in the order of 1 8, 4 5 and 7 7' and 6 6' to construct the phase transformer. Each electrode of a leadless quad-diode with a forward voltage, V_f = 0.2 V, is wire-bonded to a terminal of 2', 3', 6' or 7' of the pair of phase transformers to complete the DBM.

The Measuring System

Figure 6 shows a block diagram of the measurement system for frequency characteristics, such as conversion loss, intercept point and isolation, for the DBM. The DBM is soldered to a 0.4 mm thick teflon substrate, and the measurement of isolation is done with RF port to LO port. Other measurements are also possible when unnecessary ports are terminated with a 50 Ω resistor.

Effects of the Width and Length of a Conductor Line

Figure 7 shows the relationship between frequency characteristic and conversion loss with the width of the conductor lines (coils). As the line width increases, the minimum value of the conversion loss shifts in the direction of higher frequency. This means that the phase trans-

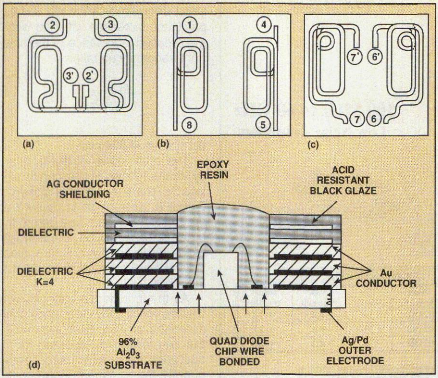

Fig. 5 The multilayer coils of the phase transformer; (a) the first layer with the pair of coils 2, 2', 3 and 3'; (b) the next layer with coils 1, 8, 4 and 5; (c) the next layer with coils 7, 7', 6 and 6'; and (d) the cross-section of the printed and fired phase transformer.

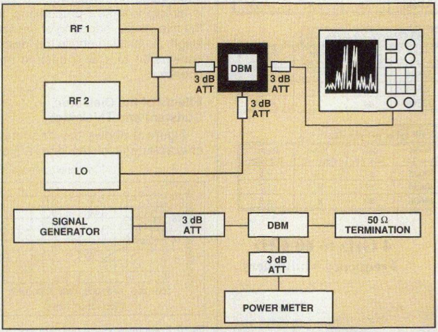

Fig. 6 The measurement system for frequency characteristics.

former, made of thick-film multilayers, is a resonance type transformer that includes not only pure inductance, but also capacitance. The inductance at the higher frequencies decreases with an increase of the line width, and the minimum value of the conversion loss moves to a higher frequency. Therefore, an adjustment of the line width can obtain the lowest loss point of the conversion loss at a de-

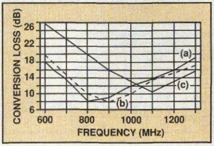

Fig. 7 Frequency vs. conversion loss for conductor coil line widths of (a) 0.1, (b) 0.15 and (c) 0.2 mm.

sired frequency. Although the capacitance increases with line width, the reduced inductance in the resonant frequency equation

$$f \propto \frac{1}{\sqrt{LC}}$$

dominates in this case.

The relationship of the frequency characteristic of the conversion loss vs. the line length is shown in Figure 8. The length is defined as the total length from one end to the other of a spiral line. Each length of the three coils is different, since the coils are crossed to connect to the diode.

As the inductance changes with the line length, the frequency characteristic is also changed. When the line length decreases, its inductance decreases, and consequently the minimum value of the conversion loss shifts in the high frequency direction. Because the frequency that results in the minimum value of the conversion loss is almost inversely proportional to the line length, adjusting of the line length is useful to obtain the lowest conversion loss at a desired frequency.

Effects of the Dielectric Constant and Thickness

Figure 9 shows the frequency characteristic of the conversion

[Continued on page 96]

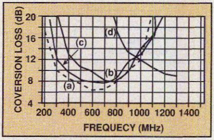

Fig. 8 Frequency vs. conversion loss for conductor coil line lengths of (a) 15.6, (b) 12.7, (c) 13.5 and (d) 6.7 mm.

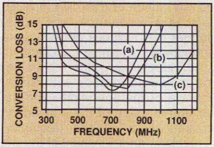

Fig. 9 Frequency vs. conversion loss for dielectric constants of (a) 10, (b) 7 and (c) 4.

loss vs. the dielectric constant of the insulation layer between the coils with dielectric thickness of 30 to 40 μm fired. As the dielectric constant decreases, the minimum value of the conversion loss shifts in the direction of higher frequency.

Figure 10 shows the frequency characteristic of the conversion loss vs. the thickness of the insulation layer between the coils, with a dielectric constant of 7. The frequency characteristic is a function of the capacitance derived from the thickness of the dielectric layers. The thicker the dielectric layer, the lower the capacitance, which results in a shift of the minimum value of the conversion loss of higher frequency. However, the use of thicker dielectric layers weakens the interaction in the coils and the conversion loss tends to increase. Therefore, it is important to make the dielectric layer as thin as possible, minimizing pinholes and maintaining good insulation between the coils with the use of an available dielectric material of lower dielectric constant to realize high frequency operation of 1.5 to 1.9 GHz.

Result of Trial Production

When a multilayered transformer is formed with the use of printed and fired coils and dielectrics, the transformer is of the resonance type because it contains not only pure inductance but also capacitance. In a DBM with the resonance type phase transformer, the frequency characteristic is important.

It is necessary to optimize the width and length of the coils. The permittivity and thickness of the dielectric layers must also match the frequency characteristic of a phase transformer with the desired operating frequency.

A trial production of a DBM targeted at a center frequency of 900 MHz was completed. Critical components of the prototype DBM of are 96 percent alumina substrate, with a thickness of 0.635 mm; gold conductor paste with width = 200 μm; length = 15 to 16 mm; 20 μm (fired) thick dielectric paste; and the diode with $V_f = 0.2$ V.

In Figure 11, the conversion loss of 7 dB or less is obtained for the 900 ±100 MHz band. A conventional DBM consisting of a wire coiled around a ferrite core has a broader band of conversion loss than that of the thick film DMB, which is a resonance type transformer. However, it is unnecessary to have a band width larger than that of our thick-film DBM for practical use. The shown conversion loss is sufficiently low for practical use. Furthermore, the transformer with thick-film technology has the property of a filter, which can suppress undesired input/output signals.

Figure 12 shows the isolation property (IP) differences for each port. However, this does not interfere with practical use. Also, the DBM is operated at the power of the local oscillator (LO = 10 dBm), which can prolong the life of a battery cell. Figure 13 shows the local input power vs. conversion loss, while Figure 14 shows output characteristics including IP of 12.5 dBm and a 1 dB compression of −0.5 dBm. Figure 15 is a photograph of the DBM. It is 4.5 mm long, 5 mm wide and 1.8 mm thick.

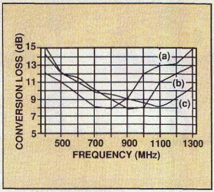

Fig. 10 Frequency vs. conversion loss for dielectric thickness of (a) 3, (b) 75 and (c) 90 μm.

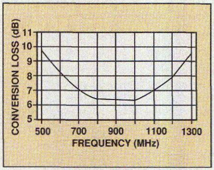

Fig. 11 Frequency vs. conversion loss for the DBM with LO=8 dBm and IF=90 MHz.

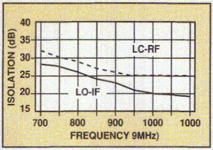

Fig. 12 Frequency vs. isolation for the DBM.

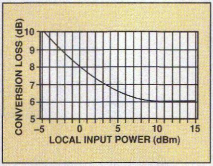

Fig. 13 Local input power vs. conversion loss for the DBM.

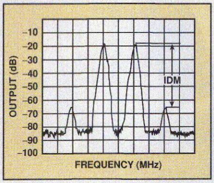

Fig. 14 Output characteristics of the DBM with the intermodulation distortion (IMD) of 46 dB indicated.

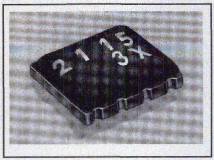

Fig. 15 A photograph of the double-balanced mixer.

Conclusion

A new, miniaturized DBM with the phase transformer coil made by thick-film technology has been developed. The resulting electrical properties are sufficient for practical use and can contribute to the miniaturization of mobile communication equipment. The DBM can be applied not only as a frequency converter, but possibly as a high speed switch, an attenuator, a frequency multiplier, or an orthogonal modulator.

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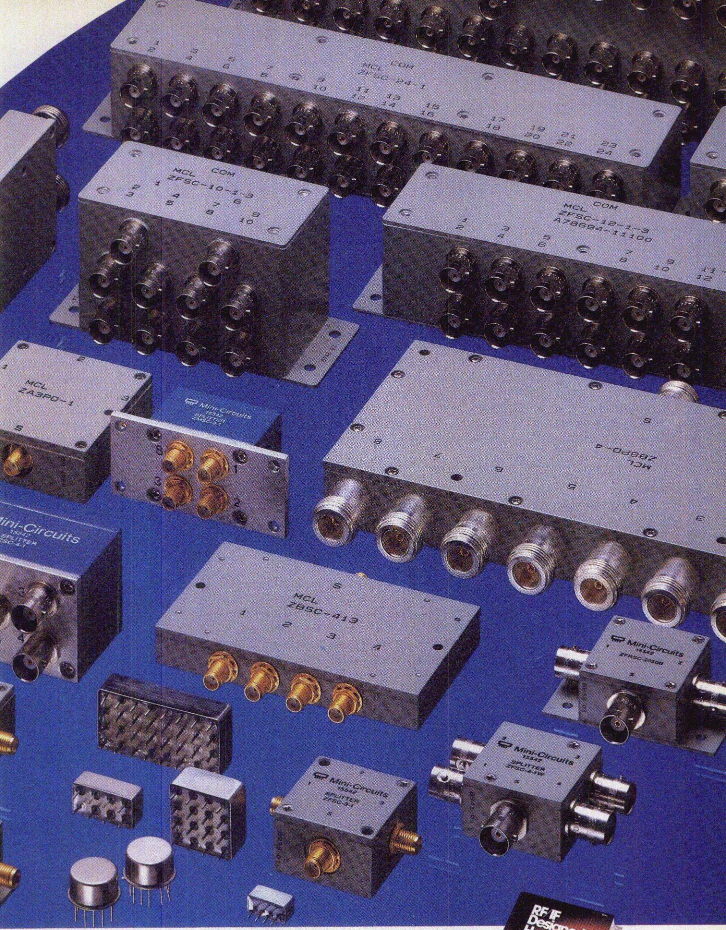

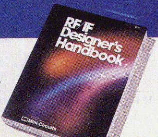

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An Alternative Stability Factor for Amplifier Design

A.J. Slobodnik, Jr. and **R.T. Webster**
Electromagnetics and Reliability Directorate
Rome Laboratory, Hanscom AFB

An alternative amplifier stability factor is presented. Compared to the traditional stability factor, this alternative can assist in the design process by providing a definitive indication of stability. This indication permits stability circle plotting to be focused on only those frequency ranges where further investigation or insight is needed. This advantage is obtained by including effects of the source or load reflection coefficient in the stability factor. In addition, the alternative stability factor works equally well with active and passive sources and loads. It is computed separately for network input and output from S-parameters and is conveniently implemented using commercial computer-aided design software.

Introduction

Stability is an important consideration when designing an amplifier.[1-3] Both the overall amplifier and each individual stage must be determined to be stable.[4,5] Unless the traditional stability factor[6] k in conjunction with[4] B_1 indicates that a network is unconditionally stable, and both a passive source and load are expected, stability circles must be computed.[2] These circles are then displayed simultaneously with the source and load reflection coefficients. This process can be tedious, particularly since k tends to predict false alarms, that is, frequencies at which the network is not unconditionally stable, but is in fact stable when operated within the range of expected source and load reflection coefficients. An alternative stability factor K_A is presented that provides a definitive indication of stability and permits the design engineer to concentrate stability circle investigations on those frequency ranges where further insight is needed.

Alternative Stability Factor

Figure 1 shows a Smith chart and source plane stability circle, including the source reflection coefficient with uncertainty radius δ_s and other parameters of interest. For simplicity purposes, it is assumed temporarily that the stable region is outside of the circle. The vector to the center point of the stability circle is given by[1]

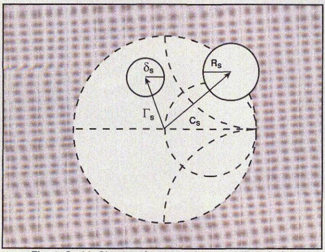

Fig. 1 Smith Chart and source plane stability circle.

$$C_s = \frac{S_{22}\Delta^* - S^*_{11}}{|\Delta|^2 - |S_{11}|^2} \qquad (1)$$

and the radius of the stability circle by[1]

$$R_s = \left| \frac{S_{12}S_{21}}{|\Delta|^2 - |S_{11}|^2} \right| \qquad (2)$$

where

$\Delta = S_{11}S_{22} - S_{12}S_{21}$

For this circuit to be stable, the source reflection coefficient Γ_s, with any associated uncertainty δ_s, must lie outside the circle. From straightforward geometric considerations, it can be seen that this condition is met if the magnitude of the difference vector between C_s and Γ_s is greater than $R_s + \delta_s$.

Therefore, the input alternative stability factor can be defined as

$$K_{AS} = \left(\frac{|C_s - \Gamma_s|}{R_s + \delta_s} \right)^{P_s} \qquad (3)$$

The exponent P_s is introduced to account for the general case where either the outside or the inside of

[Continued on page 102]

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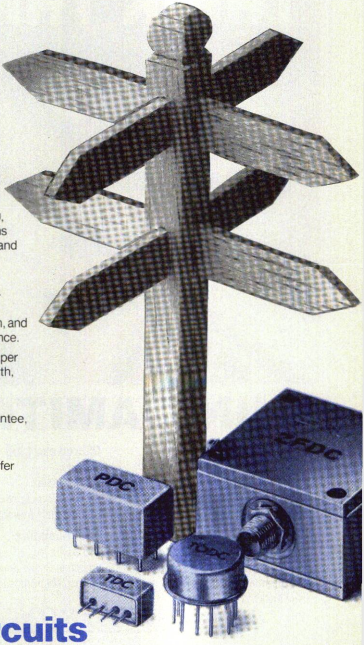

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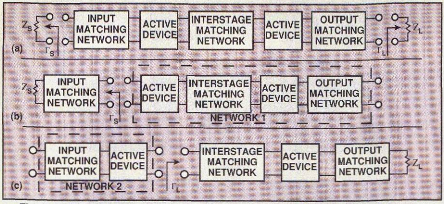

Fig. 2 (a) The two-stage amplifier; and additional circuitry (b) for checking input stability of first stage and (c) for checking output stability of first stage.

the stability circle corresponds to the stable region. P_s is determined by computing

$$S'_{22} = S_{22} + \frac{S_{12}S_{21}\Gamma_p}{1 - S_{11}\Gamma_p} \quad (4)$$

where

Γ_p = a test point chosen inside the stability circle

If $|S'_{22}| > 1$, then following definition of a stability circle, the outside of the circle is the stable region. $P_S = +1$ is then used. Otherwise, if $|S'_{22}| < 1$, the inside of the circle is the stable region and $P_S = -1$. The output alternative stability factor K_{AL} is determined in a similar manner. A definitive indication of stability is then provided as for $K_{AS} > 1$ and $K_{AL} > 1$, the network is stable under the given source and load conditions, and for $K_{AS} < 1$ or $K_{AL} < 1$ the network is unstable.

These conditions correspond as much as possible to those of the traditional stability factor, thus preserving the designer's intuitive analysis of a given design. As in the traditional analysis where two parameters, that is k and B_1, are required for a determination of stability, the two parameters K_{AS} and K_{AL} are necessary and sufficient in this design.

Example

The usefulness of the alternative stability factor can be shown with an example. Figure 2 shows the two-stage amplifier and the additional circuitry necessary for checking input and output stability of the first stage. Overall amplifier stability is evaluated in the usual manner with Γ_S and Γ_L based on the source and load impedances expected in the given application. In addition to overall amplifier stability, the stability of each individual stage should be checked.

Network 3, used for checking input stability of the second stage, consists of the active device and output matching network. The source termination is comprised of Z_S cascaded with the input matching network, active device and interstage matching network. Network 4, used for checking output stability of the second stage, is

[Continued on page 104]

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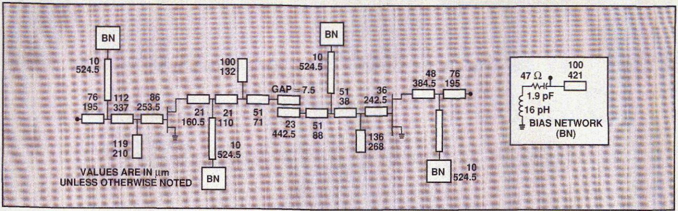


Fig. 3 Circuit element for the InP HEMT low noise amplifier design.

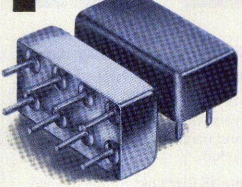
TABLE I
COEFFICIENTS TO DETERMINE MAGNITUDE AND ANGLE OF ACTIVE DEVICES PARAMETERS

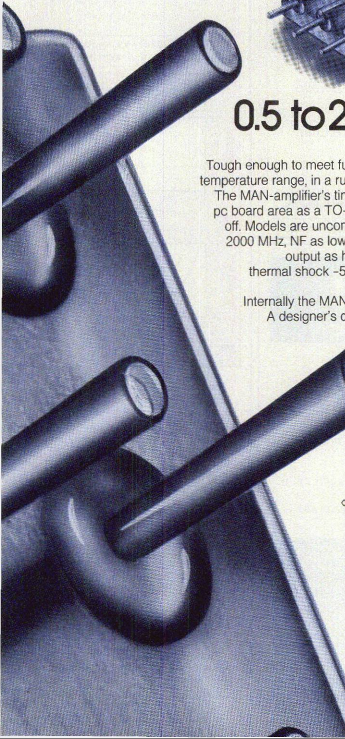
	Magnitude		
	C_0	$C_1 \times 10^2$	$C_2 \times 10^5$
S_{11}	1.0406	−0.4918	1.4032
S_{21}	2.9558	−2.6351	1.4235
S_{12}	0.0011	0.2508	−1.8808
S_{22}	0.6574	−0.1700	0.9614
	Angle		
	$C_0 \times 10^{-2}$	C_1	$C_2 \times 10^2$
S_{11}	0.0085	−2.4012	1.2751
S_{21}	1.8059	−2.1369	1.0175
S_{12}	0.9023	−1.3393	0.8765
S_{22}	0.0031	−1.4979	0.5671

made up of the input matching network, active device and interstage matching network. The active device, output matching network and Z_L cascade acts as the load termination.

To implement these networks, a 60 GHz indium phosphide high electron mobility transistor (InP HEMT) low noise amplifier design[7] was chosen. Figure 3 shows the circuit elements. Tapers to 19 µm at gates and from 10 µm at drains are not shown. The bias network node indicates both RF and DC connection point. The substrate is 100 µm thick. The active device S-parameters listed in Table 1 are used for both stages in all cases. The expression $C_0 + C_1 \times f_{GHz} + C_2 \times f^2_{GHz}$ is used to calculate

[Continued on page 106]





these parameters. Throughout this example, $Z_S = Z_L = 50\ \Omega$.

Stability vs. frequency for the overall amplifier is shown in Figure 4. Figures 5 and 6 show the amplifier first and second stage stability, respectively. K_{AS} and

[Continued on page 109]

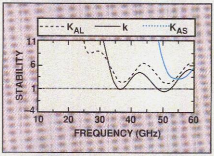


Fig. 4 Stability vs. frequency for the overall amplifier.

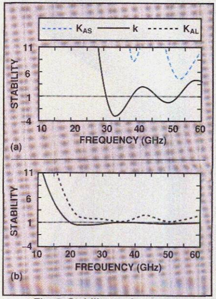


Fig. 5 Stability vs. frequency for the first stages of the networks for checking (a) input and (b) output stability.

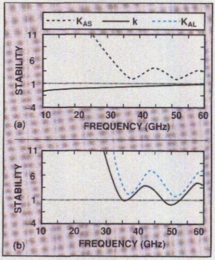


Fig. 6 Stability vs. frequency for the seconds stages of (a) network 3 and (b) network 4.

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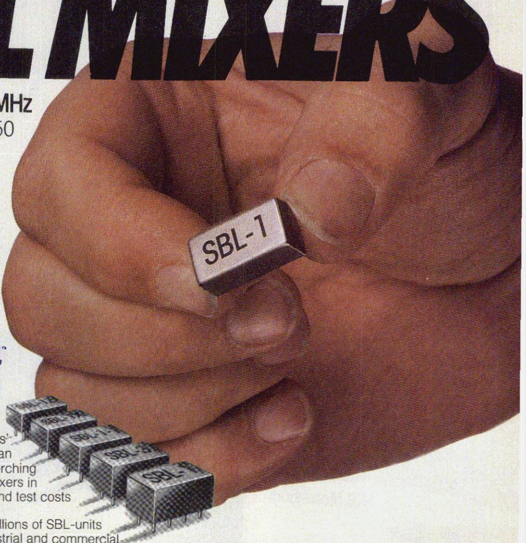

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SBL-1Z	10-1000	6.5	35	25	+7	7.25
SBL-1-1	0.1-400	5.5	35	40	+7	7.25
SBL-3	0.025-200	5.5	45	40	+7	7.25
• SBL-11	5-2000	7.0	35	30	+7	18.75
SBL-1LH	2-500	5.8	68	45	+10	5.50
SBL-1-1LH	0.2-400	5.2	64	52	+10	8.25
• SBL-1XLH	10-1000	6.0	40	55	+10	7.25
SBL-2LH	5-1000	5.9	61	54	+10	8.25
SBL-3LH	0.07-250	4.9	60	53	+10	8.25
• SBL-11LH	5-2000	7.0	45	30	+10	19.75
SBL-1MH	1-500	5.5	45	40	+13	9.80
SBL-1ZMH	2-1100	6.5	40	25	+13	11.70

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[From page 106] **SLOBODNIK**

K_{AL} are greater than one over the full frequency range, including those regions where k indicates potential instability. The alternative stability factor shows that for the source and load impedances expected here, the overall amplifier and the individual stages will be stable. For those instances where K_{AL} is very close to one, further study can be undertaken by plotting stability circles and design modifications can be considered if appropriate.

Conclusion

An alternative amplifier stability factor has been presented. It can provide definite advantages over traditional stability analysis, especially in cases where unconditional stability is not required for all passive source and load impedances. Specifically, the factor can assist in the design process by quickly focusing attention on frequency ranges in need of further investigation and stability circle plotting. These advantages are accomplished by incorporating effects of the source or load reflection coefficient into the stability factor. In addition, the alternative stability factor works equally well with active and passive sources and loads. The factor is computed separately for network input and output.

Choosing larger values for δ_S and δ_L results in more conservative stability criteria. For example, where an amplifier must remain stable for any passive load impedance, simply set $\Gamma_L = 0$ and $\delta_L = 1$. Source conditions may be evaluated independently. Alternative stability factor analysis is determined from circuit S-parameters and is readily implemented using commercial computer-aided design software. Finally, it preserves as much as possible the designer's intuitive experience, that is, $K_A > 1$ indicates stability and $K_A < 1$ means instability. ■

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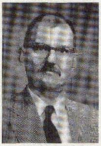

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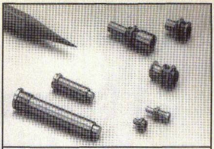

A Compact Oscillator Integrated in a Microstrip Patch Antenna

T. Razban, H. Frances, B. Robert and **A. Papiernik**
Université de Nice, Sophia Antipolis
Valbonne, France

The realization of an active antenna composed of a reflection amplifier and a notch patch radiating surface, which also acts as the resonant load, is discussed. Free oscillations are obtained by only one packaged microwave bipolar transistor directly integrated onto the radiating surface. Different configurations of the transistor assembly are studied to satisfy the oscillation conditions and frequency stability. An output power of 9 mW is measured at a frequency of 1.77 GHz.

Introduction

Active antennas incorporating oscillators are becoming of great interest.[1,2] In many antennas of this type, the active circuits are placed behind the ground plane and coupled to the antenna across via pins or apertures in the ground plane.[3] The advantage of these structures lies in the fact that spurious radiation from the active circuits and from the microstrip distributing network is negligible. Nevertheless, they use a multilayer technology that is incompatible with many industrial applications. Earlier presented works have mainly integrated the active components on the same face as the radiating element. In this case, the active circuit must be as simple as possible so as not to affect the radiation pattern. An oscillator circuit may be simple for high microwave frequencies where a nonlinear element, like a diode or a transistor, oscillates under an applied DC voltage. However, in low microwave or radio frequencies, the simplicity of an oscillator depends on the technique employed.

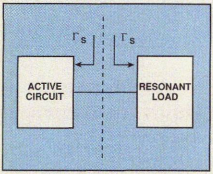

Fig. 1 An oscillator using an active circuit and a resonant load.

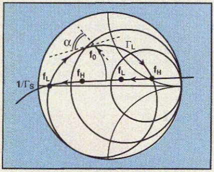

Fig. 2 Phase variation of $1/\Gamma_S$ and Γ_L for frequency stability of an oscillator.

This paper describes an active patch antenna that uses a bipolar transistor as a reflection amplifier. The transistor is placed on the same face as the radiating element. It has been shown that a transistor may affect the radiation pattern far less than passive components, such as matching stubs, bias circuits and bends.[4,5] The oscillation with f_0 = 1.77 GHz is realized in the unstable region of the amplifier where the wave reflection ratio is greater than one. This compact active antenna exhibits high gain, high frequency stability and a relatively low level of cross-polar radiation.

Oscillator Design

A previously described simple method that is compatible with S-parameter analysis is used.[6] Suppose an oscillator is a union of an active circuit with Γ_S as reflection coefficient and a resonant load with Γ_L as reflection coefficient, as shown in Figure 1. Free oscillations will be generated if the conditions of $|1/\Gamma_S| < |\Gamma_L|$ and ang $(1/\Gamma_s)$ = ang (Γ_L) are not violated.[6]

Beginning with these conditions, the magnitude of the oscillation will increase to equality between $1/\Gamma_S$ and Γ_L. To satisfy these conditions, Γ_L is the reflection coefficient of a passive circuit, that is, less than unity, and Γ_S must be greater than one, that is, an active circuit in its unstable region. The oscillation has a stable frequency f_0 if the phase variation vs. frequency of Γ_L and $1/\Gamma_S$ are in opposite directions, as shown in Figure 2. The phase stability of the oscillator depends on the angle α between the magnitude variation of $1/\Gamma_S$ at $f_0(d(1/\Gamma_S)/dA)$ and the frequency variation of Γ_L ($d\Gamma_L/dF$). With α = 90°, the stability is maximum.

When the phase variation vs. frequency Γ_L and $1/\Gamma_S$ are in opposite directions, the oscillation frequency will be between f_L and f_H. The exact frequency may be determined if $1/\Gamma_S$'s magnitude variation is known. In a resonant load with high quality factor Q, f_H-f_L area is small, and the resonant frequency is more precisely determined.

In the proposed design, the antenna plays the role of the resonant load. Therefore, the reflection coefficient at the antenna input must satisfy the conditions described for the phase variation of $1/\Gamma_s$ and Γ_L. In general, to obtain a desired input impedance, a quarter-wave transmission line is used, or the antenna is fed in a nonradiating edge point having the desired input impedance. Using a quarter-wave transmission line requires extra room on the substrate and

[Continued on page 112]

may be cumbersome when the antenna is mounted in an array. Generally, feeding an antenna in a nonradiating edge point creates an undesirable cross polarization level.[7] A probe through the substrate to connect the transistor placed behind the ground plane to a point of the radiating surface with the desired input impedance is another solution. This solution is achieved in multilayer active antennas.

A particular patch antenna is used in which the active circuits are placed in a removed part of the radiating surface, and the bias lines are etched in the ground plane. In the proposed solution, by removing a part of the radiating surface, as shown in Figure 3, the desired impedance is attained without a significant increase in the cross polarization level. The transistor is placed directly in the removed part (notch), and no other area is occupied by the active circuit.

The theoretical and experimental results on this kind of antenna show that the impedance variation, according to the feed point distance from the edge of the patch radiator, is almost the same as a coaxial feed rectangular patch radiator. A study with the moment method[8] shows that the input resistance depends on the length of the notch X and on its width S. Figure 4 gives theoretical results

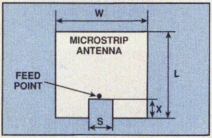

Fig. 3 Geometry of the antenna.

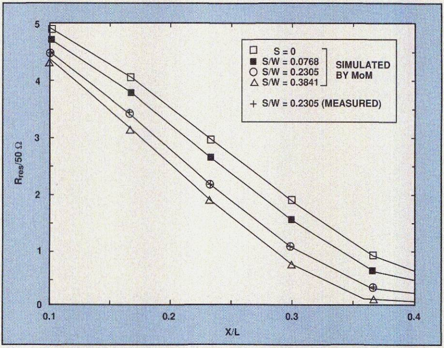

Fig. 4 Normalized resonant input resistance for a patch radiator with notch; W = L = 60 mm, $\varepsilon_r = 2.2$, h = 1.6 mm and tg $\delta = 0.001$.

showing the resonant input resistance vs. notch length for different values of notch width. There is good agreement between the measured resonant resistance and the simulation.

The width of the notch is chosen to enable the transistor integration and to avoid wave coupling between active parts and the radiating element. The deep size X is chosen to match the input resistance of the antenna to the desired value for the active circuit. Radiation patterns are nearly the same in a notched feed patch or in a full patch antenna.

Experiments of Several Configurations

With a transistor as active module, the resonant load may be connected to the collector, to the emitter or to the base of the transistor. These configurations have been developed, and their advantages and drawbacks have been observed.

In the case of the antenna connected to the collector, a loop was measured in the $1/\Gamma_S$ curve. This configuration yields oscillator lock-up modes[6] and must be avoided. In some cases, by using another transistor or by adding stubs or lines, the loop may disappear. Nevertheless, because a simple circuit without extra stubs or lines is desired, this configuration is abandoned.

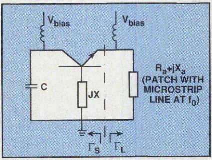

Fig. 5 Series feedback oscillator configuration.

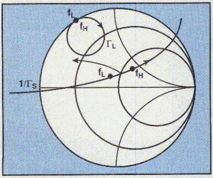

Fig. 6 Reflection coefficients of the amplifier and the antenna with $R_a < 50\ \Omega$.

In the case of the antenna connected to the base, a reflection amplifier may be realized with a transistor set in the common emitter position. The reflection coefficient is measured in the base and the resonant circuit, for example, the antenna, is connected to it. Using this configuration, codirectional phase variations are measured for $1/\Gamma_S$ and Γ_L. Thus, the oscillation might not be stable. As a solution, the Γ_L curve may be rotated by inserting a microstrip line between the transistor and the antenna. However, this is inconsistent with a compact antenna realization.

When the antenna is connected to the emitter, the transistor is set in the common base configuration. The antenna is connected to the emitter of the transistor, as shown in Figure 5. According to the antenna impedance, two cases, $R_a < 50\ \Omega$ or $R_a > 50\ \Omega$ are possible.

When $R_a < 50\ \Omega$, $1/\Gamma_S$ and Γ_L, as shown in Figure 6, have a contradirectional phase variation vs. the frequency. The oscillation is not ensured, that is, the magnitude variation of $1/\Gamma_S$ may replace its frequency positions. Because of the loop in Γ_L curve, the coincidence may not occur. As a solution, the curve may be rotated by inserting a microstrip line between the transistor and the antenna. However, this is inconsistent with a compact antenna realization.

When $R_a > 50\ \Omega$, $1/\Gamma_S$ must pass below the center point of the Smith chart. This is possible if the collector is immediately connected to the ground plane through a capacitor C (470 pF). $1/\Gamma_S$ and Γ_L, as shown in Figure 7, have a contradirectional phase variation vs. frequency. The oscillation is ensured and frequency is stable. The oscillator circuit is optimized by a microwave CAD package. The length of the microstrip line connected to the base modifies the frequencies f_L and f_H in the $1/\Gamma_S$ plot. The position of $1/\Gamma_S$ in the Smith chart is controlled by the collector circuit.

This configuration is used to realize the active antenna. The layout of the radiating face with the dimensions of W = 58 mm, L = 56.5 mm, S = 14 mm, X = 12.5 mm, h = 1.6 mm, $\varepsilon_r = 2.2$ and tgδ = 0.008 is shown in Figure 8. The emitter leads are connected to the patch radiator through a microstrip line. The base is soldered to a high impedance line and the connector is soldered to the ground plane through a capacitor. The bias circuit is connected to the collector by a probe through the substrate. The emitter bias voltage is applied to the patch center, where the electric field is equal to zero. A high purity

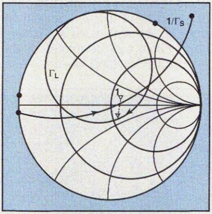

Fig. 7 Measured reflection coefficients of the antenna and the amplifier with $R_a > 50\ \Omega$.

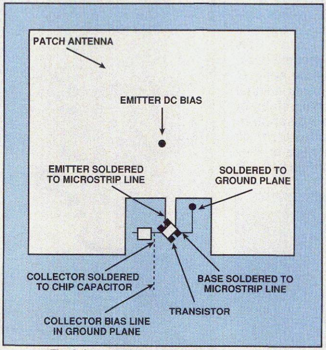

Fig. 8 Layout of the active radiating element.

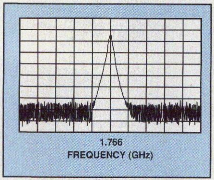

Fig. 9 Free running spectrum with span of 20 MHz.

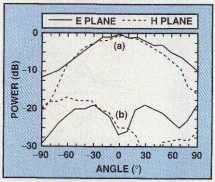

Fig. 10 (a) Copolar and (b) crosspolar radiation patterns.

and stable oscillation is obtained at 1.77 GHz, as shown in Figure 9. The radiating power is measured. Using the Friis formula, the output power is calculated at 9 mW. The radiation pattern of the antenna, shown in Figure 10, shows negligible variations compared to a passive antenna but a higher cross polarization field (–18 dB).

Conclusion

A similar design, in which the oscillator has a patch antenna in the feedback circuit, has been previously discussed.[3] The amplifier's and feedback's gain must be greater than unity, and their total phase must be zero at the oscillation frequency. In the realization, the active circuits are placed behind the ground plane and coupled to the antenna across via pins.

In this paper, the design incorporates an oscillator where the transistor works in its unstable region. The design method is different from the previously described configuration, and free oscillations will be generated if certain conditions are met. Additionally, the new design integrates the oscillator on the same layer as the patch antenna. The geometry of the antenna is modified to integrate the bipolar transistor and its passive parts directly onto the radiating surface. The obtained active antenna is not as bulky as the passive one, and avoids the use of multilayer technology. ■

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An Oscillator with a Gunn Diode Integrated in a Dielectric Resonator

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Introduction

Early oscillators involved a Gunn or Impatt diode matched in a waveguide and frequency controlled with a hollow cavity coupled to the waveguide.[1] In order to decrease size, dielectric resonators consisting of low loss, high permittivity ceramic disks have been used.[2] Figure 1 shows how these resonators are commonly coupled to the oscillator's active element, usually a transistor, through a microstrip line.

The transistor's nonlinear parameters are often not provided by the manufacturer. Moreover, the transistors suffer large dispersions, which makes it impossible to predict where along the coupling line the dielectric resonator should be located. Therefore, this line must be given some extra length to allow for tuning, which is as much wasted space.

In an effort to design an even smaller structure, namely to decrease the amount of space necessary for the coupling of the resonator, an oscillator was designed, whose active element is integrated inside a dielectric resonator. The resonant frequency of a cylindrical cavity partially filled with dielectric material is computed. A Gunn diode oscillator is then presented that delivers a pulsed peak power of over 3 W at 5.5 GHz.

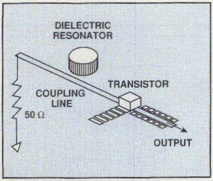

Fig. 1 A dielectric resonator oscillator on microstrip.

The Cavity

Dielectric resonators are commonly used in microstrip oscillators and filters, in which their $TE_{01\delta}$ mode is resonated.[2] They are also available with a center hole, in which the E-field of this mode is practically zero, for attaching in microstrip filters with nylon screws, for example, or to integrate a Gunn diode, as shown in Figure 2. The ceramic disk is enclosed in a cylindrical metal cavity. The diode is held to the cavity's floor by a standard filter tuner screwed through the cavity's lid. A bias voltage is applied between the floor and lid. A film of Kapton*, a polyimide film used for DC isolation purposes in metal cavity oscillators, is sandwiched between these two parts, so as to isolate them for each other as seen from the bias source. An RF short is thus formed that preserves the resonating modes of the original closed cavity.

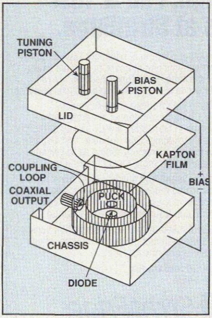

Fig. 2 A dielectric resonator oscillator in cavity.

The Gunn diode excites the TM_{010} mode of the cavity, working as a current source, in which the mode's H-field is normal to the current. The H-field transfers the generated energy to the load, through a vertical loop soldered between the output SMA connector and the cavity's side wall. A second tuner is used for matching the coupling loop to 50 Ω.

In order to determine the parameters of the loaded cavity for obtaining the desired oscillation frequency, the resonant frequency of the TM_{010} mode is computed. For this purpose, the Gunn diode and tuner's rotor are taken to be a single metal rod that has a diameter equal to the diameter of the center hole of the dielectric resonator.

The fields of a resonating mode are derived from the wave function U, which is a solution of the scalar Helmholtz equation given in cylindrical coordinates[3] as

$$\frac{1}{R}\frac{d}{dR}\left(R\frac{dU}{dR}\right)+\frac{1}{R^2}\frac{d^2U}{d\Phi^2}+\frac{d^2U}{dz^2}=0 \quad (1)$$

*Kapton is a trademark of the DuPont Co.

A general solution to Equation 1 is

$$U = \begin{Bmatrix} A_1 J_n(K_r \bullet R) + A_2 Y_n(K_r \bullet R) \\ A_3 J_n'(K_r' \bullet R) + A_4 Y_n'(K_r' \bullet R) \end{Bmatrix} \bullet \begin{Bmatrix} \cos(n \bullet \Phi) \\ \cos(n' \bullet \Phi + \Phi_0) \end{Bmatrix} \bullet \begin{Bmatrix} A_5 \sin(K_z \bullet Z) + A_6 \cos(K_z \bullet Z) \\ a < R < b \\ A_7 \sin(K_z' \bullet Z) + A_8 \cos(K_z' \bullet Z) \\ b < R < d \end{Bmatrix} \quad (2)$$

where

$$K_r'^2 + K_z'^2 = K_o^2 = \omega^2 \mu_o \varepsilon_o$$
$$K_r^2 + K_z^2 = \varepsilon_r K_o^2 \quad (3)$$

n, n' = integer numbers
J_n = Bessel function of the first kind
Y_n = Bessel function of the second kind
ε_r = relative permittivity of the ceramic disk resonator

The phase origin Φ=0 can be set anywhere in the plane Z=0.

A_1 to A_8 are determined by the boundary conditions on the fields. In any homogeneous region, fields of a general TM mode are given by

$$E_r = \frac{1}{j\omega\varepsilon} \frac{d^2U}{dR\,dz}$$
$$E_\Phi = \frac{1}{j\omega\varepsilon\, R} \frac{d^2U}{d\Phi\, dz}$$
$$E_z = \frac{1}{j\omega\varepsilon}\left(\frac{d^2}{dz^2} + K^2\right) U$$
$$H_r = \frac{1}{R}\frac{dU}{d\Phi}$$
$$H_\Phi = -\frac{dU}{dR}$$
$$H_z = 0 \quad (4)$$

Conditions at the boundaries shown in Figure 3 are applied to the fields in Equation 4, where U is given by Equations 2 and 3 and therefore

$$E_r(Z=0) \equiv E_r(Z=h) \equiv 0 => $$
$$\begin{cases} A_5 = 0 \text{ and } K_z = q\,\pi/h,\ q = 0,1,2\ldots \\ A_7 = 0 \text{ and } K_z' = q'\,\pi/h,\ q' = 0,1,2\ldots \end{cases} \quad (5)$$

and one can arbitrarily set

$$A_6 = A_8 = 1 \quad (6)$$

$$E_z(R=b^-) \equiv E_z(R=b^+) =>$$
$$n = n', \quad (7)$$
$$q = q', \quad (8)$$

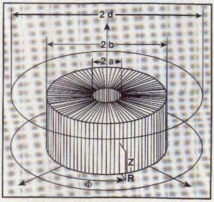

Fig. 3 Geometry of the cavity.

$$K_r^2\left(A_1 J_n(K_r \bullet b) + A_2 Y_n(K_r \bullet b)\right) =$$

$$\varepsilon_r K_r'^2\left(A_3 J_n(K_r' \bullet b) + A_4 Y_n(K_r' \bullet b)\right) \qquad (9)$$

and one can arbitrarily set:

$$\Phi_0 = 0 \qquad (10)$$

$$E_z\left(R = a^+\right) \equiv 0 => A_1 J_n(K_r \bullet a) + A_2 Y_n(K_r \bullet a) = 0 \qquad (11)$$

$$E_z\left(R = d^-\right) \equiv 0 => A_3 J_n(K_r' \bullet d) + A_4 Y_n(K_r' \bullet d) = 0 \qquad (12)$$

$$H_\phi\left(R = b^-\right) \equiv H_\phi\left(R = b^+\right) =>$$

$$K_r\left(A_1 J'_n(K_r \bullet b) + A_2 Y'_n(K_r \bullet b)\right) =$$

$$K_r'\left(A_3 J'_n(K_r' \bullet b) + A_4 Y'_n(K_r' \bullet b)\right) \qquad (13)$$

where

J'_n = derivative of J_n
Y'_n = derivative of Y_n

$$E_\phi\left(R = a^+\right) \equiv E_\phi\left(R = d^-\right) \equiv 0 => \text{either } n = 0 \text{ or } q = 0, \qquad (14)$$

Equations 9, 11, 12 and 13 have a nontrivial solution for the coefficients $A_1 \ldots A_4$ only if their determinant D vanishes.
Setting

$$n = q = 0 \qquad (15)$$

and solving

$$D = 0 \qquad (16)$$

for the lowest ω, with

$$K_r = \varepsilon_r^{1/2} K_0 \text{ and } K_r' = K_0 \qquad (17)$$

from Equations 3, 5, 8, 15 yields the resonance frequency of the TM_{010} mode. From Equation 17, K_r^2 and $\varepsilon_r K_r'^2$ fall out in Equation 9, as well as K_0 in Equation 13.
In Equation 13 one has:

$$J'_0 = -J_1 \text{ and } Y'_n = -Y_1 \qquad (18)$$

J_0, J_1, Y_0, Y_1 are computed using polynomial approximations.[4]

Determinant D is obtained through a matrix LU decomposition, and Equation 16 is solved using the bisection method.[4] In order to carry out these calculations, a short Fortran computer program was written.

The Oscillator

A prototype oscillator, shown in Figure 2, was built using a standard dielectric resonator with 2a = 2mm, 2b = 9.525 mm, h = 4.35 mm and ε_r = 36.3. It was glued with a little epoxy to the cavity's lid. A Gunn diode packaged in a custom-made case, given for a

[Continued on page 120]

pulsed bias current of 4 A, a pulsed bias voltage of 45 V and a pulsed output power of 5 W or greater between 5 and 8 GHz when tested in a hollow waveguide structure, was used. A standard tuner w-*ith a diameter of 2 a' = 1.83 mm for the tuning rotor and a brass cavity with 2d = 15 mm and external dimensions 23 × 23 × 11.3 mm, excluding the SMA connector, were also used.

Equation 16 was solved for these parameters, in which 2a' was approximated to 2 mm, yielding a resonant frequency f = 4.3 GHz. When fired up the diode drew up 3.2 A under 46 V, at the rate of 1000 pulses/s. The pulse width was a half μs.

The Gunn diode was protected from bias voltage surges with a transient voltage suppressor (TVS). The TVS works like a Zener diode, but has a stepper reverse I-V curve, and withstands higher peak currents.[5] When the voltage and current pulses were measured, the average power during one pulse was 3.2 W, centered about f = 5.55 GHz.

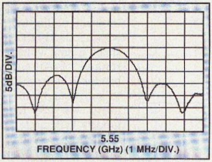

Fig. 4 Spectrum of the output signal.

The diode generates less power in the present configuration than in the test fixture used by the manufacturer because the dielectric losses of the dielectric resonator add to the conductivity losses of the cavity walls. The discrepancy between simulated and measured f may be attributed to two things. The output coupling loop and the piston used for matching it were not accounted for in the model. Including these two elements in the model of the oscillator would be mathematically so involved that it would take more time than building and testing an actual device.

Moreover, the Gunn diode was modeled into a metal rod, and its impedance ignored in the analysis. The design has to accept this crude approximation because the manufacturer does not provide data on the diode's impedance, which is difficult to measure. This limitation makes a more accurate model even less feasible.

Figure 4 shows the detected, generated RF signal's spectrum. The mainlobe bandwidth is 4 MHz = 2/(0.5 μs);[6] mainlobe zeros are below –22 dBc; secondary lobes maxima are below –12 dBc (for a theoretical –13 dBc); and second harmonic is below –28 dBc.

Conclusion

A dielectric resonator oscillator with an integrated Gunn diode was presented and tested. Integration was pushed to the extreme, still allowing for good performance.

Acknowledgment

The authors wish to thank SAT for supporting their research, and Chuck Vozzella from M/A-COM, Burlington, MA for providing them with custom-made samples.

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Franck Bachelot*graduated from the LTP La Baronnerie in 1986, with an advanced technician degree. Since that time, he has been working as a senior R&D technician at SAT, Paris, on the design of switching power supplies, high voltage modulators for magnetrons, and logic circuitry.*

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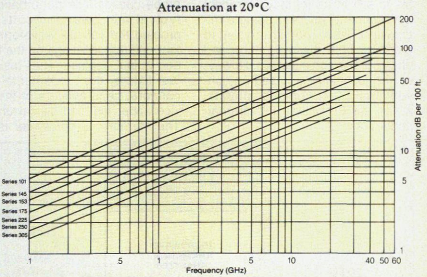

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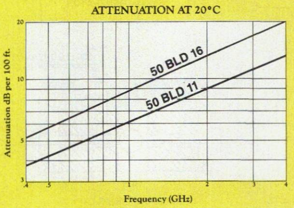

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Noninvasive Waveform Probing for Nonlinear Network Analysis

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A novel and noninvasive technique has been developed for the measurement of fundamental and harmonic S-parameters as functions of input frequency and power. The advantage of this technique was demonstrated on a GaAs field-effect transistor by plotting its drain current vs. voltage characteristic at 5 GHz, which clearly shows the origin of its nonlinearity.

Introduction

In spite of the rapid advancement of on-wafer linear network analysis, nonlinear network analysis is still in its infancy. A recent development[1] involves using a microwave transition analyzer to measure both the magnitude and phase of harmonic signals. However, the technique is based on conventional 50 Ω coplanar probes, which are unsuitable for internal-node probing.

A new technique using a 500 Ω module probe in conjunction with the transition analyzer has been developed. The high impedance probe causes little perturbation to typical microwave circuits. By probing the voltage waveforms at four different locations on the input and output coplanar lines inside a test fixture, the fundamental and harmonic S-parameters of the device under test can be calculated. The harmonic S-parameter is defined as the ratio of the harmonic voltage response to the fundamental voltage stimulus.

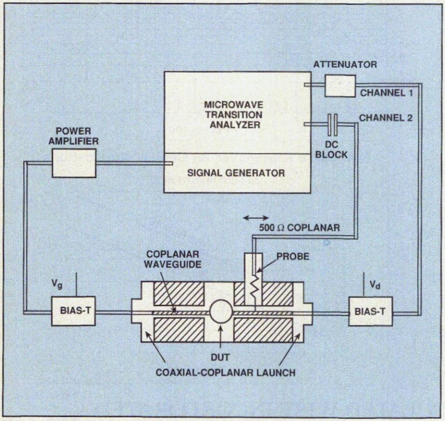


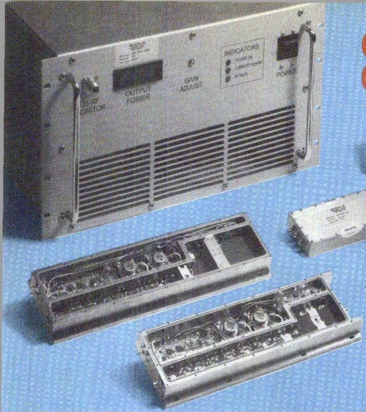
Fig. 1 The measurement set-up.

The advantages of this technique are that it provides complete information on both the voltage and current waveforms of the incident, reflected and transmitted waves at the fundamental and harmonic frequencies; it is a noninvasive technique for internal-node probing under different source and load-pull conditions; and its in-situ measurement eliminates the requirement for precision fixtures and impedance standards. Therefore, this new technique is a viable alternative to optical probing, which tends to be expensive and difficult to implement.[2]

Experiment

The measurement set-up is shown schematically in Figure 1. The high impedance probe has a nominal bandwidth of 12.5 GHz and a dynamic range of 40 dB for nonlinear network analysis up to 40 GHz. The probe can be calibrated with or without ground contacts at the probe tip. For accurate broadband measurement, ground contacts are provided through 50 Ω coplanar lines. The calibration procedure involves de-embedding the high impedance probe from a series combination of high impedance probe, a 50 Ω through line and a conventional 50 Ω probe. The calibration was verified by

[Continued on page 124]



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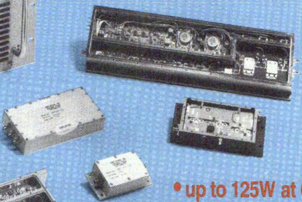

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AMP09XX-XX *	800 -960	40	44/45	40/47

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MODEL SERIES	FREQUENCY (GHz)	GAIN (dB)	NOISE FIGURE (dB)	IP3 (dBm)	P-1 dBc (dBm)
AMP1718-33	1.7 - 1.8	44	2	43	33
AMP1718-43	1.7 - 1.8	44	-	53	43
AMP1718-47	1.7 - 1.8	45	-	CLASS AB	47

GSM AMPLIFIERS

MODEL SERIES	FREQUENCY (GHz)	GAIN (dB)	NOISE FIGURE (dB)	P-1 dBc (dBm)	IP3 (dBm)
AMP0937-47HL	935 - 960	44	-	47	57
AMP0937-33HL	935 - 960	40	-	33	43
AMP09XX-XL*	800 - 960	38 - 44	1.5	33/43	23/33
AMP09XX-HL*	800 - 960	40	-	**49**	**63**

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comparing the measured vs. simulated waveforms through a Schottky-barrier diode of known characteristics, as shown in Figure 2.

The actual experiment involves measuring the voltage waveforms, which contain information on the harmonic magnitudes and phases, as functions of input frequency, power and probe location. The relative phase of the fundamental signal at each location is determined by referencing the phase of the load signal, while the phases of the harmonic signals are referenced to the phase of the fundamental signal. Knowing the nth harmonic voltages at two locations of a predetermined separation, the nth harmonic signals of both the incident and reflected currents can be calculated. Usually a separation of one-tenth of the wavelength is sufficient for accurate current calculation. For the following example, 1.5 cm long coplanar lines are used that are more than adequate for 2 to 26.5 GHz measurements. This results in up to the fifth harmonic for a frequency sweep between 2 and 5 GHz.

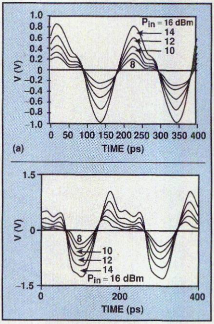

Fig. 2 (a) Measured and (b) simulated voltage waveforms through the Schottky-barrier diode.

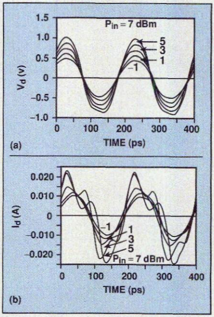

Fig. 3 FET output waveforms; time-domain drain (a) voltage and (b) current.

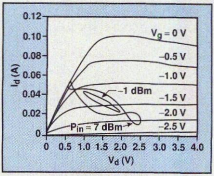

Fig. 4 An RF waveform superimposed on transistor drain characteristics.

Results

As an example, the measured results from a GaAs power field-effect transistor of 1 μm gate length and 400 μm gate width are reported. To eliminate the influence of heating effects, the device was conservatively biased at a gate voltage of –1.7 V and a drain voltage of 1.5 V, with a quiescent drain current of 32 mA. Figure 3 shows the time-domain drain voltage and current waveforms, under an input drive of 5 GHz and –1 to 7 dBm. With increasing input power, the voltage wave becomes clamped in the negative direction when the device is operating in the linear region. The results can be better visualized by superimposing the RF waveform on the DC drain characteristics, as shown in Figure 4. Under an input of –1 dBm, the RF characteristic is essentially elliptical around the 50 Ω load line. Under an input of 7 dBm, the waveform is considerably distorted as the device swings near the linear and pinch-off regions.

Figure 5 shows the fundamental S-parameters as functions of input frequency and power. While the magnitude of S_{11} changes little, the magnitude of S_{11} decreases significantly with increasing input power. Figure 6 shows S_{21} of the

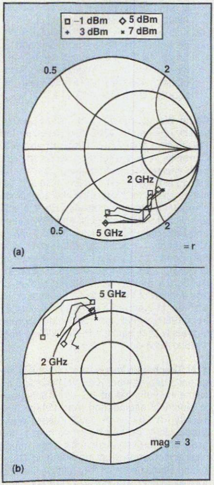

Fig. 5 S-parameters as functions of (a) input frequency and (b) power.

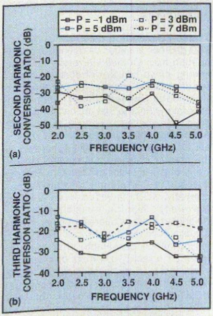

Fig. 6 S_{21} of (a) the second- and (b) third-harmonics.

second and third harmonics. As expected, the third harmonics are higher than the second harmonics because the waveform is more square under high input powers.

Conclusion

The voltage and current waveforms of a nonlinear microwave device were measured using a high impedance probe in conjunction with a microwave transition analyzer. Fundamental and harmonic S-parameters up to 26.5 GHz were calculated as functions of input frequency and power. By superimposing the RF waveform on the DC drain characteristics, the origin of the device nonlinearity was clearly shown. The results characterize the nonlinear behavior and verify the large-signal model of the device in both the time and frequency domains. This technique can readily be extended to internal-node probing and load-pull measurement without the interference of fixture effects. It presents a viable alternative to optical probing, which tends to be expensive and difficult to implement. ■

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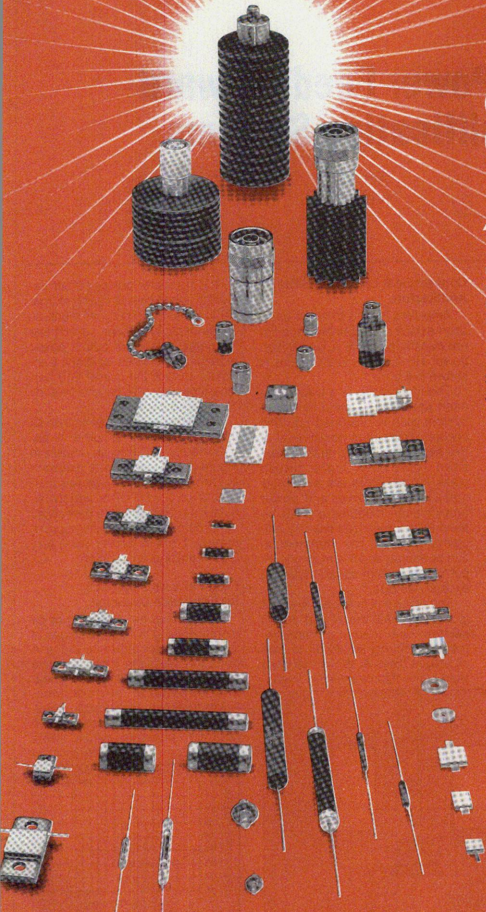
Cejun Wei graduated from Tsing-Hua University, Beijing in 1962 and received his PhD degree from Academia Sinica in 1966. Currently, he is a research scientist of electrical engineering and computer sciences at Lehigh University. His present research activities are in microwave device and circuit characterization and modeling. His interests are also in optoelectronics, and high-speed and heterojunction devices. From 1978 to 1986, he was a professor at the Institute of Semiconductors, and a honorary director of GaAs IC Lab, Microelectronics Center, Academia Sinica. As a visiting professor and a fellow of the Humboldt foundation, he worked at Aachen Technical University from 1980 to 1982, and at Berlin Technical University and Heinrich-Hertz Institute from 1986 to 1988.

Y.A. Tkachenko received his electrical engineer's degree from Kiev Polytechnical Institute in 1993, and his BS and MS degrees in electrical engineering from Lehigh University, in 1991 and 1993, respectively. Since 1991, he has been working in the area of microwave devices and circuits characterization and modeling at Compound Semiconductor Technology Laboratory at Lehigh University. Currently, he is working on his PhD degree at Lehigh University. Tkachenko is a member of IEEE and the Phi Beta Delta society for international scholars.

James C.M. Hwang received his MS and PhD degrees in materials science and engineering from Cornell University. In 1988, Hwang joined Lehigh University as professor of electrical engineering and director of Compound Semiconductor Technology Laboratory. Prior to that, he had 12 years of industrial experience working at Gain, GE, AT&T and IBM. Currently, he is a consultant for the Air Force Wright Laboratory, in the area of microwave integrated circuits. He is also a director of Quantum Epitaxial Designs, a GaAs epitaxial wafer supply company, which he helped found at Lehigh University's high tech incubation center. Hwang's research interests center around thin-film materials and devices. He invented silicon-nitride passivation that improved MESFET reliability by orders of magnitude, enabling it to be deployed in space. He fabricated the world's first quarter-micron HEMT that was used to detect the VOYAGER II signal during its encounter with Neptune. He has been granted three US patents.



High Power Feed Forward Amplification Systems

PST Inc.
Melville, NY

Introduction

The proliferation of satellite communications networks has called for modern communication equipment to maintain high levels of spectral efficiency. Conventional high power RF/microwave amplifiers were once required to handle only a single carrier communications channel. Contemporary networks use single tone or closely spaced multicarrier signals using QPSK modulation techniques for maximum data handling. The FCC requires these systems to operate with minimized adjacent out-of-band spectral emissions (spectral containment). These unwanted frequency components are primarily the result of intermodulation distortion products produced by this type of modulation propagating through nonlinear solid-state devices. This article focuses on feed forward system design and improvements in linearity over conventional linear RF power amplifiers.

Conventional Linear Amplifier Architecture

Amplifiers biased to linear operation exhibit a reasonably good linear transfer function. A typical high power RF amplifier architecture is shown in Figure 1.

The input stage is a class A biased predriver. A majority of the system gain is designed into this section. The output power level of this section generally does not exceed 10 to 20 W since biased class A transistors are extremely inefficient. The driver and power amplification modules are AB biased for an optimized linearity-efficiency tradeoff. The intermodulation performance for a multitone input to this system usually does not exceed –35 dBc.

The weak link in the architecture is the class AB driver and output section. One means of improvement in linearity would be to bias all stages class A. While this does yield some improvement in linearity, the transistor power output capability, when bias is changed from AB to A, is reduced by as much as 70 percent. Therefore, to achieve the same amount of output power requires three times as many transistors. In fact, the overall IMD performance may only be improved by 10 to 15 dB.

The typical IMD performance of the high power RF amplifier is approximately –30 dBc, as shown in Figure 2. However, some multitone systems have spectral requirements of ≥ –60 dBc, which requires the transistors to be backed off in output even further, approximately 1 dB in power for every 2 dB reduction in distortion.

Feed Forward Approach for Enhanced Linearity

It has become evident that by merely biasing the output stages of a linear RF amplifier to class A does not yield the most effective approach to achieving ultra linear intermodulation performance. Aside from the economical standpoint, heavily biased class A amplifiers also consume considerable

[Continued on page 130]

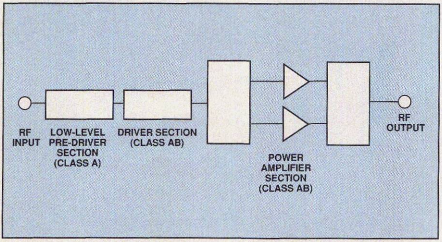


Fig. 1 Conventional power amplifier architecture.

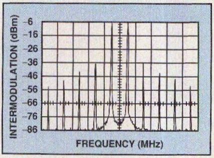
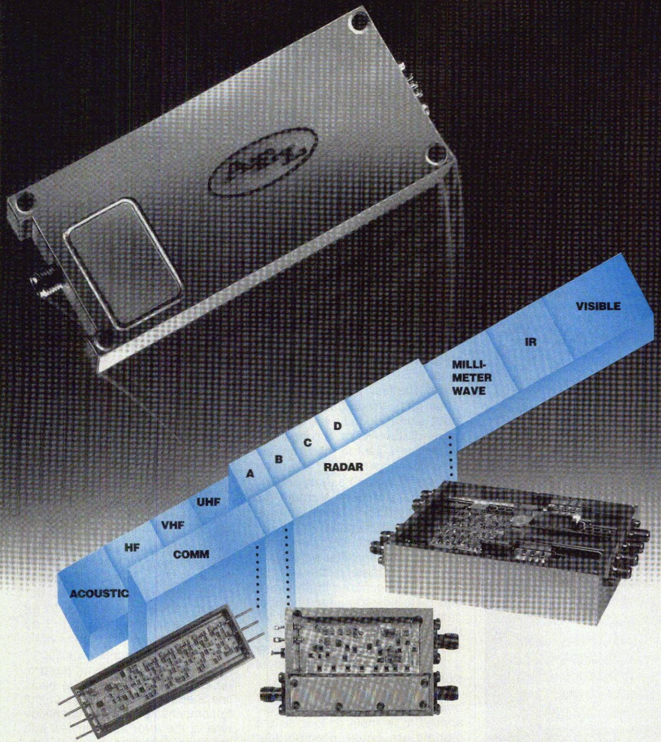


Fig. 2 Uncorrected amplifier output intermodulation spectrum.



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CIRCLE 11 ON READER SERVICE CARD

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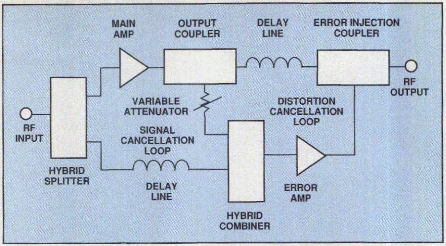

Fig. 3 Basic feed forward system.

amounts of DC power. Figure 3 shows the operation of the basic feed forward architecture.

In theory, the operation of the basic feed forward architecture is simple. There are essentially two loops. The first, the signal cancellation loop, divides the multitone input signal equally via a hybrid power divider. Half of the input signal power is sent to the main amplifier for amplification. The other half is sent through a delay line. As the signal proceeds through the main amplifier, intermodulation products are generated.

The directional coupler on the output of the amplifier provides a low-level sample of the output. This output contains both signal and distortion frequency components. These components are fed to one input of a 0° power combiner. The other side of the combiner is fed the intrinsic multitone input signal.

The 0° combiner will algebraically sum two signals that are applied to its input as long as the signals are equal in amplitude, phase and time references. If the signals are equal in time reference and amplitude, but 180° out of phase reference, they will cancel each other.

The express purpose of the delay line is to delay the intrinsic multitone input signal such that it arrives at the combiner at the same time reference but 180° out of phase with the signal from the directional coupler. The amplitudes of the signals are matched by an adjustable attenuator in line with the coupler output.

The combiner's output is described by

$$e_o(t) = (e_s(t) + e_d(t)) - e_s(t)$$
$$e_o = e_d(t) \qquad (1)$$

where

$e_o(t)$ = combiner output signal
$e_s(t)$ = multitone input signal
$e_d(t)$ = intermodulation distortion products

Equation 1 shows that the output of the combiner contains only distortion products. These frequency components are then fed to an ultra linear class A amplifier.

The class A amplifier is part of the distortion cancellation loop. The function of this loop is virtually the same as the signal cancellation loop. The output of the error amplifier is fed to a directional coupler for distortion elimination. In the distortion cancellation loop, a 10 dB coupler is used instead of a 3 dB hybrid combiner to reduce main line losses of the output amplifier.

Two signal spectrums need to be combined. Therefore, a delay line is added to the mainline output to compensate for the propagation time of the error amplifier. As with the signal cancellation loop, it is required that the two spectrums must reach the coupler equal time reference, 180° out of phase. However, the amplitude of the distortion spectrum must be +10 dB higher to overcome the directional coupler coupling factor.

Coupler output is described by

$$e_c(t) = (e_s(t) + e_d(t)) - e_d(t)$$
$$e_c = e_s(t) \qquad (2)$$

where

$e_c(t)$ = coupler output
$e_s(t)$ = signal spectrum
$e_d(t)$ = distortion spectrum

[Continued on page 133]

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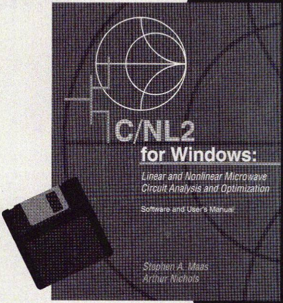

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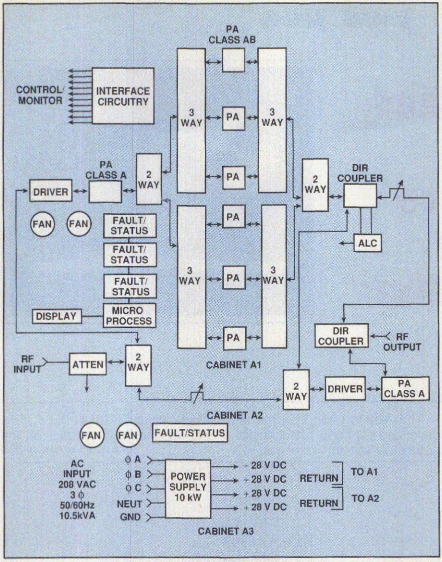


Fig. 4 Amplifier 1 kW 149 MHz feed forward design.

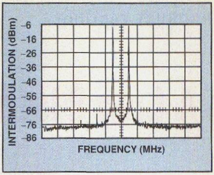


Fig. 5 Corrected amplifier output intermodulation spectrum.

The output of the coupler contains only signal components. In theory, all distortion components are cancelled.

Figure 4 shows a block diagram of the feed forward system. The main amplifier is a conventional high power amplifier system. It consists of a low level driver feeding a class A P/A, which drives a hybrid divider network that splits the power into six equal phase/amplitude ports for further amplification by six class AB power modules. The outputs are recombined into one by a six port combiner.

All power modules input/outputs are matched to 50 Ω via broadband transformers. The combiners are 0° coaxial type. The main amplifier was tested above with a multitone signal to determine its intermodulation performance. The amplifier was designed to have an optimum IMD response since the better the IMDs are initially, the easier it is to cancel the distortion spectrum. The main AB linear output amplifier operates over the 148 to 150.05 MHz frequency range. Its gain is +56 dB; its gain ripple is < 0.4 dB peak-to-peak (max); and input/output SWR is 1.5 (max) for a 50 Ω system.

The error amplifier is the single most critical design in any feed forward system. It must have an ultra linear transfer function, small propagation delay time and high gain.

Ultra linearity is required since any intermodulation products it generates will be injected into the output and will become a limiting factor in distortion cancellation. It is necessary for this amplifier to have a small propagation time since any delay it has must be compensated for by placing a delay line in the output section. The longer this delay line is, the more insertion loss is present in the amplifier output. This means that the main amplifier has to be driven harder to produce the same output power. Unfortunately, this impairs the intermodulation performance.

The error amplifier gain must be high since it must amplify a relatively small amplitude distortion spectrum to a level that is +10 dB higher than the output distortion. The class A ultra linear amplifier operates over the 148 to 150.05 MHz frequency range. Its gain is +78 dB and its input/output SWR is 1.5 (max). The directional couplers are high power stripline type. The mainline output coupler has approximately –50 dB coupling; the error injection coupler has –10 dB.

System Performance

The multitone performance of the uncorrected main amplifier is –30 dBc. Figure 5 shows the addition of the signal and distortion cancellation loops. Intermodulation products have been reduced by –30 to –40 dB. In fact, the intermodulation performance exceeds most class A amplifiers operating 20 dB below their 1 dB compression.

The complete feed forward system is housed in three 19" rack-mounted cabinets. The system also contains circuitry for built-in capability to monitor thermal faults, overcurrent/voltage, module status, load SWR and overdrive.

Conclusion

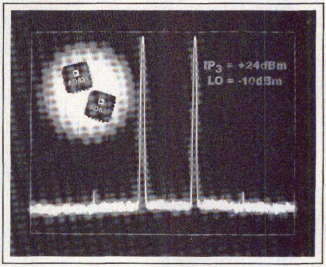
A high power feed forward amplifier system design has been described. This design achieves improvements in linearity and maintains high levels of spectral efficiency required for modern communications equipment.

PST Inc., Melville, NY (516) 777-8900.

Circle No. 302

PRODUCT FEATURE

A Low Distortion, High Performance 500 MHz Monolithic Mixer



Analog Devices Inc.
Wilmington, MA

Introduction

The model AD831 RF mixer offers low distortion of +24 dBm at third-order intercept point for –10 dBm LO power over a 500 MHz bandwidth. Port-to-port isolation is greater than 70 dB (LO-RF at 100 MHz). These specifications make the device suitable for digital mobile radio base stations, high performance HF receivers and military equipment. A schematic diagram of the AD831 low distortion mixer is shown in Figure 1. Two AD831 mixers may have their RF inputs connected in parallel and have their LO inputs driven in phase quadrature, to provide demodulated in-phase (I) and quadrature (Q) outputs, as shown in Figure 2.

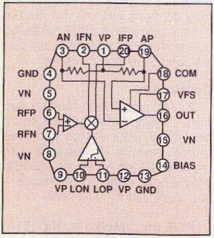


Fig. 1 The schematic diagram of the model AD831 monolithic mixer.

The AD831 integrates the LO driver and low-noise output amplifier together with the mixer core in a single, compact 20-pin PLCC. This allows it to match or exceed the

[Continued on page 137]

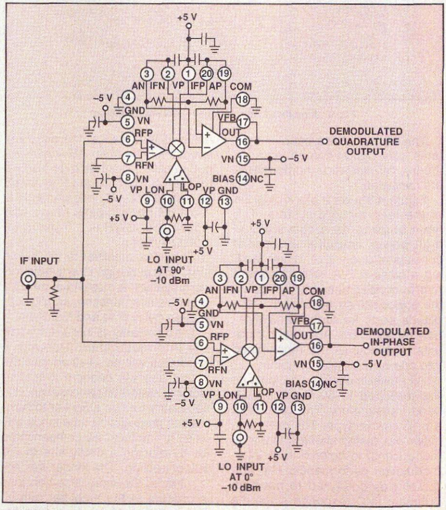


Fig. 2 Connectors for quadrature demodulation. The numbers are the PIN numbers.

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performance of the best discrete designs in a smaller footprint. Designers can avoid using external amplifiers, with their associated cost and isolation problems, and give less attention to expensive filters or shielding. Unlike passive mixers, the AD831 mixer is termination-insensitive.

The RF, IF and LO ports may either be DC coupled when the device operates from ±5 V or AC coupled when operated from +9 V. The IF output is available as either a single-ended voltage or a differential current, which can be taken directly from the mixer cell, allowing users to operate their own amplifiers. For voltage output, the mixer includes a dedicated low-noise amplifier, which can be used to drive filters, 50 Ω loads and A/D converters and provides a +10 dBm and 1 dB compression point.

Other product highlights are single-ended voltage output, user-programmable power and gain, no insertion loss, and single, +9 V, or dual, ±5 V, supply operation. The mixer's overall noise figure is 12 dB using its output amplifier. Unlike passive mixers, the AD831 has no insertion loss, and does not require an external diplexer or passive termination.

A programmable-bias feature allows the user to reduce power consumption, with a reduction in the 1 dB compression point and third-order intercept. This permits a tradeoff between dynamic range and power consumption. For example, the AD831 may be used as a second mixer in cellular and two-way radio base stations at reduced power, while still providing a substantial performance improvement over passive mixers.

The output amplifier can be used for driving reverse-terminated loads and IF bandpass filters. The mixer's linear wideband output amplifier results in an increase of RF-to-IF gain, thus compensating for insertion and termination losses.

The mixer is one of the most important parts in an RF system because at this stage the greatest requirement for dynamic range exists. The AD831's combination of specifications make it well suited to a wide variety of RF roles. Its primary applications are as the first mixer stage in LF, HF and VHF receivers and as the second (or third) mixer stage in digital mobile base stations, where it will be used for downconversion from 70 MHz IF to a 455 kHz IF. However, the mixer has secondary applications ranging from medical ultrasound imaging to military electronics.

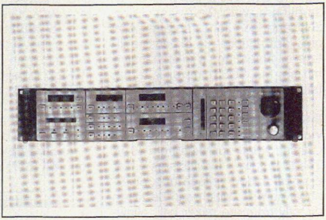
The AD831 mixer is available in a 20-pin PLCC package and is priced at $12 each in 1000 quantities. Delivery is from stock.

Analog Devices Inc., Wilmington, MA (617) 937-1428.

Circle No. 304

PRODUCT FEATURE

A Compact, General Purpose Telemetry Receiver



Microdyne Corp.
Ocala, FL

The 700-MR compact series receiver provides telemetry and general purpose users with a state-of-the-art receiver in a 3.5" high panel. It features full remote control with availability of a P-band, L-band and upper and lower S-band tuner. Full demodulation capabilities, including FM, PM, BPSK and QPSK, are all in one receiver. The front panel of the 700-MR series is extremely user friendly. Data entry is performed either by a numeric keypad or a manual tuning knob.

The receiver utilizes alpha/numeric LED displays for visual aids and prompting purposes. Several colored LEDs are used for identification and status. The readouts for the various displays are selected via SEL keys that light the function's LEDs. Changes, where applicable, are accomplished utilizing the keyboard and TUNE control and then entered by the SET key.

Some of the displays are additionally used as voltmeters, as well as status. All internal levels in need of adjustment are available on the front panel, requiring no external test equipment.

This receiver can be controlled remotely via IEEE-488.2, RS-232C or RS-422 interfaces. It features complete hands-off, allowing the remote controller access to all functions that are available locally.

General Receiver

The block diagram for the 700-MR receiver is shown in Figure 1. Options include the tuner, second IFs and demodulators.

The 700-MR receiver provides reception of telemetry and general purpose signals in the range of 50 to 2485 MHz. The RF tuner is available in a single or multiband configuration. An all-inclusive multiband tuner is available that

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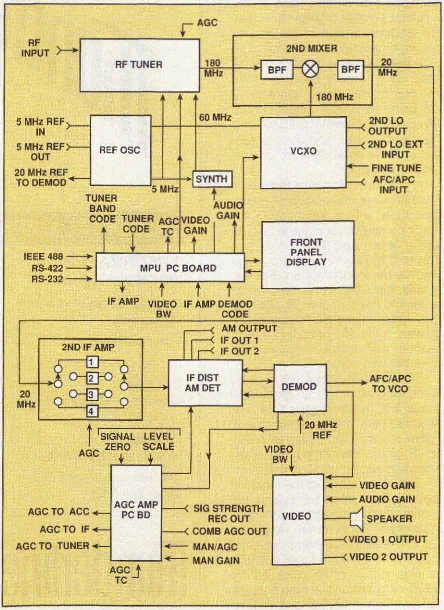
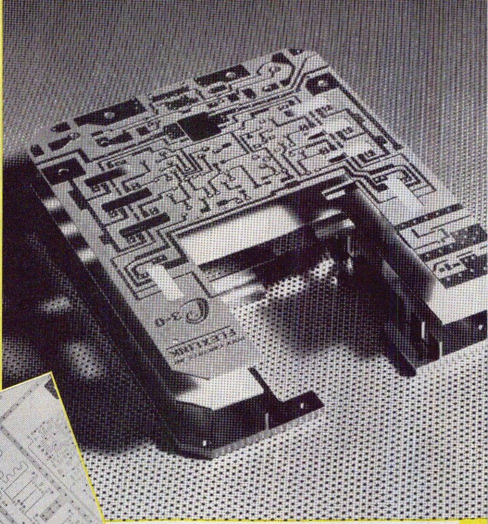
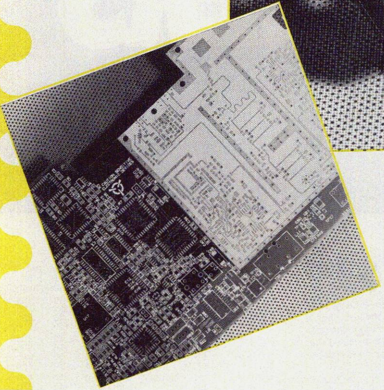


Fig. 1 A block diagram of the 700-MR receiver.





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covers P-band, L-band, and both lower and upper S-bands.

The receiver frequency is established by the synthesizer in 100 kHz tuning steps over the range of the tuner's RF bandwidth(s). The resultant first IF frequency of 160 MHz is routed to the second mixer module. Coherency is established by the external or internal reference oscillator module for all of the pertinent modules in the receiver, including the tuner, synthesizer, demodulator and VCXO.

The VCXO's output is directed to the second mixer, establishing the 20 MHz second IF frequency. Fine tune (±100 kHz) and AFC/APC (±250 kHz) are summed into the VCXO and the resultant correction is sent to the second mixer. The 20 MHz second IF signal is directed to one of the five second IF BWs that are available from 10 kHz up to 12 MHz.

The output of the second IF is sent to the IF distribution/AM dector module, whose output is sent to the demodulator module. Two demods are available, FM only and a multimode demod having PM, FM, BPSK and QPSK formats. The demod can handle data rates up to 5 Mbps for NRZ codes in FM, and up to 6.5 Mbps for BPSK and QPSK. Both I and Q channels are available for QPSK.

The output of the demod is sent to the video filter modules, where up to 12 bandwidths between 12.5 kHz and 6 MHz are available. Bypass is also provided. The MPU contains a 32-bit microprocessor and is used to control all modules, including the front panel display and remote control.

The power supply is a switching supply for added efficiency. Power is less than 70 W total for the entire receiver. Options include a programmable downconverter (zero to 5.575 MHz). Other options are planned for future expansion.

Applications

This receiver was designed to meet demand for a full-featured, compact, lightweight, low power receiver. Along with the companion compact model 1620-PC combiner, it will reduce valuable rack space by 50 percent. Some applications include general telemetry reception, data reduction, tracking systems, satellite monitoring, predetection record and playback systems, airborne and shipboard operation and video reception of remote platforms.

Conclusion

The 700-MR receiver provides telemetry and general purpose users with a product that has great time performance. It features compact size, weight and low power at competitive pricing. Size: 3.5" × 19" × 22".

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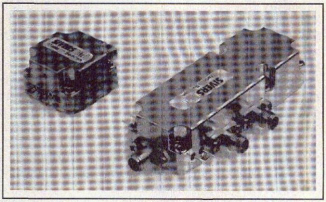


Sivers Ima AB
Stockholm, Sweden

Introduction

The low noise of YIG oscillators (YTO) makes them suitable for telecommunications and measurements applications. As YTOs also can be tuned linearly over wide bands, they are frequently used in microwave instruments and EW applications.

Increasing market demands for portability of equipment require a reduction in size and weight, and demands for lower costs are obtained by a.o. improved assembly methods like drop-in connection of the oscillators. These new miniature YTOs meet these requirements. In addition, these units offer features of enhanced tuning speed and modulation bandwidth that may create new application areas for YIG oscillators.

Other types of miniature YTOs have been limited to an upper frequency of about 8 GHz and an FM coil bandwidth of less than 1 MHz. No integration of additional microwave functions has been offered. The YO2014 mini-YIG family has a new basic design and offers some unique features, unavailable in the products currently on the market.

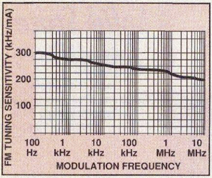


Fig. 1 FM modulation sensitivity vs. modulation frequency.

Features

The YO2014 mini-YIG family shares traditional YIG characteristics such as low noise that is 30 dB below VCOs, wide tuning in octaves, and tuning of 0.1 percent nonlinearity.The YO2014 family also shares existing miniature YIG features including small size of 25 × 25 × 16 mm, low weight of 30 grams, fast tuning of > 15 MHz/μs and drop-in connection. New patent-pending features include a 16 GHz frequency, simple PLL connection, low cost step response optimization and single package multi-YIG subsystem. The 16 GHz frequency is obtainable with the specified package, and 13 GHz versions are being delivered. Frequencies above 16 GHz require a somewhat larger package.

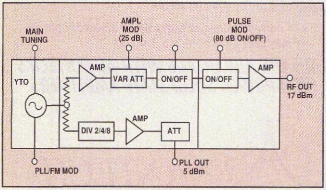


Fig. 2 A single package PLL connected oscillator with AGC and a pulse modulated RF output.

A simple PLL/FM modulation connection with a fine tuning coil is available. This connection is considerably faster (> 5 MHz FM BW) than other available products and still offers a deviation of ±100 MHz. Figure 1 shows the FM modulation sensitivity vs. modulation frequency.

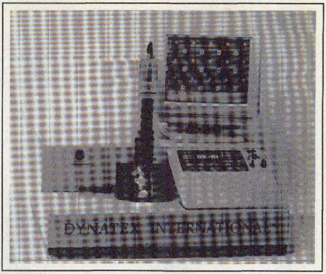
The low cost step response optimization of the main and FM coils is also important. In this YTO, the new type of magnetic circuit only has one time delay constant, as compared to five constants for normal designs. This construction simplifies the design of the external equalization circuitry required to obtain the fastest step response.

The single package multi-YIG subsystem is possible because the exterior design is relatively independent of the magnetic circuitry. This concept allows one or more YIG functions and additional microwave circuitry to be housed in one package. Interfacing SMA connectors that would add losses, SWR and intermodulation are eliminated. Allocating the total responsibility of the microwave functions to one single supplier, and receiving a single package that reduces the cost and risk in the final assembly stage is also possible. Figure 2 shows a single package PLL oscillator with a pulse-modulated RF output.

Sivers Ima AB, Stockholm, Sweden +46-8-7036800.

Circle No. 305

A Scribe and Break System for Wafer Processing



Dynatex International
Santa Rosa, CA

The DX-III ScriberBreaker system is capable of complete automatic scribing and breaking of semiconductor wafers and is fully programmable for all scribing and breaking parameters, including True Angle™ diamond tool positioning. The system has several advantages over sawing: increased production rates; higher die density on the wafer; reduced chipping; less residual stress in the die; and no toxic water discharge. Figure 1 shows a close-up view of the scribe module.

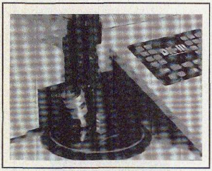


Fig. 1 Close up of DX-II scribe module.

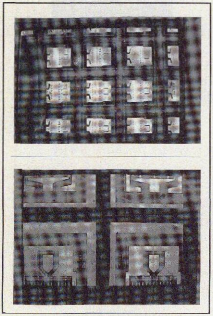


Fig. 2 View of expanded wafer processed on the DS-III ScriberBreaker.

The DX-III ScriberBreaker can process wafers up to five times faster than traditional sawing methods. Scribe speeds of up to 4" per second are possible using Ultra Fine™ scribe technology. These speeds do not damage the wafer as cutting does, because the diamond is just scratching the surface. Speed is controlled by a DC servo system and different speeds may be programmed for each wafer. Figure 2 shows a view of an expanded wafer processed on the scriberbreaker.

The ScriberBreaker increases traditional wafer density up to 25 percent by reducing street width. A street width of only 0.002" (50 μm) is required. No material is removed, so the final die size is the size of the die on the wafer. The scribe width is usually less than 5 μm. Figure 3 shows multiple die size on a wafer.

With new Ultra Fine scribe technology and Chip Free™ breaking, the DX-III is capable of producing wafers with no chipping because of reduced side stress. The system detects the leading and trailing edge of the wafer and profiles it as it scribes so the minimum amount of time is spent scribing.

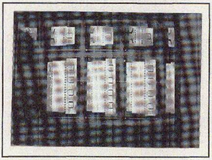


Fig. 3 Multiple die size on a wafer.

The DX-III's impact breaking system uses an impulse bar for striking the wafer beneath the scribe and causing a fracture along it. The impulse bar breaking produces high forces without significant loads on the wafer. The higher force generating capabilities of the DX-III allows very small die to be processed. Die 0.005" (125 μm) square and 0.004" (100 μm) thick have been processed.

As opposed to the sawing process, the ScriberBreaker system creates no toxic wastes. The sawing process discharges arsenic-contaminated water, but with the DX-III system, no water is used.

The DX-III system satisfies the criteria for ISO 9000 certification. Parameters for the processing of up to 16 different wafer types can be programmed into memory. It also can process wafers up to 39 mils thick and die 5 mils square. For sensitive devices, such as air bridges, the optional Top Free™ Breaker eliminates any contact with the top side of the wafer during the breaking process. The DX-III system also uses True Angle diamond positioning technology, which places diamonds at the correct angle in 0.1° increments.

Dynatex International, Santa Rosa, CA (707) 542-4227.

Circle No. 301

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ORBIT Advanced Technologies has the industry's most extensive line of Programmable Positioner Controllers for Antenna, RCS and Tracking applications. All ORBIT controllers are equipped with IEEE 488 and RS232 interfaces and are bus compatible; so that a program written for one controller works with all the other models. Hardware and software triggers are provided for interfacing with other instruments. A Binary/BCD output interface with a 5 KHz update rate is a standard feature, useful for applications that require high speed position data. The following position and velocity sensors are supported: Synchro (dual and single speed) Inductosyn®, Optical Encoder, Inclinometer, and Tachometer. Simultaneous Dual Axis Movement can be supported as required. Each controller model interfaces with ORBIT Positioners and Power Control Units as well as those of other manufacturers. The AL-2000 Antenna Measurement Software package and most third party antenna and RCS software packages support ORBIT Positioner Controllers. Whatever your budget or application, ORBIT can supply a system which meets your requirements.

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AL-4706-3A

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AL-4806-3A

AL-4906-3A

AL-4806-3A

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AL-4906-3A

Low cost; up to 6 axes; single axis digital display; programmable.

AL-4901-3A

AL-4901-3A

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AL-4146-2

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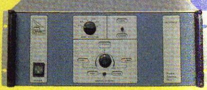
The units can be linked via fiber optics in a master/slave configuration using an AL-4706-3B Controller. This allows up to 36 axes to be controlled from a central location. This feature is very useful in large ranges which require long distances between the control room and positioning equipment and the control of many axes.



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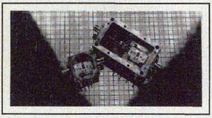
0.5 - 18 GHz Biphase Modulators



The MX1016 and -17 series biphase modulators cover the frequency ranges from 0.5 to 2 GHz and from 2 to 18 GHz, respectively. Insertion loss is 4 dB (max.) (MX1016) and 5.5 dB (max.) (MX1017). For both series, rise time is 10 ns (max.); switching speed is 10 MHz; biphase error is 0.75 dB and 7°; and power requirements are +5 V and –15 V at 40 mA. Size: 1" × 1" × 0.5" not including field-replaceable SMA connectors. **Alpha Industries Inc., Components & Subsystems Division, Methuen, MA (508) 682-4661.**

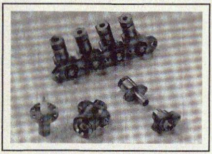
Circle No. 215

DC - 80 MHz, 118 - 400 MHz FM Band Suppression Filter

The model NX88-108 FM broadcast band suppression filter operates over the frequency ranges from DC to 80 MHz and from 118 to 400 MHz, and suppresses the 88 to 108 MHz FM broadcast band. Passband insertion loss is 0.5 dB (max.); SWR is 1.4 (max.); and power handling capability is 25 W CW. Connectors are BNC, N, SMA and TNC. Operating temperature range is from –54° to +95°C. The unit meets numerous MIL-STD-202 and -454 test methods and requirements. Size: 2.25" × 1.45" × 4.3". Weight: 10 oz (typ.). Price: $175 each. Delivery: 4 to 6 weeks. **Trilithic Inc., Indianapolis, IN (800) 344-2412.**

Circle No. 236

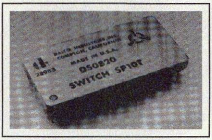
Blind Mate Connectors



The BZ and BMZ blind mate connector series consist of ruggedized stainless steel bodies that accommodate large variations in alignment tolerances. The connectors' interfaces meet MIL-STD-348. The BMZ series is designed in accordance with DESC drawings 91012 and 91013. The connectors have spring-loaded plugs. **Specialty Connector, Nashua, NH (603) 881-5932.**

Circle No. 231

10 - 1500 MHz PIN Diode Nonreflective Switch



The model DSO820 SP10T PIN diode nonreflective switch operates over the frequency range from 10 to 1500 MHz. DC current is 15 mA at a +5 V DC supply; insertion loss is 0.95 dB from 10 to 500 MHz and 1.6 dB from 500 to 1500 MHz; switching speed is 3 µs at 50% control to 10%/90% RF; isolation is 46 dB from 10 to 1000 MHz and 42 dB from 1000 to 1500 MHz; and SWR is 1.3. **Daico Industries Inc., Rancho Dominguez, CA (310) 631-1143.**

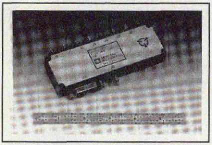
Circle No. 217

5 - 2000 MHz SP4T GaAs Switch

The model HTGS402 SP4T GaAs switch operates over the frequency range from 5 to 2000 MHz. From 5 to 1000 MHz, insertion loss is 1.2 dB (typ.), isolation is 45 dB (typ.) and SWR is 1.2 (typ.). From 1000 to 2000 MHz, insertion loss is 1.6 (typ.), isolation is 40 dB (typ.) and SWR is 1.8 (typ.). Switching time is 15 ns; continuous RF input power is +30 dBm; and DC voltage is +6 V. Operating temperature range is from –55° to +100°C. **Hybrid-Tek Inc., Clarksburg, NJ (609) 259-3355.**

Circle No. 219

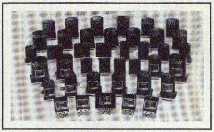
1 - 18 GHz PIN Diode Switches



The series F9180 broadband eight-throw PIN diode switches operate over the frequency range from 1 to 18 GHz. For the reflective design, insertion loss is 1.5 dB at 1 GHz and 3.8 dB at 18 GHz; for the nonreflective design, insertion loss is 2 dB at 1 GHz and 4.2 dB at 18 GHz. Isolation is 60 dB at 1 GHz and 50 dB at 18 GHz; SWR is from 1.7 to 2, depending on frequency; and switching time is < 200 ns. RF power handling is 75 W (peak) and 1 W (avg). Operating temperature range is from –55° to +110°C. Size: 4.65" × 1.5" × 0.75". **General Microwave Corp., Amityville, NY (516) 226-8900.**

Circle No. 218

Electromechanical Switches



The SEM series of SPDT to SP6T electromechanical switches operates from 28 V DC power supplies. Switch options include indicators, internal terminations and TTL interfaces. Connectors are SMA, and some models are available with type N connectors and failsafe and latching models. Prices: start at $145. **Loral Microwave-Narda, Hauppauge, NY (516) 231-1700.**

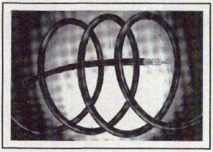
Circle No. 222

2500 - 2686 MHz Wireless Cable Downconverter

The model MM-3120 wireless cable downconverter operates over the RF frequency range from 2500 to 2686 MHz, and over the IF output frequency range from 222 to 408 MHz. It consists of a preselector filter, low noise amplifier front end, IC mixer-oscillator, filter, IF amplifier, and voltage-regulating and output-monitoring circuitry. Gain is 20 dB ±1.5 dB; noise figure is 1.6 dB (max.); 1 dB compression point is +12 dBm (min.); phase noise is > 75 dBc/Hz; image rejection is 50 dB (min.); and third-order intercept point is +25 dBm. **Princeton Microsystems Inc., Cranbury, NJ (609) 734-2194.**

Circle No. 226

Flexible Communications Cable



The model LMR™-400 flexible communications cable is suitable for use in short antenna feeders, jumpers and interconnections in mobile radio, cellular and paging systems. Attenuation is 3.9 dB/100 feet at 900 MHz. The cable construction consists of a copper-clad aluminum center conductor, polyethylene foam dielectric, a tape/braid outer shield and a black polyethylene jacket for weather protection. Diameter: 0.405" (0.24" through 1.67" diameters also available). Price: $0.50/ft. Delivery: stock. **Times Microwave Systems, Wallingford, CT (203) 949-8432.**

Circle No. 235

[Continued on page 152]

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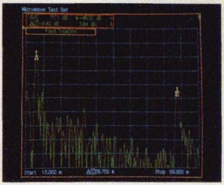

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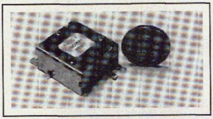
820 - 900 MHz Surface Mount Isolator



The model 2SD2NK surface mount isolator operates over the frequency range from 820 to 900 MHz. Isolation is 22 dB (min.); insertion loss is 0.5 dB (max.); SWR is 1.25 (max.); and termination is 5 W. Operating temperature range is from –30° to +60°C. Size: 1" × 1" × 0.5". **Renaissance Electronics Corp., Acton, MA (508) 263-4994.**

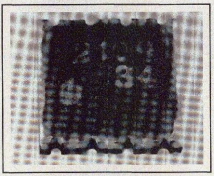
Circle No. 227

10 - 200 MHz, 800 - 1000 MHz FET Mixer

The model HDM1 high dynamic range FET mixer operates over the IF frequency range from 10 to 200 MHz and over the RF/LO frequency range from 800 to 1000 MHz. It is suitable for use in applications at the cell-site level of cellular communications networks. Maximum noise figure is 9 dB (typ.); and third-order intercept point is +40 dBm (typ.) with LO drive of 21 dBm (nom.) and conversion loss of 8 dB (typ.). The mixer is available in a low-cost, surface-mount package and on tape and reel for high-volume manufacturing. **Watkins-Johnson Co., Palo Alto, CA (415) 493-4141.**

Circle No. 238

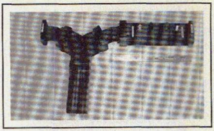
860 - 970 MHz Chip Double-Balanced Mixer



The model CDB-2109 chip double-balanced mixer operates over the frequency range from 860 to 970 MHz. Conversion loss is 8 dB (max.); compression point is 0 dBm; LO-to-RF isolation is 20 dB (min.); and RF-to-IF is 14 dB (max.). The chip is available on tape and reel. Size: 0.177" × 0.197" × 0.06". Price: $4.95 (25 to 1000). Delivery: stock. **ST Olektron Corp., Beverly, MA (508) 922-0019, ext. 614.**

Circle No. 275

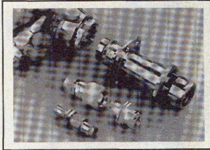
8 - 18 GHz RF Output Module



The model WPM650-1-C I/J-band RF output module operates over the frequency range from 8 to 18 GHz. RF power handling is 300 W CW (min.); insertion loss is 1 dB (max.); SWR is 1.45 (max.); and reverse isolation is 15 dB (min.). The module consists of an input ferrite isolator and dual 40-dB, loop-type, directional couplers. It is suitable for use in broadband military ECM/EW transmitters and commercial EMI/RFI test sets protecting high-power TWTAs. **Microwave Resources Inc., Norcross, GA (404) 441-9193.**

Circle No. 271

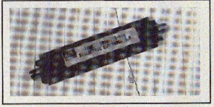
Quick Connect-Disconnect Connectors



These quick connect-disconnect connectors correspond to type C, SC, LC, BNC and TNC connectors for applications where quick action and positive locking are required. Configurations include receptacles, jacks, panel jacks and plugs. Adapters also are available. **Tru-Connector Corp., Peabody, MA (508) 532-0775.**

Circle No. 237

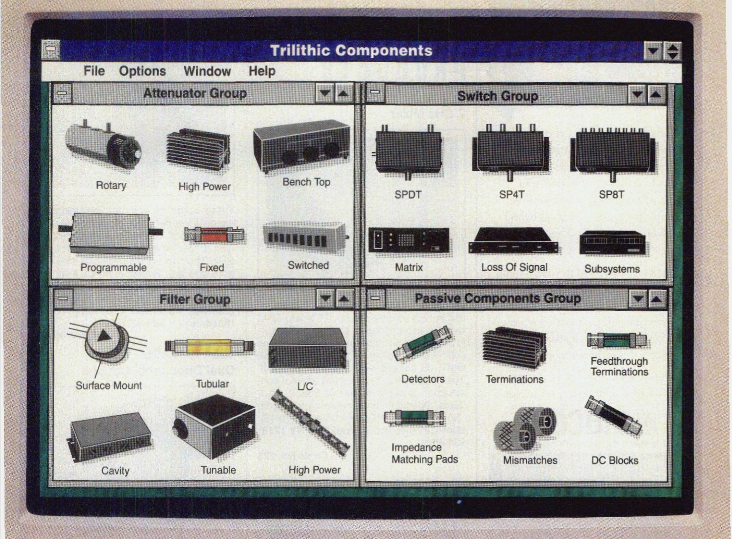
1030 MHz Dielectric Resonator Filter



The model 12DR21-1030/T15-O/O 12-section dielectric resonator filter operates at a center frequency of 1030 MHz. Insertion loss is 8.5 dB (max.) at 1030 MHz; 3 dBc bandwidth is 16 MHz; 70 dBc bandwidth is 37.2 MHz; and SWR is 1.5. The hermetically sealed filter has removable SMA connectors. Size: 2.85" × 0.3" × 0.6". **K&L Microwave Inc., Salisbury, MD (410) 749-2424.**

Circle No. 221

[Continued on page 154]



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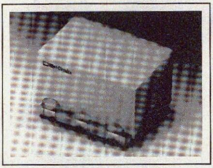


The model RMS-11F mixer is suitable for use in high volume cellular, PCN and GSM wireless applications up to 2 GHz. The surface-mount unit has low conversion loss controlled to better than 4.5 σ from mean and 1 dB compression at 1 dBm RF input. The mixer features all-welded internal construction and meets MIL-M-28837 standards. Operating temperature range is from –55° to +100°C. Price: $4.95 each (10-49). **Mini-Circuits Inc., Brooklyn, NY (718) 934-4500.**

Circle No. 225

80 - 1000 MHz Dual Directional Couplers

The models DC6180 and -6280 dual directional couplers operate over the frequency range from 80 to 1000 MHz. For the model DC6180, power is 600 W CW (avg.) and 1000 W (peak); and coupling factor is 60 ±1 dB. For the model DC6280, power is 1500 W CW; and coupling factor is 63 ±1 dB. For both, directivity is 25 dB (typ.); and insertion loss is 0.15 dB (max.). Price: $900 (DC6180) and $1100 (DC6280). Delivery: 6 weeks (max.). **Amplifier Research, Souderton, PA (215) 723-8181.**

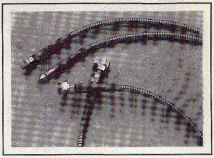
Circle No. 216

DC - 2000 MHz Standard Coaxial Rotary Joint

The model FRJ5471 standard coaxial rotary joint operates over the frequency range from DC to 2000 MHz. SWR is 1.1 (max.); insertion loss is 0.13 dB (max.); and power is 500 W (avg.) at 1 GHz and 10 kW (peak). The unit is weatherized for operation under environmental extremes, has precious metal contact junctions, and meets MIL-E-5400 Class II standards. Size: 3.38" × 1.25" (diameter). **Sage Laboratories Inc., Natick, MA (508) 653-0844.**

Circle No. 230

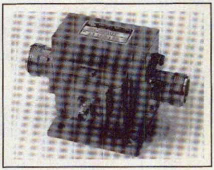
40 GHz VNA Test Cables



These vector network analyzer test cables are designed for harsh production test environments and operate at frequencies to 40 GHz. Phase stability vs. flexure is < 0.125°/GHz. The cables have stainless steel exteriors and are available with 2.4 mm, 2.9 mm, 3.5 mm, 7 mm, SMA, N and TNC connectors. Length: up to 5 m. **Storm Products Co., Advanced Technology Group, Hinsdale, IL (708) 323-9121.**

Circle No. 232

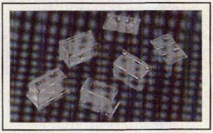
125 - 1500 MHz Dual Directional Coupler



The model C-9301 high power, dual directional coupler operates over the frequency range from 125 to 1500 MHz. Directivity is > 20 dB; nominal coupling is 50 dB; coupling flatness is ±1 dB; SWR is 1.1 (max.); insertion loss is 0.15 dB; and power handling is 2000 W CW. **Western Microwave Inc., Sunnyvale, CA (408) 738-2300.**

Circle No. 272

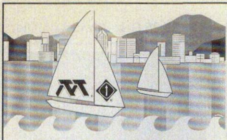
Elliptic Response Bandpass Filters



These elliptic response bandpass filters cover most popular IF frequency bands in use. Insertion loss is 1.5 dB (max.); SWR is 1.2 (typ.) in the passband; and out-of-band rejection is as high as 45 dB. The devices are packaged in relay headers that can be modified into leaded and nonleaded surface-mount configurations. Price: $17.85 (1-9) (relay headers); and $19.85 (leaded and nonleaded surface mount). **Synergy Microwave Corp., Paterson, NJ (201) 881-8800.**

Circle No. 233

[Continued on page 156]



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NEW PRODUCTS

18.1 - 18.6 GHz Isolator

The model IS42-K-30 isolator operates over the frequency range from 18.1 to 18.6 GHz. SWR is 1.1; insertion loss is 0.3 dB; isolation is 30 dB (min.); and power rating is 2 W (max.). Size: 1.75" × 1.25" × 1.125". **RFCircuits Inc., Hatboro, PA (215) 675-8003.**

Circle No. 228

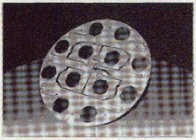
Antennas

806 - 960 MHz Flat Panel Antennas

The models FP-824, -936 and -1148 flat panel antennas operate over the frequency ranges from 806 to 866 MHz, from 820 to 925 MHz, and from 870 to 960 MHz, respectively. Gain ranges from 8 to 11.5 dBd; and 5°, 10° and 15° electrical downtilts, and 83° and 105° horizontal beamwidths are available. The antennas are suitable for use in SMR, GSM, SCADA and cellular communication applications. Width: 9". Height: from 24" to 48". **Radiation Systems Inc., Mark Antennas Division, Des Plaines, IL (708) 298-9420.**

Circle No. 240

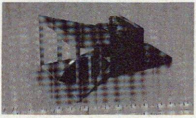
1698 - 1707 MHz Axisymmetric L-Band Printed Circuit Antenna



The model 9328-800 axisymmetric L-band printed circuit antenna operates over the frequency range from 1698 to 1707 MHz. Gain is 16 dBic (min.); SWR is 1.5 (max.); and axial ratio is 2 dB (max.); RF connector is SMA female. Size: 18" (diameter) × 0.125". **Seavey Engineering Associates Inc., Cohasset, MA (617) 383-9722.**

Circle No. 241

4 - 65 GHz Horn Antenna

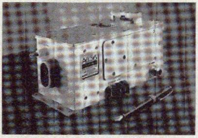


The model DRH-0465 double-ridge horn antenna operates over the frequency range from 4 to 65 GHz. Nominal midband gain is 18 dBi; impedance is 50 Ω; and input power is 100 W (max.). Polarization is linear. Weight: 0.9 lbs. **Spectrum Technologies International Inc., Norcross, GA (404) 840-0107.**

Circle No. 242

Amplifiers

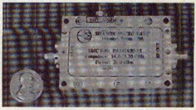
200 - 1200 MHz High Power Cavity Amplifier



This modular single-planar triode amplifier operates over the frequency range from 200 to 1200 MHz. Peak power levels are from 1 to 30 kW; and duty factors are up to 10%. The amplifier can be supplied as a complete turnkey system. Size: 4" × 4" × 10". **AccSys Technology Inc., Pleasanton, CA (510) 462-6949.**

Circle No. 243

14.2 - 15.35 GHz Power Amplifier



The model PA141630-15 power amplifier targets terrestrial radio applications over the frequency range from 14.2 to 15.35 GHz. Gain is 15 dB (max.); flatness is ±1.5 dB (max.); saturated output power is +30 dBm (min.); and DC power is +10 V DC at 2 A (max.) with internal voltage regulation. The amplifier is equipped with SMA-F input/output connectors. Size: 2.45" × 1.6" × 0.5". **Shason Microwave Corp., Houston, TX (713) 333-1950.**

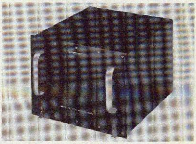
Circle No. 273

7.5 - 8.7 GHz High Power Amplifier

The model MSH-6426801 high power amplifier operates over the frequency range from 7.5 to 8.7 GHz and is suitable for use in test and radar systems. Output power is 39.5 dBm (9 W) (min.). Typical gain is 30 dB (min.) with different options available. Input and output SWR is 2 (max.). Connectors are SMA female and DC power is ±12 V DC at 6.5 mA. **Microwave Solutions Inc., National City, CA (800) 967-4267.**

Circle No. 248

60 W High Power Amplifier



The model PWAL 1643-12/14920 60 W high power amplifier measures power output with two, 30 W tones that produce < 25 dBc third order intermodulation. Power dissipation is 250 W (max.). The amplifier incorporates 16 dB output power control in 1 dB steps. Input SWR is 2; output SWR is 1.25 (max.); and the unit is capable of driving SWR loads of up to 2 in all phases. Harmonics are 0 dBw up to 12 GHz and –35 dBw from 12 to 18 GHz. **Microwave Power Devices Inc., Hauppauge, NY (516) 231-1400.**

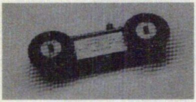
Circle No. 247

MMIC Amplifiers

This series of MMIC amplifiers operates with 3 dB bandwidths of kHz to 2.2 GHz. The amplifiers are matched 50 Ω gain blocks consisting of DC-coupled Darlington amplifiers. Package styles -11, -85 and -86 are available on tape and reel with minimum reel size of 2000 pieces. Package styles -35 and -70 can be environmentally

screened to MIL-STD-833 to the extent of this company's screening table. **Amplifonix, Philadelphia, PA (215) 464-4000.**
Circle No. 277

30 - 35 GHz Solid-State Power Amplifier



The model DBS-3035N27 solid-state power amplifier operates over any 1 GHz frequency band in the frequency range from 30 to 35 GHz. Power output is +27 dBm (min.); gain is 20 dB (min.); noise figure is 7.5 dB (typ.); and input/output SWR is 2.2 (max.). DC power is 12 to 15 V at 950 mA (max.). Input and output connectors are WR-22 type. **DBS Microwave Inc., El Dorado Hills, CA (916) 939-7545.**
Circle No. 276

5 GHz Dual Differential Amplifier IC

The model HFA3102, 5 GHz dual differential amplifier chip is suitable for RF and IF down- and upconvert applications in wireless communications systems. Wireless R/T applications for the IC include single-balanced mixers and automatic gain control circuits for RF or first IF amplifiers, multipliers and local oscillators. End applications include GSM, CT-1 and CT-2 cellular telephones, wireless fax modems and mobile computing products. The chip is packaged in a 14-pin SOIC. Price: $2.66 (1000). **Harris Semiconductor, Melbourne, FL (800) 442-7747, ext. 7154.**
Circle No. 245

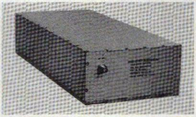
Monolithic Variable-Gain Amplifier

The model AD603 X-AMP™ monolithic low-noise, variable-gain amplifier features wide bandwidth and low distortion and is suitable for use in cost-sensitive automatic gain control and programmable-gain applications. The unit utilizes a variable attenuator and high-speed, fixed-gain amplifier. Gain is continuously adjustable over a 42 dB range, and bandwidth is independent of voltage-controlled gain. The amplifier is available in 8-pin CERDIP or SO-8 packaging. Prices: start at $5.75 (1000). Delivery: from stock. **Analog Devices Inc., Wilmington, MA (617) 937-1428.**
Circle No. 244

1.625 - 1.661 GHz 50 W Rack Mount L-Band SSPA

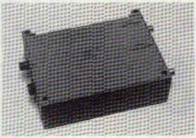
The model PLA-1650/R 50 W SSPA operates over the frequency range from 1.625 to 1.661 GHz. It is packaged in an EIA standard, 19-inch rack mount chassis with integral metering and fault detection circuitry. Options include front panel in/out test couplers, redundant and outdoor configurations and other power levels. **MAXTECH Inc., State College, PA (814) 238-2700.**
Circle No. 246

100 - 500 MHz Solid-State Transmitter Booster Amplifier



The model BME1858-200/2997 broadband solid-state transmitter booster amplifier operates over the frequency range from 100 to 500 MHz. It delivers 200 W (min.) power into a load SWR of 2. Low harmonic distortion of –23 dBc (typ.) and efficiency of 23% (typ.) make this amplifier suitable as a power booster for VHF/UHF tactical radios. Operating temperature range is from –10° to +40°C. **Power Systems Technology Inc., Melville, NY (516) 777-8900.**
Circle No. 249

100 W, C-Band Solid-State Amplifier



This 100 W, C-band, class-A amplifier has a cold plate for water cooling and is designed for high-data-rate communication in military applications. DC-to-RF efficiency is 25%; gain is 56 dB (min.); harmonic signals are –80 dBc; and attenuation is 50 dB. **Systron Donner, Microwave/Instrument Divisions, Sylmar, CA (818) 362-9900.**
Circle No. 250

Lightwave

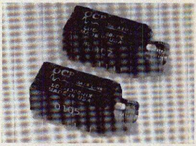
Microwave Optical Simultaneous Transmission Cable and Connectors

These cables and connectors transmit RF or electrical signals and optical signals simultaneously. RF performance is equal to 0.034" diameter and 0.047" diameter semi-rigid coaxial optical fiber, and can be single- or multimode. The connectors are SMA type and include end launcher, plugs and jacks. **Haverhill Cable & Manufacturing Corp., Haverhill, MA (508) 372-6386.**
Circle No. 251

[Continued on page 158]

NEW PRODUCTS

Data Link Modules



The LDL series plastic data link modules are now available with FC-RECEPTACLE (in addition to the ST version) interfaces. These data link modules are actively aligned within the connector receptacle to minimize coupling losses to the mating FC connectorized fiber. The model LDL-1300-FC logic-to-light transmitters incorporate a reliable InGaAsP surface-emitting LED, while the light-to-logic receivers incorporate a high speed InGaAs/InP PIN photodiode. Price: < $100 per module in OEM quantities. **Optical Communication Products Inc., Chatsworth, CA (818) 701-0164.**

Circle No. 252

Device

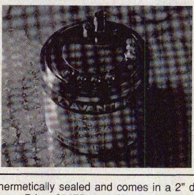
1 - 2 GHz RF Microwave Power Transistor

The model MRF2000-5L microwave power transistor is intended for large-signal output and driver linear amplifier stages operating in the frequency range from 1 to 2 GHz for use in personal, military and commercial communications systems. The transistor operates from a 20 V DC supply which delivers 5 W of output power for 1 W RF power input. Price: $129. **Motorola Inc., Semiconductor Products Sector, Phoenix, AZ (602) 244-6108.**

Circle No. 253

Sources

20 - 40 GHz YIG-Tuned Oscillator



The model AV-20040 YIG-tuned oscillator tunes over the frequency range from 20 to 40 GHz. It is a fundamental-output signal source that uses no frequency multiplication and has a low spurious signal output of –60 dBc (min.). Output power is +10 dBm (min.); and frequency drift is 60 MHz (max.). The oscillator is hermetically sealed and comes in a 2" diameter × 1.53" high package. Price: $3675 (1-9). **Hewlett-Packard Co., Cupertino, CA.**

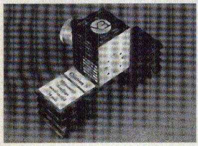
Circle No. 255

70 MHz - 20 GHz Pulse Modulator

The model 6145 pulse modulator operates over the frequency range from 70 MHz to 20 GHz. It provides a simplified solution to testing the three key parameters measured by radar systems' users, including minimum discernible signal, 1 dB compression and sub clutter visibility. Insertion gain is 5 dB; on/off ration is > 70 dB; and rise and fall times are < 5 ns. Price: $6185. Delivery: 8 to 10 weeks (ARO). **Marconi Instruments Inc., Allendale, NJ (800) 233-2955 or (201) 934-9050.**

Circle No. 256

W-Band, Mechanically Tuned Gunn Oscillator

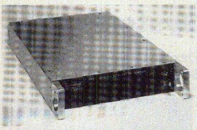


This W-band mechanically tunable InP Gunn oscillator has over 10 GHz tuning bandwidth and 20 dBm output power. Frequency is centered at 94 GHz. Additionally, the oscillator offers ±50 to ±100 MHz bias tuning, suitable for most FM modulation applications. **Epsilon Lambda Electronics Corp., Geneva, IL (708) 232-9611.**

Circle No. 254

Test Equipment

10 - 1000 MHz Multicoupler



The model CS-2002C multicoupler operates over the frequency range from 10 to 1000 MHz. Output-to-output isolation is > 70 dB; output-to-input isolation is > 90 dB; noise figure is < 7 dB; and gain is 0 dB. The unit has a continuous 90 to 260 V AC supply. Other frequencies and configurations are available. Size: 1.75" × 8.5" rack-mount housing. **Communication Solutions Inc., Baltimore, MD (410) 574-4557.**

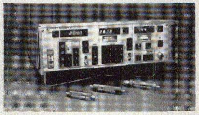
Circle No. 257

50 and 200 MHz Real-Time Oscilloscopes

The model TDS 310 and TDS 350 digital, real-time oscilloscopes operate at 50 MHz and 200 MHz, respectively. The TDS 310's two channels digitize at a rate of 200 megasamples per second and the TDS 350 digitizes at one gigasample per second. They provide accurate representations of waveforms at the full bandwidth of each scope, even for single-shot events. Price: $2295 (310) and $3995 (350). **Tektronix Inc., Beaverton, OR (800) 426-2200, ext. 183.**

Circle No. 259

10 - 2047 MHz Noise Gain Analyzers



The MT2075C noise gain analyzer is a noise figure meter that accepts signals in the range from 10 to 2047 MHz. Uncertainty is better than ±0.05 dB and sweep speed is > 200 freq./sec. The model MT2075C06 noise gain analyzer with high speed option 06 adds 50 ms/frequency sweep times to the basic model. **Maury Microwave Corp., Ontario, California (909) 987-4715.**

Circle No. 258

SDH/SONET Analyzers

The model ME3520A and ME3620A SDH/SONET analyzers test the major mapping formats of Europe and North America. They access the network node interface of synchronous multiplexer/demultiplexer systems at 52, 156, 622, and 2488 Mbits/s and is used for quality evaluation and operation and maintenance testing. The analyzers link signals for large capacity B-ISDN and ATM telecommunications at STS-3c, STS-12c and STS-48c. They also can add and drop at 139 M, DS3, 2M and DS1. Optical interfaces at wavelengths of 1.31 and 1.31/1.55 μm are available as plug-in units. Price: $64,875 (ME3520A) and $77,855 (ME3620A). **Anritsu-Wiltron Sales Co., Morgan Hill, CA (408) 776-8300.**

Circle No. 278

DC - 18 GHz Test Fixture

The model QBE-0101-AA RF test fixture is designed for use in the DC to 18 GHz frequency range in scalar and vector network analyzer systems. The test circuit can be inserted and ready to test in < 10 s. Port-to-port loss is < 1 dB up to 10 GHz and is as low as 3 dB at 18 GHz. Impedance is 50 Ω. Construction is of gold-plated solid brass. Connectors are SMA female. Size: 2.2" × 1.6" × 1.1". **Quinstar Technology, Torrance, CA (310) 320-1111.**

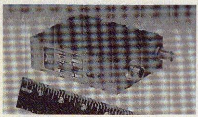
Circle No. 274

[Continued on page 160]

NEW PRODUCTS

Subsystems

1400 - 2400 MHz Airborne Receivers



The series RCC-210 UHF command control receivers are available with input frequency ranges from 1400 to 1550 MHz, from 1700 to 1850 MHz and from 2200 to 2400 MHz. Frequency stability is ±0.003%; signal input is 2 V RMS (max.); signal strength is 1 to 4 V DC (nom.) into 10 kΩ load; SWR is 2 (max.); and noise figure is 6 dB (max.). **Aydin Vector Division, Newtown, PA (215) 968-4271.**

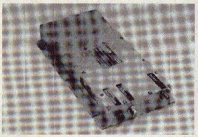
Circle No. 260

Compact Combiner

The model 1620-PC combiner operates at a pre-detection bandwidth to 12 MHz and a post-detection bandwidth to 15 MHz. Signal improvement is 2.5 dB; and fade rates are to 20 kHz. The combiner has hands-off remote control via RS-232C, RS-422 and IEEE-488 and an internal pre-detection record converter or bit syncs. Size: 3.5" high. **Microdyne Corp., Ocala, FL (904) 687-4633.**

Circle No. 262

1 - 16 GHz Frequency Synthesizers



The MLO-16400 series of multichannel frequency synthesizers is designed for military, land, air and sea radar and communications STALO applications. Ten selectable crystal stabilized outputs are available over a 4% bandwidth. Output power is +17 dBm with noise performance at X-band of –100 dBc at 1 kHz of frequency offset. Spurious signals are –90 dBc from 80 MHz from the carrier frequency. Power supply is +28 V DC at 400 mA. **M/A-COM Inc., Wakefield, MA (800) 366-2266 or (617) 224-5600.**

Circle No. 261

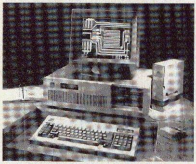
Software

CAD Software for Windows and Workstations

The Serenade version 6.0 CAD software for Microsoft Windows and version 4.0 for workstations provide integrated tools for schematic capture, linear, nonlinear and optoelectronic simulation, coupled with physical layout and back-annotation facilities. The 6.0 release has an intuitive graphics user-interface that is fully Windows-compliant. The 4.0 release provides an exact solution for oscillator phase and mixer noise analysis. **Compact Software Inc., Paterson, NJ (201) 881-1200.**

Circle No. 264

Electrical CAD Design Software



The CADnexion PC-based ECAD system allows HF designers to move from mechanical CAD systems, such as AutoCAD, into this new electrical CAD system. Through-hole as well as surface-mount parts are available from SMT, ECL, Analog, CMOS and discrete libraries. The output is on a WYSIWYG display; and the editor is tailored for the PC, supporting 150 graphic cards, ranging from EGA to 600 × 800 dpi resolution. Prices: start at $4995. **Bay Technology, Aptos, CA (408) 688-8919.**

Circle No. 263

Analog and Digital Simulation Software

The Design Center™ 6.0 analog and digital simulation software contains a comprehensive library of over 9000 analog and digital simulation models and the support of more than 4000 commercial programmable logic devices (PLD). For this new release, 1796 Japanese models, 128 domestic models, 5 TTL models and over 4000 commercial PLDs have been added. The programmable logic synthesis package has a device database including speed, price, power and packaging information for over 4000 devices from 22 manufacturers. Price: $1495 to $15,900 depending on platform and configuration. **MicroSim Corp., Irvine, CA (800) 245-3022.**

Circle No. 265

Layer Protocol Packaging Software Addition

The model DA-30 internetworking analyzer's software has added a layer protocol package (LPP), which "glues" protocol layers together and allows users to load any protocol at any layer. Any offset between two protocol layers can be specified by loading this package between them. Intervening bits or bytes of proprietary encapsulation information can be skipped. A second LPP supports Cisco routers' proprietary SLE protocol at Layer 2, which transmits routing information between two networks. **Wandel & Goltermann GmbH & Co., Eningen, Germany +49 71 2186-1816.**

Circle No. 266

Active Filter Design Software

The AFD^{PLUS} software designs active filters including lowpass, highpass, bandpass, bandreject and allpass filters. It creates the needed design in a choice of circuit realizations and includes complete, integrated graphical analysis. The software operates on IBM-PC and compatible machines with 640K RAM, a hard drive, modern or vintage graphics hardware, a printer or plotter and DOS 3.0 or later. A math coprocessor is recommended. Price: $995 including manual. Delivery: stock. **Webb Laboratories, Brookfield, WI (414) 367-6825.**

Circle No. 267

Service

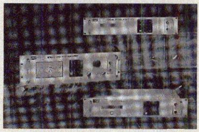
MSC Amplifier Repair Service

This company offers repair of Microwave Semiconductor Corp. (MSC) silicon amplifiers produced from 1970 to 1992. It can repair and restore amplifiers to specification compliance, can substitute equivalent MSC transistors for currently unavailable types and can adapt other manufacturers' transistors to accomplish repair. Replacement amplifiers are available for nonrepairable units. There is no charge for evaluation. **T/MAC Inc., New Brunswick, NJ (908) 247-0022.**

Circle No. 268

System

Flexible Spread Spectrum System



This mobile/cellular/satellite flexible spread spectrum system consists of three models, the MSC-T spread spectrum generator, the MCS-R spread spectrum receiver and the PNCG multimode pseudorandom code generator. The generator covers frequency bands from 800 to 900 MHz, 900 to 930 MHz, 1800 to 2000 MHz and 2400 to 2500 MHz with a bandwidth of 100 MHz (max.). The entire system can be configured in field-deployed or simulated, end-to-end wireless, and cellular telephone applications. **LNR Communications, Hauppauge, NY (516) 273-7111.**

Circle No. 269

NEW LITERATURE

Military/Aerospace Product Reference Manual

This 1408-page reference manual contains information on products for military, aerospace and radiation-tolerant applications. Products include analog-to-digital and digital-to-analog converters, operational amplifiers, digital signal processors, multipliers and sensors. **Analog Devices Inc., Norwood, MA (617) 937-1428.**

Circle No. 201

Antenna and Accessory Catalog

This 61-page catalog contains information on individually-calibrated antennas and accessories for EMI testing. Engineering services and quality assurance and calibration methods are described. Specifications are listed; and photographs and performance graphs are provided. **Antenna Research Assoc. Inc., Beltsville, MD (301) 937-8888.**

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Solid-State Amplifier Brochure

This 20-page brochure gives information on thin-film solid-state MIC amplifiers. Specifications are listed, including frequency range, gain, gain variation, noise figure, SWR, power output, intercept point, DC power and dimensions. Photographs, outline drawings and performance graphs are provided. **Aydin Corp. West, San Jose, CA (408) 629-1100.**

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Product Catalog

This four-page catalog provides information on this company's complete product line, including power amplifiers, solid-state amplifiers, E-field sensors, pre-amplifiers, field generating antennas and EMC test rooms. Specifications are listed, and photographs are provided. **Instruments for Industry, Ronkonkoma, NY (516) 467-8400.**

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Chip Capacitor Production Manual

This 29-page manual contains information on single-layer chip capacitor production. Measurement standards, environmental tests, mechanical tests, visual and dimensional inspection, selection table screening, and installation mounting and connecting are described, and general specifications are included. **Tecdia, Mountain View, CA (415) 967-2828.**

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Microwave Component and Instrument Catalog

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Circuit Board Capability Brochure

This brochure contains information on this company's circuit board engineering and manufacturing capabilities. Facilities and quality assurance methods are described. Photographs are provided. **Janco P/C Inc., Dover, NH (603) 742-1581.**

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Printed Wiring Board Capability Brochure

This brochure gives information on this company's printed wiring board material capabilities. Products and services include surface mount technology, epoxy- and solder-filled holes, buried and blind vias, precious metal plating, solder masking and heat sink bonding. Quality standards and testing and inspection methods are listed. **Methode Electronics Inc. East, Willingsboro, NJ (609) 871-3500.**

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Linear Power Amplifier Catalog

This 29-page catalog contains information on linear power, cellular-band power, PCN, microwave pulse power, and GaAs FET power amplifiers. Specifications are listed, including frequency, output power, gain, gain flatness, SWR, voltage, current and dimensions. Outline drawings and performance graphs are provided. **UNITEQ Inc., Glen Rock, PA (717) 235-6341.**

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MICRO-ADS

Computational Electromagnetics

Korada Umashankar and Allen Taflove

Artech House Inc.
708 pages; $88, £70

This powerful, well-organized book discusses one method of computational electromagnetics (EM) involving the principles of the frequency domain integro-differential equation approach with solutions by the method of moments (MOM). Although the book seems intimidating because of its bulk and the number of equations, it quickly soothes the reader with its clear illustrations and detailed explanations of each equation's meaning. As a result, the reader can more easily understand computational electronics, a somewhat daunting, although important, subject.

The book is divided into six chapters and two appendices. Chapter 1 is a tutorial introduction that traces the history of EM theory and marks important developments and events such as Klerk Maxwell's 1873 development of a unified electric and magnetic field theory and Harrington's systematic, functional-space description of EM interactions, MOM, in the 1960s. Chapter 2 explains Maxwell's equations in the time and frequency domains, charge density distribution, electric current density distribution, Gauss's law for EM fields, EM boundary conditions and the plane wave solution.

Chapter 3 focuses on general field equations of two-dimensional objects with TM polarization, including a perfectly conducting cylinder and objects of arbitrary cross section. Chapter 4 deals with the general field equations of the same objects with TE polarization. Chapter 5 defines general field equations for a two-dimensional homogeneous dielectric object for both TM and TE polarizations. Dielectric cylinders and arbitrary cross-sections are included in the discussion.

Chapter 6 focuses on dielectric-layered objects and includes circular multilayer loading and numerical solutions to arbitrary cross-section solutions of TM and TE polarizations. The book also has two appendices. Appendix A presents vector operations, identities and transformation. Appendix B includes Bessel functions and equations and coordinate transformation.

This book is a well-written, extremely well-illustrated work on Maxwell's laws and their application to practical problems. A sequel to this book, on the time-domain differential-equation approach with a solution via the finite-difference time-domain method, is planned.

To order this book, contact: Artech House Inc., 685 Canton St., Norwood, MA 02062 (617) 769-9750, ext. 4002.

Electromagnetic Waves

David H. Staelin, Ann W. Morgenthaler and Jin Au Kong

Prentice Hall
562 pages; $62

From the hallowed halls of the Massachusetts Institute of Technology, which still reverberate with the genius of Vannevar Bush and Norbert Wiener, comes a new book on electromagnetic waves (EM). Compared with similar texts steeped in the classic tradition of Faraday-Maxwell's laws, this work is a breath of fresh air, unveiling the mysteries of the physical forces acting on each other in EM wave transmission and propagation. The book evolved over a period of thirty years and includes such modern topics as fiber-optic transmission lines, waveguides and acoustic resonators and radiators. The book is user-friendly for students with its logical sequence and down-to-earth explanations of derivations of equations. Maxwell's equations are not easy to solve, but this book guides the reader through the necessary steps.

The book is divided into ten chapters. Since it was written as a second year college text, every chapter ends with a problem section with 10 to 20 problems that test the reader's understanding of the subject. Chapter 1 serves as the introduction to Maxwell's equations and waves and the Lorentz force law. It includes uniform waves, time harmonic fields, polarization, the Poynting theorem and nonelectromagnetic waves and problems.

Chapter 2 deals with radiation by currents and charges in free space and includes static solutions to Maxwell's equations, radiation by dynamic currents and dipoles, and radiation from a single Hertzian dipole and from arrays of Hertzian dipoles. Chapter 3 discusses anisotropic and polarizable media, the concept of group and phase velocities, the gyromagnetic medium, Faraday rotation and waves in plasma.

Bounded waves and transmission lines are treated in Chapters 4 through 8, and include waveguides, coaxial cables and dielectric slab transmission lines. Resonators are the subject of Chapter 8; antennas are the focus of Chapter 9; and acoustic waves round out the text in Chapter 10.

This book is exceedingly well-written, well-illustrated, and well worth the wait. It will enchant electrical engineering students and practicing engineers, as well as readers wishing to enhance their understanding of electromagnetic waves.

To order this book, contact: Prentice Hall, Prentice Hall Building, Englewood Cliffs, NJ 07632 (201) 767-5937.

Martin R. Stiglitz
Julie Callahan
Martin R. Stiglitz and Julie Callahan are members of the Microwave Journal *staff.*

The Microwave Theory and Techniques Society of the Institute of Electrical and Electronics Engineers will hold a Topical Congress on Technologies for Wireless Applications in Conjunction with

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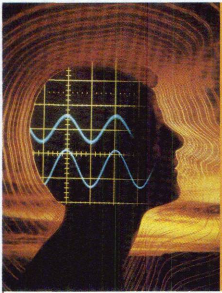

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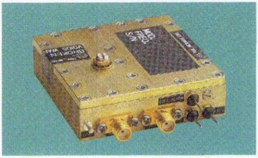

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100 KHz	-118 dBc/Hz
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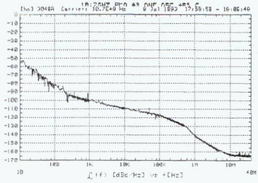

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