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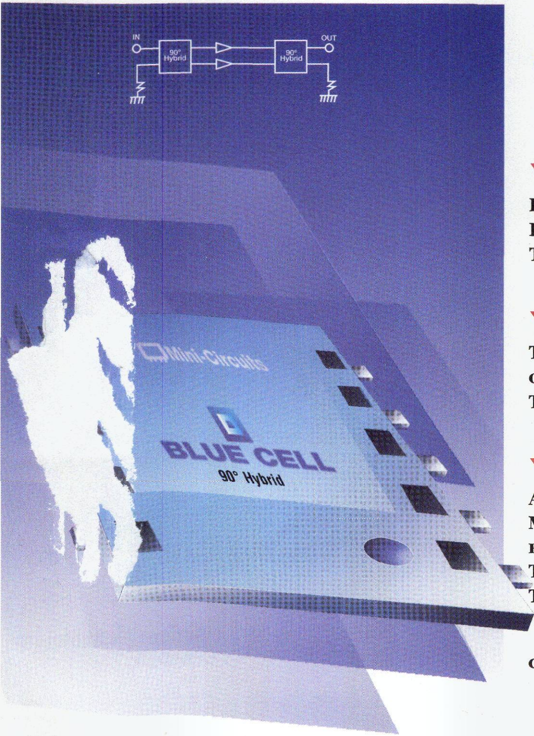

SEMICONDUCTORS AND MMICs

HIGH POWER RF LDMOS TRANSISTORS

THERMAL DESIGN OF WIDE BANDGAP TRANSISTORS

ACTIVE LOAD-PULL MEASUREMENT FOR HARMONIC TUNING OF POWER TRANSISTORS

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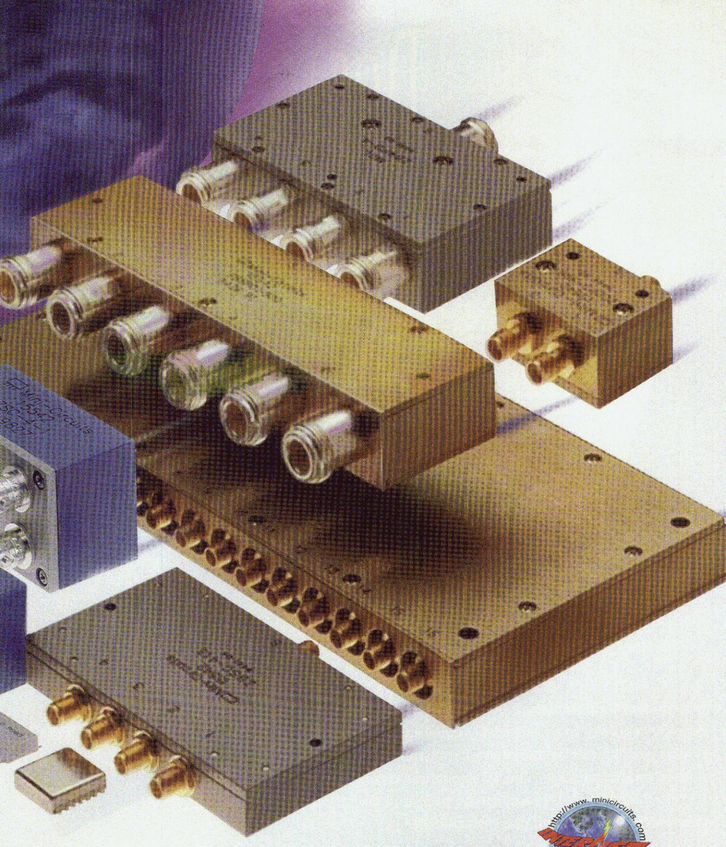


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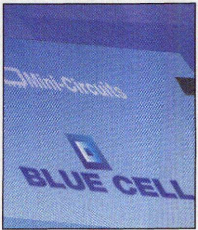

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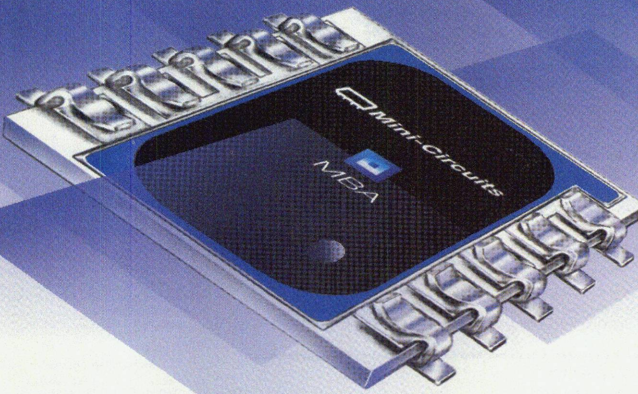

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COMING EVENTS

NIWeek 2000
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Sponsor: National Instruments. Topics: Computer-based measurement and automation, system integration and development, instrument manufacturing and increasing system performance. Contact: National Instruments, 11500 N. Mopac Expwy, Austin, TX 78759-3504 (800) 258-7022, fax (512) 683-9300 or e-mail: niweek@ni.com. Additional information can be found at www.ni.com/niweek.

2000 IEEE International Symposium on Electromagnetic Compatibility
August 21–25, 2000
Washington, DC

Sponsor: IEEE EMC Society. Topics: Electromagnetic compatibility management, certification and accreditation, testing, shielding and grounding, electrostatic discharge, spectrum efficiency and monitoring, product and environmental safety, international government standards, new product designs, commercial and military trends, new personnel and laboratory ideas for electromagnetic compatibility corporate management. Contact: William Duff, Computer Sciences Corp. (703) 914-8450, fax (703) 914-8499 or e-mail: wduff@csc.com.

2000 IEEE Radio and Wireless Conference (RAWCON 2000)
September 10–13, 2000
Denver, CO

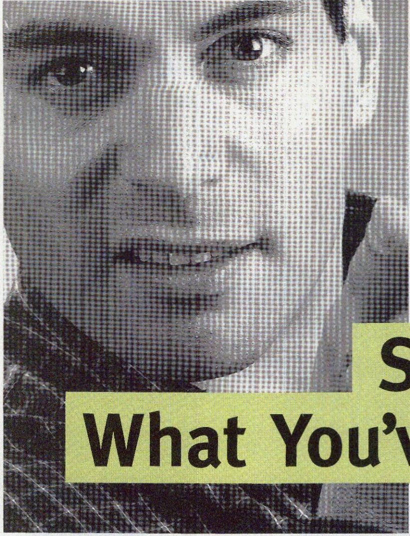
Sponsor: IEEE MTT-S. Topics: Interdisciplinary aspects of RF technology and communications system design, including system architecture and performance, antennas and propagation, active/passive devices, wireless data, smart antennas, ultrawideband systems and software radio architectures. Contact: Michael Heutmaker, Lucent Technologies (609) 639-3116, fax (609) 639-3197 or e-mail: heutmaker @lucent.com. Visit www.rawcon.org for additional conference information and updates.

Wireless Workshop
October 22–25, 2000
Sedona, AZ

Sponsors: Rogers Corp. and Merix Corp. Topics: Innovative applications and designs, design and simulation considerations and issues, software tools for design and simulation, interdependence of high frequency packaging requirements and system design, MMIC and hybrid circuits, new packaging techniques and structures, advancements in high frequency-compatible materials, materials testing and characterization, circuit fabrication challenges and innovations, interconnection and assembly considerations, system and component reliability, and high volume manufacturing. Contact: Sharon Aspden, Rogers Corp. (480) 961-8206 or e-mail: sharon.aspden@rogers-corp.com. Additional conference information can be found at www.az-ww.com.

Connector and Interconnection Technology Symposium
October 23–25, 2000
Orlando, FL

Sponsors: International Institute of Connector and Interconnection Technology Inc. and the Electronic Components, Assemblies Equipment and Supplies Association. Topics: RF interconnection, including design/new interface style; quality; automation; surface-mount technology; automotive interconnects; space flight connector technology; medical applications; materials, finishes and plating; and test methods. Contact: Steve Ulett, Avnet, 6321 San Ignacio Ave., San Jose, CA 95119 (408) 360-4113, fax (408) 281-8722 or e-mail: steve.ulett@avnet.com.



COMING EVENTS

2000 IEEE-APS Conference on Antennas and Propagation for Wireless Communications (APWC 2000)
November 6–8, 2000
Waltham, MA

Sponsors: IEEE Antenna and Propagation Society and IEEE Boston Section. Topics: Military to commercial technology transition, architecture trends, base station and satellite antenna developments, adaptive and active wireless communications arrays, novel antennas and passive array configuration, multiband operation and polarization characteristics, mobile antennas and vehicle modeling, packaging integration and portable devices, antenna CAD, human interaction with antennas, MEMS, and indoor/outdoor propagation and channel models. For additional information, contact the conference office at (781) 890-5290 or e-mail: bostonieee@aol.com.

Eighth IEEE International Symposium on Electron Devices for Microwave and Optoelectronic Applications (EDMO 2000)
November 13–14, 2000
Glasgow, Scotland

Call for papers. Sponsors: The University of Glasgow, IEEE UK&RI MTT-S, Electron Device Society, Antennas & Propagation Society, Lasers and Electro-Optic Society Joint Chapter and the Scottish Chapter of the IEEE Lasers and Electro-Optics Society. Topics: III-V transistors, high speed laser diodes, optical modulators and photodetectors; Si- and SiGe-based devices for RF and optoelectronics applications; wide bandgap devices for microwave and optoelectronic applications; low distortion microwave devices; optical control of microwave and mm-wave devices; microwave and optoelectronic photonic crystal devices; and components for fiber radio applications. Send: abstract. Send to: Iain Thayne, University of Glasgow, G12 8LT, Scotland, UK +44 (0)141 330 3859, fax +44 (0)141 330 6010 or e-mail: edmo@elec.gla.ac.uk. **Deadline: September 1, 2000.** Additional information is available at www.elec.gla.ac.uk/edmo2000.

2000 Asia-Pacific Microwave Conference (APMC 2000)
December 3–6, 2000
Sydney, Australia

Sponsors: CSIRO Telecommunications and Industrial Physics, IEEE South Wales and South Australia sections and IEEE MTT-S. Topics: Computational electromagnetics, CAD, guided waves, EMC/EMI, ferrite and solid-state devices, MMIC technology, medical/biological applications of microwaves, microwave superconductivity, high speed digital circuits, microstrip and planar antennas, microwave acoustics and measurements, optical devices and systems, optoelectronic techniques, microwave-optical interactions, phased- and active-array techniques, mobile communications systems and remote sensing. Contact: ICMS Pty Ltd. +61 2 9290 3366, fax +61 2 9290 2444 or e-mail: apmc@icms.com.au. Additional information is available at www.icms.au/apmc.

Army Science Conference
December 12–13, 2000
Baltimore, MD

Sponsor: Assistant Secretary of the Army (Acquisition, Logistics and Technology). Topics: Advanced materials and manufacturing, microelectronics and photonics, advanced propulsion technologies, engineering sciences, environmental and geosciences, biomedical and behavioral sciences, force protection, high performance computing and simulation, soldier systems, and sensors and information processing. Contact: Army Science Conference Registration Desk (757) 357-4011, fax (757) 357-5108 or e-mail: asc2000info@aol.com. Additional conference information is available at www.asc-2000.com.

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PTF 10052	1000	35	12.0	28	20235	N
PTF 10015	1000	50	12.0	28	20235	N
PTF 10031	1000	50	12.0	28	20222	N
PTF 10139*	1000	60	12.0	28	20235	N
PTF 10138*	1000	60	12.0	28	20222	N
PTF 10009	1000	85	12.0	28	20230	N
PTF 10049	470–860	85	12.0	32	20240	I
PTF 10159	470–860	120	12.0	32/28	20240	I
PTF 10019	860–900	70	13.0	28	20237	I
PTF 10133	860–900	85	13.0	28	20237	I
PTF 10100	860–900	165	12.0	28	20250	I
PTF 10162	860–960	18	14.0	26	20222	N
PTF 10036	860–960	85	11.0	28	20240	I
PTF 10160*	860–960	85	15.0	26	20248	I/O
PTF 10020	860–960	125	11.0	28	20240	I
PTF 10149	921–960	70	15.0	26	20252	I
1.0–2.2 GHz – GOLDMOS FET						
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PTF 10107	2000	5	11.0	26	20244	N
PTF 10135	2000	5	11.0	26	20249	N
PTF 10041*	2000	12	10.0	26	20249	N
PTF 10053	2000	12	10.0	26	20244	N
PTF 10021	1400–1600	30	11.0	28	20237	I/O
PTF 10125	1400–1600	135	11.5	28	20250	I/O
PTF 10045	1600–1650	30	10.0	28	20222	N
PTF 10112	1800–2000	60	11.0	28	20248	I/O
PTF 10153*	1800–2000	60	12.5	28	20248	I/O
PTF 10120	1800–2000	120	10.0	28	20250	I/O
PTF 10043	1900–2000	12	11.0	26	20222	I
PTF 10035	1900–2000	30	11.0	28	20237	I/O
PTF 10123*	2100–2200	5	11.0	28	20244	N
PTF 10119	2100–2200	12	10.0	28	20222	I
PTF 10048	2100–2200	30	10.0	28	20237	I/O
PTF 10122	2100–2200	50	10.0	28	20248	I/O
PTF 10134*	2100–2200	100	10.0	28	20250	I/O

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WORKSHOPS & COURSES

Modeling and Simulation of Wireless Communication Systems

■ **Topics:** Discrete time signals and systems, Monte Carlo simulation and random number generation, modeling of functional blocks and simulation methodology. Fee: $1595
■ **Site:** Los Angeles, CA
■ **Date:** July 31 - Aug. 3, 2000
■ **Contact:** UCLA Extension, Short Course Program, 10995 Le Conte Ave., Los Angeles, CA 90024 (310) 825-1047, fax (310) 206-2815 or e-mail: mhenness@unex.ucla.edu.

CMOS Analog ICs

■ **Topics:** CMOS and BiCMOS analog IC design, electrical modeling, process parameter characterization and test ability considerations. Computer simulation is used to predict circuit performance. Fee: $1295.
■ **Site:** Atlanta, GA
■ **Date:** August 7–11, 2000
■ **Contact:** Georgia Institute of Technology, Continuing Education, Atlanta, GA 30332 (404) 385-3502 or e-mail: conted@gatech.edu.

CDMA Mobile Radio Design

■ **Topics:** Wireless communications, digital and RF systems, speech coding, data converters, RF transmitter/receiver circuits, next-generation CDMA and advanced architectures. Fee: $1495.
■ **Site:** Los Angeles, CA
■ **Date:** August 21–24, 2000
■ **Contact:** UCLA Extension, Short Course Program, 10995 Le Conte Ave., Los Angeles, CA 90024 (310) 825-1047, fax (310) 206-2815 or e-mail: mhenness@unex.ucla.edu.

Near-field Antenna Measurements and Microwave Holography

■ **Topics:** Near-field ranges (planar surface, cylindrical surface and spherical surface); basic theory, procedures and techniques for all three systems; and a tour of the National Institute of Standards and Technology near-field ranges. Fee: $1495.
■ **Site:** Boulder, CO
■ **Date:** Aug. 28 - Sept. 1, 2000
■ **Contact:** Georgia Institute of Technology, Continuing Education, Atlanta, GA 30332 (404) 385-3502 or e-mail: conted@gatech.edu.

Interactions between Microwaves and Optics

■ **Topics:** Optical processing of microwave signals. Fee: $1200.
■ **Site:** Grenoble, France
■ **Date:** Aug. 28 - Sept. 1, 2000
■ **Contact:** OMW Secretariat, LEMO-ENSERG, 23, rue des Martyrs - BP 257, 38 016 Grenoble, France +33 4 76 85 60 13 or e-mail: OMW@enserg.fr. Additonal information is available at www.enserg.fr/ecole/labos/lemo/.

High Efficiency Amplifiers for Wireless Communications Systems

■ **Topics:** Linear power amplifier (PA) design, gain/power match, load-pull and high efficiency techniques, harmonic effects, linearization and PA system issues, efficiency-enhancement techniques and design examples.
■ **Site:** Dublin, Ireland
■ **Date:** September 18–20, 2000
■ **Contact:** Continuing Education Institute (CEI)-Europe, PO Box 912, S-612 25 Finspong, Sweden +46 122 175 70 or e-mail: cei.europe@cei.se. Additional information can be obtained at www.cei.se.

RF and Microwave Receiver Design

■ **Topics:** Electronic warfare and wireless receivers from a system design point of view, and receiver requirements and flowing those requirements to the circuit design level and back. An example receiver design will be followed. Fee: $1785.
■ **Site:** Stockholm, Sweden
■ **Date:** October 24–27, 2000
■ **Contact:** Research Associates of Syracuse Inc. (RAS), 6780 Northern Blvd., Suite 100, East Syracuse, NY 13057 (315) 463-2266, fax (315) 463-8261 or e-mail: seminars@ras.com.

Phased-array Radar

■ **Topics:** Principles and technology of the phased-array antenna as well as overall system significance, design and performance.
■ **Site:** Stockholm, Sweden
■ **Date:** November 14–16, 2000
■ **Contact:** RAS, 6780 Northern Blvd., Suite 100, East Syracuse, NY 13057 (315) 463-2266, fax (315) 463-8261 or e-mail: seminars@ras.com.

HARMONIC TUNING OF POWER TRANSISTORS BY ACTIVE LOAD-PULL MEASUREMENT

A nonlinear network analyzer combined with an active multiharmonic load-pull system is described. Data acquisition uses an HP 71500 microwave transition analyzer (MTA) and force/sense bias supplies. Complete tuning and monitoring of the incoming and outgoing signals up to the third harmonic provide frequency and time domain characterization of the nonlinear transistor behavior. Signal compression curves, load-pull contours with harmonic tuning, DC and RF IV curves, and dynamic load lines are included. Typical measurements at 2 GHz show the influence of harmonic tuning on the operation of a 1 W power GaAs heterojunction bipolar transistor (HBT).

Maximum power transfer between source and load requires conjugate matching. However, if the source is a nonlinearly driven transistor, the load reflection coefficient Γ_l that meets this condition depends on the power level. The systematic collection of output power P_{out}, power-added efficiency (PAE), gain G and bias as a function of Γ_l is called load-pull measurement. All microwave device manufacturers engaged in power transistor and power amplifier (PA) development routinely make this measurement, which provides the basic information needed for developing new transistors and makes available the modeling data required in nonlinear circuit design.[1]

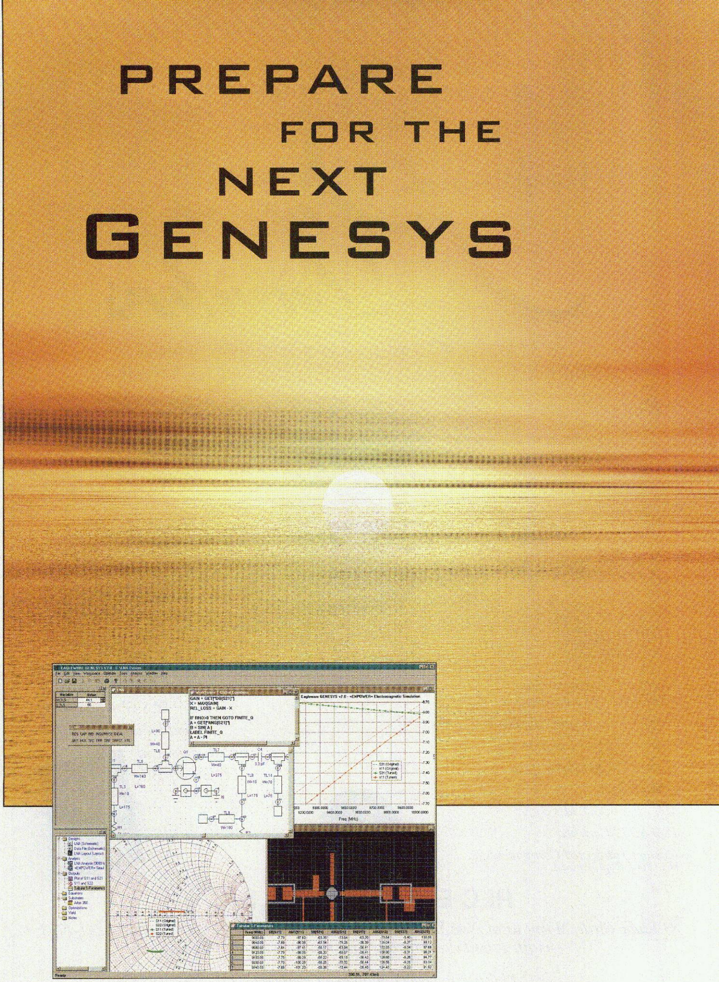
An active, multiharmonic load-pull measurement setup is described that produces the well-known contours in the Γ_l plane, marking specified P_{out} or PAE. The measurement of RF current and voltage in the transistor at a strong nonlinear drive level allows optimization of the transistor operation. The measurements are made at maximum P_{out}, PAE, best linearity and suitable Γ_{out}, avoiding high voltage breakthrough and other current-voltage waveform shaping effects. One important question is "How do the load impedances at the higher order harmonics influence these quantities?" Time domain measurements are very useful for this purpose.[2] Measurements are presented at a fundamental frequency of 2 GHz and its second- and third-order harmonics on a GaAs power HBT at low 3 V bias voltage because this is of special interest for mobile communication applications.[3]

ACTIVE OR PASSIVE LOAD PULL?

Active load pull is widely accepted as a method for characterizing power transistors in the microwave frequency range.[4] The main ad-

[Continued on page 26]

P. HEYMANN, R. DOERNER AND M. RUDOLPH
Ferdinand-Braun-Institut für Höchstfrequenztechnik
Berlin, Germany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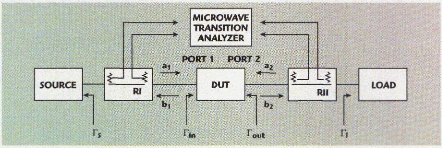
vantage over passive methods is the theoretically unlimited range of Γ_l (including $|\Gamma_l| = 1$), which enables conjugate complex loading at the fundamental frequency and proper termination at the higher harmonics. Passive load pull can be used if the losses between the tuner and the device under test (DUT) and inside the tuner itself are sufficiently small. However, power transistors often require Γ_l near unity for output match. For example, HBT power cells for handsets in mobile communication need operation at $V_{ce} \leq 3$ V but show output resistances of less than 5 Ω, which must be matched at more than 1 W output power. Strong transformation with a passive tuner always yields high losses that can be corrected by calibration of today's high precision tuner systems. However, the need for at least a probe and a cable between the DUT and the tuner prevents access to the $|\Gamma_l|$ range right next to the short.

At 2 GHz, a mechanical tuner including cable, bias-tee and microwave probe has 6 dB loss when transforming from 50 to 5 Ω. When the reflectometers between tuner and DUT are necessary for the vectorial RF current-voltage measurements, the loss is even higher. The ability to reach $|\Gamma_l| = 1$ (short, open) at the harmonics is important for the described system with harmonic tuning and can be realized only by an active system. While active load pull is the method of choice, it is not without serious limitations. The main problem is to provide the power for the reflected signal a_2 from the active load to the highly mismatched transistor output, as shown in ***Figure 1***.

Fig. 1 Power waves and reflection coefficients of the DUT between source and load.



The maximum power delivered to the load in the case of conjugate match ($\Gamma_l = \Gamma_{out}{}^*$) is given by

$$P_l = b_2^2 - a_2^2 \tag{1}$$

where the signal ratio is determined by the reflection coefficient

$$\Gamma_l = \frac{a_2}{b_2} \tag{2}$$

This relationship yields the power a_2^2 from the active load, which generates the required reflection coefficient at a specific level of output power, as shown in ***Figure 2***:

$$a_2^2 = P_l \frac{|\Gamma_l|^2}{1 - |\Gamma_l|^2} \tag{3}$$

This power strongly increases with decreasing output resistance of the transistor. Thus, handling problems, particularly in on-wafer measurement systems, are to be expected. For example, the realization of Γ_l = 0.92/180° (Z_{out} = 2 Ω real) for a 2 W transistor requires 12 W from the amplifier feeding the reflected signal a_2. In addition, the unavoidable loss in cables, directional couplers, bias-tee, switches and probes makes the short inaccessible. While this fact is

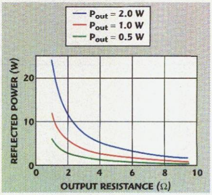


Fig. 2 Power of the reflected signal a_2 required for load match vs. transistor output resistance for various output power levels.

[Continued on page 28]

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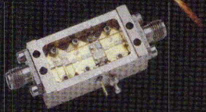

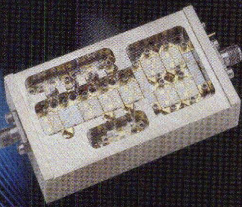

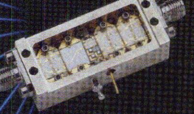

ULTRA BROAD BAND

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA018-203	0.5-18.0	20	5.0	2.5	7	17	2.0:1	250
JCA018-204	0.5-18.0	25	4.0	2.5	10	20	2.0:1	300
JCA218-506	2.0-18.0	35	5.0	2.5	15	25	2.0:1	400
JCA218-507	2.0-18.0	35	5.0	2.5	18	28	2.0:1	450
JCA218-407	2.0-18.0	30	5.0	2.5	21	31	2.0:1	500

MULTI OCTAVE AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA04-403	0.5-4.0	27	5.0	1.5	17	27	2.0:1	550
JCA08-417	0.5-8.0	32	4.5	1.5	17	27	2.0:1	550
JCA28-305	2.0-8.0	22	5.0	1.0	20	30	2.0:1	550
JCA212-603	2.0-12.0	32	5.0	3.0	14	24	2.0:1	550
JCA618-406	6.0-18.0	20	6.0	2.0	25	35	2.0:1	600
JCA618-507	6.0-18.0	25	6.0	2.0	27	37	2.0:1	800

MEDIUM POWER AMPLIFIERS

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-P01	1.35-1.85	35	4.0	1.0	33	41	2.0:1	1000
JCA34-P02	3.1-3.5	40	4.5	1.0	37	45	2.0:1	2200
JCA56-P01	5.9-6.4	30	5.0	1.0	34	42	2.0:1	1200
JCA812-P03	8.0-12.0	40	5.0	1.5	33	40	2.0:1	1700
JCA1218-P02	12.0-18.0	22	4.0	2.0	25	35	2.0:1	700

LOW NOISE OCTAVE BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-3001	1.0-2.0	40	0.8	1.0	10	20	2.0:1	200
JCA24-3001	2.0-4.0	32	1.2	1.0	10	20	2.0:1	200
JCA48-3001	4.0-8.0	40	1.3	1.0	10	20	2.0:1	200
JCA812-3001	8.0-12.0	32	1.8	1.0	10	20	2.0:1	200
JCA1218-800	12.0-18.0	45	2.0	1.0	10	20	2.0:1	250

NARROW BAND LNA'S

Model	Freq. Range GHz	Gain dB min	N/F dB max	Gain Flat +/-dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-1000	1.2-1.6	25	0.75	0.5	10	20	2.0:1	80
JCA23-302	2.2-2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7-4.2	30	1.0	0.5	10	20	2.0:1	90
JCA56-401	5.4-5.9	40	1.0	0.5	10	20	2.0:1	120
JCA78-300	7.25-7.75	27	1.2	0.5	13	23	2.0:1	120
JCA910-3000	9.0-9.5	25	1.2	0.5	13	23	1.5:1	150
JCA910-3001	9.5-10.0	25	1.2	0.5	13	23	1.5:1	150
JCA1112-3000	11.7-12.2	27	1.1	0.5	13	23	1.5:1	150
JCA1213-3001	12.2-12.7	25	1.1	0.5	10	20	2.0:1	200
JCA1415-3001	14.4-15.4	35	1.4	1.0	14	24	2.0:1	200
JCA1819-3001	18.1-18.6	25	1.8	0.5	10	20	2.0:1	200
JCA2021-3001	20.2-21.2	25	2.0	0.5	10	20	2.0:1	200

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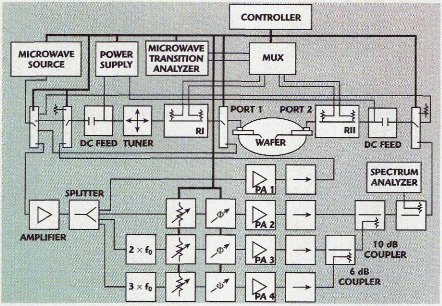
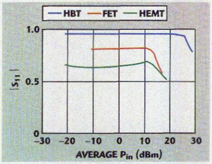


▲ *Fig. 3 The 2 GHz active harmonic load-pull system.*



▲ *Fig. 4 Decrease in input reflection coefficient with increasing input power for various devices.*

well known in passive load-pull setups, it also exists in active load systems, although at a different impedance level.

MEASUREMENT SYSTEM

Figure 3 shows a block diagram of the measurement setup comprising an on-wafer nonlinear network analyzer and active harmonic load-pull system for frequencies between 0.5 and 18 GHz. (The actual frequency range depends on narrowband components such as PAs and circulators.) The fundamental output (2 GHz) of the synthesizer is split into a source and three load parts. The fundamental wave a_1 is fed to port 1 via PA 1 (2 W), a bias-tee and reflectometer RI. The wave incident to port 2 is adjusted in magnitude and phase with respect to a_1 by an attenuator (79 dB, 1 dB step) and variable phase shifter. It is amplified by PA 2 (8 W) and forms the fundamental signal a_2. The output bias-tee must meet the requirements of testing high gain, broadband power devices in addition to withstanding more than 10 W RF power and 2 A DC current and providing very low reflection down to a few megahertz in order to prevent oscillations of the DUT.

The second- (4 GHz) and third-harmonic (6 GHz) signals are generated by a frequency doubler and tripler, respectively. These waves are adjusted in magnitude and phase, amplified to 1 W and combined by two directional couplers. The fundamental signal propagates in the main line to avoid any unnecessary loss. The other signals are coupled through the side arms. These three harmonics are superimposed at port 2 on the reflected signal a_2. The transmitted signal b_2 (including the harmonics) is absorbed by the circulator after passing the output reflectometer RII.

The signals at the input (a_1, b_1) and output (a_2, b_2) of the DUT are resolved by the reflectometers and measured by the HP 71500 MTA, an instrument similar to a vector network analyzer (VNA). The MTA measures complex wave ratios and scalar power values in the frequency domain and allows waveform measurements in the time domain at a very high dynamic range. The calibration of an MTA is the same as for a VNA (for example, short-open-line-thru), with the additional terms of power and phase distortion.[5] (The ratio of the power in the main line of the reflectometer to the value indicated by the MTA sampler must be calibrated and used for correction.) For power tuning, three harmonics are included; for waveform measurements, up to six harmonics (12 GHz) are used. The reflectometers RI and RII must be calibrated for measurement of the complete wave situation using the MTA.

As shown previously, considerable power is required to realize the small optimum load resistance for a 3 V HBT. It should be mentioned that the power handling in the output part of the setup requires several precautions for DC and RF feed. Therefore, attenuators, phase shifters and most switches are located in the low power area of the system. At the highest power levels above 1 W, it is very important to avoid load states with high voltages instead of high currents inside the transistor. Practically, this condition means the device most likely will be destroyed when Γ_l is located off the real axis. Hence, an automatic search algorithm that moves around the optimum point unconstrained is not recommended. An interactive measurement procedure is the most appropriate. Harmonic signal stability problems do not appear since 2f and 3f are generated independently for the DUT by frequency multipliers. Nevertheless, harmonic tuning at the power limit of the device can be painstaking work. The mutual interdependence of fundamental power, active harmonic feed to port 2 and harmonic generation by the DUT itself requires prudent operation to measure Γ_l.

INPUT TUNER OR 50 Ω SOURCE?

While predistortion of the input signal can improve linearity or efficiency of a PA, it is not within the scope of this article. The sinusoidal source is of interest with respect to its available power and reflection coefficient. There are two solutions for the input feed: a 50 Ω source realized by a PA and an isolator, or insertion of a tuner for conjugate input match in order to boost the power gain. Both arrangements were tested in the described system. The test setup includes a mechanical input tuner. The HBTs dealt with are highly mismatched devices at both the input and the output. Typical values for $|\Gamma_{in}|$ are shown in ***Figure 4***. The

[Continued on page 30]

change of S_{11} with increasing power is different for HBTs and FETs. Whereas the S_{11} of HBTs is nearly constant up to high power levels, FETs show a strong decrease due to the growing gate current.

Two other problems arise: A significant interdependence of Γ_{in} and Γ_l (particularly for bipolars) must be considered by changing the tuner transformation. In addition, the high input reflection coefficient $\Gamma_{in} \approx 0.95/180°$ of the HBT can hardly be matched by a passive tuner. Thus, even the strongest transformation cannot provide a conjugate source. This shortcoming is the same as discussed previously for the output match in passive load-pull systems for on-wafer measurements. The losses prevent the required transformation. The improved power transfer to the device is at the expense of increased losses in the tuner itself.

Another problem is to determine the value of Γ_s for the actual transformation state. If premeasured values are used, it is difficult to account for the changing Γ_{in} with power and Γ_l. Thus, the actual setting must be measured. Either way, the reflectometer RI is required in front of the DUT. The Γ_s measurement cannot be made without the switch between reflectometer RI and the DUT. The switch enables a stimulus signal to be fed in the opposite direction in order to measure the Γ_s coefficient in the network analyzer mode when the PA is switched off. Further error due to the tuner is introduced by the strong re-reflection of incident and reflected waves in the input line where the waves a_1 and b_1 are measured with the reflectometer RI. These disadvantages reduce the effectiveness of the tuner between the source and the DUT and, thus, the tuner is not used in this investigation and the measurements are made with the 50 Ω source only. The absence of re-reflections from the source means that the absorbed power of the DUT can be obtained from the difference of the power waves.

HARMONIC TUNING

The limitation in output power of a transistor can be understood from its DC current-voltage characteristics, as shown in ***Figure 5***. Using the device in low voltage amplifier operation (≤ 3 V), not much clearance exists to extend the voltage swing down-

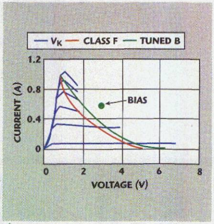


Fig. 5 IV characteristics of a 10 (3 × 30) GaAs HBT with load lines for harmonic tuning.

[Continued on page 32]

ward. The device knee voltage V_K marks the lower boundary ($v(t) \geq V_K$) and is determined by the ohmic region of a FET or by the saturation region of a bipolar junction transistor or HBT. Technological efforts to lower this value by reducing the parasitic resistances of the device are necessary but of limited use for this purpose. On the other hand, the maximum voltage can cause breakthrough ($v(t) \leq V_{BR}$). Possibilities exist for improvement of the device by optimum design. The current swing is restricted by the maximum current I_{max} of the device. Therefore, it is important to increase this value by technological measures.

Improvement of the power performance by means of harmonic tuning can be achieved by shaping the voltage waveform in such a way that the fundamental frequency amplitude becomes maximal. Superposition of harmonic sine waves with tunable phase and amplitude provides insight into the performance of power transistors and the shape of current and voltage in the output circuit of the device.[6] It is generally accepted that only three harmonics can be effectively controlled in a practical circuit, particularly in MMICs.[7] The number of circuit elements, the required expensive chip area for spacious passive components and the increasing loss of transformation elements prevent tuning of harmonics higher than the third one.

Simple analytic expressions for the superposition of voltage and current waveforms include

$$v(t) = V_0 + V_1 \sin(\omega t) + V_2 \sin\left(2\omega t - \frac{\pi}{2}\right) + V_3 \sin(3\omega t)$$

$$i(t) = I_0 + I_1 \sin(\omega t + \pi) + I_2 \sin\left(2\omega t + 2\pi - \frac{\pi}{2}\right) + I_3 \sin(3\omega t + 3\pi) \quad (4)$$

The DC bias (V_0, I_0) and voltage and current amplitudes of the fundamental and second- and third-harmonic waves (V_1, V_2, V_3) and (I_1, I_2, I_3) depend on the current-voltage characteristic of the transistor used.

The harmonic tuning effects are demonstrated on a GaAs HBT that has been developed as a low voltage power cell for applications in the lower gigahertz frequency range.[3] ***Table 1*** lists the HBT's key features. The boundary conditions are such that the actual currents and voltages do not penetrate into the prohibited areas of the IV characteristic. Thus, it must be assured that

$$v(t) \geq V_K \qquad i(t) \leq I_{max} \quad (5)$$

Therefore, the amplitudes and phases of the harmonics must be arranged in such a way that the bottom of the voltage wave, for example, becomes flat and fits smoothly into the low voltage part of the DC IV characteristic.

These considerations lead to the Fourier coefficients of RF current and voltage as a function of the device properties, as listed in ***Table 2***. The load reflection coefficient at the harmonic frequencies determines the class of operation, while the load at the fundamental frequency is conjugately matched. The first case (2f short, 3f open) is an approximation of class F operation with its attempt to square the sinewaves. The second case (2f open, 3f short) raises the peak voltage with the effect of higher P_{out} and PAE and has recently been referred to as tuned B operation.[7]

The Fourier coefficients are derived from the key features of power HBTs for tuned B operation. The knee voltage $V_K = 0.9$ V at high collector current is obtained from the IV characteristic. The collector bias voltage $V_0 = 3$ V is predetermined by the requirements of low voltage operation. The maximum current is assumed to be $I_{max} = 1$ A since it corresponds to a current density of 1.1×10^5 A/cm^2 and is not a hard saturation. This value is within the range of $1\ldots2 \times 10^5$ A/cm^2, which determines the typical limit of these devices. The breakdown voltage $V_{BR} > 12$ V is not reached and, therefore, is not a limiting parameter.

The superposition of the harmonics is such that

$$I_{max} = I_0 + I_1 - I_3$$
$$I_{min} = I_0 - I_1 + I_3 = 0$$
$$V_K = V_0 - V_1 + V_2 \quad (6)$$

From the condition of maximally flat curves it follows that [9]

$$I_3 = \frac{1}{9} I_1 \qquad V_2 = \frac{1}{4} V_1 \quad (7)$$

This relationship leads to

$$I_0 = \frac{1}{2} I_{max} = 0.5 \text{ A}$$

$$I_1 = \frac{9}{16} I_{max} = 0.56 \text{ A}$$

$$V_1 = \frac{4}{3}(V_0 - V_K) = 2.8 \text{ V} \quad (8)$$

The results are shown in the previously displayed IV characteristics as

[Continued on page 34]

TABLE I

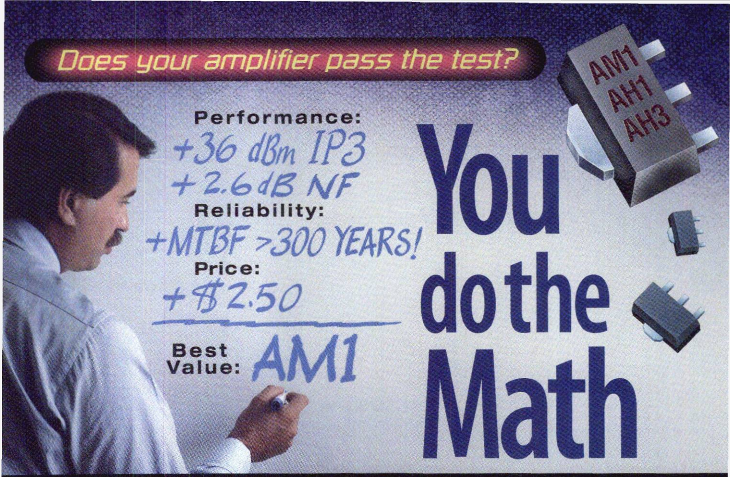
THE POWER HBT'S KEY FEATURES

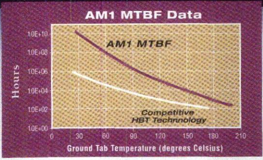
Material	GaInP/GaAs
Emitter area (μm^2)	900
Fingers	10
I_{max} (A)	1
V_K (V)	0.9
V_{BR} (V)	> 12
V_0 (V)	3

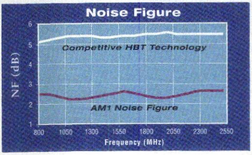
TABLE II

FOURIER COEFFICIENTS OF CURRENT AND VOLTAGE WAVES DERIVED FROM THE DC IV CHARACTERISTICS (V_0 = 3 V)

Harmonic Control	Loading at Harmonic		Voltage			Current			
	2nd	3rd	V_1	V_2	V_3	I_0	I_1	I_2	I_3
class F	short	open	$V_0 + V_3 - V_K$	0	$V_1/9$	(3/8) I_{max}	(4/5) I_{max}	$I_1/4$	0
tuned B	open	short	$V_0 + V_2 - V_K$	$V_1/4$	0	(1/2) I_{max}	(9/16) I_{max}	0	$I_1/9$
none	load	load	$V_0 + V_2 + V_3 - V_K$	$V_1/8$	$V_1/9$	(1/2) I_{max}	(1/2) I_{max}	$V_2/50$	$V_3/50$







WJ High Dynamic Range Amplifiers

Product	Frequency (MHz)	IP3 (dBm, typ.)	P1dB (dBm, typ.)	NF (dB, typ.)	Bias current (mA, typ.)
AM1	250-3000	36	18	2.6	75
AH1	250-3000	41	21	2.9	150
AH3	50-450	40	21	2.8	150

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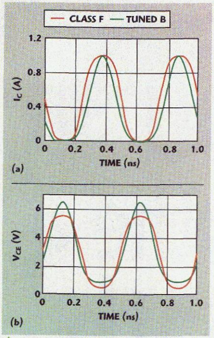


▲ *Fig. 6 The GaAs HBT device's (a) current and (b) voltage waveforms.*

Fig. 7 Effects of harmonic tuning on P_{out} and PAE at the fundamental frequency. ▼

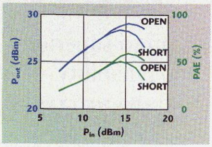
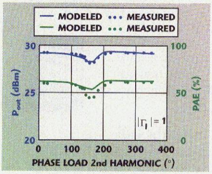
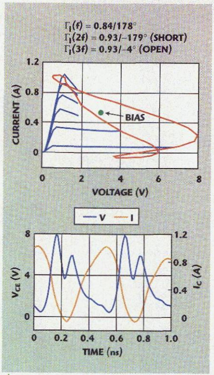


Fig. 8 P_{out} and PAE at 2 GHz vs. the phase angle Γ_l at the 4 GHz second harmonic. ▼



well as the I_C and V_{CE} vs. time plots shown in ***Figure 6*** and confirm that tuned B operation with a second-harmonic open and third-harmonic short is a promising concept for low voltage PAs when only these two harmonics are included. The time dependences of tuned B and class F harmonic control lead to the IV contours in accordance with Equation 4.

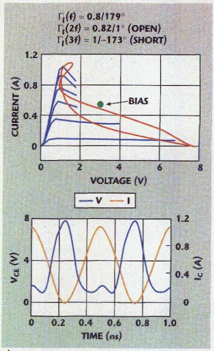


▲ *Fig. 9 Measured current-voltage contours produced by squaring the sinewave with three harmonics for an HBT where P_{out} = 28.4 dBm and PAE = 38%.*

CURRENT-VOLTAGE HBT MEASUREMENTS AT 1 W POWER LEVEL

The distinctive feature of the presented system is its ability to measure RF performance at realistic power levels of 1 W and above and tune harmonic loads to any value on the Smith chart. The superposition of harmonic voltages and currents is a very simplified approach to the real situation in the output circuit of a PA. Nevertheless, it is clear that the waveforms become asymmetrical due to the harmonic content, and this asymmetry can be used to increase the amplitude of the fundamental wave (that is, the peak voltage can be greater than $2 \times (V_0 - V_K)$).

Figure 7 shows typical P_{out} vs. P_{in} measurements for an HBT with an optimized load at 2 GHz. The saturated value is higher if the second harmonic is open instead of a short. Maximum P_{out} and PAE are shown in ***Figure 8*** where the available source power is 22.5 dB and the load at 2 GHz (0.78 Ω/177°) is optimized for maximum P_{out}. When the phase of the load reflection coefficient at the second harmonic (4 GHz) is varied, a distinct minimum of both quantities is observed near the second-harmonic



▲ *Fig. 10 Measured current-voltage contours using tuned B operation with three harmonics for an HBT with voltage peaking and optimum contour in the device's saturation range where P_{out} = 29.6 dBm and PAE = 51%.*

short (180°). This result is confirmed by harmonic balance calculations of the nonlinear transistor model.[8]

The IV contours in the microwave range are strongly influenced by the reactive components of the transistor. Thus, the measured waveforms of a power HBT near the 1 dB compression point, as shown in ***Figures 9*** and ***10***, indicate the wave shaping that actually can be achieved. The basic effect of harmonic tuning can be seen clearly. The reduction of V_l with a 2f short corresponds to squaring the sinewave (class F).[9] The increase of V_l with a 2f open is the reason for increasing P_{out} and PAE (tuned B). In addition, the flattening of the bottom part, enabling the smooth fit to the left part of the IV characteristic, becomes obvious. These very peculiar waveforms can be verified only by a comprehensive nonlinear transistor model. On the other hand, verification of these measured waveforms and the other load-pull results from the model calculations represents the most stringent test of such a model.

The question of linearity arises because the high voltage amplitude at 2f is expected to deteriorate the intermodulation performance of the

[Continued on page 37]

device. This possible disadvantage can be addressed by predistortion of the input signal. However, the realization of hybrid PAs reported by Heima et al.[7] demonstrates that the adjacent-channel power rejection of tuned B is not worse than that of class F, while P_{out} and PAE are much better.

CONCLUSION

A powerful and affordable tool is described for nonlinear on-wafer measurements in the 0.5 to 18 GHz frequency range that is useful for designing high efficiency PAs for mobile communications. The device meets foundry requirements for tuning process parameters for new power transistors and tests nonlinear CAD models of those devices. One special feature is the access to vectorial RF current and voltage waveforms, which are the most important intrinsic parameters of transistor operation. These measurements can be performed at power levels of more than 1 W with $|\Gamma_l| \leq 0.9$ for the fundamental wave and for $|\Gamma_l| = 1$ at the second and third harmonics. ■

References

1. M. van den Bossche, "Accurate and Traceable High Frequency Large Signal Measurements of Two Ports," *Proceedings of HP Workshop*, European Microwave Week, München, 1999, pp. 1/1–1/15.
2. J. Verspecht, P. Debie, A. Barel and L. Martens, "Accurate On-wafer Measurements of the Spectral Components of Incident and Scattered Voltage Waves at the Signal Ports of a Nonlinear Microwave Device," *IEEE MTT-S International Microwave Symposium Digest*, Orlando, 1995, pp. 1029–1032.
3. M. Achouche et al., "GaAs Power HBTs for Mobile Communications," *GaAs 99 Digest*, München, 1999, pp. 448–451.
4. P. Berini, M. Desgagne, F. Ghannouchi and G. Bosisio, "An Experimental Study of the Effects of Harmonic Loading on Microwave MESFET Oscillators and Amplifiers," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, 1994, pp. 943–950.
5. G. Kompa and F. van Raay, "Error-corrected Large Signal Waveform Measurement System Combining Network Analyzer and Sampling Oscilloscope Capabilities," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 38, 1990.
6. P. Colantonio, F. Giannini, G. Leuzzi and E. Limiti, "A Unified Approach to High Efficiency Microwave Power Amplifier Design," *GaAs 99 Digest*, München, 1999, pp. 272–275.
7. T. Heima, A. Inoue, A. Ohta, N. Tanino and K. Sato, "A New Practical Harmonics Tune for High Efficiency Power Amplifier," *29th European Microwave Conference Digest*, München, 1999, pp. 271–274.
8. M. Rudolph, F. Lenk, R. Doerner and P. Heymann, "Influence of 2 GHz Harmonic Load-pull on HBT and MESFET Output Power and Efficiency," *IEEE MTT-S International Microwave Symposium Digest*, Anaheim, CA, 1999, pp. 741–744.
9. F.H. Raab, "Class F Power Amplifiers with Maximally Flat Waveforms," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 45, Nov. 1997, pp. 2007–2011.

Peter Heymann *received his Dipl. Phys. and Dr. rer. nat. degrees in physics from the University of Greifswald, Germany in 1963 and 1968, respectively. From 1963 to 1982, he worked on different projects in the field of wave plasma interaction, including wave propagation, RF plasma sources and heating, and microwave and far infrared plasma diagnostics. Since 1982, Heymann has been working on GaAs microwave electronics. In 1992, he joined the Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin. He currently is responsible for measurement, characterization and modeling of active and passive components of microwave MMICs.*

Ralf Doerner *received his Dipl. Ing. degree in communications engineering from the Technical University Ilmenau, Germany in 1990. Since 1989, he has been working on microwave measuring techniques. In 1992, Doerner joined the Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin. His current research is focused on calibration problems in on-wafer millimeter-wave measurements of active and passive devices and circuits and on nonlinear characterization of microwave power transistors.*

Matthias Rudolph *received his Dipl. Ing. degree in electrical engineering from Technical University Berlin, Germany in 1996. Since then, he has been working toward his Dr. Ing. degree at Ferdinand-Braun-Institut für Höchstfrequenztechnik, Berlin. Rudolph's research focuses on characterization and modeling of FETs and HBTs.*

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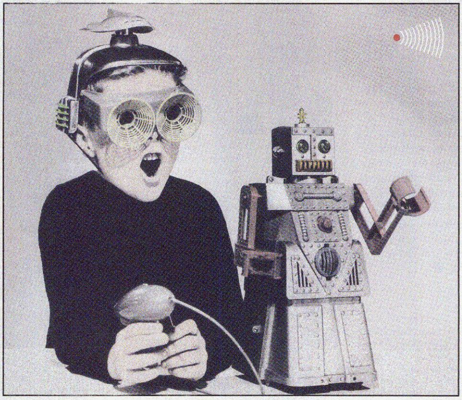

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ADE-5	3	5-1500	+7	6.6	40**	15	3.45
ADE-13	2	50-1600	+7	8.1	40**	11	3.10
ADE-20	3	1500-2000	+7	5.4	31	14	4.95
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Defense Department Air Traffic Control Modernization Moves Forward

Recent decisions made at the US Air Force Electronic Systems Center, Hanscom Air Force Base, MA, and within the Department of Defense (DoD) have had positive effects on the DoD's overall effort to modernize its air traffic control (ATC) systems. The completion of the Electronic Systems Center's preproduction activities with the system have led to a positive decision for low rate initial production (LRIP) of the Raytheon ASR-11 Digital Airport Surveillance Radar (DASR). In addition, the DoD made a similar decision earlier this year to proceed with LRIP for the Raytheon Standard Terminal Automation Replacement System (STARS), also known as the DoD Advanced Automation System (DAAS). Both decisions followed successful development/operational tests of the two systems at Eglin AFB, FL, which were completed in December 1999.

The Eglin AFB system is the first step in the DoD's plans to procure up to 104 ASR-11s and up to 191 STARS for its radar approach control facilities and associated ATC towers. Both programs are joint procurements with the Federal Aviation Administration (FAA); the DoD leads the radar procurement and the FAA leads STARS. Live operation of the ASR-11 and STARS at Eglin AFB is scheduled to begin early this summer.

The ASR-11 DASR is a solid-state airport surveillance radar with primary surveillance coverage to 60 miles and secondary coverage to 120 miles, which can detect up to six levels of weather. Up to 216 ASR-11s are being planned for DoD and FAA procurement. The STARS/DAAS is an open-architecture air traffic automation system that provides high resolution color displays as well as improved computer processing and communication equipment. The system has six-level weather display and multiradar tracking capability and allows incorporation of new hardware and software features. Planned total procurement of STARS for terminal ATC facilities is 331 systems.

US Fighter Aircraft FLIR Market to Reach $1 B by 2009

A new study from the Teal Group, "Fighter FLIR Market Forecast," predicts that the production value of US fighter aircraft Forward-looking Infrared (FLIR) systems will reach $1 B by 2009. According to the study, the next-generation fighter FLIR market has been fairly well settled by recent major contract awards. Raytheon will produce more than 500 ATFLIR pods for the F/A-18C/D and E/F, and the Northrop Grumman/Rafael Litening II is entering production for more than 200 US Marine Corps AV-8Bs and US Air National Guard F-16s.

The study notes that Lockheed Martin, presently the world's largest FLIR manufacturer, is without a major program for its third-generation FLIR, the Sniper, a situation probably not in the Pentagon's best long-range interests. A predictable solution to this problem is seen in the US Air Force's plans to install targeting pods on its F-16CJs for destruction as well as suppression of enemy air defenses. Analysts expect that the Sniper is suitable for the Advance Targeting Pod application and has the added benefit of maintaining some commonality with the hundreds of Air Force dual-pod LANTIRNS already in service. The projected production of several hundred Sniper pods will position that system between Litening II and ATFLIR in dollar value US sales. In the international market, all three US systems are expected to enjoy strong sales. For additional information, contact David Rockwell, Teal Group (703) 385-1992, ext. 106.

Study Examines Effects of Changing Threats on Sensor Development

A new study from Frost & Sullivan, "World Naval Radar and Sonar Markets," examines the changing nature of naval military threats as well as the effect of those changes on radar and sonar sensor development and the sensor markets. The study identifies asymmetric warfare — a scenario in which a combatant exploits an adversary's weakness while avoiding its strength — as the major stimulation for the development of small, high firepower ships (and the new generation of sonar and radar sensors to equip them). Many nations are in the process of procuring smaller naval vessels in the frigate and patrol boat classes as the interest in smaller vessels with improved capabilities and firepower grows. The market is expected to benefit from this new interest and is forecast to increase from its 1999 level of $633.4 M to $1 B by 2005. This strong growth is expected to continue through 2008.

Information technology advancements are increasingly being applied to the naval sensor markets as demands for the effective integration of radar and sonar sensor data grow. The processing and integration of data from multiple platforms reduce reliance on any individual source that might be disabled and improve chances for mission success. In addition, the area of operations is expanded and clutter in the target area being surveyed also may be reduced due to improved threat identification.

Mine countermeasures applications are viewed as excellent opportunities for growth of the sonar sensor market. A new generation of mine sweepers as well as mine detection equipment requirements for combat vessels are there to be served by new sonar mine detection and identification systems. For additional information, contact Rolf Gatlin, Frost & Sullivan (210) 348-1017 or e-mail: rgatlin@frost.com. The company's Web address is www.frost.com.

Navy Exercises First-Year Production Option for SATCOM Systems

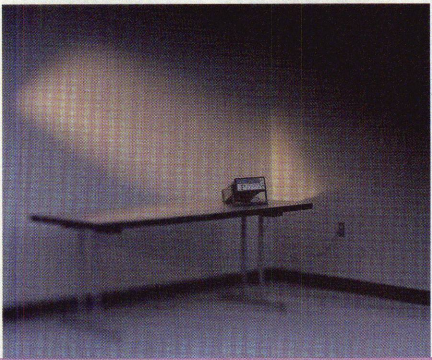
The US Navy has exercised its first-year options for production of satellite communication (SATCOM) systems for surface ships, shore stations and submarines. The order to Raytheon Co. has a value in excess of $54 M. The procurement for the Navy Extremely High Frequency (EHF) SATCOM Program Low Data Rate/Medium Data Rate (LDR/MDR) follow-on terminal includes options for the acquisition of additional systems this year as well as over the remaining four years of the program. If all options are exercised, LDR/MDR terminal production, installation and commissioning could be worth up to $414 M.

The LDR/MDR terminal is the successor to Raytheon's AN/USC-38 EHF low data rate military SATCOM (MILSATCOM) terminal. It comprises a common communications equipment suite fitted with one of four antenna sets adapted for surface ships, submarines and shore stations. The program provides secure, reliable satellite connectivity for two-way imagery and data and voice communications anywhere in the world using the Milstar, UHF follow-on and polar orbiting satellite constellations. Plans are also underway to permit terminals aboard submarines to communicate via the Defense Satellite Communication System as well.

US Multiband Multimission Radio Contract Awarded

The US Special Operations Command (USSOCOM) has awarded a four-year contract to Raytheon Co. for the production of Multiband Multimission Radio (MBMMR) systems. The initial award under the indefinite delivery, indefinite quantity agreement has a value of $5.75 M and covers the delivery of two vehicular and 227 manpack systems. Fully exercised options would increase the total value of the contract to $179 M.

The MBMMR is an enhanced system designed for US Army, Navy and Air Force special operations forces. The new radio lightens the load of a special forces soldier by 18 pounds while replacing several single-band radios currently used to communicate on different networks. Its enhancements include Have Quick II; SINCGARS SIP, an enhanced key management system for secure communications links; 30 to 512 MHz frequency coverage; and high speed, line-of-sight data transmission. ■



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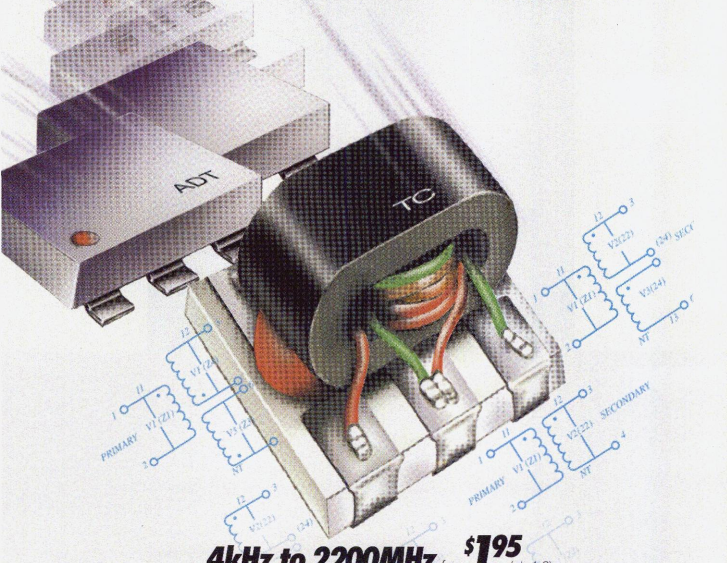

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INTERNATIONAL REPORT

Martin Streetly, International Correspondent

Egypt to Acquire Shore-based GMDSS Communications Infrastructure

Egyptian service provider Egypt Telecom, Cairo, Egypt, has contracted with a consortium comprising Thomson-CSF Systems Canada and Mackay Radio Systems Inc., Youngsville, NC, to provide the shore-based communications infrastructure for Egypt's national Global Maritime Distress and Safety System (GMDSS) as well as its public maritime correspondence network. The programme will establish a digital communications system to serve Egyptian coastal waters along the country's Mediterranean and Red Sea coasts together with the Suez Canal. The network will comprise three communications control centres and 22 radio sites that will provide coverage along 2450 km of coastline. The service provided will operate in the VHF (30 to 300 MHz) band and extend out from the coastline to a range of approximately 56 km from the coast. The network will incorporate digital selective calling to facilitate automated radio watch keeping on the maritime distress and calling channels together with automatic direct dial public telephone connectivity between ships at sea and Egypt Telecom's terrestrial telephone network. The network's GMDSS function is designed to provide automatic warning of emergencies at sea using digital communications technology. The approach has been adopted by the United Nations' International Maritime Organisation as a worldwide standard and the organisation's member states have agreed to install GMDSS equipment with their merchant fleets as an article of the International Convention for the Safety of Life at Sea. Funding for the maintenance of the network's GMDSS capability is to be partly derived from the revenue raised by the system's public access ship-to-shore/shore-to-ship communications element.

Racal Outlines Noncooperative Bistatic Radar

UK contractor Racal Defence Electronics has issued the first open source description of its Triton noncooperative, passive bistatic radar system, which apparently is related to an application Racal may be supplying to the UK's Royal Navy (RN) for use within its submarine fleet. Triton is a passive enhancement to an existing electronic support (ES) capability, which generates a radar-type picture of a vessel's surroundings (including other ships and coastline features) that is updated in real time. As such, the system exploits noncooperative donor radar to calculate the range and angle of a target via comparison of the direct transmissions from the donor radar and reflections from the target.

Functionally, Triton makes use of an automatic search algorithm that identifies an optimum donor radar. An integral recall feature allows use of optimum gain, range, automatic gain control and fade settings for any scenario. The system offers both real-time and snapshot operating modes. The real-time option provides a traditional plan position indicator display that plots each successive sweep of the donor radar's antenna with a fade control adjusting clutter levels and contact intensities. In snapshot mode, Triton allows its operator to record a selectable time-slice of the donor radar. Once recorded, the data can be plotted immediately or stored for subsequent analysis.

The system comprises an antenna assembly, receiver unit, processor and optional local controller. The antenna assembly can be either the omnidirectional array of the host ES equipment or a dedicated omni unit. The receiver is high sensitivity, low noise, ruggedised, commercial-off-the-shelf (COTS) superheterodyne equipment that is designed for installation in standard 19-inch (48 cm) racking. Similarly, the equipment's processor is a COTS device that incorporates digital signal processing cards and integral DVD random access memory discs. The processor also includes an interface for an optional differential Global Positioning System receiver. The display generated by Triton can be overlaid on the host ES system's display or presented on the optional local controller, which takes the form of a ruggedised laptop computer. Racal notes that the Triton system can make use of most commonly used radar bands and has a minimum and maximum range of 0.19 km and 74+ km, respectively. The equipment's range resolution is 25 m (typ), with an azimuth resolution value of 0.1° (typ).

MAMBA Specified

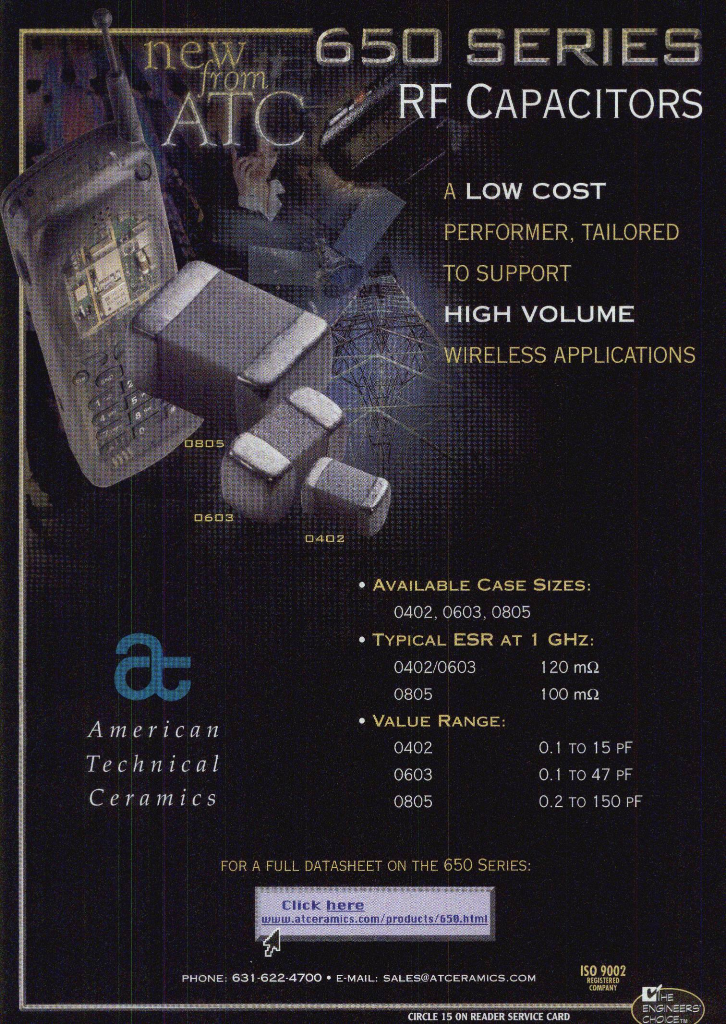
Information received by 'International Report' has started to flesh out the bones of the British Army's proposed Mobile Artillery Monitoring Battlefield (MAMBA) radar programme. Designed to support the evolving Joint Rapid Reaction Force, the MAMBA requirement will provide a highly mobile mortar and in-flight munition detecting radar that is capable of round-the-clock operation in all weather conditions. Key user requirements include a minimum range of 15 km, air transportability, a 75 m circular error of probability against a 155 mm shell at a range of 15 km and an elevation of 25°, a 50 percent probability of detection, an operational availability figure of at least 95 percent over a 30-day in-action period and interoperability with indirect fire systems via digital links. As currently scheduled, a preferred MAMBA bidder is expected to be selected by the end of this year, with a procurement contract being signed by the end of March 2001. The envisaged initial operating capability for the first five MAMBA systems is set at 2002/3, with a second tranche of four radars having a target in-service date of 2008/9. The British Army already evaluated the Swedish Arthur and American Firefinder radars in the MAMBA context in 1999. It is not known whether this evaluation was intended to define the MAMBA requirement or examine systems capable of fulfilling the programme specification.

Royal Navy Buys New Surface-to-air Communications System

Northrop Grumman's UK-based subsidiary, Park Air Electronics, Lincolnshire, England, is supplying the UK's RN with a new VHF-band radio system to facilitate communications between its surface ships and civilian aircraft. According to Park Air, the requirement for such a capability has been focused by the need to coordinate communications in areas where its operations are likely to impinge on civilian airspace users. The urgency of the requirement was also driven by the recent introduction of 8.33 kHz channel spacing in the VHF air mobile band and a continuing desire on the service's part to comply with the latest relevant International Civil Aviation Organisation (ICAO) standards. Park Air's T6M base station is at the heart of the new capability and features a compact design that is suitable for installation aboard ships of varying sizes. T6M makes use of digital signal processing technology that enables it to support the recently introduced 8.33 and 25 kHz channel spacings laid out in the latest ICAO standards. Each installed base station will be equipped with four parallel remote control interfaces that will allow it to be operated from key communications positions around its host vessel. In addition, T6M is able to automatically monitor the 121.5 MHz international distress frequency using its integral scanning facility. Park Air is also under contract to install the system and run the necessary trials prior to the equipment's introduction into service.

Russia Markets Fuze Jammer

Russia's Bryansk Electromechanical Plant is reportedly marketing the new SPR-2 proximity fuze jamming system. Installed aboard an eight-wheeled BTR-70 armoured personnel carrier, the 500 kg SPR-2 system operates in the 100 to 500 MHz frequency band and is designed to protect high value targets (such as artillery batteries) from attack by proximity fuzed munitions. SPR-2 provides area coverage of between 200,000 and 600,000 m^2 and can detonate incoming shells at an altitude of approximately 400 m. The system is operable while the carrier vehicle is moving or stationary, and is believed to have been in service with the Russian Army since the late 1990s. ■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Consumer Two-way Broadband Satellite Internet Service Set to Debut

Gilat-to-Home Inc., a joint venture of Gilat Satellite Networks Ltd., Microsoft and, with its recent \$50 M investment in the venture, EchoStar Communications Corp., plans to introduce the first US two-way satellite broadband service later this year. Under the terms of an earlier agreement, EchoStar and Gilat planned to jointly offer two-way, Ku-band, high speed satellite Internet access along with EchoStar's DISH Network™ satellite television programming via a single 24" × 36" consumer dish. As part of the latest agreement, EchoStar will distribute Gilat-to-Home broadband Internet service powered by MSN along with DISH Network satellite TV service through its 23,000 plus retailers across the US. DISH Network customers will be able to add "always on" Internet access with an MSN-Gilat-to-Home co-branded portal.

Verizon Wireless to Invest \$3 B in Network

Verizon Wireless, the new company formed by the combination of the US wireless assets of Bell Atlantic Corp. and Vodafone AirTouch Plc with PrimeCo Personal Communications, is expected to expand its coverage even further when the merger of Bell Atlantic and GTE Corp. is completed within the next couple of months. At that time, Verizon Wireless will serve nearly 90 percent of the US population and 96 of the top 100 US wireless markets. The new company, including GTE Wireless, has announced plans to invest \$3 B in its network this year. The investment will be one of the largest ever made in the industry and will expand the company's digital service areas and increase its capacity for wireless voice and data services to its 24 million plus customers. Planned network enhancements, technology trials and new services include testing of the first wireless two-way short messaging service, testing of third-generation network technology through field trials, expansion of the CDMA digital network, wireless network support for General Motors' On-Star personal calling feature and deployment of Over-the-Air provisioning via the CDMA digital network.

In collaboration with Lucent Technologies and Nortel Networks, Verizon Wireless plans to offer the first wireless nationwide two-way short messaging service. Using Kyocera and Motorola handsets for delivery, the service introduction is planned for the third quarter and will permit mobile users to send text messages to compatible mobile handsets or Internet users. Messages will be possible while subscribers are on voice or data calls and may be composed on keypads or selected from standard messages stored in the handsets. Delivery confirmation and user acknowledgment features will accompany the service. The General Motors agreement deals with a backbone wireless network that Verizon Wireless will provide to serve the personal calling feature to be added to GM's On-Star system. Approximately four million of these systems are expected to be in service within the next three years. The Over-the-Air provisioning service will provide remote activation and telephone number and area code changes via the company's CDMA digital network. Additional enhancements will make it possible to update wireless telephone software.

Audiovox Communications and Verizon Reach Major Handset Agreement

In related news, audiovox Communications Corp. has reached an agreement with Verizon under which Audiovox will supply Verizon with one million CDM-9000s, the company's new tri-mode, Web browsing cellular handset. Weighing 4.8 ounces, the CDM-9000 supports CDMA and AMPS 800 MHz systems as well as the 1900 MHz PCS band. It features a Web browser that offers soft-touch navigational keys for Internet access, a vibrating alert and alarm clock, voice-activated dialing, data capability, an enhanced phonebook and memory, caller ID with name, short message service, voice mail notification and a choice of 15 audible rings.

Broadband Market to Exceed \$580 B by 2010

A new study from COMSYS, "The Broadband Report," analyzes demand for broadband services on a country by country basis in both the Small to Medium Enterprise (SME) and Household markets and forecasts that global demand for the services in those markets will surpass \$580 B by 2010. Approximately 14 million addressable SMEs are expected to be active in the US by 2010. However, the combination of market size, greater dependence on high speed networks and higher economic growth is expected to lead to higher levels in Europe by 2005 and in Asia by 2010. The total Household sector is projected to include 600 million households in the addressable market this year. While the US is expected to lead the demand for household broadband connectivity, surges in both European and Asian markets are expected to quickly make those areas the most active. By 2010, Asian demand, while covering only 26 percent of regional households, is projected to be double that of the US. Total global SME demand is forecast to reach \$100 B by 2010. For additional information, contact Niall Rudd, COMSYS +44-1727-832288 or e-mail: niall@comsys.co.uk.

European Long-haul Fiber Demand Triples 1997 Level

A new study from KMI Corp., "Networks of Fiber-based Pan-European Carriers: Market Developments and Forecasts," reports that pan-European operators deployed six million kilometers of fiber in 1999 and will probably do the same in 2000. According to the study, the sustained growth is fueled by regulatory changes, liberalization and opportunities to challenge recently privatized PTTs with modern, next-generation networks. Since January 1997, more than 20 pan-European network operators have announced plans to build fiber-optic networks. Another group of pan-European carriers will lease fiber or capacity to provide services to their users, raising the total number of carriers offering services over fiber to 40. To serve the demand, typical installations involve more than 100 fibers of the non-zero dispersion-shifted variety, a high performance fiber that will carry multiple-wavelength channels over long distances.

A number of the US-based pan-European carriers are building European networks that will connect with their North American networks. Others are extending their reach by building metropolitan area networks. The study also forecasts that pan-European operators will install 16.7 million fiber-km from 1998 through 2002 and notes that 90 percent of the backbone fiber installed will be deployed by operators who were not offering long-haul services before 1998. Non-zero dispersion shifted fiber is expected to account for 75 percent of new deployments in Europe with 96-fiber cable dominating backbone installations and 144-fiber cable typical of MAN installations. For additional information, contact KMI Corp. (401) 849-6771 or e-mail: info@kmicorp.com.

Internet Capability Via Satellite Telephone and Globalstar Network Demonstrated

Earlier this year, a successful test transmission of Internet data through the Globalstar network via a tri-mode telephone was demonstrated from a South American site. The demonstration employed a standard laptop computer connected to a QUALCOMM tri-mode telephone suitable for use on analog and CDMA cellular systems as well on the Globalstar network. E-mail messages and other data traffic were transmitted and received across the Internet at rates of up to 9600 bps. ■

INDUSTRY NEWS

Industry friend and colleague **Thomas James Zinkowsky ("TZ")** died April 30 in Santa Cruz, CA following a motorcycle accident. He was 35. For the past 18 years, TZ worked for Signal Technology Corporation, Danvers, MA, rising to the position of director of corporate sales and marketing in addition to his role as senior sales manager for the California Operation. Among his many interests, TZ was an avid rock and ice climber and enjoyed adventure travel. He brought a unique passion to all of his endeavors and a sincere, caring nature to all who were privileged to know him. He will be sorely missed.

■ **dBm LLC**, Wayne, NJ, has finalized an agreement to purchase the satellite test equipment line from **Telecom Analysis Systems**, Eatontown, NJ. This asset acquisition enhances dBm's position as a supplier of RF link emulation equipment for the satellite industry. Financial terms of the transaction were not disclosed.

■ **ITT Industries Inc.**, White Plains, NY, has signed an agreement to acquire **C&K Components Inc.**, Watertown, MA, a privately held designer and manufacturer of switches for the telecommunications, computer and electronic equipment markets. The acquisition is valued at approximately $117 M after accounting for cash and debt in the company to be acquired and will make ITT Industries the largest switch manufacturer in the world. C&K will operate as part of ITT's Cannon Division.

■ **SEMX Corp**'s subsidiary, **Polese Company**, San Diego, CA, has completed its acquisition of the assets of ceramic package manufacturer **Advanced Packaging Concepts**, Vista, CA. Specific terms of the transaction were not disclosed.

■ **Conexant Systems Inc.** has agreed to acquire **Philsar Semiconductor Inc.**, Ottawa, Ontario, Canada, a privately held developer of RF semiconductor solutions for personal wireless connectivity. The Philsar team will join Conexant's Wireless Communications Division, which provides a broad range of wireless components, RF subsystems and complete semiconductor system solutions for digital cellular and cordless telephone handsets as well as Global Positioning System (GPS) products, but will retain the Philsar name.

■ **ADC Telecommunications Inc.**, Minneapolis, MN, has entered into agreement to acquire the television broadcast assets of **Continental Electronics Corp. (CEC)**, Dallas, TX. The deal is a cash transaction that was expected to close during ADC's second fiscal quarter ending April 30.

■ **Litton Interconnect Technologies**, Springfield, MO, has purchased six Excellon Automation XLP drilling systems from **Excellon Automation Co.**, Torrance, CA. The purchase is intended to help expand Litton's PCB operations' capacity to produce high performance, high speed backplanes. The XLPs will be equipped with Excellon's exclusive EFS technology for the precise depth controlled drilling required.

■ **W.L. Gore & Associates Inc.**, Eau Claire, WI, has purchased its second ScanMan™ automated flip-chip carrier test system from **Everett Charles Technologies (ECT)**, Pomona, CA.

■ Proprietary RFIC provider **RF Micro Devices Inc.**, Greensboro, NC, has established a local sales and support team in Taiwan, ROC. The team comprises Taiwanese sales and application engineering personnel and is the first such expansion for the company into the Asia-Pacific region.

■ **Wide Band Systems Inc.**, Rockaway, NJ, has established a Defense Systems Division in a new, 12,000-square-foot facility in Neshanic Station, NJ. The new division was established to develop advanced electronic warfare (EW) systems incorporating the company's patented receiver technology, including its digital frequency discriminators and instantaneous frequency measurement receiver systems.

■ **Seiko Instruments USA Inc.'s Fiber Optics Group**, Torrance, CA, has expanded its production facility under the direction of Mark Kim, a newly appointed senior production manager, in an attempt to meet the growing market demands for cable assemblies and termination solutions. Expansion plans are currently underway and were expected to double the company's capacity in March and triple the capacity by August. Plans also include creating a fully electrostatic discharge-compliant class 10,000 clean room to provide optimal quality and cleanliness, which is critical in the fiber-optics industry.

■ Cavity filter and diplexer designer and manufacturer **Wireless Technologies Corp.**, Springdale, AR, has opened a new field office in San Francisco to specifically serve the needs of the Silicon Valley. For more information, call (877) 420-7983.

■ **MJM Solutions Inc.** has expanded its manufacturing operations into a new, 11,000-square-foot facility located at 4321 Ingot Street, Fremont, CA 94539. The company will retain its corporate headquarters on Hotchkiss Street in Fremont, where it will continue its engineering and prototyping activities.

■ **Xemod Inc.**, Santa Clara, CA, has completed its expansion into Tempe, AZ as well as relocation of its headquarters to Santa Clara, CA. The expansion more than

[Continued on page 59]


Synergy Microwave Corporation introduces a new line of Patent Pending I&Q Modulator/Demodulator with High Dynamic Range in a Miniature Package measuring 0.5 x 0.5 x 0.22 inch.
Being a passive device, it eliminates the need for external supporting circuitry, thus, simplifying the overall application design at reduced cost. These devices are specifically optimized for frequencies in the range of 800 to 2000 MHz.
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Low Cost
modulator
demodulator
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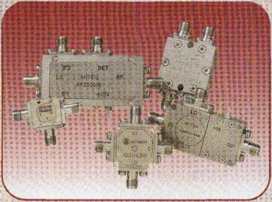
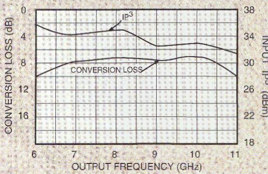
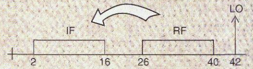
- Broadband **Double- and Triple-Balanced Mixers**
- **Image Rejection Mixers**
- **Single Sideband Modulators**
- Ultra High Dynamic Range **FET Based Mixers**
- Microwave **Phase Detectors and I/Q Mixers**
- Microwave **QAM, QPSK and Biphase Modulators**
- **Sampling Mixers** (Sampling Phase Detectors)
- Broadband Active and Passive **Multipliers**



HIGH DYNAMIC RANGE MESFET MIXER



MILLIMETER-WAVE BLOCK CONVERSION

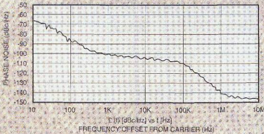


BLOCK CONVERSION MIXER TB0440LW1	
RF and LO	4 to 44 GHz
IF	0.5 to 20 GHz
Conversion loss	10.5 dB

FREQUENCY SOURCES TO 40 GHz

- **Frequency Synthesizers**
  Phase-locked loop communication band synthesizers
  Single-loop fast acquisition synthesizers
  Octave band YIG-based synthesizers
- **Free-Running and Phase-Locked VCOs**
  Cavity and coaxial resonator designs
  Fundamental to 4 GHz
  Multiplied to 40 GHz
  Octave band L-C VCOs
- **Free-Running and Phase-Locked DROs**
  Fundamental bipolar-based designs to 12 GHz
  FET designs to 25 GHz

4 TO 8 GHz YIG SYNTHESIZER PHASE NOISE



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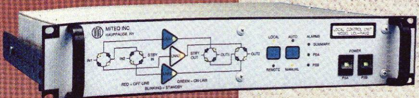

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Assembly and
Control Unit

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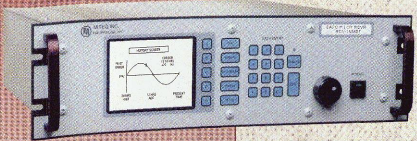
- **Low-Noise Amplifiers and Redundant Amplifier Systems**
- **Variable Group Delay and Amplitude Slope Equalizers,** 70 and 140 MHz
- **Test Translators**



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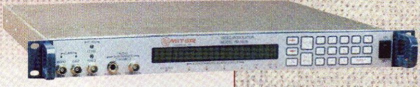
EAFC Receiver

- **INMARSAT Equipment**
  Converters
  EAFC pilot receiver
  Translators
  Pilot generators
- **Uplink Power Control Systems**
- **Custom-Designed Subsystems to Customer Specification**



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- **Video Modulators and Demodulators**
- **Video/Audio/IF Redundancy Switching Systems**
  1:1, 1:4 (up to four) and 1:N (up to eight)

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doubles the company's square footage and enables it to house increased manufacturing and engineering personnel. Over the next year the number of Xemod employees is projected to grow by 100 percent.

■ Next-generation broadband wireless access equipment supplier **Ensemble Communications Inc.** has entered into a nonexclusive worldwide marketing and distribution agreement with **Digital Microwave Corp.** under which Digital Microwave will place an initial purchase order for approximately $5 M for Ensemble's Fiberless™ system. Subsequent purchases, driven by anticipated growth in the market, are expected to follow. Work to integrate the system with network management and other enhancements will begin immediately.

■ **Richardson Electronics** has been appointed a worldwide distributor for **LBA Technology Inc. (LBAT)**. LBAT designs and manufactures highly specialized medium-wave antenna systems.

■ **QUALCOMM Inc.**, San Diego, CA, and **Microsoft Corp.** have announced their intent to form a strategic alliance to jointly define and develop advanced wireless, multimedia-capable devices. The companies will focus on developing hardware reference designs for mobile devices including smart phones based on the Microsoft Mobile Explorer™ wireless communications platform and wireless pocket PCs using **QUALCOMM CDMA Technologies'** iMSM4100 Internet Mobile Station Modem (iMSM™) chipset and system software.

■ **Agilent Technologies Inc.**, Palo Alto, CA, has entered into a global license and support agreement with **Motorola** to supply software tools, training and technical support for the design of Motorola's next-generation communications PC boards, ICs and systems worldwide. Under the terms of the agreement, all Motorola designers will have broad access to Agilent's full line of electronic design automation simulation tools.

■ Superconducting product manufacturer **Superconductor Technologies Inc. (STI)**, Santa Barbara, CA, has signed a supply agreement with **ALLTEL**, Little Rock, AR, a pioneer in the deployment of superconducting technology in a cellular network. Under the terms of the agreement, **ALLTEL Communication Products** will designate STI as its supplier of high temperature superconductor base station receiver solutions for analog and CDMA cellular and PCS networks.

■ **RangeStar Wireless**, Aptos, CA, and **Molded Interconnect Device (MID) LLC**, Rochester, NY, have entered into a strategic manufacturing agreement. The partnership brings together RangeStar's embedded antenna design and integration with MID LLC's injection-molded plastic and selective metallized applications. In related news, RangeStar also announced an agreement with **Zucotto Systems**, San Diego, CA, to offer RangeStar's Total Bluetooth Solution, which will significantly improve time to market.

■ **Peregrine Semiconductor** and **Symbol Technologies** have agreed to jointly develop complete solutions for the rapidly emerging Bluetooth wireless high speed personal area networking market. Peregrine's ultra-thin silicon CMOS technology (UTSi®) and expertise in RF integrated circuit development will be combined with Symbol's baseband processing, software and systems knowledge to develop complete Bluetooth subsystems.

■ **CTS Corp.**, Elkhart, IN, has formed a joint strategic relationship with both **Kyocera Corp.** and **Kinseki Ltd.** Under the terms of the two technology exchange and license agreements, CTS will exchange the license of patents and intellectual property with regard to the design and manufacture of frequency control products with each company, predominantly for wireless communications applications. Specific details of the agreements were not disclosed.

■ **Rogers Corp.** and **Gould Electronics Inc.** have jointly introduced high performance flexible materials with electrodeposited (ED) copper foils. Rogers will sell versions of its R/flex® flexible circuit materials with the ED foils, complementing its full family of flexible laminates. The product is a result of a joint effort by Gould's Foil Division, Eastlake, OH, and Rogers' Circuit Materials Division, Chandler, AZ.

■ **ANADIGICS**, Warren, NJ, has shipped production volumes of multiband power amplifiers (PA) for use in **Ericsson's** T18d dual-band wireless phones, which feature digital fax/data and full graphic display capabilities. This is the third T-class platform to utilize ANADIGICS' patented multiband technology, which enables operation in DAMPS 900 MHz and TDMA 1900 MHz bands using one PA.

■ Microwave component and value-added service supplier **M2 Global Technology Ltd.**, San Antonio, TX, has received ISO 9001 certification.

■ Electronic filter and oscillator designer and manufacturer **Networks International Corp.**, Overland Park, KS, received ISO 9001 certification effective January 1.

■ **Comtech PST Corp.**, a division of **Comtech Telecommunications Corp.**, has successfully completed a recertification audit of its ISO 9001:1994 quality system.

■ **Quasar Microwave Technology Ltd.**, Newton Abbot, Devon, UK, has been named Top Small Exporting Company in the South West of the UK. The company received the award at the British Trade International-sponsored Export Awards for Smaller Businesses.

FINANCIAL NEWS

■ **STMicroelectronics**, Saint-Genis-Pouilly, France, reports sales of $1.7 B for the first quarter, ended April 1, compared to $1.1 B for the same quarter last year. Net income was $238.4 M (78¢/diluted share), compared to $105.1 M for the same period last year.

[Continued on page 62]

Hittite Introduces A New MMIC Line....

Digital Attenuators!

2, 3, or 5 Bit Control

Positive Bias, +3V to +5V

Low Distortion, to +54 dBm IP3

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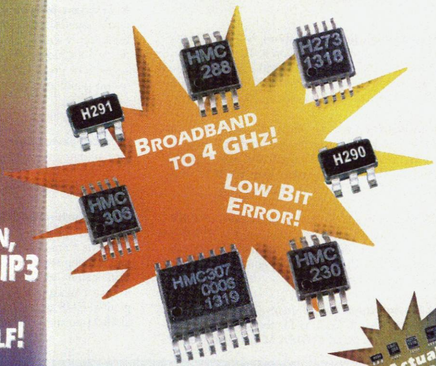

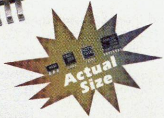

7 Low Cost Digital Attenuators Covering DC - 4 GHz *

Part Number	Features	Freq. Range (GHz)	Atten. Step Size(dB)	Ref. Insertion Loss (dB)	Bit Error (dB)	Input IP3 (dBm)	Package Area (mm^2)
HMC273MS10G	5 Bit, 1 to 31 dB Pos. Bias	0.7 - 3.7	1, 2, 4, 8, 16	2.4	**± 0.5**	+ 48	14.8
HMC307QS16G	5 Bit ,1 to 31 dB Neg. Bias	DC - 4	1, 2, 4, 8, 16	2	**± 0.5**	+ 44	29.4
HMC306MS10	5 Bit, 0.5 to 15.5 dB Pos. Bias	0.7 - 3.7	0.5, 1, 2, 4, 8	1.8	**± 0.25**	+ 52	14.8
HMC230MS8	3 Bit, 2 to 28 dB Pos. Bias	0.75 - 2	4, 8, 16	1.8	**± 0.5**	+ 46	14.8
HMC288MS8	3 Bit, 2 to 28 dB Pos. Bias	0.7 -3.7	2, 4, 8	1.5	**± 0.3**	+ 51	14.8
HMC291	2 Bit, 4 to 12 dB Pos. Bias	0.7 - 4	4, 8	0.9	**± 0.2**	+ 54	9
HMC290	2 Bit, 2 to 6 dB Pos. Bias	0.7 - 4	2, 4	0.6	**± 0.2**	+ 52	9

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TÜV

■ **Andrew Corp.**, Orland Park, IL, reports sales of $242.7 M for the second quarter, ended March 31, compared to $172 M for the same quarter last year. Net income was $17.3 M (21¢/diluted share), compared to a net income of $7.3 M (9¢/diluted share) for the first quarter of 1999.

■ **RF Micro Devices Inc.**, Greensboro, NC, reports sales of $289 M for the year, ended March 31, compared to $152.9 M last year. Net income was $50.1 M (58¢/diluted share). Sales for the fourth quarter were $84.8 M, compared to $56.6 M for the same period in 1999.

■ **Alpha Industries Inc.**, Woburn, MA, reports record sales of $184.7 M for the year, ended April 2, compared to $126.3 M last year. Net income was $24.4 M (6¢/share). Sales for the fourth quarter were $56.9 M, compared to $34.3 M for the fourth quarter last year.

■ **REMEC Inc.**, San Diego, CA, reports sales of $189.2 M for the year ended January 31, compared to $179.2 M last year. Net loss was $6.7 M (27¢/diluted share). Sales for the fourth quarter were $50.3 M, compared to $42.5 M for the same period last year.

■ **Norsat International Inc.**, Burnaby, British Columbia, Canada, reports sales of $63.5 M for the year, ended December 31, 1999, compared to $43.4 M last year. Net loss was $7.9 M (37¢/share). Sales for the fourth quarter were $20.7 M, compared to $10.7 for the fourth quarter of 1998.

■ **Microwave Power Devices Inc.**, Hauppauge, NY, reports sales of $12.4 M for the first quarter, ended March 31, compared to $17.2 M for the same quarter last year. Net loss was $1 M (9¢/share), compared to a net income of $832 K (8¢/diluted share) for the first quarter of 1999.

■ **Ericsson Microelectronics** has purchased 375,000 newly issued shares of **Merrimac Industries Inc.** common stock, representing approximately 17.5 percent of Merrimac's outstanding stock, at a price of $9 per share. This agreement gives Ericsson priority access to Merrimac's patent-pending Multi-Mix™ microtechnology.

CONTRACTS

■ **Microwave Power Devices Inc. (MPD)** has entered into an agreement with Unique Broadband Systems Inc. to supply amplifiers to be used in a terrestrial repeater system. The contract is valued at $13.3 M.

■ **EMS Technologies Inc.'s Space & Technology Group**, Montreal, Quebec, Canada, has received a $6 M contract from the Canadian Space Agency to provide the research and development for a demonstration digital-mesh-connectivity system on Telesat's Ank F2 satellite. In related news, Telesat Canada and Hughes Space & Communications have granted EMS an authorization to proceed worth an additional $9 M on the flight unit. EMS will provide the satellite's

[Continued on page 65]

onboard digital signal processor (SpaceMux), which will enable individual users to communicate with each other at 2 MB data rates without having to pass through a gateway.

■ **Giga-tronics Inc.'s Instrument Division**, San Ramon, CA, has received an order in excess of $2.3 M for its three-slot VXI microwave synthesizer. The order came through Midoriya Electric Co. Ltd., Instrument Division's distributor in Tokyo, Japan, and is for ultimate delivery to Advantest Corp. for use in automatic test systems.

■ **Signal Technology Corp.'s Keltec Division**, Walton Beach, FL, has been awarded in excess of $10.5 M worth of new development and follow-on production contracts during the first quarter of this year. The majority of these awards have follow-on potential for 2001 and beyond. The new development awards add Keltec's presence on such platforms as the NH-90 helicopter, Mirage, Navy surface ships and GPS guided ordnance.

■ **Communications & Power Industries Holding Corp.-Microwave Power Products Division (CPI-MPP)**, Palo Alto, CA, has been awarded a contract for the production of 29 dual-pulsed traveling-wave tube assemblies by ITT Industries' Avionics Division. The award is a follow on to an earlier contract received in 1998. In related news, CPI-MPP also announced receipt of a contract to supply 100 helix vacuum electron devices to support the IDECM ALE-55 towed decoy system. Financial details of either contract were not disclosed.

■ **Alpha Industries**, Woburn, MA, has received design wins and initial production orders for RF semiconductors to be used by three of the world's largest personal computer manufacturers in high speed wireless data modules. Alpha's semiconductors perform RF switching in Windows and Macintosh computers and other mobile computing devices, providing wireless access to local area networks and wireless synchronization with personal digital assistants and cellular handsets.

PERSONNEL

■ Condor Systems Inc. has appointed **Kent Hutchinson** president, CEO and chairman of the board. Previously, Hutchinson was president of Norden Systems and executive VP of Kaman Aerospace Corp.

▲ David Aldrich

▲ Tom Leonard

■ Alpha Industries Inc. has elected **David Aldrich** president, CEO and a member of the board of directors. Aldrich, who had been president and chief operating officer at the company, succeeds **Tom Leonard**, who has been elected chairman of the board of directors.

[Continued on page 66]

AROUND THE CIRCUIT

■ **Jim Derbyshire** has been appointed CEO at SiGe Microsystems. He will be responsible for the company's strategy, corporate development initiatives and executive leadership. Derbyshire brings 25 years of design and engineering management and operational experience to the company and formerly was CEO at Symbionics.


▲ *Charlie Miller*

■ **Charlie Miller** has been appointed VP of sales at Simpod Inc. Miller has nearly 25 years of experience in the engineering software business and joins Simpod from Design Acceleration Inc.

■ CTS Corp. has named **Patrick J. Dennis** senior VP, finance and chief financial officer. Most recently, Dennis was VP/corporate controller at Johnson Controls Inc.

■ Recent corporate refocusing at Semflex Inc., Mesa, AZ, has resulted in several new personnel assignments within the company. Product line expansion has created the new position of VP of strategic alliances, which will be filled by former VP of sales **Doug Hartje**. **Jim Rawlins**, previously the director of sales for Southwest Microwave, has been named Semflex's new VP of sales.


▲ *M. Kirk Nelson*

■ In conjunction with the formation of the Defense Systems Division (DSD), Wide Band Systems Inc. has named **Rick Ianieri** VP/general manager at the new division. In turn, Ianieri appointed **M. Kirk Nelson** program manager for EW systems at DSD. Most recently, Nelson completed a distinguished 20-year career in the US Navy as a senior chief electronic warfare technician.

■ M/A-COM SIGINT Products has named **Bruce Mead** director of engineering. Previously, Mead was with Sanders as a systems engineering manager leading advanced communication initiatives.

■ CPI Satcom Division has named **Robert Blanchfield** director of materials. Previously, Blanchfield held the same position at ARGOSYSTEMS Inc., a subsidiary of the Boeing Company, for 14 years.

■ Interconnect Devices Inc. (IDI) has appointed **Dave Gast** director of marketing. Gast will also lead strategic planning and marketing activities for Synergetix, a division of IDI. Previously, he worked at Mallinckrodt/Nellcor Puritan Bennett as marketing director for the sleep and portable ventilation business.

■ Metelics Corp. has named sales engineer **Chris McAllister** to head a new sales office in Newburyport, MA.

■ Taconic has announced several new personnel appointments, including **Bob Gatta** as director of strategic planning, **Peter Malone** as process engineer for the the company's Advanced Dielectric Division, **Bruce Carnevale** as quality systems manager and **Krista Ritter** as marketing specialist. Previously, Gatta played an instrumental role in the reorganization of IPD's North American operation and Malone spent eight years with Isola Laminate Systems, formally Allied Signal Inc. Carnevale has spent most of his career in quality improvement roles; Ritter worked in purchasing and market development.


▲ *John C. Wilber*

■ Microwave Instrumentation Technologies LLC has named **John C. Wilber** director of business management. Wilber has more than 17 years of industry experience and will be responsible for the company's proposal, contract and order management activities as well as import/export control.

■ UltraRF has appointed **Mandel Berenberg** manager of quality control and reliability. Before joining the company in December 1999, Berenberg handled key senior management positions for Spectrian Corp., UltraRF's parent company.

■ The Chicago business units of Storm Products Co. have announced several new personnel appointments. **Jeff Walker** has been named sales and marketing manager of Storm Products-Microwave. Most recently, Walker was director of sales for CSA Wireless. Joining Storm Products-Fiber Optics are **Randy Gritters** as product marketing manager, **Mark Parrish** as regional account manager and **Melanie Corns** in field sales.

REP APPOINTMENTS

■ **Wireless Technologies Corp.**, Springdale, AR, has named four firms to represent its filters and diplexers. **Left Coast Ventures** will cover Northern California while **Excellence Engineering** has come on board for China. Israel will be covered by **Bentronix Ltd.** and Sweden by **IE Komponenter**.

■ **Radio Engineering Services**, Torino, Italy, has appointed **Hal Tenney** to represent the company's HERALD radio link design software in the US and Canada. Tenney is a wireless industry consultant based in Fair Oaks, CA.

■ **BCP (Bird Component Products)**, Largo, FL, has appointed two companies to represent its line of attenuators, loads, power divider/combiners and couplers. **Spectra-West Sales Inc.** will cover Southern California, Arizona and southern Nevada; **High-tech Sales Inc.** will cover Massachusetts, Connecticut, New Hampshire, Maine, Rhode Island and Vermont.

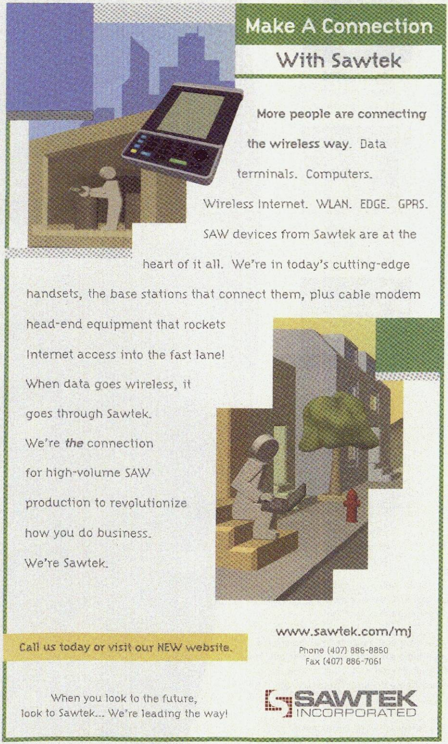
■ **L-3 Communications' Celerity Systems Division**, Cupertino, CA, has appointed two new sales representatives. **Advanced Technical Marketing (ATM)** will represent the company's broadband deep memory signal generation and analysis test and measurement equipment in New York, New Jersey, eastern Pennsylvania and New England; **Base 8** will cover the Midwest region, in-

[Continued on page 68]

cluding Minnesota, North and South Dakota, Nebraska, Kansas, Missouri, Iowa, Wisconsin, Illinois, Indiana and Kentucky.

■ **Renaissance Electronics Corp.**, Boxborough, MA, has selected **Microwave Components Marketing (MCM)**, Melbourne, FL, to represent its products in Florida. Renaissance manufactures isolators, circulators, couplers, combiners, receiver multicouplers, transmitter combiners and MMDS transceivers.

■ **Emerson & Cuming Microwave Products Inc.** has appointed **Cain Southwest Inc.**, Tempe, AZ, as its exclusive sales and technical representative in Arizona and New Mexico. Cain will represent the ECCOSORB®, ECCOSTOCK® and ECCOSHIELD® product lines.



NEW MARKET ENTRY

■ **Intimate Resource Counseling (IRC)**, a consulting firm founded by Robert G. Barbaria, former VP of Mica Microwave, offers a complete solution to marketing, PR, AD composition and production as well as technical support and product evaluation services. For additional information, call (408) 997-1550 or fax (408) 268-1453.

WEB SITES

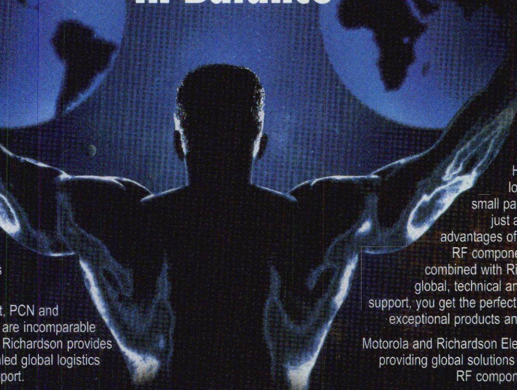
■ **Zeta**, an **Integrated Defense Technologies** company, has launched a newly designed Web site that allows customers to access up-to-date information about the company's products and capabilities. The site, www.zeta-idt.com, permits users to instantly download brochures on microwave and RF power product capabilities and data sheets on signal intercept and location systems.

■ **M/A-COM Inc.** has announced that its Web site (www.macom.com) is now accessible using any Web-enabled mobile phone. Incorporating menu-driven technology, the site has the capability of allowing users to e-mail or fax information directly from their telephone. Users will also be able to search for M/A-COM contact listings. This enhanced functionality can only be accessed through Web-enabled phones at http://209.67.226.186.

■ **Andrew Corp.** has launched a new document delivery service that conveys information about the company's products and services at any time. The service can be accessed directly from www.andrew.com and contains more than 2000 documents that can be viewed, e-mailed or sent to a fax machine. The system also may be used to order printed copies of available literature.

■ As part of **Rockwell Collins'** continuing effort to offer expanded service, customers may now access the Collins Aviation Services Mall at www.shopcollins.com. The site provides real-time access to an "e-Mall" that offers an array of on-line services, including the ability to order parts, check shipment status, direct repairs to appropriate service centers and team with the company to achieve optimal product performance. Technical publications are also available for downloading.

Motorola & Richardson— Keeping Worldwide RF Customers in Balance



Motorola and Richardson Electronics offer the perfect balance of exceptional products and services.

Motorola's broadcast, PCN and cellular components are incomparable in performance, and Richardson provides the stability of unrivaled global logistics and engineering support.

High power, low cost and small packages are just a few of the advantages of Motorola's RF components. When combined with Richardson's global, technical and logistical support, you get the perfect balance of exceptional products and services.

Motorola and Richardson Electronics — providing global solutions for all your RF component needs.

PCN PRODUCT

Device	Frequency	Voltage	Oper. Gain (Typ.)	Output Power
MRF18060A/AS	1805-1880 MHz	26 Volts	13.0 dB	60 Watts CW
MRF18060B/BS	1805-1880 MHz	26 Volts	13.0 dB	60 Watts CW
MRF18090A/AS	1930-1990 MHz	26 Volts	13.5 dB	90 Watts CW
MRF18090B/BS	1930-1990 MHz	26 Volts	13.5 dB	90 Watts CW
MRF19030/S	1930-1990 MHz	26 Volts	13.0 dB	30 Watts PEP
MRF19045/S	1930-1990 MHz	26 Volts	14.0 dB	45 Watts PEP
MRF19060/S	1930-1990 MHz	26 Volts	12.5 dB	60 Watts PEP
MRF19085/S	1930-1990 MHz	26 Volts	12.5 dB	90 Watts PEP
MRF19125/S	1930-1990 MHz	26 Volts	12.5 dB	125 Watts PEP
MRF21125/S	1930-1990 MHz	28 Volts	12.0 dB	125 Watts PEP
MRF21180/S	1930-1990 MHz	28 Volts	11.3 dB	160 Watts PEP

CELLULAR

Device	Frequency	Voltage	Oper. Gain (Typ.)	Output Power
MRF9180	880 MHz	26 Volts	17.0 dB	180 Watts PEP
MRF9085/S	880 MHz	26 Volts	17.0 dB	85 Watts PEP
MRF9045/S	945 MHz	28 Volts	18.0 dB	45 Watts PEP
MRF9045M	945 MHz	28 Volts	16.0 dB	45 Watts PEP

BROADCAST

Device	Frequency	Voltage	Oper. Gain (Typ.)	Output Power
MRF372	470-860 MHz	28 Volts	14.0 dB	180 Watts PEP
MRF373A/AS*	470-860 MHz	28 Volts	11.2 dB	100 Watts PEP
MRF374A*	470-860 MHz	28 Volts	12.0 dB	100 Watts PEP

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SIMULATION OF INTERDIGITATED STRUCTURES USING TWO-COUPLED-LINE MODELS

Some commercial microwave CAD programs do not incorporate models for more than three coupled lines. This fact is especially critical in the design and analysis of multiple-line planar structures, such as interdigital, combline and hairpin filters, meander lines, spiral inductors and couplers. This article presents a new, simple technique to simulate circuits with multiple coupled lines in commercial simulators without suitable models. The negative transmission line (NTL) method uses pairs of two coupled lines, single transmission lines, current-controlled current sources (CCCS) and voltage-controlled voltage sources (VCVS), which are available in any commercial microwave CAD program. One of the greatest advantages of the proposed technique is that the analysis and optimization parameters are the physical dimensions of the coupled structure (line widths and spacings); therefore, optimization and tuning of the structure are easy and fast.

Accurate models for the analysis of multiconductor structures are not available in some commercial microwave CAD programs. Therefore, the analysis and simulation of multiple-line planar structures such as interdigital, combline and hairpin filters, meander lines, spiral inductors and couplers using these types of simulators require new methods. To overcome this limitation, two alternative approaches have been proposed. One approach uses an equivalent circuit composed of ideal noncoupled transmission lines and short-circuited stubs.[1–4] (This technique does not include effects such as losses in the substrate and conductors, discontinuities and dispersive effects of the transmission lines, which are very important in the case of microstrip lines.) The other approach consists of modeling the multiple-line structure by decomposing it into pairs of coupled lines.[5–7] This method is based on the identities developed by Grayzel,[8] which divide every line into several parts to form pairs of coupled lines. Using this technique, every coupling can be simulated with the model of two coupled lines, which is available in any microwave CAD tool. In most cases, dispersive effects

[Continued on page 73]

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Departamento de Señales, Sistemas y Radiocomunicaciones, E.T.S.I. Telecomunicación, Universidad Politécnica de Madrid
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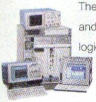

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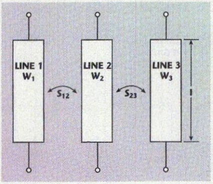
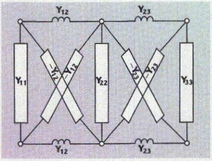
Available From Stock In North And South America • Tel. (631) 588-3877 • Fax. (631) 588-3879 and substrate and conductor losses are not considered.[6,7] However, Denig's approach[5] takes them into account. The main disadvantages of this technique are that it is only valid for coupled lines of equal width and the optimization and tuning process is very tedious because the structure parameters are even- and odd-mode impedances that need to be calculated every time a geometrical modification in the coupled structure is performed. Additionally, a coupled structure whose even- and odd-mode impedances do not have a physical realization can be obtained.

The proposed technique utilizes pairs of coupled lines and solves the problems with Denig's method. The physical dimensions of the coupled structure are used as parameters so the optimization process is easier and faster and the physical perspective of the design is not lost. Using this technique, n coupled lines (which can be of different widths) are transformed into (n – 1) pairs of coupled lines and (n – 2) single transmission lines loaded by an element referred to as a negator. This element can be implemented by CCCSs and VCVSs. As in Denig's approach, the proposed technique does not take into account coupling between nonadjacent lines.



▲ *Fig. 1 A planar structure of three coupled lines.*



▲ *Fig. 2 The noncoupled equivalent circuit for three coupled lines.*

PROCEDURE FUNDAMENTALS

The method described in this article is based on the noncoupled equivalent circuit for coupled lines proposed by Sato and Cristal,[1] where the multiple-coupled-transmission-line structure is transformed into a set of noncoupled transmission lines. ***Figure 1*** shows the physical parameters for three coupled lines where W_1, W_2 and W_3 are the widths of the lines and S_{12} and S_{23} are the spacings between lines 1 and 2 and 2 and 3, respectively. The structure length is l. Sato and Cristal's equivalent circuit for the three-coupled-line case is shown in ***Figure 2***. The coils represent short-circuited stubs. The length of all of these lines is the same as the multiple-line structure, and the characteristic admittances Y_{ii} and Y_{ij} are elements of its characteristic admittance matrix. Lines of characteristic admittances $-Y_{12}$ and $-Y_{23}$ are NTLs.

If a line of characteristic admittance $-Y_{22}$ of the same length is introduced, as shown in ***Figure 3***, as well as another line of characteristic admittance Y_{22} in parallel, an equivalent network is obtained. However, in this network, the coupling between lines 1 and 2 can be separated from the coupling between lines 2 and 3. In this way, the coupled structure has been decomposed into two independent couplings plus an NTL.

NTL SIMULATION

The ABCD matrix of a lossless NTL of characteristic impedance $-Z_0$ ($Z_0 > 0$) is represented as

$$[ABCD] = \begin{pmatrix} \cos(\theta) & -jZ_0\tan(\theta) \\ \dfrac{-j\tan(\theta)}{Z_0} & \cos(\theta) \end{pmatrix} \quad (1)$$

where

θ = electrical length

The matrix of Equation 1 can be obtained by multiplying both sides of the ABCD matrix of the transmission line Z_0 as

$$\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \cos(\theta) & jZ_0\tan(\theta) \\ \dfrac{j\tan(\theta)}{Z_0} & \cos(\theta) \end{pmatrix} \bullet \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} \cos(\theta) & -jZ_0\tan(\theta) \\ \dfrac{-j\tan(\theta)}{Z_0} & \cos(\theta) \end{pmatrix} \quad (2)$$

Then, Equation 2 can be seen as the resultant ABCD matrix of three quadripoles connected in cascade where the central matrix corresponds to a transmission line of impedance Z_0. The first and last matrices correspond to the elements called negators. An equivalent circuit for a possible implementation of the negator is shown in ***Figure 4***. This component can be implemented by a CCCS and VCVS. Therefore, an NTL can be replaced by an identical line with positive characteristic impedance and two negators.

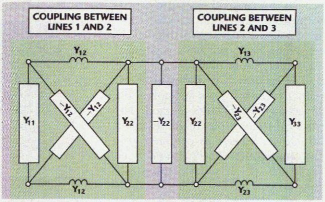
GENERALIZATION OF THE TECHNIQUE

Using the negators, the three-coupled-line network ends up as shown in ***Figure 5***. A line of characteristic admittance, Y_{22}, and two negators appear instead of the previous NTL. It can be proved that the geometric parameters of the independent couplings are the same as the physical parameters of the original structure after performing two approximations: The width of the line i, W_i, depends only on the characteristic admittance of this line, Y_{ii}. In addition, the spacing between lines i and i + 1, $S_{i,i+1}$, depends only on the characteristic admittances of these lines (Y_{ii} and $Y_{i+1,i+1}$) and the mutual characteristic admittance $Y_{i,i+1}$. As a result, the separated coupling between lines 1 and 2 can be characterized by the width of lines 1 and 2 of the original structure and by the physical spacing between them. The same can be said of the separated coupling between lines 2 and 3. The width of the single transmission line Y_{22} will be the width of line 2.

The generalization to the n-coupled-line case is shown in ***Figure 6***, where the negators have been included. The shaded area corresponds to the couplings between adjacent lines. Every single line, together with its two negators, comprises an NTL. As stated previously, the parameters of this network are the physical parameters of the coupled structure. The pairs of coupled lines and the single transmission lines can be simulated using the corresponding models of the simulator. Since these models include losses, the NTL method is capable of estimating them.

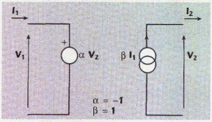
SIMULATIONS AND MEASUREMENTS

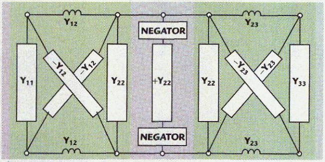
In order to test the utility and validity of the proposed technique, an example of a microstrip tapped-line interdigital filter is presented. It is a



▲ *Fig. 3 Coupling separation in a three-coupled-line structure.*

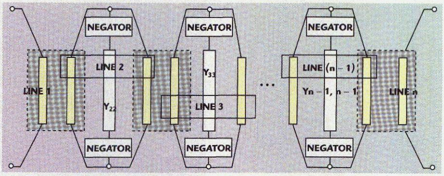
▼ *Fig. 4 A negator circuit representation.*





▲ *Fig. 5 A three-coupled-line structure using negators.*

Fig. 6 The generalized structure for n coupled lines. ▼



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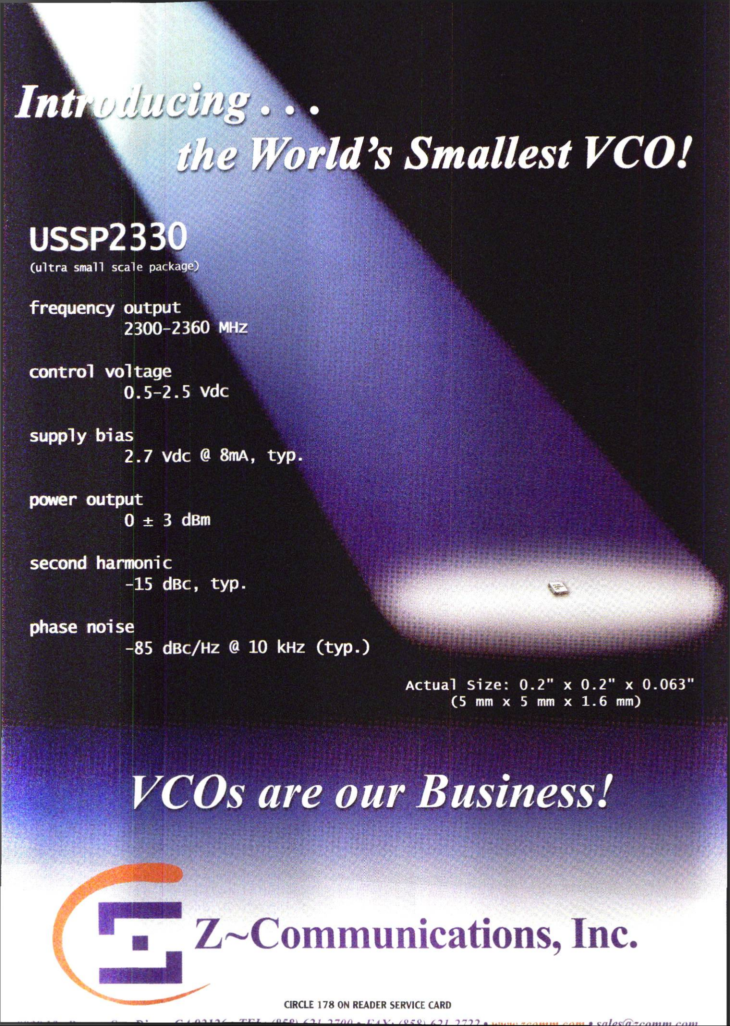
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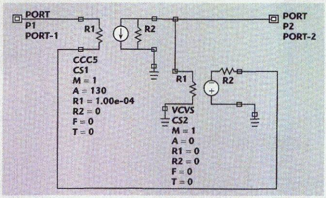
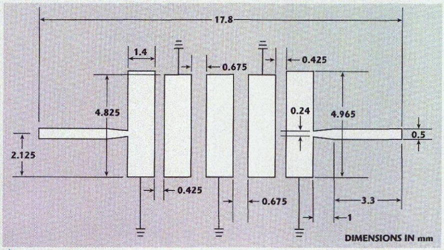
TABLE I

CALCULATED FILTER PARAMETERS

Strip	Z_{oe} (Ω)	Z_{oo} (Ω)	W (mm)	S (mm)
1 and 2	35.36	26.00	1.400	0.425
2 and 3	34.25	27.62	1.400	0.675
3 and 4	34.25	27.62	1.400	0.675
4 and 5	35.36	26.00	1.400	0.425
Tap point (l_2)		2.125 mm		
$l_1 + l_2$		4.825 mm		
l_a		0.140 mm		



▲ *Fig. 9 A practical implementation of the negator using the LIBRA series IV simulator.*



▲ *Fig. 7 The filter layout.*

▼ *Fig. 8 The filter's implementation using the developed technique.*

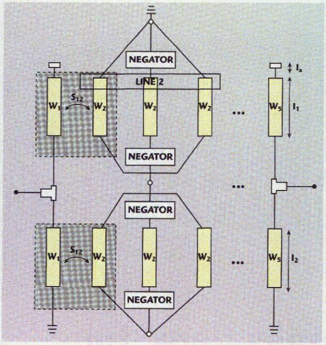
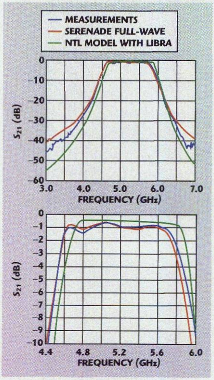


Fig. 10 Simulation vs. measurements of the filter's transmission characteristics. ▼



fifth-order Chebyshev filter with 0.01 dB of ripple and a passband from 4.5 to 5.5 GHz. The plastic substrate chosen was 0.025"-thick epsilom-10 with a dielectric constant of 9.9. This filter has been designed using the method proposed by Caspi and Adelman.[9] ***Table 1*** lists the calculated filter parameters. The layout and schematic of the filter are shown in ***Figures 7*** and ***8***, respectively. Although it has been removed from these figures for clarity, the ground connection of the resonators has been modeled by an inductance of 0.05 nH.

If the filter is simulated using the n-coupled-line generalization shown previously, convergence problems arise, which can be overcome with a small resistor placed as shown in ***Figure 9***. A value of 10^{-3} Ω has been used in the simulation so that its presence does not affect the simulation results.

The simulations are performed using the HP EEsof LIBRA Series IV simulator, and the results are compared with Ansoft's SERENADE 7.5 simulator, which is a CAD tool providing a full-wave model for multiple coupled lines. The LIBRA circuit file used to simulate the filter is shown in ***Appendix A***. The NTL method has also been tested using SERENADE to show its dependence on the two-coupled-line model used. Additionally, a comparison with the measurements is made.

Figure 10 shows the transmission behavior of the filter predicted by the NTL method in LIBRA compared with

[Continued on page 78]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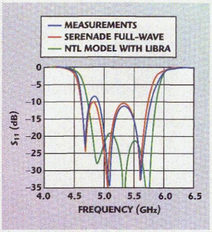
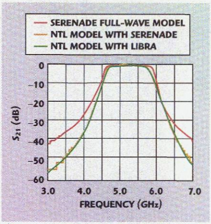
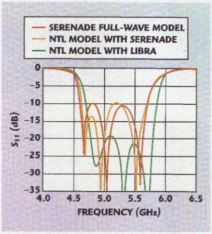


▲ *Fig. 11 Simulated vs. measured input reflection characteristics.*



▲ *Fig. 12 Transmission behavior simulation comparison using the full-wave model and NTL method in SERENADE and the NTL method in LIBRA.*



▲ *Fig. 13 Reflection behavior simulation.*

the response of the full-wave model of SERENADE. In the filter passband, the agreement between SERENADE and the measurements is excellent because the full-wave model is very accurate. Since the NTL model is approximate, it provides a good estimation of the bandwidth and passband losses with a small frequency shift (approximately 100 MHz upwards) of the passband. However, the disagreement with the measurements increases around the filter edges. The main reason is that the NTL method does not consider coupling between nonadjacent lines. Even though the SERENADE model does not have this limitation, it cannot adjust very well for the filter edges either.

With regard to the reflection behavior, shown in **Figure 11**, the deviations of the NTL model are larger — up to 10 dB more optimistic. The difference is not due to the NTL model itself but the two-coupled line model used by LIBRA.

If the NTL method is implemented in SERENADE, the response in the passband is closer to the full-wave model, as shown in **Figures 12** and **13**. This result illustrates the dependence of the NTL method on the

[Continued on page 80]

coupled-line model used. Around the filter edges, the behavior of the NTL method in SERENADE is very close to that in LIBRA because the NTL method does not consider the coupling between nonadjacent lines.

CONCLUSION

A new technique that allows simulation of multiple-coupled-transmission-line structures using commercial microwave CAD simulators without suitable models has been demonstrated. The coupled structure is decomposed into a cascade of two-coupled-line and single-transmission-line sections loaded by negators. Every negator can be implemented using a CCCS or VCVS. This method uses the physical dimensions as analysis and optimization parameters. For that reason, the physical aspect of the structure is always accounted for. Optimization and tuning are easier and faster than with previous techniques. The new method provides a good estimate of the behavior of the coupled structure that is useful in the design stage.

ACKNOWLEDGMENT

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References

1. R. Sato and E.G. Cristal, "Simplified Analysis of Coupled Transmission-line Networks," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 18, No. 3, March 1970, pp. 122–131.
2. G. Matthaei, L. Young and E.M.T. Jones, *Microwave Filters, Impedance-matching Networks and Coupling Structures*, McGraw-Hill, New York, 1964.
3. J.A.G. Malherbe, *Microwave Transmission Line Filters*, Artech House, Norwood, MA, 1979.
4. E.G. Cristal, "Tapped-line Coupled Transmission Lines with Applications to Interdigital and Combline Filters," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 23, No. 12, December 1975, pp. 1007–1012.
5. C. Denig, "Using Microwave CAD Programs to Analyze Microstrip Interdigital Filters," *Microwave Journal*, Vol. 32, No. 3, March 1989, pp. 147–152.
6. M.A. Larson, "A New Element-saving Equivalent Circuit for the Analysis of General Coupled n-Wire Transmission Lines," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 39, No. 11, April 1988, pp. 1855–1861.
7. G. Mazzarela, "CAD Modeling of Interdigital Structures," *IEEE Transactions on Education*, Vol. 42, No. 1, February 1999, pp. 81–87.
8. A.I. Grayzel, "A Useful Identity for the Analysis of a Class of Coupled Transmission-line Structures," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 22, October 1974, pp. 904–906.
9 S. Caspi and J. Adelman, "Design of Combline and Interdigital Filters with Tapped-line Input," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 36, No. 4, April 1988, pp. 759–763.

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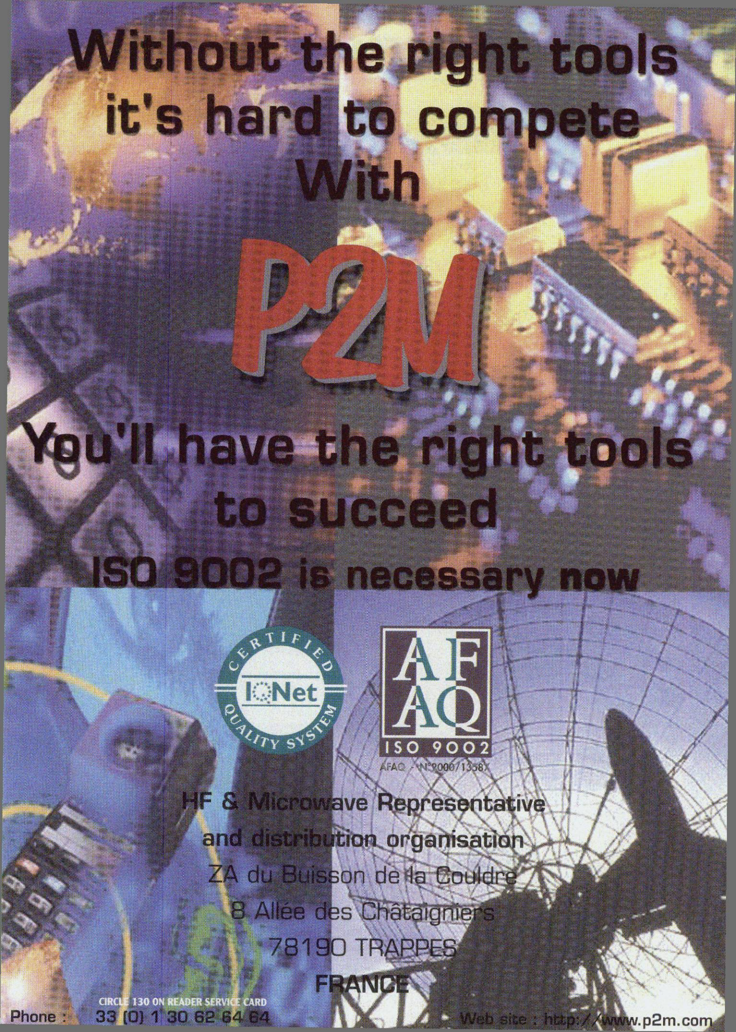
APPENDIX A

LIBRA SIMULATION FILE OF THE INTERDIGITAL FILTER

The LIBRA Simulation File shown here lists the LIBRA circuit file used to simulate the filter described in this article. This file is suitable for both LIBRA 3.5 and TOUCHSTONE. The filter

[Continued on page 82]



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APPENDIX A (cont.)

schematic with LIBRA Series IV has not been included for clarity. However, it can be deduced from this circuit file and the n-coupled-line generalization diagram. The results obtained using LIBRA 3.5 and LIBRA Series IV are similar because the models are the same. The circuit file follows the schematic of the n-coupled-line generalization, considering the inductances as a connection to ground for the resonators.

```
! FILE ntl_ts.CKT
! NTL model for TOUCHSTONE and LIBRA.
! Parasitic effects and discontinuities are included.

DIM
  FREQ MHZ  !HZ KHZ MHZ
  RES OH   !KOH MOH
  IND NH   !PH MH H
  CAP PF   !MF FF NF F
  LNG UM   !MIL CM M
  TIME PS  !NS SEC
  COND /OH  !/KOH /MOH
  ANG DEG  !RAD

! VARIABLES.

VAR
  ! Width of the resonators
  WR=1400
  ! Tapper Connection Width
  Wt=240
  ! Separation between lines 1-2 and 4-5
  SUNO=425
  ! Separation between lines 2-3 and 3-4
  SDOS=675
  ! Tap point
  LT=2125
  ! (Resonator length) - (Tap point)
  L1=2700
  ! Additional length of resonator 1 and 5
  Lstub=140
  ! Parasitic inductance modeling the connection to
  !ground
  Lpar=0.05

CKT
  MSUB ER=9.9 H=635 T=25 RHO=0.77 RGH=0
  TAND TAND=9e-4

  ! Implementation of the negator
  VCVS 3 2 0 0 M=1 A=0 R1=0 R2=0 F=0 T=0
  CCCS 1 3 2 0 M=1 A=180 R1=1e-3 R2=0 F=0 T=0
  DEF2P 1 3 NEGATOR

  ! Coupling between lines 1 and 2
  MCLIN 1 2 4 3 W^WR S^SUNO L^L1
  MCLIN 5 2 7 6 W^WR S^SUNO L^LT

  ! Negator+ line 2 +Negator
  NEGATOR 2 8
  MLIN 8 9 W^WR L^L1
  NEGATOR 9 4

  NEGATOR 2 10
  MLIN 10 11 W^WR L^LT
  NEGATOR 11 7

  ! Coupling between lines 2 and 3
  MCLIN 2 12 13 4 W^WR S^SDOS L^L1
  MCLIN 2 12 14 7 W^WR S^SDOS L^LT

  ! Negator+ line 3 +Negator
  NEGATOR 12 15
  MLIN 15 16 W^WR L^L1
  NEGATOR 16 13

  NEGATOR 12 17
  MLIN 17 18 W^WR L^LT
  NEGATOR 18 14

  ! Coupling between lines 3 and 4
  MCLIN 12 19 20 13 W^WR S^SDOS L^L1
  MCLIN 12 19 21 14 W^WR S^SDOS L^LT

  ! Negator+ line 4 +Negator
  NEGATOR 19 22
  MLIN 22 23 W^WR L^L1
  NEGATOR 23 20

  NEGATOR 19 24
  MLIN 24 25 W^WR L^LT
  NEGATOR 25 21

  ! Coupling between lines 4 and 5
  MCLIN 19 26 27 20 W^WR S^SUNO L^L1
  MCLIN 19 28 29 21 W^WR S^SUNO L^LT

  ! (Input line) + (taper) + (TEE discontinuity)
  MTEE 1 5 40 W1^WR W2^WR W3^Wt
  MTAPER 40 41 W1^Wt W2=500 L=1000
  MLIN 41 42 W=500 L=3300

  ! (Output line) + (taper) + (TEE discontinuity)
  MTEE 26 28 43 W1^WR W2^WR W3^Wt
  MTAPER 43 44 W1^Wt W2=500 L=1000
  MLIN 44 45 W=500 L=3300

  ! Line additionally included in resonators 1 and 5.
  ! Open at one end
  MLEF 3 W^WR L^Lstub
  MLEF 27 W^WR L^Lstub


  ! Discontinuities to simulate open at end
  !of resonators 2, 3 and 4
  MLEF 7 W^WR L=0
  MLEF 13 W^WR L=0
  MLEF 21 W^WR L=0

  ! Simulation of the ground connection of the resonators
  IND 6 0 L^Lpar
  IND 4 0 L^Lpar
  IND 14 0 L^Lpar
  IND 20 0 L^Lpar
  IND 29 0 L^Lpar

DEF2P 42 45 FILTER


FREQ
  SWEEP 3000 7000 20

OUT
  FILTER DB[S21] GR1
  FILTER DB[S11] GR1A
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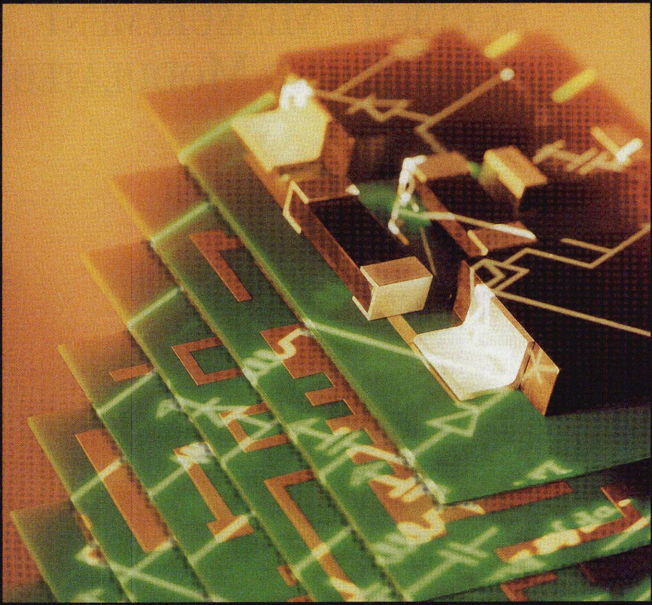

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ACCURATE MEASUREMENT OF WIDEBAND MODULATED SIGNALS

Phase and/or amplitude modulated signals are often used for information transmission in microwave communications systems. For simulating such a communications system, these types of signals are most naturally represented by their lowpass equivalent (LPE)[1] signal. The LPE signal is the carrier envelope with a time-varying amplitude and phase. The microwave signal can be derived from the LPE signal by a linear transformation. In LPE modeling, components such as amplifiers are modeled in terms of their response to the signal envelope. To complement an LPE model, it is desirable to have a time domain measurement of the modulated microwave signal. Such a signal measurement can be used not only for modeling, but also for verifying compliance to systems specifications and for understanding of deviations from ideal performance.[2]

Two basic methods can be used to measure a modulated microwave signal in the time domain. One method measures the signal directly at the carrier frequency using a high speed digital storage oscilloscope (DSO). The other method downconverts the signal to a lower frequency before measurement. Downconverting before measurement increases complexity, but there are several accuracy advantages in measuring a signal at a lower frequency. These advantages pertain especially if the signal is downconverted all the way to baseband using a local oscillator coherent with the microwave carrier. The measured baseband waveform is the envelope of the microwave signal, which is its LPE representation.

One advantage of coherent downconversion is that it eliminates the phase noise of the carrier from the measurement. Another advantage is that the sample rate can be reduced by the ratio of half the signal bandwidth to the carrier frequency since the carrier need not be sampled. This method allows for a longer time record or higher time resolution of the signal for the same number of samples. (This is the same reason LPE signals are used in modeling.) A third advantage is that DSO accuracy is better at lower frequencies. The higher the carrier frequency, the more inaccurate the direct measurement; the accuracy of the baseband measurement is independent of the carrier frequency. Because of these advantages, major instrument manufacturers have specialized instruments that perform time domain measurements of microwave communications signals at baseband. Signals with bandwidths up to 200 MHz and carrier frequencies up to 110 GHz are supported.[2]

This article presents a method to accurately measure signals with bandwidths higher than those supported by off-the-shelf solutions. How to perform accurate time domain measurements of modulated microwave or millimeter-wave signals having gigahertz bandwidths using a calibrated downconverting receiver (DCR) in conjunction with a DSO[3] will

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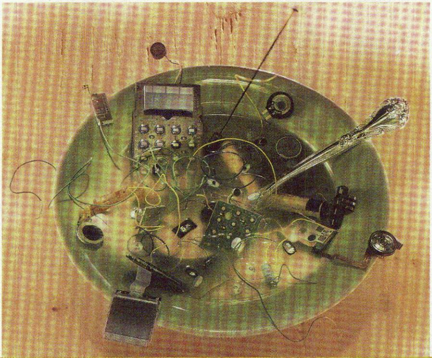

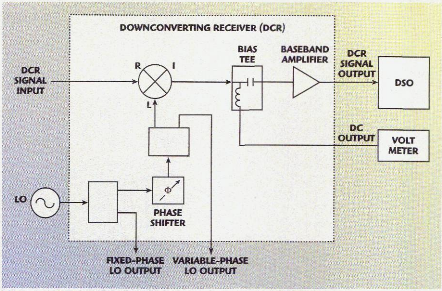

▲ *Fig. 1 The time domain waveform measurement setup block diagram.*

be presented. By calibrating the DCR the linear distortion of the receiver can be characterized and eliminated from the signal measurement.

A coherent LO is required for downconversion to baseband. The signal must be repetitive because the LPE representation of a microwave signal has two baseband components: an in-phase and a quadrature waveform that are not measured simultaneously but consecutively in this procedure. Waveforms may be measured directly at the output of a modulator or after passing through a linear or nonlinear distorting communications channel. These measurements then may be used to characterize either the modulator or the components in the channel.

MEASUREMENT SETUP

The measurement system consists of a DCR followed by a DSO, as shown in ***Figure 1***. The DCR includes a mixer followed by a baseband amplifier. The mixer LO port is fed by an LO with a phase shifter that is adjusted to enable measurement of the in-phase and quadrature baseband waveform components. The DC level, which corresponds to the Fourier component of the signal coherent with the carrier, is measured separately by means of a bias tee and a voltmeter at the output of the downconverting mixer. The DC level must be measured separately because most wideband baseband amplifiers block the DC component. The DCR has two coherent LO outputs: a fixed-phase and a variable-phase LO. The LO outputs are required for the two test mixers in the described calibration procedure.

CALIBRATION PROCEDURE

The DCR introduces both linear and nonlinear distortion into the signal. The nonlinear distortion caused by the downconverter can be minimized by filtering unwanted mixing products and ensuring that the signal level into the mixer and other components is in its linear range of operation. For baseband downconversion the unwanted mixing products are located at multiples of the LO frequency and can be eliminated by lowpass filtering. The baseband amplifier provides lowpass filtering and, if required, an external lowpass filter can be added. The linear distortion of the downconverter can be minimized by using components with a much wider frequency response than the bandwidth of the signal to be measured and by minimizing SWR interactions, which introduce ripple to the frequency response.

For sufficiently narrowband signals, the combined frequency response of the DSO and DCR has little variation and may be ignored. However, for wideband signals such as those used in high data rate communication systems, the DCR distortion may be significant. The response variations of the DSO over bandwidths of a few gigahertz are negligi-

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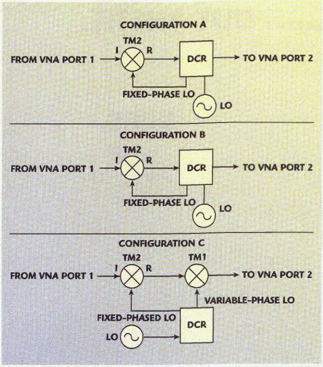

▲ *Fig. 2 Block diagrams of the three measurement configurations for DCR calibration.*

ble since a 20 GHz bandwidth sampling front end is used.[4] In this instance, the bandwidth of the wideband communications signal is 10 percent or less of the bandwidth of the DSO sampling front end. However, since the bandwidth of the DCR used here is approximately 4 GHz, a wideband signal occupies a large portion of the available bandwidth. Thus, linear distortion in the DCR introduces the only significant error in the measured LPE waveforms.

Since the input to the DCR is located at the signal's carrier frequency and the output of the DCR is located at baseband, its linear distortion cannot be measured using a vector network analyzer (VNA). A two-part procedure has been developed to accurately measure the DCR frequency response. Part 1 measures the DCR response at all frequencies other than the carrier frequency by means of the baseband-double-sideband frequency translating device (FTD) measurement technique.[5] Part 2 measures the DCR response at the carrier frequency, which is DC at the baseband output and measured using a voltmeter.

THE BASEBAND-DOUBLE-SIDEBAND FTD PROCEDURE

To calibrate the DCR at frequencies other than the carrier frequency, three test configurations using two test mixers (TM1 and TM2) and the DCR are measured using a VNA, as shown in ***Figure 2***. The three configurations are (A) TM1 to DCR, (B) TM2 to DCR and (C) TM2 to TM1. The VNA sweeps over the baseband frequency range; the first mixer in each configuration serves as an upconverter, and the second serves as a downconverter. Because the input signal is at baseband and there is no filter at the output of the upconverting mixer, an upper and a lower sideband are transmitted to the downconverting mixer.

Two measurements in each test configuration are required to capture the response of both sidebands. The first measurement is performed at a given arbitrary setting of the DCR phase shifter, which is referred to as phase shifter setting 1. In the second measurement, the phase shifter is adjusted by 90°. This setting is referred to as phase shifter setting 2 (phase shifter setting 1 + 90°). The VNA measurements are performed for each of the three configurations A, B and C. The LPE transmission response, $\Pi_X(f)$ (expressed as a complex number at each frequency), of each of the back-to-back FTD pairs is given by

$$\Pi_X(f) = \frac{1}{2}\left[M^{*}_{X1}(-f) + jM^{*}_{X2}(-f)\right], \quad f \le 0$$

(lower sideband response) (1a)

$$\Pi_X(f) = \frac{1}{2}\left[M_{X1}(-f) + jM_{X2}(f)\right], \quad f \ge 0$$

(upper sideband response) (1b)

where

$*$ = the complex conjugate operation
j = square root of –1
$M_{X1}(f)$ = complex S_{21} response of the back-to-back FTD pairs at phase shifter setting 1
$M_{X2}(f)$ = complex S_{21} response of the back-to-back FTD pairs at phase shifting setting 2 (setting 2 – setting 1 = + 90°)
X = A,B, C

The LPE response of the DCR may be derived from the pair responses. First, each pair response is converted from a complex representation to decibels and degrees such that

$$R_X(f) = 20\log|\Pi_X(f)|\ \text{dB}$$
$$\text{or } \angle\Pi_X(f)\ \text{degrees},\ X = A,B,C \quad (2)$$

Then, the frequency response of the DCR (in decibels and degrees) may be expressed as

$$R_{DCR}(f) = \frac{R_A(f) + R_B(f) - R_C(f)}{2} \quad (3)$$

Note that a VNA cannot measure down to zero signal frequency, so a careful procedure must be followed to interpolate the zero frequency response between the lower and upper sidebands. The overall response must be continuous in phase at zero frequency, and the value of the phase at zero frequency must be correct. Note also that the phase at zero frequency is important even though the signal out of the amplifier has no DC component because it ensures the correct phase at other frequencies.

The DCR phase response at zero baseband frequency can have only one of two possible values, 0° or 180°, depending on whether the signal path through the DCR is noninverting or inverting, respectively. Both the mixer and baseband amplifier can be either inverting or noninverting as the baseband frequency tends to zero. Thus, the sign of the DCR phase response at DC may be either

[Continued on page 91]

positive or negative depending on the product of the responses of the mixer and the amplifier near DC. This sign is most easily determined if the two components are characterized separately, before they are integrated into the DCR. The mixer can be tested by putting the same CW carrier signal into both the L and R ports simultaneously with zero phase difference and observing whether a positive (noninverting) or a negative (inverting) voltage is obtained. The amplifier can be tested by injecting a low frequency CW signal and determining if the output is in phase (noninverting) or 180° out of phase (inverting).

Part 2 of the DCR frequency response measurement is to locate the response of the DCR at the carrier frequency, which at baseband is DC. The first step in calibrating the DC voltage is to perform a zeroing procedure with no signal applied at the DCR input. The first measurement, V_{o1}, is made at phase shifter setting 1 used in the DCR response calibration procedure. The next measurement, V_{o2}, is made at phase shifter setting 2. The V_{o3} measurement is made at phase shifter setting 3 (phase shifter setting 1 + 180°), and the V_{o4} measurement is made at phase shifter setting 4 (phase shifter setting 1 + 270°). By storing these measured offset voltages at each of these settings and subtracting them from the DC values acquired during a waveform measurement, the offset errors are eliminated.

The second step in the DC calibration process is to calibrate the gain of the DCR at the carrier frequency. Since the DC output of the mixer in the DCR is measured prior to the baseband amplifier, the gain at the carrier frequency must be calibrated independently of other frequencies. This step is performed simply by applying a CW signal of known power P to the input of the DCR, acquiring the DC voltages V_1, V_2, V_3 and V_4 at the four LO phase shifter settings, respectively, and calculating a gain factor such that

$$G_{DC} = \pm\sqrt{\frac{4P}{\left[\left(V_1 + V_{o1}\right) - \left(V_3 - V_{o3}\right)\right]^2 + \left[\left(V_2 - V_{o2}\right) - \left(V_4 - V_{o4}\right)\right]^2}} \quad (4)$$

G_{DC} is a proportionality constant whose value depends on the power and voltage units used. G_{DC} determines the gain of the DCR at the carrier frequency (the DC gain at baseband) and is applied to the measured DC component of the signal. Note that the DC signal path is taken directly from the mixer prior to the amplifier. Thus, G_{DC} will be either positive or negative depending only on whether the mixer response is noninverting or inverting at DC.

MEASUREMENT AND POSTPROCESSING PROCEDURE

Once these calibration procedures are completed, a waveform of interest is applied. At phase shifter setting 1, the waveform w_1 is acquired by the DSO and a DC voltage

[Continued on page 93]

V_1 is acquired by the voltmeter. Similarly, w_2 and V_2 are acquired at phase shifter setting 2. At phase shifter settings 3 and 4, only DC voltage measurements V_3 and V_4, respectively, are required, not waveform acquisitions. The waveforms acquired at the two settings must be combined and corrected for the receiver response and then combined with the DC voltages to determine a corrected LPE waveform.

As part of the postprocessing procedure, the two waveforms are combined to form an uncorrected LPE waveform:

$$w(n) = w_1(n) + jw_2(n) \tag{5}$$

This waveform must be corrected for the DCR frequency response. One way to accomplish this correction is to transform the LPE waveform to the frequency domain, then divide the frequency domain waveform representation by the DCR response (expressed as a complex number at each frequency). The DCR frequency response must be linearly interpolated and extended in frequency to agree with the discrete frequencies of the waveform. Normally, the DCR response would be calibrated out to frequencies beyond the total span of the signal. In this case, windowing is unnecessary and the amplitude of the DCR response may be set to infinity at frequencies beyond the band of the measured response. This procedure forces the Fourier coefficients of the corrected waveform to zero at these frequencies.

After the LPE waveform is corrected for the receiver response, the corrected LPE waveform is then transformed back to the time domain. The corrected time domain LPE waveform, denoted as $w_c(n)$, has no DC component because the amplifier blocks DC. Hence, the DC component measured by the voltmeter must be added to the waveform according to the formula

$$w_{LPE}(n) = G_{AC}w_c(n) + \frac{G_{DC}}{2} \bullet \left\{\left[\left(V_1 - V_{o1}\right) - \left(V_3 - V_{o3}\right)\right] + j\left[\left(V_2 - V_{o2}\right) - \left(V_4 - V_{o4}\right)\right]\right\} \tag{6}$$

After the first waveform measurement, the gain factor G_{AC} is adjusted so that the calculated power in w_{LPE} is equal to the signal power as measured with a power meter. G_{AC} is a proportionality constant whose value depends on the power and voltage units used. This gain factor then can be used for all subsequent measurements.

BASEBAND DC VOLTAGE CALIBRATION AND MEASUREMENT

The mixer in the DCR acts as a phase and amplitude detector with regard to the signal component at the carrier frequency. Typically when a mixer is used only as a phase detector (such as in a phase lock loop), the carrier power on both the R and L ports is large enough to saturate the mixer diodes. Here, the signal on the R port must

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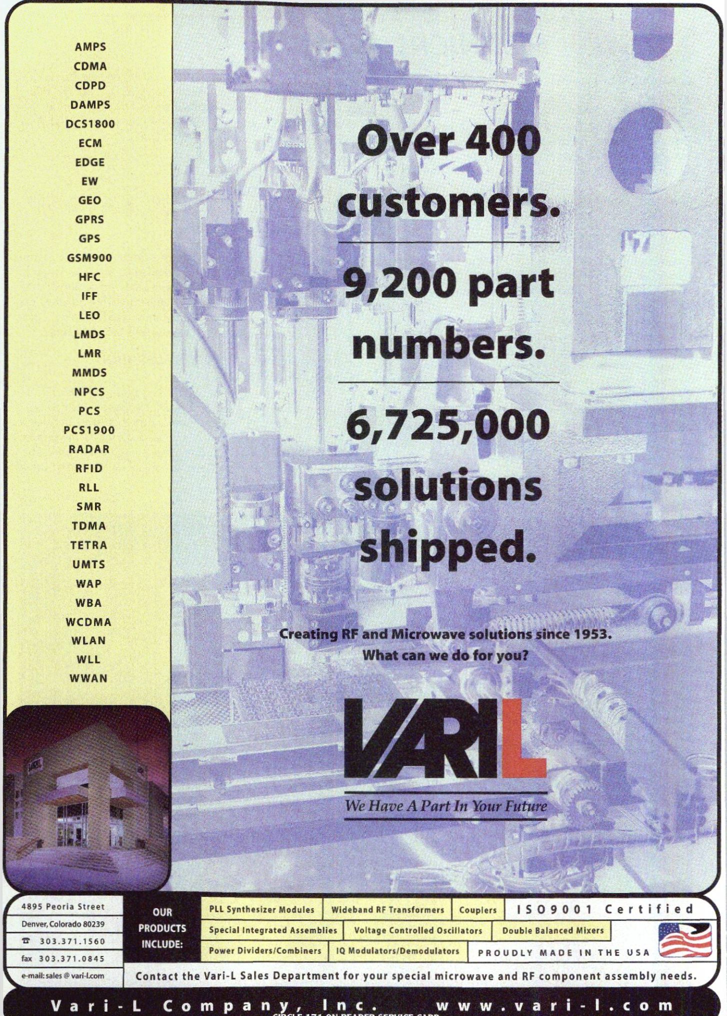

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be in the linear range of mixer operation while the CW signal at the L port must be large enough to saturate the mixer diodes. In this case, if the mixer were perfectly balanced, the DC voltage at the I port would be

$$V = \frac{\sqrt{P}}{G_{DC}} \cos \Phi$$

where

- P = power at the carrier frequency at the R port
- G_{DC} = a proportionality constant
- Φ = phase difference between the carrier at the L port and the carrier at the R port at phase shifter setting 1

For imperfectly balanced mixers, there is also a temperature-dependent DC offset voltage at the IF output port, even when no signal is applied to the RF port. This DC offset voltage is a function of mixer balance and the carrier power applied at the LO port. Since the phase shifter on the LO port displays some amplitude variation vs. setting, the offset voltage is, in turn, a function of phase setting. Hence, with no signal applied to the R port, four slightly different DC offset voltages (V_{o1}, V_{o2}, V_{o3} and V_{o4} at phase shifter settings 1 through 4, respectively) are measured. When the CW calibration signal of power P is applied to the mixer's R port, the DC output at the I port then consists of the sum of the offset voltage and the DC voltage produced in response to the input signal component at the carrier frequency. At phase setting 1,

$$V_1 = \frac{\sqrt{P}}{G_{DC}} \cos \Phi + V_{o1} \qquad (7)$$

At phase setting 2,

$$V_2 = \frac{\sqrt{P}}{G_{DC}} \cos\left(\Phi + 90°\right) + V_{o2} \qquad (8)$$

Note that settings 3 and 4 are 180° from settings 1 and 2, respectively. Thus,

$$V_3 = -\frac{\sqrt{P}}{G_{DC}} \cos \Phi + V_{o3} \qquad (9)$$

$$V_4 = -\frac{\sqrt{P}}{G_{DC}} \cos\left(\Phi + 90°\right) + V_{o4} \qquad (10)$$

It is assumed that the proportionality constant G_{DC} is independent of phase shifter setting. Equation 4, the expression for G_{DC}, can be derived by combining Equations 7 through 10. Note that G_{DC} could have been derived equally well from Equations 7 and 8 alone, but in practice using all four phase settings provides more immunity against long-term thermal drift of the DC offsets.

In the case of a modulated signal input, Equations 7 through 10 still apply if P is interpreted as the power in the Fourier component of the signal at the carrier frequency. The voltage measurement at setting 1 provides the real part of the Fourier coefficient and the measurement at setting 2 provides the imaginary part in Equation 6.

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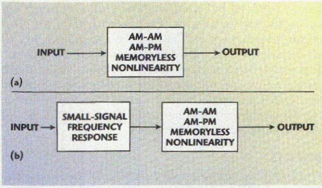


▲ *Fig. 3 Nonlinear amplifier block models; the (a) one-box and (b) two-box models.*

APPLICATION TO POWER AMPLIFIER MODELING

An application of the previously described technique to the measurement and modeling of a 20 GHz wideband solid-state amplifier will now be presented. Measurements of the input and output waveforms using binary phase shift-keying (BPSK) modulation were performed at several data rates. By using different data rates, the measurement and modeling techniques were evaluated over a range of bandwidths. The performance of two nonlinear block models for the 20 GHz solid-state amplifier is compared to measured results. The first model, the one-box model, shown in ***Figure 3***, consists of a memoryless nonlinearity only. In this model, the nonlinear device is characterized by the bandcenter nonlinear amplitude (AM-AM) and phase (AM-PM) conversion functions, which operate on the instantaneous envelope of the input signal. The second model, the two-box model, includes an input filter prior to a memoryless nonlinearity. Here, the first box is the small-signal frequency response of the nonlinear device. The second box is the same AM-AM, AM-PM nonlinearity used in the one-box model. Both of these models are constructed strictly from single-tone VNA measurements. In all cases the measurements and simulations were performed at an amplifier operating point near saturation.

QUANTIFYING WAVEFORM FIDELITY

A means of quantifying the agreement between the modeled and measured time domain waveforms is necessary. A convenient metric to use for this purpose is the normalized mean square error (NMSE):

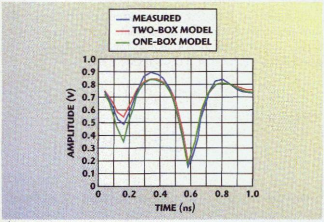
$$\mathrm{NMSE} \equiv 10\log\left(\frac{\sum_{k=1}^{M}\left[\left(y_{I,k}^{meas}-y_{I,k}^{mod}\right)^2+\left(y_{Q,k}^{meas}-y_{Q,k}^{mod}\right)^2\right]}{\sum_{k=1}^{M}\left[\left(y_{I,k}^{meas}\right)^2+\left(y_{Q,k}^{meas}\right)^2\right]}\right) \tag{11}$$

where the measured and modeled in-phase (y_I) and quadrature (y_Q) waveforms have M sample points. To calculate the NMSE it is first necessary to line up the two waveforms in both time and phase. This lineup can be conve-

TABLE I

AMPLIFIER MODEL NMSE FOR BPSK SIGNALS

	Data Rate (Mbps) 150	600	1200	2400
One-box model NMSE (dB)	–27.92	–22.64	–19.84	–18.72
Two-box model NMSE (dB)	–33.69	–28.34	–26.24	–24.31
Two-box model improvement (dB)	5.77	5.70	6.40	5.59



▲ *Fig. 4 Modeled vs. measured outputs for a 2.4 Gbps BPSK modulated input.*

niently achieved by maximizing the cross correlation between the two waveforms. The metric is the total error vector magnitude power between the measured and modeled waveforms normalized to the measured signal power. It is assumed that the true waveform is much closer to the measured waveform than to the modeled waveform, so the NMSE is a model fidelity metric. The NMSE metric can be useful for assessing model predictive fidelity for many communications applications.

RESULTS

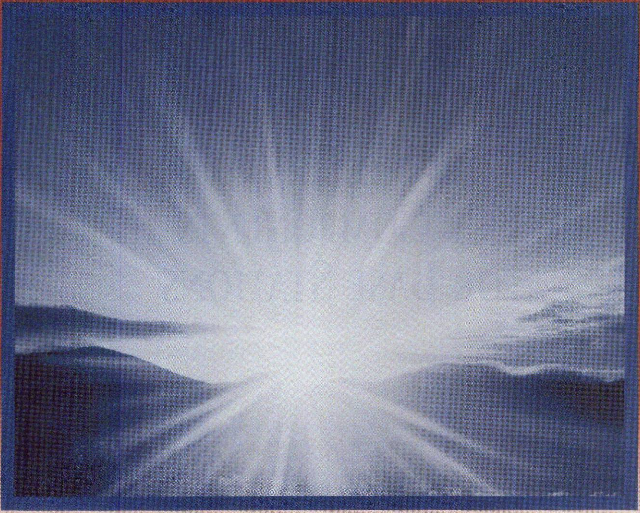
The BPSK signals applied vary in bit rate from 150 Mbps to 2.4 Gbps. A 5 GHz bandlimiting filter was inserted before the amplifier for these signals. The operating point was chosen at the 3 dB gain compression point. ***Table 1*** lists the NMSE results for the various BPSK signals as well as the difference between the two models. Note that the fidelity of both models decreases as the bandwidth of the signal increases. However, the two-box model provides more than 5 dB improvement over the one-box model for all bandwidths. To illustrate one of these cases, ***Figure 4*** shows the amplitude envelope of the 2.4 Gbps BPSK output for the two models vs. the measured waveform. A small portion of the time record is shown to enable the differences between the measured and modeled waveforms to be seen.

CONCLUSION

A novel technique for accurately measuring wideband communications waveforms has been presented. The waveform measurements were made at baseband using a calibrated downconverting receiver to take advantage of the inherent accuracy of available DSOs. A correction technique removed any errors in the waveforms caused by the frequency response of the downconverting receiver. The measured input and output communications signal waveforms have been applied to develop a simulation model of a 20 GHz solid-state amplifier over a bandwidth of 4.8 GHz. ■

References

1. M. Schwartz, W.R. Bennett and S. Stein, *Communication Systems and Techniques*, McGraw-Hill, New York, 1966.
2. G. Dow, J. Yang, K. Yen, R. Matreci, E. Spotted-Elk, S. Pettis and L. Trinh "Vector Signal Measurement for 38 GHz Digital Radio Applications," *Microwave Journal*, Vol. 42, No. 10, October 1999, pp. 94–106.
3. A. Moulthrop, M.S. Muha, C.P. Silva and C.J. Clark, "A New Time-domain Measurement Technique for Microwave Devices," *1998 IEEE MTT-S International Microwave Symposium Digest*, Vol. 2, June 1998, pp. 945–948.
4. J. Verspecht and K. Rush, "Individual Characterization of Broadband Sampling Oscilloscopes with a Nose-to-nose Calibration Procedure," *IEEE Trans. Instrument. Measure.*, Vol. IM-43, No. 2, April 1994, pp. 347–354.
5. C.J. Clark, A.A. Moulthrop, M.S. Muha and C.P. Silva, "Network Analyzer Measurements of Frequency Translating Devices," *Microwave Journal*, Vol. 39, No. 11, November 1996, pp. 114–126.



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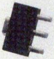

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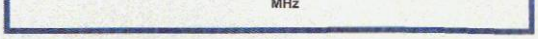

Typical device performance. Bias =5V @ 110mA typ.

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Low Noise VCOs: Key Components for Base Stations

The great economic success of modern mobile radio systems such as GSM and the digital communication system (DCS) means even greater utilization of the capacity of existing channels. Therefore, it is immensely important to adhere to GSM specifications exactly. In GSM, the available frequency range is divided according to the frequency division multiple access (FDMA) procedure[1,2] into radio channels of 200 kHz bandwidth each. On the other hand, each radio channel is divided into eight traffic channels through a time multiplexing (TDMA) procedure[1,2] and contains information (voice and signals) in so-called bursts. In the case of a channel width of 200 kHz, this allocation typically produces 124 GSM channels with a bandwidth of 25 MHz (the first channel is not normally used) and 372 DCS channels with a bandwidth of 75 MHz.

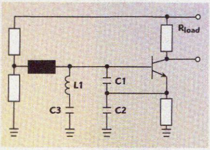
The block diagram shown in ***Figure 1*** displays the frequency processing that takes place in a base station. In the transmitter (TX), the working signal must be converted into an RF signal; in the reception path (RX), the received RF signal is converted into one (or two) fixed intermediate frequencies (IF). Each of the two conversion processes requires an LO. Since a base station works in full duplex mode, the RX and TX paths must be viewed separately and have their own LOs. With mobile phones, a common LO is sufficient because it features a half-duplex operation due to the TDMA time slots.

Fig. 1 Block diagram of a base station.

"... it is clear that the VCO, together with the [phase-locked loop] PLL, represents an elementary unit that makes an important contribution to the design of a base station."

[Continued on page 102]

Frank Baberg
Tekelec Temex
Munich, Germany



▲ *Fig. 2 Switching operation of a Clapp oscillator.*

Fig. 3 The Clapp oscillator's RF equivalent circuit. ▼

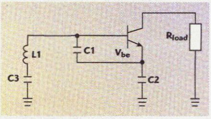
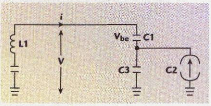


Fig. 4 The Clapp oscillator's simplified equivalent circuit. ▼



Obviously, the actual concepts used can differ significantly from this configuration. For example, the RX path also can be constructed using only one IF. In modern communication systems, a synthesizer is normally used; that is, an oscillator is synchronized through a reference fed to a phase-locked loop (PLL). There are a number of different ways to create the reference, such as deriving it from the fixed network clock or by synchronization via the Global Positioning System. However, these methods are not discussed in this article. A VCO is used as an LO because its frequency is dependent on an applied direct voltage. Thus, the VCO can be switched to the various channel frequencies relatively simply and quickly.

VCO STRUCTURES

Microwave oscillators are typically analyzed using the concept of negative resistance.[3] When designing oscillators, various basic switching operations can be found in the literature, such as the Hartley-Meissner or Colpitts switching operations. The so-called Clapp switching operation has proven itself in VCOs in particular. The Clapp switching operation is very similar to the Colpitts switching operation, only the inductance is replaced by a resonant circuit, as shown in ***Figure 2***. The equivalent circuit for the Clapp oscillator is shown in ***Figure 3***, restricted to the RF components that are important for the operation. ***Figure 4*** shows the simplified equivalent circuit diagram, displaying only the basic principle. The impedance of the serial resonant circuit can be expressed as

$$Z = \frac{v}{i} = \frac{v_{be} + v_{c2}}{i}$$

$$= \frac{\frac{i}{j\omega C1} + \frac{i}{j\omega C2} + \frac{g_m}{j\omega C3}}{i}$$

$$= \frac{L}{j\omega C1} + \frac{L}{j\omega C2} - \frac{g_m}{\omega^2 C1C2} \quad (1)$$

Thus, from Equation 1, the oscillation condition to produce a negative resistance becomes

$$\frac{1}{j\omega C1} + \frac{1}{j\omega C2} \le \frac{g_m}{\omega^2 C1C2} \quad (2)$$

The resulting frequency from the series connection of the three capacitors is found to be

$$\omega^2 = \frac{1}{L1}\left(\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}\right) \quad (3)$$

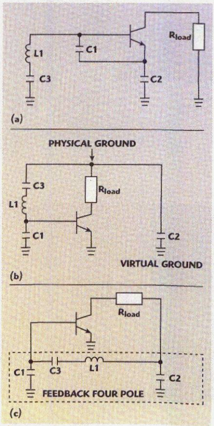
In RF technology, the oscillator is often shown as a four-pole amplifier with amplification V, whose output voltage is fed back to the input via a feedback network. If the Clapp oscillator is drawn as shown in ***Figure 5*** (introducing a virtual ground), then the four-pole switching operation becomes evident.

In order to now determine the frequency of the oscillator using a direct voltage, one of the capacitors is replaced by a junction varactor. This component exploits the junction capacity of a diode operated in the reverse direction and is dependent on the reverse voltage applied. Analogous to a capacitor, the junction capacity of a PN junction is dependent on the cross-section surface and width of the junction. A theoretical analysis determines the relationship for the voltage dependency of the junction capacity[2] as

$$C_j = \frac{C_{j0}}{\left[1 + \frac{|V_R|}{V_D}\right]^m}$$

$$\approx C_{j0}\left[1 + \frac{|V_R|}{V_D}\right]^{-m} \quad \text{for} \quad V_D << V_R \quad (4)$$

In this relationship, C1 is the junction capacity C_j where $V = V_R$, C_{j0} at $V_R = 0$ V, V_D = the diffusion potential (approximately 0.65 V for silicon) and V_R = the reverse voltage applied. The exponent m depends on the course of doping and is decisive for the voltage dependency of the junction capacity. In a diffused junction, the transition of the acceptor density N_A (P area) is linear with respect to the donor density N_D (N area). In this case, m = 0.33. With an abrupt junction, the transfer is carried out suddenly. In this case, m = 0.5. If a particularly strong dependency of the junction capacity on the voltage is required, m



▲ *Fig. 5 Feedback in the Clapp oscillator; (a) the physical equivalent circuit, (b) introduction of virtual ground and (c) a four-pole representation.*

[Continued on page 104]

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The Applications Engineer Said No.
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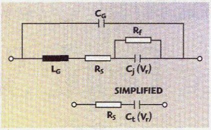
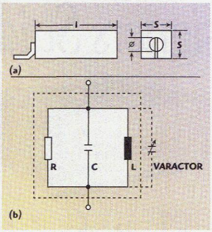


▲ *Fig. 6 Equivalent circuit of the junction varactor in its case.*

Fig. 7 A ceramic coaxial resonator's (a) structure and (b) equivalent circuit. ▼



must be > 0.5. In this case, the doping density must be greater than for the abrupt junction. Such doping profiles are called hyperabrupt.

Figure 6 shows the small-signal equivalent circuit diagram of a junction varactor. The resistance R_s takes into consideration the reverse current of the diode and should be as large as possible in the interest of low noise (shot noise). In the case of higher frequencies, the bulk resistances become most noticeable. The influence of the case is described by the series inductance L_G as well as the case capacity C_G.

In addition to the capacity relationship $C1/C_{j0}$, the quality factor Q is a decisive characteristic. Analogous to the capacitor, the Q of the varactor is also defined as the relationship between the reactive and the active performance. From the simplified equivalent circuit, $C_T = C_j + C_G$, thus resulting in

$$Q = \frac{1}{\omega C_t(V_R)R_b} \qquad (5)$$

Basically, the quality of abrupt junction crossings is significantly better than that of hyperabrupt crossings. However, very high reverse voltages of up to 90 V are required to achieve sufficiently large capacity variations. These high reverse voltages are required because, in the case of voltages (which lie significantly below the breakdown voltage), the reverse zone is only partially purged. The ohmic resistance still lies within the non-purged zone in series with the capacitance. For these reasons, hyperabrupt junctions mainly are used as oscillating circuit capacitors. In selecting a suitable varactor, it is also important that the connection between the reverse voltage and junction capacity be defined over as wide a range as possible.

PHASE NOISE PROPERTIES

Since modern high Q capacitors offer excellent quality,[4,5] the selection of inductance L (in addition to the varactor) determines the phase noise to a significant extent. In the case of low phase noise requirements, the inductance can be realized through a coil printed onto the PCB. Better results are obtained by using air-core reactors in a surface-mount device.

The best characteristics are obtained using coaxial resonators, as shown in ***Figure 7***. Ceramic resonators are shaped as cubes with a coaxial bore. The inner and outer surfaces are metallized. The capacity, inductance and resistance of the metallization provide an RF resonant circuit that oscillates in the TEM mode. The quarter-wave $\lambda/4$ types are particularly space-saving. The additional metallization of an end face creates the required short circuit.

The resonance frequency is obtained from the relative permittivity and the length of the resonator. Basically, the length l for $\lambda/4$ resonators is determined using

$$l = \frac{\lambda_0}{4} \bullet \frac{1}{\sqrt{\varepsilon_r}} \qquad (6)$$

Dielectric values between $\varepsilon_r = 20$ and 78 are available. The Q is almost exclusively determined by the final conductivity of the metallization to a value of $Q < 800$. Where higher Qs are required, a special silver metallization is recommended; in the case of price-sensitive applications, a copper-plated metallization is preferred. The no-

[Continued on page 106]

TABLE I

TYPICAL VCO CHARACTERISTICS

Frequency Range (MHz)	Output Power (dBm)	Tuning Voltage (V)	Phase Noise @ 10 kHz (dBc/Hz)	Phase Noise @ 100 kHz (dBc/Hz)	Phase Noise @ 800 kHz (dBc/Hz)	Second Harmonic (dBc)	Power Supply (V/mA)
195 to 220	8	1 to 14	–110	–130		–8	12/20
255 to 320	8	1 to 9	–100	–120		–8	12/20
380 to 430	0	0 to 5	–112	–132		–8	12/20
809 to 845	5	0.5 to 5	–115	–135	–152	–12	5/25
925 to 960	3	1.5 to 6.5	–115	–135	–15	–12	5/25
950 to 986	3	1 to 6	–115	–135	–15	–12	5/25
1250 to 1350	3	1 to 8	–100	–120		–12	8/25
1450 to 1550	3	1 to 8	–105	–125	–145	–12	5/25
1500 to 1650	1	1 to 8	–97	–117	–137	–12	5/25
1594 to 1669	3	1 to 6.5	–105	–125	–145	–15	5/25
1750 to 1900	1	1 to 8	–97	–117	–187	–12	8/16
1800 to 2700	1	0 to 19	–85	–105		–8	12/25
2650 to 2850	2	0 to 12	–90	–110		–12	8/20

load operating Q (Q_0) is defined as the quotient of the resonant frequency and 3 dB bandwidth B_{3dB} of the resonance response curve:

$$Q_0 = \frac{f_r}{B_{3dB}} \qquad (7)$$

Q_0 increases in the first approximation by $\sqrt{f}$. Higher Q values can be achieved using larger cross-section measurements where it is then critical to integrate the resonator into the normally small VCO case.

VCO CHARACTERISTICS

VCOs are customer-specific modules. Each user design is different and, thus, the VCO modules must be adapted to customer specifications. Typical VCO performance specifications are listed in ***Table 1***.[6] These details can only be used as guide values for typical designs.

Phase Noise

Phase noise is the most critical parameter for designing a VCO and, therefore, must be specified with particular care. In the case of sensitive pre-amplifiers, normally only the amplitude noise is taken into consideration as it characterizes the sensitivity of the amplifier. On the other hand, with oscillators, the amplitude noise plays only a subordinate role. What is decisive here are the stochastic changes in the zero transits of the sinusoidal oscillation created by the oscillator. Thus, the phase noise characteristic describes the relationship of the carrier level to the noise level in the environment of the carrier frequency. This relationship is described as a function $\xi = F(f_m)$, depending on the carrier offset. The fundamental significance of the phase noise is that it determines the interference in the neighboring channel. Therefore, a typical VCO specification states values of phase noise depending on the carrier offset.

The phase noise of a VCO has been observed in numerous theoretical experiments,[6,7] and is described using

$$\xi(f_m) = 10\log\left\{\left[1 + \frac{f_0^2}{\left(2f_m Q_{load}\right)^2}\right] \bullet \left(1 + \frac{f_c}{f_m}\right)\frac{FkT}{2P_{out}} + \frac{2kTRV_0^2}{f_m^2}\right\} \qquad (8)$$

where

$\xi(f_m)$ = ratio of the phase noise in a 1 Hz bandwidth to the common VCO output level (dBc/Hz)
f_m = carrier frequency offset
f_0 = carrier frequency
f_c = noise edge of the flicker or 1/f noise of the active oscillator
Q_{load} = Q of the loaded resonator (resonance circuit with active load and parasitic elements)
F = noise figure of the four-pole active oscillator
K = Boltzmann constant ($k = 1.38 \times 10^{-23}$ J/K)
T = temperature in Kelvins
P_{av} = oscillator output power level
R = equivalent noise resistance of the varactor
V_0 = voltage amplification of the oscillator

Even though this relationship is based on idealized values, some important parameters can be derived for the design of VCOs. The Q of the loaded resonator directly affects the phase noise. For this reason, coaxial resonators must be used in the case of very low phase noise requirements. Low noise oscillators require components with a low corner frequency of the flicker or 1/f noise; therefore, bipolar transistors are normally used in VCOs instead of FETs. Components based on GaAs are not well suited as their noise edge is significantly higher than that of the silicon transistors.

The noise figure F of the oscillator, which is internal to the switching, depends not only on the noise figure of the active component, but also on the switching configuration. The power output setting of the oscillator also influences the noise. However, the oscillator's current consumption must not be neglected.

One very important point that is not taken into consideration in Equation 8 is a clean voltage supply. Significant fluctuations can occur in the voltage supply, particularly through the end stage. Unwanted modulation side bands, which lie outside the loop bandwidth of the PLL switching operation, are produced from the fluc-

[Continued on page 108]

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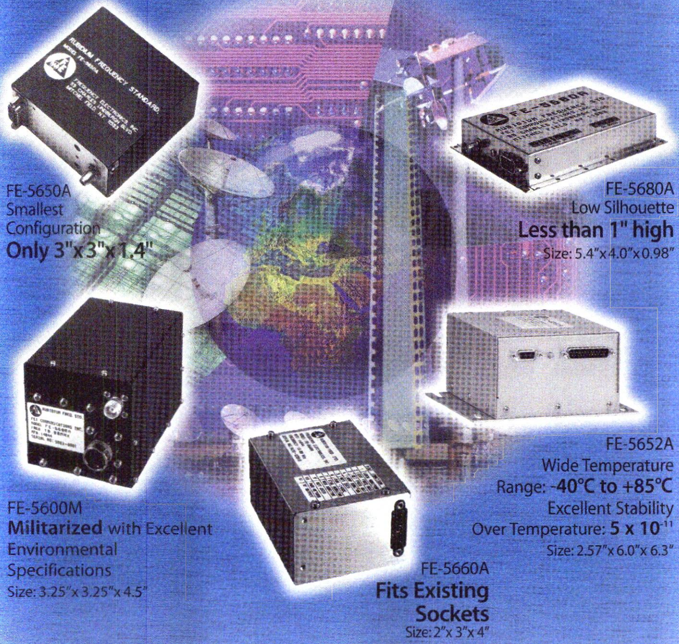

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tuations in the bias voltage at the modulation input of the VCO.

Tuning Sensitivity

Tuning sensitivity describes the tuning frequency range as a function of the tuning voltage at the varactor input. The tuning sensitivity depends on the available capacity variation and is inversely proportional to the loaded Q of the resonant circuit. However, frequency dependency of the tuning sensitivity also must be borne in mind. If the frequency dependence is too great, then the performance of the synthesizers is adversely affected.

Load Pulling

Load pulling describes the sensitivity of the free-running VCOs to load fluctuations at the VCO output. This load pulling is specified for a mismatched load with a defined SWR (for example, SWR = 2.0) where the phase angle can lie between 0° and 360°. At its simplest, this requirement may be achieved using an additional buffer amplifier. Such a buffer amplifier also improves the output power level of the VCO, which must supply the RF scaler of the PLL synthesizer in addition to a pulsating stage. However, a buffer amplifier increases the current supply of the VCO. Load pulling of the transmitter branch VCO is particularly critical due to the last stage and its load.

CONCLUSION

This article has presented the fundamentals for the design and use of VCOs. From what has been said, it is clear that the VCO, together with the PLL, represents an elementary unit that makes an important contribution to the design of a base station. Therefore, it makes sense that the manufacturers of VCOs are also involved in the production of suitable PLL components, and it is conceivable that both VCO and PLL modules could be integrated into one case. ■

References

1. Hans Lobensommer, *Die Technik der modernen Mobilkommunikation* (*The Technology of Modern Mobile Communications*), Franzis-Verlag.
2. Heinz Preibisch, *GSM Mobilfunk: Übertragungstechnik* (*GSM Mobile Radio Transmission Technology*), Schiele & Schön, 1994.
3. J.W. Boyles, "The Oscillator as a Reflection Amplifier: An Intuitive Approach to Oscillator Design," *Microwave Journal*, Vol. 29, No. 6, June 1986, pp. 83–98.
4. Frank Baberg, *Kapazitive Bauelemente für Hochfrequenzapplikationen* (*Capacitive Components for Radio Frequency Applications*), HF Report, May 2/99.
5. *Microwave & RF Devices, Ceramics and Capacitors, Time and Frequency Products Catalogue 2000*, issued by Tekelec Temex S.A., Montreuil.
6. D.R. Leeson, "A Simple Model of Feedback Oscillator Noise Spectrum," *Proceedings of the IEEE*, 1966, pp. 329–330.
7. Ulrich Rohde and Frank Hagemeyer: "Feedback Technique Improves Oscillator Phase Noise," *Microwaves & RF*, November 1998.
8. Wolf Dieter Schleifer, *Hochfrequenz-und Mikrowellen-Meßtechnik in der Praxis Radio Frequency and Microwave Measurement Techniques in Practice*, Hüthig.

THERMAL DESIGN CONSIDERATIONS FOR WIDE BANDGAP TRANSISTORS

The peak junction temperature of a transistor is an important factor in determining its lifetime and output power degradation over time. Many design parameters determine the temperature rise in the semiconductor, including the transistor performance, semiconductor material and device dimensions. Thermal issues are of particular concern in wide bandgap transistors due to their intrinsic high power density. This article investigates the effect the number of gate fingers, gate geometry and epitaxial layer thickness has on the peak junction temperature of high power gallium nitride (GaN) and silicon carbide (SiC) transistors.[1]

Future radar and communications systems will require devices with significant improvement in output power over current technology. Wide bandgap semiconductors will be used in many of these applications. Small periphery, wide bandgap transistors have achieved an order of magnitude increase in power density over typical GaAs power transistors.[2,3] The temperature of larger periphery devices can be significantly higher than small periphery devices due to thermal coupling between gate fingers. A thorough understanding of thermal modeling and associated device design issues is critical to achieving high power densities with large periphery devices.

The method of images is used in this article to calculate peak junction temperatures, and accounts for the temperature rise due to the power dissipated by a single gate as well as the contribution of heat from surrounding gate fingers.[4] This contribution is significant for accurately modeling the peak junction temperature. The method of images provides the accuracy of finite element techniques with a comparatively significant reduction in the time required for problem definition and simulation.

The method of images used here predicts the temperature rise through one layer of material and not the overall peak junction temperature due to all of the layers in the thermal path. However, it permits accurate and efficient calculation of the peak junction temperature rise in the semiconductor substrate, which is typically the largest contributor to the overall temperature rise. Temperature rises in the other layers of the thermal stackup are created by differences in the packaging, not the semiconductor. Device power density, efficiency, thermal conductivity and dimensions, shown in

[Continued on page 113]

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AND AMY J. BILLUPS
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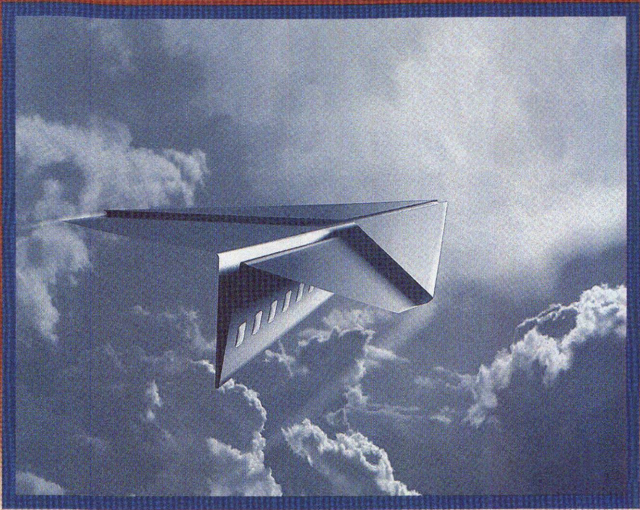

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NGA-186	0.1-6.0	4.1	50.0	12.5	14.6	32.9	120
NGA-286	0.1-6.0	4.0	50.0	15.5	15.2	32.0	120
NGA-386	0.1-5.0	4.0	35.0	20.8	14.5	25.8	144
NGA-486	0.1-6.0	5.0	80.0	14.8	18.3	39.5	118
NGA-586	0.1-6.0	5.0	80.0	19.9	18.9	39.6	121
NGA-686	0.1-6.0	5.9	80.0	11.8	19.5	37.5	121

Data at 1 GHz and is typical of device performance.

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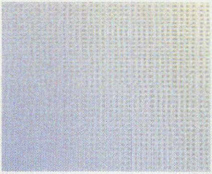


▲ *Fig. 1 Transistor dimensions.*

Figure 1, are all that is required to determine the temperature rise.

At 25°C, the thermal conductivity, K_0, of GaN is 1.3 W/cm°C and the semi-insulating, SiC substrate is 3.3 W/cm°C. Thermal conductivity is temperature dependent and given by $K_t(T) = K_0\ (300/T)$, where the device temperature, T, is in Kelvins.[4,5] The temperature rise due to the temperature dependence of the thermal conductivity is given by $T = T_0\ (e^{T/T_0})$, where T_0 is the baseplate temperature in Kelvins and T is the temperature rise in degrees Celsius.

THERMAL SENSITIVITY TO THE NUMBER OF GATE FINGERS

The temperature of a device is dependent on the number of gate fingers used in the transistor. When the gate pitch is sufficiently small and the substrate is thick enough to allow heat spreading, the heat sources will couple. Coupling will increase the temperature of a multiple-finger device compared to the temperature of a single-finger device. Thus, thermal coupling will degrade the power density as the number of gate fingers increases.

In this effort, the number of gate fingers was varied to assess their effect on peak junction temperature. The first example used a 100-µm-thick SiC substrate. The gate length was set to 0.35 µm with a gate width of 125 µm to represent dimensions typically used at X band. Each device had a pitch of 20 µm. Power density was set to 5.0 W/mm^2 and transistor efficiency was assumed to be 50 percent.[2] The X-band efficiency assumed is much higher than that achieved with SiC and will require future development. ***Table 1*** lists the device peak junction temperature calculated using these parameters for 1, 4, 10, 20, 25, 50, 75 and 100 gate fingers. ***Table 2*** lists a similar analysis performed with a 0.5 µm gate length and 400 µm gate width to represent devices at S band with all of the other parameters held constant. In this case, the SiC efficiency is similar to demonstrated levels.

TABLE I

PEAK JUNCTION TEMPERATURE VS. NUMBER OF GATE FINGERS FOR SiC X-BAND DEVICES

Gate Fingers	Temperature (°C)
1	37
4	52
10	73
20	80
25	81
50	82
75	82
100	82

TABLE II

PEAK JUNCTION TEMPERATURE VS. NUMBER OF GATE FINGERS FOR SiC S-BAND DEVICES

Gate Fingers	Temperature (°C)
1	37
4	59
10	89
20	104
25	106
50	108
75	108
100	108

The data show that there is a significant difference in peak junction temperature for as many as 20 gate fingers in X- and S-band devices. This result is important since large periphery devices are designed by scaling measured power densities in small periphery transistors. Measured power densities from 20-finger devices with the selected gate pitch could be used to estimate the output power performance of larger periphery devices.

THERMAL SENSITIVITY TO GATE PITCH

Thermal coupling between gate fingers is reduced as the gate pitch increases. The gate pitch plays an important role in determining the device's peak junction temperature. Gate pitch also determines the width of a high power device. Accordingly, the area of a high power transistor or MMIC is directly proportional to the gate pitch. A small gate pitch will reduce size and cost, but a minimum pitch must be maintained for thermal management.

The gate pitch was varied to assess its effect on high power density devices. The first gate pitch example uses devices with the same X-band gate dimensions used previously. In this case, both 100-μm-thick SiC and GaN substrates were analyzed. The number of gate fingers for each substrate was set to 100. The power density for both semiconductors was set to 5.0 W/mm^2, and the transistor efficiency was assumed to be 50 percent.[3] ***Table 3*** shows the peak device junction temperature with the prior parameters for a 20, 30 and 40 μm pitch. The peak junction temperature of the X-band SiC transistor with a gate pitch of 20 μm is 81°C lower than the comparable GaN transistor with a pitch of 40 μm. SiC devices provide a significantly lower peak junction temperature at X band while requiring less than one-half the area of a device on a GaN substrate if equivalent efficiency can be achieved.

A similar analysis was performed with the prior S-band gate length and width. All of the other parameters used previously were maintained and the results are listed in ***Table 4***. At S band, the GaN substrate requires at least twice the device area with a > 100°C temperature increase as compared to that on a SiC substrate. In this case, the excessive SiC temperature with a gate pitch of 20 μm would likely force a pitch greater than 30 μm.

While wide bandgap devices may operate reliably at temperatures higher than GaAs devices, the output power degrades with temperature. It is likely that a peak junction temperature similar to GaAs devices will be necessary to achieve the required

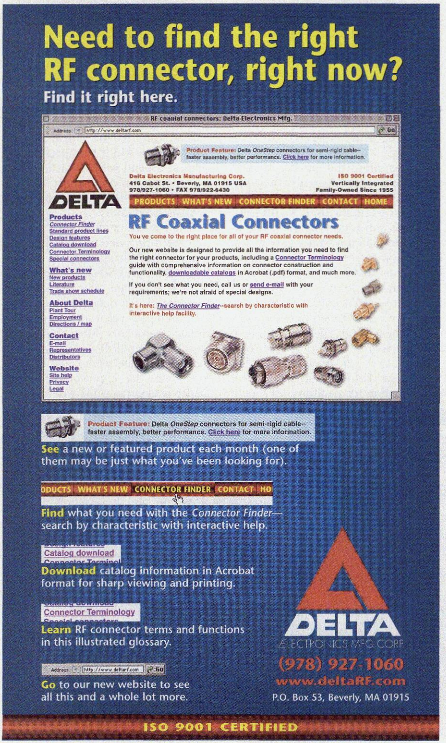


TABLE III
PEAK JUNCTION TEMPERATURE VS. GATE PITCH FOR X-BAND DEVICES

	Gate Pitch (μm)	Temperature (°C)
GaN	20	213
	30	156
	40	131
SiC	20	82
	30	62
	40	53

TABLE IV
PEAK JUNCTION TEMPERATURE VS. GATE PITCH FOR S-BAND DEVICES

	Gate Pitch (μm)	Temperature (°C)
GaN	20	296
	30	202
	40	163
SiC	20	108
	30	78
	40	65

[Continued on page 116]

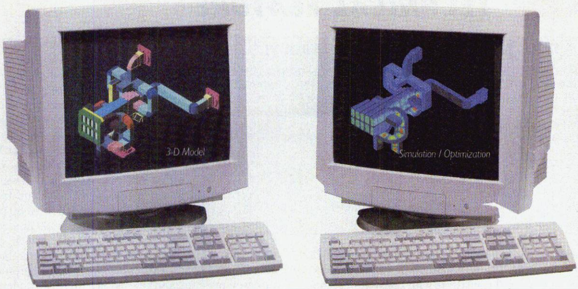

3-D Model
Simulation / Optimization

TABLE V

JUNCTION TEMPERATURE VS. SUBSTRATE THICKNESS FOR X-BAND DEVICES

	Epitaxial Thickness (μm)	Temperature (°C)
GaN	1	34
	2	43
	4	51
SiC	1	15
	2	19
	4	22

TABLE VI

JUNCTION TEMPERATURE VS. SUBSTRATE THICKNESS FOR S-BAND DEVICES

	Epitaxial Thickness (μm)	Temperature (°C)
GaN	1	32
	2	40
	4	49
SiC	1	14
	2	18
	4	21

performance. Excessive peak junction temperatures will preclude the use of GaN wafers for high power, high power density S- and X-band transistors with conventional die attachment techniques. SiC will require improvements in X-band efficiency for thermal management.

THERMAL SENSITIVITY TO SUBSTRATE THICKNESS

Growth of an epitaxial layer of GaN onto a SiC substrate is one technique to overcome the excessive thermal resistance of a GaN substrate. An analysis was performed with the same X- and S-band gate parameters with SiC and GaN epitaxial layer thicknesses set to 1, 2 and 4 μm. A gate pitch of 20 μm was used for all cases, and the results are listed in ***Tables 5*** and ***6***. The thin layers analyzed do not permit thermal coupling at a typical gate pitch. Additional temperature rise in the semiconductor substrate beneath the epitaxial layer can be assumed constant for both cases if they are on SiC substrates.

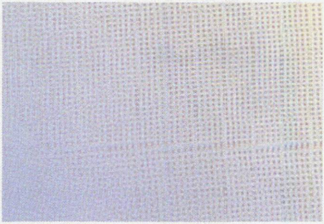
This calculation shows that a significant temperature increase occurs in the first few microns of material and predicts that GaN will have a 30°C higher temperature rise than a SiC layer of similar thickness. This additional temperature rise does not prohibit the use of a GaN epitaxial layer on a SiC substrate, but demonstrates the performance advantage for SiC. The epitaxial layer thickness of the GaN is also a critical thermal design parameter.

FLIP-CHIP DIE ATTACHMENT

Flip-chip die attachment can eliminate the GaN wafer or sapphire substrate from the thermal path of a GaN epitaxial layer device. Heat generated in the flip-chip GaN epitaxial layer underneath the gate moves laterally to the source heat sink. This lateral movement restricts the spreading of heat within the epitaxial layer, as shown in ***Figure 2***. The heat restriction increases the junction temperature rise experienced in the epitaxial layer when compared to a conventionally mounted device. A flip-chip is also mounted onto an electrical insulator to enable electrical contact to the gate and drain. The electrical insulators with the highest thermal conductivity are aluminum nitride (AlN) and beryllium oxide (BeO) at 1.7 and 2.15 W/cm°C, respectively. Both insulators have lower thermal conductivity than SiC. This temperature rise through the insulator can be much higher than through the SiC wafer for a conventional GaN device fabricated on a SiC wafer.

A finite element model of a flip-chip GaN device was used to evaluate flip-chip thermal issues. A 75-μm-thick GaN substrate was analyzed. The thickness of the semiconductor wafer has little or no effect on the flip-chip device's thermal resistance since the thermal spreading will not enter the substrate. The gate length was set to 0.35 μm with a gate width of 125 μm, again to represent dimensions typically used at X band. One hundred gate fingers were used with a gate pitch of 30 μm. Power density was set to 5.0 W/mm^2, and transistor efficiency was assumed to be 50 percent. The source heat sink is 100 μm high, and the device was attached with a 5-μm-thick layer of Au/Sn (80/20) solder. The source heat sink has a thermal conductivity of 4 W/cm°C to represent a silver-based material, and the solder's thermal conductivity is 2.4 W/cm/°C. A 0.015"-thick AlN substrate was used as the insulator and mounted to a 0.040"-thick baseplate of copper molybdenum (20/80) with a thermal conductivity of 1.97 W/cm°C. The layers of AlN and CuMo must be extended beyond the layer of solder to allow the heat to spread, avoiding any additional temperature increase in the device. The resulting finite element plot is shown in ***Figure 3***.

The peak junction temperature of the flip-chip device is 274°C. A conventionally mounted device comprising GaN



▲ *Fig. 2 Flip-chip cross section showing restricted heat flow from gate to source contacts.*

Fig. 3 Finite element model of a flip-chip GaN device mounted on an AlN substrate and CuMo base plate showing heat flow. ▼

[Continued on page 118]

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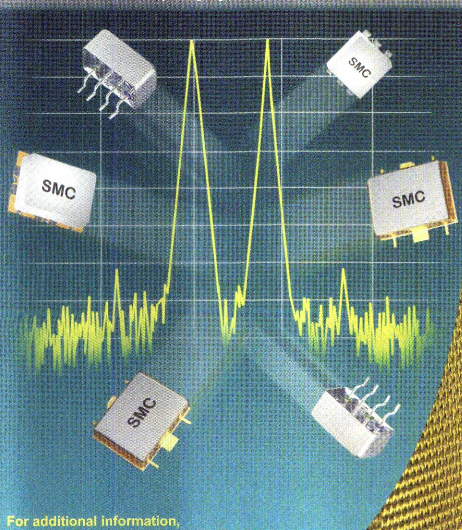

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epitaxy on a SiC substrate does not have the restricted heat flow and insulating substrate limitations of flip-chip, and will likely become the preferred approach to realize high power density, high periphery GaN devices.

Flip-chip attachment poses many other significant issues related to thermal management. Silver-based source heat sinks are often proposed to lower the device's thermal resistance. This method introduces electromigration issues due to the high field strengths associated with GaN devices that can be addressed by using a gold heat sink, but results in a junction temperature rise of 313°C for the prior example's parameters.

The junction temperature can be made lower if a higher thermal conductivity baseplate is used. This material must be matched to the coefficient of thermal expansion (CTE) of the substrate to ensure a reliable solder contact. Similarly, the electrically insulating substrate also must have a CTE reasonably matched to the semiconductor to prevent solder or device mechanical damage due to thermal stress.[7,8] The difficulty in addressing these issues increases with device area and will be particularly challenging for large-area power devices. Finally, stress induced in the epitaxial layer from the flip-chip attachment also can create undesired piezoelectric effects.[9]

CONCLUSION

The method of images has been used to show how the number of gate fingers in a device affects peak junction temperature. By varying the number and pitch of the fingers, temperature rise due to one gate and the contributions due to thermal spreading from other gates are calculated. The results of this finite element modeling also show the influence of other device features such as power density, efficiency, material thermal conductivity and dimensions upon device lifetime and performance degradation. ■

References

1. G.J. Sullivan et al., "High-power 10 GHz Operation of AlGaN HFETs on Insulating SiC," *IEEE Electron Device Letters*, June 1998, pp. 198–200.
2. S.T. Allen et al., "Recent Progress in SiC Microwave MESFETs," *Proceedings of the Materials Research Society*, Vol. 572, April 1999.
3. S.T. Sheppard et al., "High-power Microwave GaN/AlGaN HEMTs on Semi-insulating SiC Substrates," *IEEE Electron Device Letters*, April 1999, pp. 161–163.
4. D. Dawson, "Thermal Modeling, Measurements and Design Considerations of GaAs Microwave Devices," *IEEE GaAs Symposium Proceedings*, 1994, pp. 285–290.
5. Private conversation, Dr. Scott Allen, Cree Research Inc.
6. J.J. Xu et al., "1–8 GHz GaN-based Power Amplifier Using Flip-chip Bonding," *IEEE Microwave and Guided Wave Letters*, July 1999, pp. 277–279.
7. J. Bedinger, "Microwave Flip Chip and BGA Technology," IEEE MTT-S 2000.
8. Zhang et al., "RF and Mechanical Characterization of Flip-chip Interconnect," IEEE MTT, December 1998, p. 2269–2275.
9. E.T. Yu et al., "Measurement of Piezoelectrically Induced Charge in GaN/AlGaN Heterostructure Field-effect Transistors," *Applied Physics Letters*, November 1997, pp. 2794–2796.

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HIGH POWER RF LDMOS TRANSISTORS FOR AVIONICS APPLICATIONS

This article describes the inherent advantages of using laterally diffused metal oxide semiconductor (LDMOS) amplifiers in high power avionics transponder applications. In comparing this technology to bipolars, key device features such as gain, linearity, switching, thermal issues and reduced parts count become clear.

The continuous growth of air traffic adds new safety and efficiency challenges, which impact the design of the transponder. Traditional ground-based air traffic control systems excel in managing incoming/outgoing flights but lack the real-time performance needed by airborne traffic collision avoidance systems (TCAS). Onboard every commercial and military aircraft, these transponders transmit and receive essential data such as forward speed, altitude and position coordinates to other aircraft occupying similar airspace. These data are disseminated by the transponder and provide the pilot with instructions to safely direct the flight path. In addition, flight crews depend on other safety features such as weather radar, distance measuring systems, navigation and communications.

As the number of aircraft safety tools increases, space becomes a premium within the electronics bay. System redundancy also detracts from available room. Because TCAS shares the same frequency band as other critical systems, integration of multibox units into one has become the most recent design criterion. Consolidation offers reduction in overall size and weight, enhancing installation and maintenance. A multibox concept also reduces the number of power supplies and related circuitry, improving overall power efficiencies. Using a single multifunction transponder will lower the costs of procurement, installation and maintenance.

With multicarrier operation, managing critical performance factors such as pulse shapes can be difficult. Pulse on/off transition times, linearity and compression come into play. Maximizing overall power-added efficiency and reducing surrounding ambient bay temperatures by using less DC current are also a concern. This article describes devices that greatly improve the performance of microwave power amplifiers employed in TCAS transponders using the latest LDMOS technology (LDMOST). Traditional common-base-configuration class C bipolar transistors vs. linear, higher gain, lateral structure FETs will be examined.

LDMOST was originally designed for use in GSM and PCS base station cellular sites. Minor optimizations in the technology have made the structure extremely suitable for avionics

[Continued on page 122]

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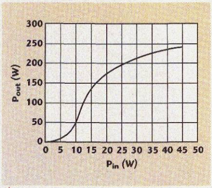
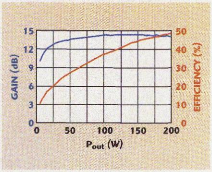
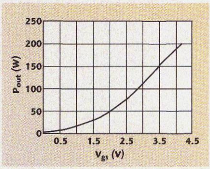


▲ *Fig. 1 Typical output vs. input power for a 200 W bipolar transistor.*



▲ *Fig. 2 Gain and efficiency vs. output power for an LDMOS power device at 150 mA quiescent current.*

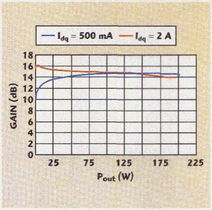


▲ *Fig. 3 Output power vs. modulation voltage, V_{gs}, for 7.95 W input power at 1030 MHz.*

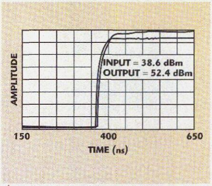
applications. The lineup discussed in this article features a 200 W output part using an all-gold metal system. Enhancements were made to the gates for this application as well as input and output matching over the 1030 to 1090 MHz frequency band.

DEVICE PERFORMANCE

Up to now amplifiers were designed with bipolar devices, which posed a number of problems when designing the complete lineup after taking into account the previously mentioned requirements. The most significant of these requirements is the gain linearity of the output power over a large dynamic range. A typical



▲ *Fig. 4 Gain vs. output power for two values of quiescent current.*



▲ *Fig. 5 Trace of input and output pulse showing insignificant switching deterioration.*

plot of the output power vs. input power of a 200 W bipolar transistor, intended for use in an avionics application, is shown in ***Figure 1***. It can be seen that the gain varies over the entire range of the input power. Obviously, using such a device has serious implications for the gain linearity of the entire lineup.

A device using LDMOST was utilized to overcome this problem. With this technology, devices can be made that show excellent linearity over a large dynamic range. The gain and efficiency vs. output power for such a LDMOS device is shown in ***Figure 2***. At 200 W, the device is still far from saturation with a dynamic range of more than 30 dB. Moreover, the device has a gain of 14 dB compared to the typical 8 dB of bipolar devices. This performance means that a considerable reduction in both the number of components and the PCB space can be achieved for the complete lineup. In addition, overall power-added efficiency is improved.

Additional advantages of LDMOST compared to bipolar technology include excellent thermal stability due to the negative temperature coefficient of the die technology. Thermal runaway is not an issue, and excellent ruggedness (SWR < 6) can be achieved due to the high breakdown voltage (80 V, typ). In addition, pulse shaping in LDMOST using the V_{gs} is relatively easy compared to bipolar devices. ***Figure 3*** shows the easy gain control that is possible by simply modulating the V_{gs} of the device. The package does not contain toxic BeO. Removal of the BeO DC isolator, the source terminal of die that is attached directly to the heat spreader (flange), reduces thermal impedance.

As shown in ***Figure 4***, the linearity of the device depends on the quiescent current. The two plots depict the gain at different quiescent current: 500 mA and 2 A. Setting a higher quiescent current means biasing the device more toward class A. Consequently, the maximum feasible efficiency will be lower. Such a bias condition is required only at low output power levels. At higher output power levels a class AB biasing is preferred. An optimum trade-off can be made between output power, linearity and efficiency simply by modulating the gate source voltage reciprocal to the required output power. By designing a device with a high power capability, no decrease in linearity will occur due to the device going into compression. In bipolar technology, fast switching times at high output powers are often difficult to achieve, a characteristic that is inherent in the bipolar structure.

Figure 5 shows that the rise time of the device is excellent while maintaining good gain linearity over a large dynamic range. It can be seen that the switching time has not increased significantly between the input signal and output signal through the device and that values of less than 50 ns are achieved at an output power of 52.4 dBm. Obviously the design of the biasing will have an influence on the behavior of the device. Good decoupling of low frequency components is essential.

RELIABILITY AND THERMAL BEHAVIOR

One big advantage of LDMOST compared to bipolar is that the mode of operation is common source

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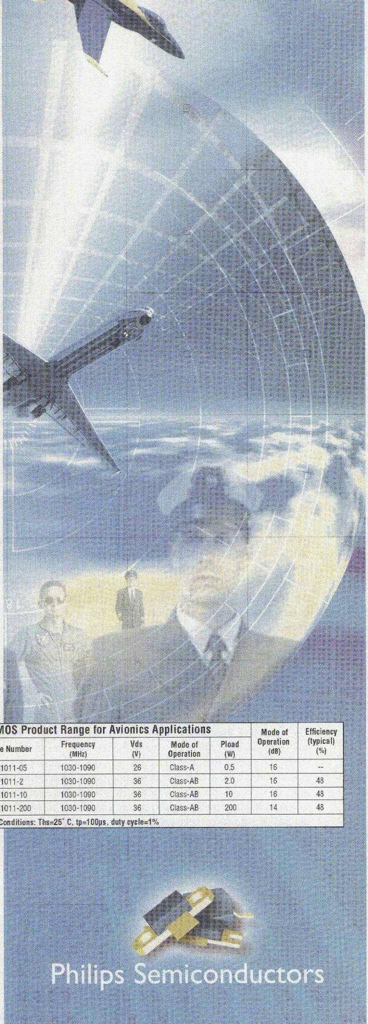

LDMOS Product Range for Avionics Applications

Type Number	Frequency (MHz)	Vds (V)	Mode of Operation	Pload (W)	Mode of Operation (dB)	Efficiency (typical) (%)
BLA1011-05	1030-1090	26	Class-A	0.5	16	--
BLA1011-2	1030-1090	36	Class-AB	2.0	16	48
BLA1011-10	1030-1090	36	Class-AB	10	16	48
BLA1011-200	1030-1090	36	Class-AB	200	14	48

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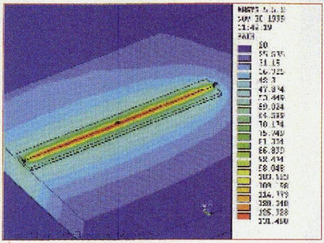
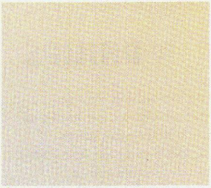
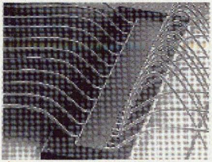


▲ *Fig. 6 Temperature distribution in an SOT502 package at t = 1.2 ms, η = 50%, P_{diss} = 250 W and T_{hs} = 20°C.*



▲ *Fig. 7 Temperature profile in an SOT502 package at t = 1.2 ms, η = 50%, P_{diss} = 250 W and T_{hs} = 20°C.*



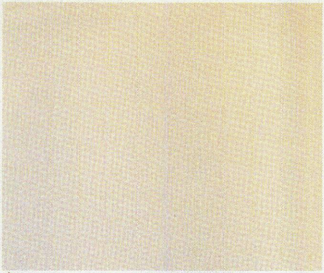
▲ *Fig. 8 Wirebonding of a single LDMOST die.*

(source connected to ground), reducing parasitic source inductance and providing an excellent thermal interface. In bipolars the bulk of the material is the collector, which must be electrically isolated from ground (usually the heatsink) without degrading the thermal impedance. This configuration produces a better thermal behavior of the LDMOST compared to the bipolar.

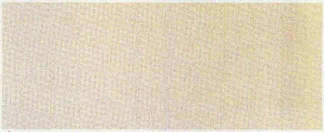
Figures 6 and ***7*** show the results of thermal transient finite element method simulations for the die. In the simulations, a uniform distribution of power is illustrated under RF excitation conditions. This uniformity will be dominated by the quality and consistency of the assembly process of the device, which depends largely on the use of automated die attach and wire bonding equipment (minimizing lot-to-lot variation). The wire bonding of a single LDMOST die is shown in ***Figure 8***.

DEVICE TECHNOLOGY

Figure 9 shows the cross section of an LDMOST structure. The p^+ via is used to ensure good electrical contact between the source contact and ground and eliminates the use of source bonding wires, which lowers the source inductance and increases the intrinsic device gain. A shielding is placed between the gate and drain to reduce the feedback capacitance. The die technology used in this 200 W device is based on 1 GHz technology optimized for the specific requirements of an avionics application that required enhanced gate periphery. The design is optimized to meet the required gain linearity over a large dynamic range. This optimization will improve both gain and intermodulation distortion performance as well as the RF stability of the device.



▲ *Fig. 9 Cross section of a 1 GHz LDMOST device.*



▲ *Fig. 10 A 200 W amplifier lineup.*

The MonoMOS structure — the separate active areas of a conventional high power RF die replaced by one highly integrated area — lends itself to easily incorporating internal input and output matching. MonoMOS uses metallized gates to reduce series resistance in order to increase power gain. The structure was designed for minimum I_{dq} drift. Without any burn-in, the typical I_{dq} drift is below 10 percent over 20 years. The gold top metallization, in combination with the gold bond wires, avoids intermetallic issues where the flexibility of gold compared to aluminum bond wires ensures excellent reliability under pulsed operation. The concept of this die has proven to be very reliable based on high volume production for base station products. In order to provide a cost-effective approach, the device uses a commercial, off-the-shelf, nonhermetic package.

APPLICATIONS

The total lineup of a 200 W LDMOS amplifier is shown in ***Figure 10***. The overall gain of 46 dB is achieved using three amplifier stages. A comparable bipolar lineup would consist of approximately six amplifier stages (depending on individual device gain) to achieve similar over-

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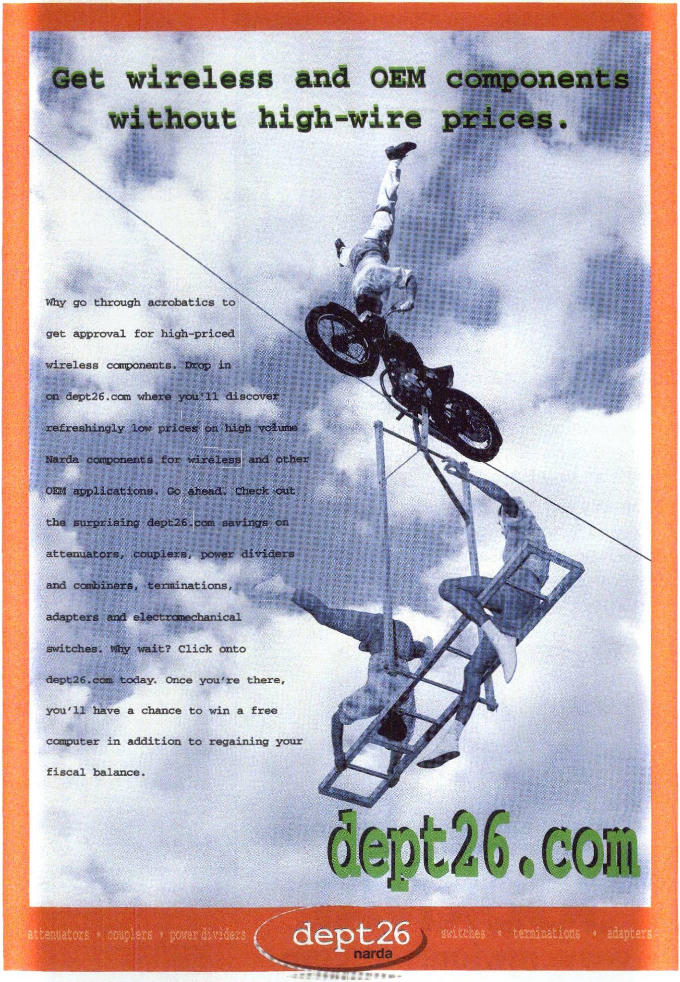
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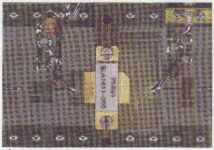

▲ *Fig. 11 Application circuit of a 200 W LDMOS device for the 1030 to 1090 MHz band (ε_r = 6.15).*

all gain. ***Figure 11*** shows the application circuit for the 200 W device used for the described characterization. This device contains internal input and output matching, which simplifies the design of the application circuit. The internal matching brings the device impedances to a level that is favorable in a manufacturing environment. Higher impedances create a situation that is less critical for component placement and substrate tolerances, enhancing final yield while eliminating rework.

CONCLUSION

It has been demonstrated that the use of the LDMOS transistor greatly improves the design of amplifiers for avionics applications. Transponders using LDMOST will enjoy gain linearity over a high dynamic range, easy gain control using the gate voltage and an almost zero switching time delay between input and output. Other features of this technology include better thermal control, nontoxic packaging and reduced parts count. The potential cost savings due to lower power supply costs, a gold metallization system, and automated die attach and wire bonding equipment ensure device consistency in high volume production. This consistency will enhance customer yield and reduce rework. ■

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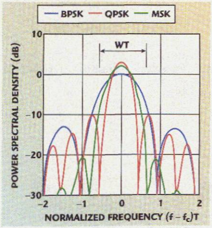
FRACTIONAL OUT-OF-BAND POWER FORMULAS FOR BPSK, QPSK AND MSK

Fractional out-of-band power (FOBP) has for some time been a standard metric of spectral containment for digital data signals.[1] For any given modulation scheme the FOBP can be measured experimentally or calculated theoretically. The theoretical calculation often may take the form of numerical integration on an existing tabulation of power spectral density (PSD) obtained from a Monte Carlo simulation or, perhaps, may be evaluated directly from a closed-form expression for PSD. If an analytical expression is available for PSD, then the option is open for the derivation of a closed-form expression for the FOBP as well. Though numerical integration can generally be refined to yield whatever precision is desired, the closed-form expression may be preferable for the insight it provides into asymptotic behavior, or for the validation of similar closed-form results available from other sources.

Fig. 1 Power spectral densities for BPSK, QPSK and MSK normalized for unit transmitter power.



This article offers closed-form expressions for FOBP for classical binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK) (including offset QPSK (OQPSK)) and minimum-shift keying (MSK) modulation. Of these three cases, the classical MSK presents the greatest challenge. In all cases the FOBP is expressible in terms of well-known, widely tabulated functions. The derivation of closed-form FOBP begins, of course, with the analytic expression for PSD. All of the PSDs mentioned thus far are shown in ***Figure 1***. The FOBP characteristics are shown in ***Figure 2***. The FOBP expressions reported here

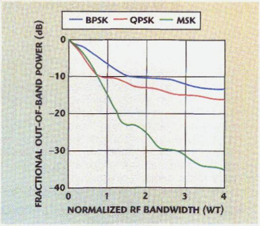


Fig. 2 FOBP for BPSK, QPSK and MSK.

[Continued on page 130]

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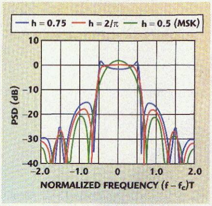

▲ *Fig. 3 PSD for digital FSK for various values of modulation index h, including MSK, normalized for unit transmitter power.*

were derived and subsequently verified against the results of numerical integration on known PSD.

BPSK AND QPSK CASES

The expressions for the PSD of classical BPSK, QPSK and OQPSK take the same familiar general form.[1] For the present purposes it is convenient to normalize all PSDs for unit signal power so that the FOBP is simply equal to the out-of-band power itself. When the data signal is denoted by s(t), the PSD is usually denoted by $|S(f)|^2$, whose normalized expression becomes

For BPSK at Bit Rate R = 1/T

$$|S(f)|^2 = \frac{\sin^2\left[\pi(f-f_c)T\right]}{\pi^2(f-f_c)^2 T}$$

Note that the factor T in the denominator is not squared. As usual, f_c indicates the RF carrier.

The FOBP is readily determined in closed form in terms of the widely[2] tabulated Si(x) function:

$$\mathrm{Si}(x) = \int_0^x \frac{\sin t}{t}\,dt$$

The frequency variable for FOBP has been defined by various authors as either the upper band edge frequency or the normalized doublesided bandwidth WT as previously illustrated in the PSD plots. The FOBP (designated here as FOBP1) becomes

$$\mathrm{FOBP1}(WT) = 1 - 2\left[\frac{\mathrm{Si}(\pi WT)}{\pi} + \frac{\cos(\pi WT) - 1}{\pi^2 WT}\right]$$

for BPSK.

For QPSK, OQPSK at Net Link Bit Rate R = 1/T, Combining I and Q Channels

The power spectral density of QPSK (and OQPSK) takes the same form as that of BPSK, except for a factor of 2 compression in the frequency domain.[1] That compression is the well-known doubling of spectral efficiency attained by reverting to QPSK or OQPSK. The resulting FOBP characteristic is similarly compressed in frequency, leading to FOBP2:

$$\mathrm{FOBP2}(WT) = 1 - 2\left[\frac{\mathrm{Si}(2\pi WT)}{\pi} + \frac{\cos(2\pi WT) - 1}{2\pi^2 WT}\right]$$

for QPSK, OQPSK.

MSK CASE

The normalized PSD of MSK is simply expressed as[3]

$$|S(f)|^2 = T\left[\frac{4\cos\left[2\pi(f-f_c)T\right]}{\pi\left[1 - 16(f-f_c)^2 T^2\right]}\right]^2$$

However, the expression for FOBP is somewhat more complicated than for the BPSK case. Here it is convenient to invoke a new function Xi(x) based on the widely[2] tabulated Ci(x) function:

$$\mathrm{Xi}(x) = \int_0^x \frac{\cos t - 1}{t}\,dt = \ln\gamma x - \mathrm{Ci}(x)$$

where

γ = Euler's constant (1.781072)

$$\mathrm{Ci}(x) = -\int_x^\infty \frac{\cos t}{t}\,dt$$

Now the required expression is given as FOBP3:

$$\mathrm{FOBP3}(WT) = 1 - \frac{4WT\left[1 + \cos(2\pi WT)\right]}{\pi^2\left[1 - (2WT)^2\right]} - \frac{\mathrm{Si}(2\pi WT - \pi) + \mathrm{Si}(2\pi WT + \pi)}{\pi} - \frac{\mathrm{Xi}(2\pi WT - \pi) - \mathrm{Xi}(2\pi WT + \pi)}{\pi^2}$$

SOFTWARE IMPLEMENTATION

Most contemporary mathematical software packages either include the Si(x) and Ci(x) functions explicitly or allow their inclusion implicitly as user-defined integrals for numerical evaluation. All of these software packages will most likely suffice for the production of plots over the abscissa range shown previously in the FOBP plot. However, for large WT some of the available software may produce unsteady, ragged plots. Therefore, it may be helpful to state the Taylor series expansions of Si(x) and Xi(x):

$$\mathrm{Si}(x) = \sum_{p=1}^{\infty} -1^{p+1} \frac{x^{2p-1}}{(2p-1)(2p-1)!}$$

$$\mathrm{Xi}(x) = \sum_{p=1}^{\infty} -1^{p} \frac{x^{2p}}{2p(2p)!}$$

If the upper limit of ∞ is replaced, for example, by p = 60 in both series, then the series provide accuracy to within a truncation error of less than 2×10^{-14} for values of x up to 36. In addition, the following asymptotic expressions may be substituted for the required functions for extremely large values of x:

$$\mathrm{Si}(x) \Rightarrow \frac{\pi}{2} - \frac{\cos x}{x}$$

$$\mathrm{Xi}(x) \Rightarrow \frac{\sin x}{x} - \ln(x) - 0.577215665$$

GENERALIZATION OF MSK SPECTRAL DENSITY

The MSK modulation format is a special case of binary frequency-shift keying (FSK) in which the selected modulation index is h = 0.5, which is the value that forces a phase change of $\pm\pi/2$ on each bit interval. In general, the normalized PSD for FSK over a large range of h is given by[4,5]

$$|S(f)|^2 = \frac{4T}{\pi^2}\frac{h^2}{\left[(2F)^2 - h^2\right]^2} \bullet \frac{\left[\cos 2\pi F - \cos \pi h\right]^2}{\left[\cos 2\pi F - \cos \pi h\right]^2 + \sin^2 2\pi F}$$

where

$F = (f - f_c)T$

This family of normalized PSD is shown in ***Figure 3***. To date, no

[Continued on page 134]

closed-form expression for FOBP has been made widely available. Expressions for the PSD of more complex digital FSK schemes are available from more recent sources.[6,7]

CONCLUSION

Closed-form expressions for FOBP for classical BPSK, QPSK and MSK modulation have been derived and compared to PSD calculations to verify their accuracy. These expressions may be used in place of numerical integration to determine asymptotic behavior or to validate other similar closed-form results for FOBP analysis of digital data signals. ■

References

1. F. Amoroso, "The Bandwidth of Digital Data Signals," *IEEE Communications Magazine*, Vol. 18, No. 6, November 1980, pp. 13–24.
2. E. Jahnke and F. Emde, *Tables of Functions*, Dover, New York, 1945.
3. F. Amoroso, "The Use of Quasi-bandlimited Pulses in MSK Transmission," *IEEE Transactions on Communications*, Vol. COM-27, No. 10, October 1979, pp. 1616–1624.
4. M.G. Pelchat, "The Autocorrelation Function and Power Spectrum of PCM/FM with Random Binary Modulating Waveforms," *IEEE Transactions on Space Electronics and Telemetry*, Vol. SET-10, March 1964, pp. 39–44.
5. T.T. Tjhung, "Band Occupancy of Digital FM Signals," *IEEE Transactions on Communication Technology*, Vol. COM-12, No. 4, December 1964, pp. 211–216.
6. J.G. Proakis, *Digital Communications*, McGraw-Hill, New York, 1983.
7. J.B. Anderson et al., *Digital Phase Modulation*, Plenum Press, New York, 1986.

Frank Amoroso *received his BS and MS degrees in electrical engineering from the Massachusetts Institute of Technology in 1958, then pursued additional graduate studies at Purdue University of Turin, Italy. His career in the US industry included such organizations as the Hughes Aircraft Co., the RCA David Sarnoff Research Laboratories, the Mitre Corp. and the US Army Signal Corps Laboratories at Fort Monmouth, NJ. In 1989, Amoroso retired from industrial employment to begin a new career as a private consultant to a number of industrial firms, including Lincom Inc., Los Angeles, CA. He holds five US patents, has published 30 papers in various archival-quality journals and has taught seminar courses at George Washington University. Amoroso's accomplishments are recognized in the current edition of Marquis Who's Who in America.*

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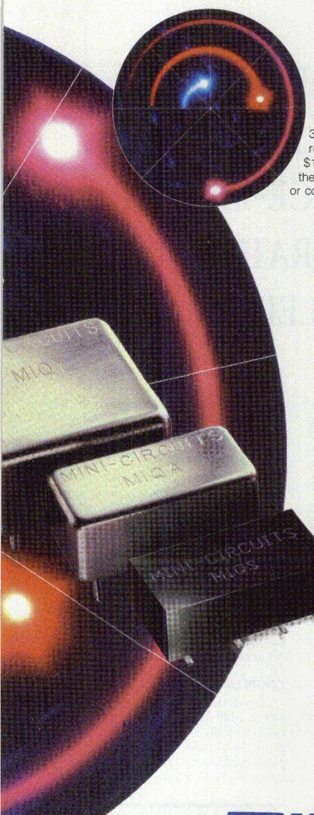

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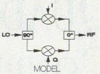
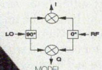


I/Q MODULATORS

MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	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-38M	34	38	5.6	0.10	48	37	54	65	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
Surface Mount Models									
☐ JCIQ-88M	52	88	5.6	0.1	40	35	45	65	49.95
☐ JCIQ-176M	104	176	5.6	0.1	35	35	45	65	54.95



I/Q DEMODULATORS

MODEL	FREQ. (MHz) f_L	f_U	CONV. LOSS (dB) $\bar{x}$	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
MIQA-70D	66	73	6.2	0.10	0.15	0.7	56	58	49.95
MIQC-38D	34	38	5.5	0.10	0.10	0.5	60	65	49.95
MIQC-60WD	20	60	5.3	0.10	0.15	1.0	55	67	79.95
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
Surface Mount Models									
☐ JCIQ-176D	104	176	5.5	0.1	0.15	2	52	65	54.95
☐ JCIQ-895D	868	895	8.6	0.1	0.2	1	45	65	99.95
☐ JCIQ-1785D	1710	1785	8	0.2	0.2	2	50	65	99.95
☐ JCIQ-1880D	1805	1880	8	0.2	0.2	2	50	65	99.95

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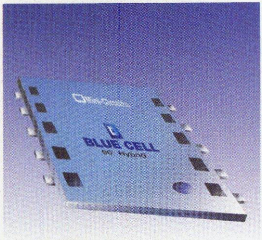
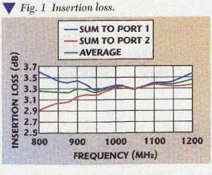


HIGH PERFORMANCE, LOW COST, SURFACE-MOUNT QUADRATURE COUPLERS

As system requirements increase, the demands placed on passive components also continue to rise in an effort to meet ever-increasing consumer demands. Industry is demanding higher performance in smaller footprints at a lower cost. Current quadrature coupler offerings suffer from various drawbacks such as narrow bandwidth and limited selection in the case of GaAs-based products, poor repeatability for core- and wire-based products, and large size and leadless surface-mount package styles for other types.

A series of high performance 3 dB quadrature couplers has been developed using Blue Cell™ technology. These products exhibit low insertion loss, amplitude unbalance and phase unbalance with good isolation covering the 800 to 2400 MHz frequency range. The finished part has an ultra-low height of 0.05", measures 0.290" × 0.300" and is targeted for high performance coupler designs for moderate to high volume markets.

▼ *Fig. 1 Insertion loss.*



COUPLER DESIGN

The designs were accomplished using HP Momentum, a 2.5-D electromagnetic simulator that allows the designer to model complex physical structures with a high level of accuracy. Using design techniques developed at Blue Cell, excellent performance was achieved with just one design iteration.

PRODUCT ASSEMBLY

The 3 dB quadrature couplers comprise a multilayer ceramic structure using processes and materials chosen for best electrical performance. Strict controls are placed on both the materials and the processes to ensure excellent performance repeatability from part to part. The use of ceramic material improves thermal dissipation and produces a hermetic structure, which results in excellent environmental ruggedness. The package consists of 10 leads welded to the substrate, forming a robust and reliable assembly. The leads are solder plated for good solderability.

COUPLER PERFORMANCE

The model QBA-12 coupler operates from 800 to 1200 MHz, and its average insertion loss is typically less than 0.3 dB across the full band. Amplitude unbalance is 0.3 dB, with phase unbalance of 2° and isolation of 22 dB across the band. ***Figure 1*** shows the QBA-12

[Continued on page 138]

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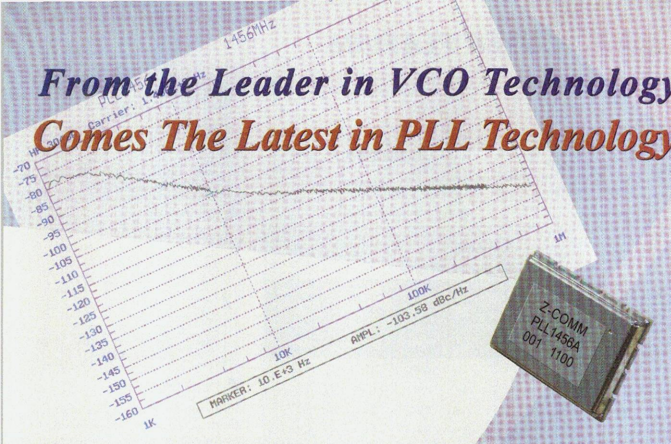

Model Number	Frequency (MHz)	Integrated ϕ_N (100 Hz-100 kHz)	SSB ϕ_N (dBc/Hz @ 100 kHz)	Frequency Range 800 1200 1600 2000 2400 2800
PLL0930A	900-960	0.75°	-130	GSM
PLL1260A	1230-1290	0.75°	-123	Terrestrial Radio
PLL1456A	1420-1490	0.75°	-125	Wireless Local Loop
PLL2710A	2670-2740	1.25°	-117	MMDS/LMDS
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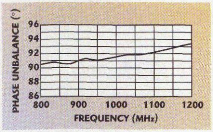
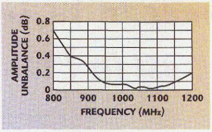
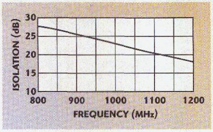


▲ *Fig. 2 Phase unbalance.*



▲ *Fig. 3 Amplitude unbalance.*



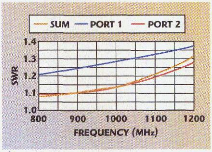
▲ *Fig. 4 Isolation.*

TABLE I

ELECTRICAL SPECIFICATIONS

Model No.	Frequency Range (MHz)	Isolation (dB)		Insertion Loss* (dB)			Phase Unbalance (°)	Amplitude Unbalance (dB)
		Typ	Min	f_L Avg	f_U Avg	Sigma	Max	Max
QBA-12N	800 to 900	28	20	0.25	0.30	0.02	3.0	1.0
QBA-12	800 to 1200	23	14	0.25	0.44	0.02	6.0	1.2
QBA-20	1800 to 2000	23	18	0.47	0.54	0.02	4.0	0.7
QBA-20W	1500 to 2200	23	16	0.41	0.58	0.02	5.0	1.2
QBA-24	1900 to 2400	21	17	0.54	0.71	0.02	6.0	0.8
QBA-24W	1700 to 2400	21	15	0.49	0.71	0.02	6.0	1.2

*Includes test fixture losses



▲ *Fig. 5 SWR performance.*

coupler's insertion loss; ***Figures 2*** and ***3*** show phase unbalance and amplitude unbalance, respectively. The unit's isolation and return loss performance are shown in ***Figures 4*** and ***5***, respectively. The model QBA-12N coupler is specified to operate over the cellular bandwidth of 800 to 900 MHz and features typical performance of 0.25 dB insertion loss, 0.3 dB amplitude unbalance, 1° phase unbalance and 24 dB isolation. Performance is dependent on the quality of the printed circuit board used for the motherboard. High performance PCB materials with dielectric thickness of 30 mil or thinner and ground vias placed less than an eighth-wavelength apart should be employed. A recommended footprint is provided in the coupler's data sheet and can be downloaded from the company's Web site at www.minicircuits.com in the "What's New" section. ***Table 1*** lists the coupler family's specifications.

APPLICATIONS

There are many applications that utilize 3 dB quadrature couplers, such as power combiners, balance amplifiers, variable attenuators, phase shifters, I/Q modulators and image-reject mixers. The couplers offer low thermal resistance and an ability to operate at an elevated temperature due to their ceramic structure. The units also can operate with up to 50 W of input power, enabling their use in moderate to high power circuits.

Power capability tests conducted indicate that each unit is capable of handling even greater power at room temperature. With 120 W of RF input power, the leads detached from the motherboard due to melting of the solder connection. After reattachment, the unit performed as before with no performance change noted. Continuous operation of the coupler at 50 W for a week indicated no performance degradation.

CONCLUSION

A series of microwave high performance, surface-mount quadrature couplers have been presented, which offer good power handling in a small footprint. These couplers are designed using Blue Cell technology and feature a very low height that is suitable for use in Personal Computer Memory Card International Association cards. The products are intended for demanding low cost, high quality, high volume applications and are priced at $6.95 in quantities of 10 to 49. Delivery is from stock.

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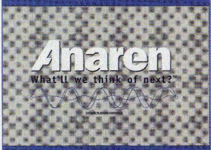

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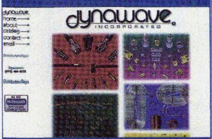

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This Web site overviews the latest technology high performance filters, diplexers, duplexers and multiplexers covering the DC to 40 GHz range. An on-line catalog and company profile can also be accessed.

Microwave Circuits Inc.,
6865 Eastern Ave. NW,
Washington, DC 20012

www.micckts.com

Waveguide Components and Subassemblies

Visit this company's Web site to discover how it became the largest independent producer of waveguide components and subassemblies in the microwave industry. In addition, learn more about waveguide bends and twists, directional couplers and monopulse comparators, rotary joints, microwave filters, rotary switches, and waveguide shutters and waveguide pressure windows.

MDL Inc.,
135 Crescent Road,
Needham Heights, MA 02494

www.micro-dev-labs.com

Components and Antennas

This new and revised Web site features electronically tunable RF components (ETRF) and electronically steerable antennas for wireless communications. Products include tunable filters, delay lines and phased-array antennas, which utilize the company's Parascan™ materials technology.

Paratek Microwave Inc.,
6935N Oakland Mills Road,
Columbia, MD 21045

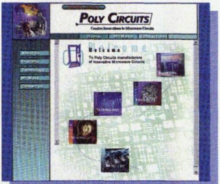
www.paratek.com

Digitally Tunable RF Filters

Visit this Web site to view standard tunable filter products, learn more about the technology utilized in the company's unique hopping filters, download its free tunable filter software or send an e-mail request for additional information.

Pole/Zero Corp.,
5530 Union Centre Drive,
West Chester, OH 45069

www.polezero.com



High Performance Printed Circuits

This Web site offers information on prototype to high volume, high performance printed circuits, including doublesided, multilayer and mixed dielectric designs. The company also bonds printed circuits to metal carriers using Flexlink II conductive adhesive. Laminates used include Teflon, PTFE, Duroid, Rogers 4350, Getek and polyimide. Finishes include tin/lead, immersion and electrolytic nickel/gold, silver and OSP over copper.

Poly Circuits,
215 Park Street, Bensenville, IL 60106

www.mwav.com

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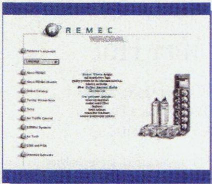

Interference and Combining Solutions

This multilingual, interactive e-commerce Web site describes the company's filter-based products, including tower-top amplifiers and bandpass, lowpass and notch filters for the land mobile radio paging, SMR, cellular and PCS markets. Sections cover air traffic control, TETRA, paging, amateur radio and specialty 200 MHz systems. Data sheets and a price list can be downloaded as PDF files.

REMEC Wacom LP,
PO Box 21145, Waco, TX 76702

www.remecwacom.com

Component Sourcing Solution

This newly designed Web site emphasizes the company's manufacturers and vendors. There are on-line ordering capabilities where the customer can select parts from the industry's leading manufacturers, view product data sheets and place orders. In addition, an on-line catalog includes convenient part number and key characteristic searching capabilities.

Richardson Electronics,
40W267 Keslinger Rd.,
La Fox, IL 60147

www.rfpowernet.com

High Frequency Laminates

This Web site provides information about this supplier of high frequency laminates for RF and microwave applications such as cellular and PCS base stations, power amplifiers, low noise blocks for direct broadcast systems, patch antennas for a wide variety of applications and high performance, high speed digital circuits.

Rogers Corp.,
Microwave Materials Division,
100 S. Roosevelt Ave.,
Chandler, AZ 85226

www.rogers-corp.com/mwu/index.htm

RF Filters

This Web site provides concise information about SAW filters and SAW-based subsystems, including product data sheets and company and investor information plus SAW basics. The site is continually being updated, and a new expansion is scheduled to go on line in late June highlighting the company's Microsensor Systems Inc. division and its wide range of chemical sensing equipment.

Sawtek,
1818 S. Hwy. 441, PO Box 609501,
Orlando, FL 32860-9501

www.sawtek.com

Test and Measurement Marketplace

This comprehensive test and measurement Web site — the most visited site of its kind — has recently added major enhancements featuring significantly expanded content, integrated product comparison and automated commerce functions that make it a more secure and convenient environment for transactions.

TestMart,
851 Traeger Avenue,
San Bruno, CA 94066

www.testsmart.com

Microwave/RF Products

This updated Web site highlights microwave and RF filters, dielectric resonators and magnetic materials and offers CARD/COAX and CRAFT software for dielectric and coaxial resonator and filter selection. A new user interface enables users to quickly surf the site for information.

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Adamstown, MD 21710

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Model	Attenuation (dB) Nominal	Accuracy*	Length (Inches)
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BW-S2W2	2	±0.40	.85
BW-S3W2	3	±0.40	.85
BW-S4W2	4	±0.40	.85
BW-S5W2	5	±0.40	.85
BW-S6W2	6	±0.40	.85
BW-S7W2	7	±0.60	.85
BW-S8W2	8	±0.60	.85
BW-S9W2	9	±0.60	.85
BW-S10W2	10	±0.60	.85
BW-S12W2	12	±0.60	.85
BW-S15W2	15	±0.60	.99
BW-S20W2	20	±0.60	.99
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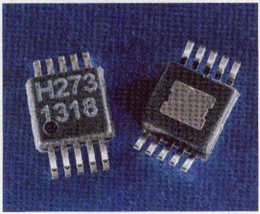


Broadband DC to 4 GHz Digital Attenuators with High Accuracy

Control of signal strength while maintaining signal integrity in the transmit and receive paths of wireless systems has always been a concern of RF design engineers. A family of seven low cost two-, three- and five-bit digital attenuator (DATT) GaAs ICs has been developed to address these needs. The new attenuators offer unprecedented bandwidth from DC to 4 GHz, positive bias and control, and ±0.2 to ±0.5 dB (typ) accuracy in plastic packages as small as a six-lead SOT26 configuration. Excellent input IP3 performance of +44 to +54 dBm characterizes these attenuators, satisfying today's linearity requirements for cellular/PCS/3G/industrial, scientific and medical (ISM) and broadband datacom systems.

Table 1 lists the attenuator product line's typical characteristics. All designs were optimized for the greatest bandwidth. Product specifications are targeted toward the frequency bands of 0.7 to 1.4 GHz (cellular, personal digital cellular and personal handyphone system), 1.4 to 2.3 GHz (PCS and 3G), 2.3 to 2.7 GHz (ISM, Home RF, Bluetooth and multichannel multipoint distribution system) and 2.7 to 3.7 GHz (wireless local loop).

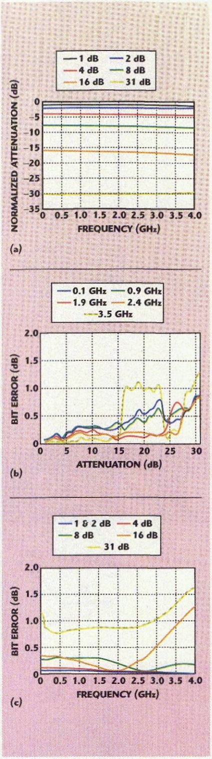
Exceptional DC to 4 GHz performance allows the model HMC307QS16G to address cable modem, instrumentation and all IF applications down to DC. The model HMC306MS10 DATT offers the least significant bit (LSB) step of 0.5 dB while maintaining a bit error of ±0.25 dB. Both the models HMC273MS10G and HMC307QS16G offer traditional 1 dB least significant bit steps to a maximum of 31 dB. Occupying only 14.8 mm^2 in a 10-lead MSOP package, the HMC273MS10G device is the smallest five-bit, 1 to 31 dB digital attenuator available today. Reference insertion loss is typically less than 2.5 dB for each five-bit product. For base station applications, these three DATT products can help increase

Hittite Microwave Corp.
Chelmsford, MA

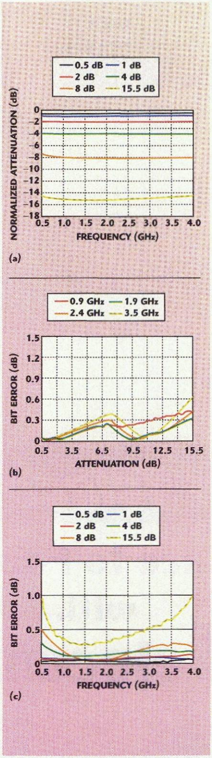
TABLE I
GaAs IC DIGITAL ATTENUATOR CHARACTERISTICS*

Part Number	Description	Frequency Range (GHz)	Attenuation Step Sizes (dB)	Insertion Loss (dB)	Bit Error (dB)	Input IP3 (dBm)	Package Area (mm²)
HMC273MS10G	five bit 1 to 31 dB positive bias	0.7 to 3.7	1, 2, 4, 8, 16	2.4	±0.5	+48	14.8
HMC307QS16G	five bit 1 to 31 dB negative bias	DC to 4.0	1, 2, 4, 8, 16	2.0	±0.5	+44	29.4
HMC306MS10	five bit 0.5 to 15.5 dB positive bias	0.7 to 4.0	0.5, 1, 2, 4, 8	1.8	±0.25	+52	14.8
HMC230MS8	three bit 4 to 28 dB positive bias	0.75 to 2.0	4, 8, 16	1.8	±0.5	+46	14.8
HMC288MS8	three bit 2 to 14 dB positive bias	0.7 to 3.7	2, 4, 8	1.5	±0.3	+51	14.8
HMC291	two bit 4 to 12 dB positive bias	0.7 to 4.0	4, 8	0.9	±0.2	+54	9
HMC290	two bit 2 to 6 dB positive bias	0.7 to 4.0	2, 4	0.6	±0.2	+52	9

*All data are mid-band typical



▲ *Fig. 1 The model HMC307QS16G DATT's (a) normalized attenuation, (b) bit error vs. attenuation and (c) bit error vs. frequency characteristics.*



▲ *Fig. 2 The model HMC306MS10 DATT's (a) normalized attenuation, (b) bit error vs. attenuation and (c) bit error vs. frequency characteristics.*

accuracy and reduce PCB size. They also may be cascaded for greater attenuation range.

The models HMC230MS8 and HMC288MS8 three-bit DATTs bridge the gap between minimal control line requirements of three and maximum attenuation of 28 and 14 dB, respectively. The HMC230MS8 attenuator competes with several 4 to 28 dB products on the market, offering pin-for-pin compatibility. The HMC288MS8 unit steps from 2 to 14 dB with exceptional accuracy of ±0.3 dB and input IP3 of +51 dBm. The attenuator's eight-lead MSOP package requires only 14.8 mm^2 of PCB area.

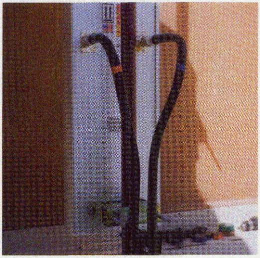
For circuit designers who require coarse gain adjustments, the models HMC290 and HMC291 provide two-bit control in step sizes of 4 and 8 dB to a 12 dB maximum attenuation and 2 and 4 dB to a 6 dB maximum attenuation, respectively. These products also offer minimal bit error at ±0.2 dB (typ). Input IP3 for each part is excellent at +52 to +54 dBm with less than 0.9 dB reference insertion loss. For driver amplifier and low noise amplifier gain control, handset and base station designers will find this performance a great alternative to higher loss voltage-variable attenuators. Assembled into six-lead SOT26 packages, the HMC290 and HMC-291 products offer two-bit attenuator control in only 9 mm^2.

Figures 1 and ***2*** show the DC to 4 GHz performance of the HMC307-QS16G and HMC306MS10 DATTs, respectively. All of the attenuators require only a single control voltage for each attenuator bit, minimizing logic interface and package lead count. A single positive bias supplied through an external 5 kΩ resistor is utilized by all products except the negative-bias HMC307QS16G unit. Control and bias currents for each device are minimal at 100 to 250 µA (typ). The seven DATT ICs are manufactured using a high volume production GaAs MESFET process, resulting in a low cost family of products with consistent performance. Standard fine lead pitch plastic packaging minimizes the footprint of each part to between 9 and 29.4 mm^2.

Full data sheets with the company's guarantee of electrical performance over temperature are available in its new June 2000 catalog supplement or on the Web site at www.hittite.com. The products are available immediately from stock.

Hittite Microwave Corp., Chelmsford, MA (978) 250-3343.

Circle No. 324

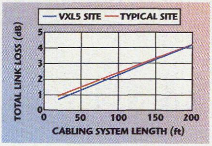


A Single Cable for Base Station Main Feeder and Jumper Applications

Wireless communications rely on coaxial cable transmission lines to link tower-mounted antennas to base station radio equipment. The traditional way to form this link is to use a main feeder cable and jumper cables. The main feeder is normally a 7/8-inch (dia) cable or larger. This size cable has good transmission efficiency to minimize signal loss. Jumper cables, at each end of the feeder, are 1/2-inch (dia) or smaller. They are typically five to 10 feet in length and have a smaller bend radius than the main feeder to ease attachment of the transmission line to the equipment and antenna.

With each extra cable installed in a feeder system, some performance is sacrificed and installation time and cost increase. To address this issue, a single cable has been developed that performs both main feeder and jumper functions. This new type VXL5-50 7/8-inch cable offers the efficiency of a main feeder cable but is lighter in weight and has the bending and flexing capabilities of a typical jumper cable. In wireless applications, the VXL5 cable can be a single-cable solution for the transmission line function. Performance benefits from using a single cable are realized for both return loss and insertion loss. In addition, a single cable offers site cost savings because lighter weight and extra flexibility aid the installation process. Fewer connectors contribute to lower insertion loss and, along with requiring less weatherproofing, reduce installation time and cost at each site. The VXL5 cable may be the lowest cost solution for today's design requirements.

Fig. 1 Link loss comparison.



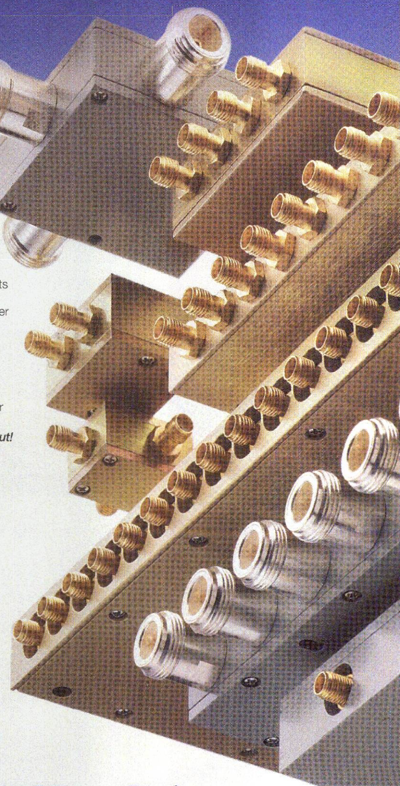
INSERTION LOSS

From the viewpoint of insertion loss, the selection of cabling for a given application is based on the overall length of transmission line run and the transmission efficiency required to meet the allowable link loss budget. Cabling system options are compared by adding up the total link loss evaluated at the maximum operating frequency of the system.

Link losses are caused by cable and additional transmission line components, such as connectors and surge arrestors. The benefits of a single cable installed directly into an antenna can be compared with a traditional installation of standard 7/8-inch feeder with a 1/2-inch jumper (10 foot) at the antenna end. ***Figure 1*** shows the link losses of the two systems as a function of installed cabling length.

[Continued on page 152]

Andrew Corp.
Orland Park, IL



Although slightly higher in attenuation than the standard feeder, the site utilizing a VXL5 cable solution has a lower total insertion loss. Shorter installation lengths, which include those having an efficiency target of 71 percent (1.5 dB of total loss) between the radio and antenna, compare even more favorably. The link loss contributions for components of each installation type are listed in ***Table 1***. For the calculations, a 100-foot installation with a maximum operating frequency of 2 GHz is assumed.

SWR PERFORMANCE

The same installations can be compared for system SWR. With a maximum SWR of 1.13 for the feeder and 1.10 for the jumper, the expected performance for system SWR is listed in ***Table 2***. Here, all connector SWR contributions are included within the feeder and jumper specifications.

TABLE I
INSERTION LOSS FOR 100-FOOT SITE INSTALLATION

Component	Standard Site IL (dB)	Site with VXL5 IL (dB)
10-foot jumper	0.33	—
Two connectors	0.14	—
90-foot feeder	1.69	—
100-foot feeder	—	2.03
Two connectors	0.14	0.14
Surge arrestor	0.10	0.10
Total link budget	2.40	2.27

Calculation references: Connector loss at 2 GHz = $(0.05 \times \sqrt{f})$ dB = 0.07 dB
LDF4* attenuation at 2 GHz = 3.27 dB/100-foot
LDF5* attenuation at 2 GHz = 1.88 dB/100-foot
VXL5 attenuation at 2 GHz = 2.03 dB/100-foot

*LDF4 is Andrew HELIAX® 1/2" and LDF5 is HELIAX 7/8" foam dielectric coaxial cable

TABLE II
SWR FOR A 100-FOOT SITE INSTALLATION

Component	Standard Site	Site with VXL5
Jumper		
SWR	1.10	—
Reflection coefficient	0.0476	—
Attenuation factor	0.667	—
Ref_1	0.032	—
Feeder		
SWR	1.13	1.13
Ref_2	0.0610	0.0610
Surge arrestor		
SWR	1.07	1.07
Ref_3	0.0338	0.0338
RSS	0.077	0.070
SUM (max reflection)	0.127	0.095
System SWR	1.17	1.15
Max SWR	1.29	1.21

Calculation references:
Attenuation factor = exp[–(feeder attenuation (dB/100 ft) × length (ft)/434.3)]
RSS = square root $(Ref_1^2 + Ref_2^2 + \ldots)$
SUM = $Ref_1 + Ref_2 + \ldots$

[Continued on page 155]

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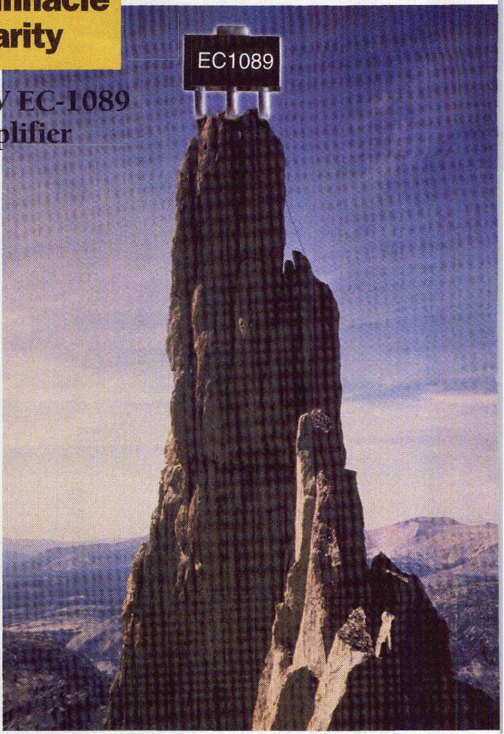

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NEW! EC-1089	15dB	23.5dBm	>42dBm	~ 85°C/W	~65°C	DC-2.5 GHz
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EC-1078	19.5dB	21dBm	37dBm	120°C/W	60°C	DC - 3 GHz
EC-1119	14.8dB	18.6dBm	36dBm	150°C/W	60°C	DC - 3 GHz

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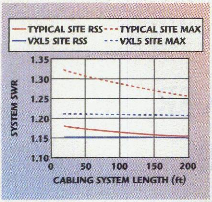


▲ *Fig. 2 SWR comparison.*

(This is not an important distinction for evaluating the effect of the jumper.) The specified SWR for each component is listed as well as its equivalent reflection coefficient, Ref_x, at the radio end of the feeder cable. These values are direct conversions of the SWR values, except for the jumper. The equivalent reflection coefficient of the jumper is obtained by multiplying the converted value by an attenuation factor, which takes into account the loss of the feeder cable.

The measured system SWR depends on the phase relationships of the individual reflections and is normally estimated in one of two ways. The first method assumes random phase relationships and uses a root sum of squares (RSS) estimate. The other method assumes all reflections add in phase (SUM) and provides the result for the worst case. The 1.17 SWR, estimated for the standard site RSS, represents a 25 percent increase in reflected power compared with the system RSS estimate of 1.15 for the site installation with the VXL5.

Figure 2 shows the system SWR behavior as a function of installed cable length. Again, the differences in performance are even more apparent as the installed length becomes shorter than the example system.

INSTALLATION COST

The VXL5 cable provides technological advantages through its simplicity and increased reliability and is a transmission line solution that has lower direct and indirect costs. Since the VXL5 cable does not require a separate jumper to the base station antenna, the costs of jumpers are saved in addition to the cost of secondary weatherproofing. ***Table 3*** lists cost comparison details between a traditional system installation and one utilizing VXL5 cable.

TABLE III
INSTALLATION COST COMPARISON

	Traditional System	System with VXL5 Cable
1/2", 10' Jumper	\$ 110.00	\$ 0.00
7/8" DIN Connectors (2)	\$ 98.00	\$ 98.00
7/8" Cable, 100' (110', VXL5)	\$ 585.00	\$ 583.00
7/8" Grounding Kit (3)	\$ 90.00	\$ 90.00
7/8" to 1/2" Weatherproofing*	\$ 38.00	\$ 0.00
7/8" Standard Hangers (30)	\$ 105.00	\$ 105.00
Total	\$ 1026.00	\$ 876.00
Savings		15%

*Weatherproofing is Andrew 3M™ ColdShrink™ self-shrinking tubing

In addition to the direct cost savings, installations are smoother and quicker, resulting in further cost savings. Less time is required because there are fewer jumpers and fewer connectors to fit. In addition, coordination is simpler because of fewer parts to order and track, and installation is simpler due to the use of more flexible feeder cable (five-inch bend radius) that is 15 percent lighter in weight and requires only one-step cable prep. Thus, the jumperless site installation results in lower costs, improved efficiency and reduced system noise. Additional information is available from the company's Web site at www.andrew.com.

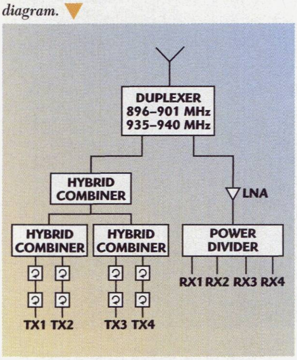
Andrew Corp.,
Orland Park, IL (708) 349-3300.

Circle No. 321

A Duplexer, Combiner and Distribution Amplifier for Wireless Applications

Today's wireless base stations operate in a duplex mode and require a duplexer at the antenna to provide low insertion loss and high power capabilities in the transmit mode and low noise amplification and steep attenuation close to the passband in the receive mode. A new duplexer assembly has been developed that is aimed at these stringent requirements and makes use of the considerable performance advantage of high Q ceramic resonators. The model 80163 duplexer/combiner/receive distribution amplifier (RXDA) is designed for 900 MHz wireless data two- or four-channel operation. The two-channel system comprises the company's models 80212 duplexer, 80189-937 combiners, 80119-2 power divider and 80251 low noise amplifier (LNA). The integrated subsystem is capable of expanding from two-channel to four-channel operation with the appropriate changes in internal components and contains duplex filtering that has been optimized for hostile RF environments.

Fig. 1 The duplexer/combiner/RXDA's block diagram.



The subsystem makes use of high Q ceramic resonators to form the filtering and offers very low insertion loss and steep attenuation to the neighboring AMPS transmit band (894 MHz) and paging frequencies (902 MHz). Featuring greater than 90 dB of RX-to-TX isolation, this duplexer offers excellent channel-to-channel isolation. In addition, the transmit path includes an integrated second-harmonic notch filter.

Figure 1 shows the unit's block diagram in a four-channel configuration. The duplexer is designed to operate over an 896 to 901 MHz RX frequency band and a 935 to 940 MHz TX band, and utilizes the latest in ceramic resonator technology to obtain maximum performance. The proprietary resonator and support design simplifies manufacture and enables production of a consistent-quality product.

The two-channel hybrid combiner comprises a microstrip design with an internal load and integrated heat sinking, allowing it to handle 60 W per channel. The design also includes two dual-stage ferrite isolators that offer –50 dB of antenna-to-TX isolation. That level combined with the isolation of the hybrid provides –80 dB of TX-to-TX isolation over the 935 to 940 MHz TX range. The two-channel combiner is available as a separate standard unit (model 80189-937), which covers the 912 to 963 MHz fre-

[Continued on page 158]

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Columbia, MD

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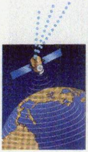

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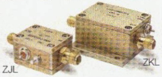
SPECIFICATIONS

Model	Freq (MHz)	Gain (typ) Midband (dB)	Gain (typ) Flat (±dB)	Max. P_{out} 1 (dBm)	Dynamic Range (Typ @2GHz 2) NF(dB)	Dynamic Range (Typ @2GHz 2) IP3(dBm)	I(mA) 3	Price $ea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5	32.0	80	129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0	24.0	50	99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5	30.5	75	129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5	24.0	50	114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5	30.5	75	129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8	22.0	45	114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0	30.0	120	149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0	31.0	120	149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0	31.0	120	149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0	31.0	115	149.95

NOTES:
1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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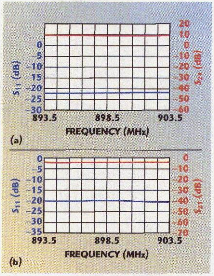


Fig. 2 The amplifier's performance with the two-way power divider in the (a) active and (b) bypass operating modes.

quency range and can be easily modified to shift higher or lower in frequency depending on the requirement.

The power divider is a shielded microstrip design composed of standard Wilkenson divider circuits. The unit is available in two-, three- and four-channel configurations as separate products (models 80119-2, 80119-3 and 80119-4, respectively). The individual units cover the 800 to 900 MHz frequency range, and a PCS version is also available.

The pre-amplifier is a low noise, high dynamic range amplifier designed for ultralinear receiver applications in the 925 to 960 MHz range.

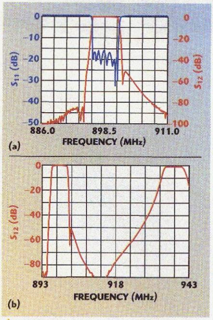


Fig. 3 Typical duplexer performance; (a) RX only and (b) RX and TX.

The circuit is matched to 50 Ω and employs a single-stage GaAs FET with internal matching to provide exceptional noise figure in combination with a high +36 dBm IP3 typ. The LNA requires +12 V DC for operation and has an integrated current monitoring circuit with TTL output and light-emitting diode status indicators. The design also includes an RF bypass switch in case of power supply or device failure. **Figure 2** shows the amplifier's performance with the two-way power divider in both active and bypass operating modes.

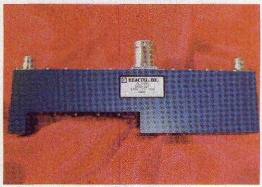
Specifications for the 80163 duplexer include an 896 to 901 MHz RX frequency passband with an insertion loss of < 1.75 dB and a return loss of > 15 dB. Attenuation in the 825 to 894 and 935 to 940 MHz bands is > 82 dB and > 90 dB, respectively. Attenuation at 902 MHz is > 40 dB. The TX passband is 935 to 940 MHz with an insertion loss of < 1 dB and return loss of > 18 dB. Attenuation at 896 to 901 MHz is > 90 dB and second harmonic suppression at 1870 to 1880 MHz is > 80 dB. **Figure 3** shows typical duplexer performance vs. frequency.

The combiner features isolation of > 80 dB TX to TX and > 50 dB antenna to TX. Maximum power handling is 60 W per channel and insertion loss per channel is < 4 dB.

The two-channel RXDA has a specified gain of 9.5 dB ±1 dB and a noise figure of < 2.7 dB. Third-order intercept is +33 dBm typ. Maximum current consumption is 250 mA at +12 V DC and the TTL output is low with an amplifier failure. The 80163 unit is housed in two stacked 19-inch rack-mounted decks and operates from –30° to +60°C. Additional information may be obtained from the company's Web site at www.fsymicrowave.com or via e-mail at sales@fsymicrowave.com.

FSY Microwave Inc.,
Columbia, MD (410) 381-5700.

Circle No. 303



A Dual-band Antenna Coupler for Cellular and PCS Applications

In today's fast-growing cellular phone systems throughout the world the amount of congestion, especially in urban areas, is becoming a significant issue. Major system providers are scrambling to find adequate solutions to the problem. The original cellular frequency band (890 to 915 MHz GSM in Europe) was later expanded by 10 MHz to 880 to 915 MHz to help ease the traffic load. This expanded band is known as extended GSM. Now even that band is full and the choice is to go to the higher assigned 1850 to 1910 MHz PCS band in the US and the 1710 to 1880 MHz DCS-1800 band in Europe.

At the present time single-band phones for PCS and GSM are being sold in the US and Europe. Soon, multiband phones will be made available to allow use of the same phone throughout the world. However, the tremendous increase in cellular phone use and tight local environmental control on sight expansion, particularly in urban areas, has put much pressure on system providers to enhance and expand their services. One solution is to use the existing base station facilities and add PCS capability to the cellular facility by using dual antennas that operate over the PCS and cellular frequency bands within the same housing. Using the model SL-7871 dual-band antenna coupler, these dual antennas now may be combined into a single cable to the base station and then separated again with an identical coupler to be fed to their respective processing equipment.

The new dual-band coupler accomplishes the combination or separation by means of combline cavity filters that introduce a mere 0.3 dB of loss in each band while isolating the two frequency bands by as much as 70 dB from each other. In addition, the SL-7871 unit has been designed to exhibit very low intermodulation while maintaining a return loss of 20 dB minimum, making antenna impedance matching easy.

[Continued on page 162]

Reactel Inc.
Gaithersburg, MD

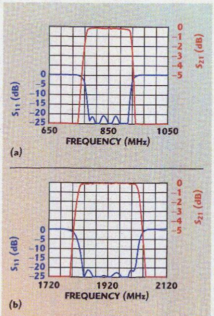


Fig. 1 The dual-band antenna coupler's passband response at the (a) cellular and (b) PCS bands.

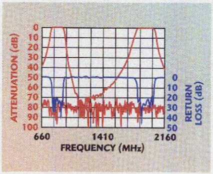


Fig. 2 The coupler's frequency band selectivity.

The new coupler is designed to handle a minimum RF power of 500 W at cellular frequencies and 250 W at PCS frequencies. In addition, it can be easily modified to accommodate GSM-900 and GSM-1800. ***Figure 1*** shows the actual coupler passband response for both cellular and PCS frequencies. ***Figure 2*** shows the coupler's measured band selectivity.

The dual-band unit is supplied with DIN 7/16 connectors for the common port and type-N female connectors for PCS and cellular ports. The coupler's housing measures 1.25" × 3.00" × 9.00". Additional information is available via e-mail at reactel@reactel.com.

Reactel Inc.,
Gaithersburg, MD
(301) 519-3660.

Circle No. 320

broadband directional couplers

10kHz to 2600MHz 6 to 30dB

Achieve accurate power sampling with high directivity and very little insertion loss using Mini-Circuits surface mount, plug-in, and coaxial directional couplers. Finding the right model for your design layouts is easy with our large, off-the-shelf selection of over 100 models in 6 to 30dB coupling ratios. Choose from broadband 50 and 75 ohm couplers capable of handling input power as high as 25 watts. High performance bi-directional couplers for monitoring forward and reflected power up to 10W are available as well. Now, highly accurate power sampling and value pricing have merged! The result...Mini-Circuits broadband directional couplers.
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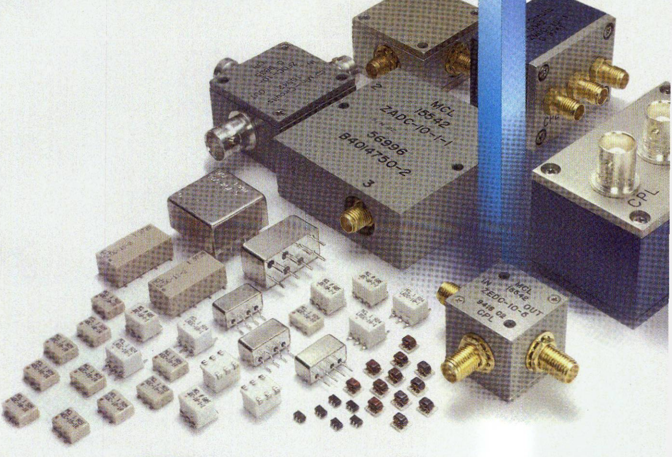

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NEW PRODUCTS

COMPONENTS

Multimode, Multiband pHEMT Switches

These 3 V pseudomorphic high electron mobility transistor (pHEMT) switches include the models AWS5509S17 triband single-pole four-throw (SP4T) switch for GSM, digital communication system (DCS) and PCS operation and AWS5510S20 dual-band SP4T switch for AMPS/TDMA 800 and AMPS 1900 handset applications. In addition to reducing component count and eliminating interconnects, the single-supply switches demonstrate the low insertion loss (0.4 dB (typ) for the model AWS5510S20), high isolation (better than 20 dB between all ports) and low harmonics (better than –65 dBc) required by wireless handset designs. The devices feature +2.7 V DC CMOS-compatible control with no negative voltage requirements. The AWS5509S17 switch is housed in a TSSOP-20 surface-mount package and is priced at $2.25 (100,000); the AWS5510S20 switch is housed in a TSSOP-16 surface-mount package and is priced at $2.10 (100,000).

ANADIGICS Inc.,
Warren, NJ (908) 668-5000.

Circle No. 215

PCB Crossover Components

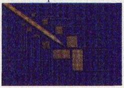
These Xinger™ surface-mount crossover components include one for DC-to-RF and one for RF-to-RF signal crossing. The units can reduce the need for expensive multilayer boards and can be mounted by tape and reel for high volume manufacturing, which provides many advantages over traditional signal-crossing methods. Both components work in the DC to 6 GHz range and provide a maximum insertion loss of less than 0.1 dB. The return loss for both is greater than 20 dB and the RF-RF component has an isolation of better than 25 dB. Package size: 0.2" × 0.2".

Anaren Microwave Inc.,
East Syracuse, NY (315) 432-8909.

Circle No. 216

Radial Leaded Capacitors

The SK and SV series radial leaded capacitors are low equivalent series resistance (ESR) solutions for a variety of power supply challenges.

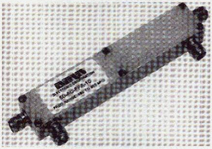


The SK series capacitors can economically replace tantalum or aluminum electrolytic metal cans in many high switching frequency power supplies. The SV series capacitors offer designers of power supplies alternatives for high voltage filtering, snubber and resonator circuits. They are made specifically for applications that require capacitors with high voltage, low leakage current and low ESR in a small package. The SK capacitors are rated from 25 to 500 V DC in C0G and X7R dielectrics with capacitance values from 1000 pF to 33 µF. Also offered is a Z5U dielectric in 25 to 200 V DC ratings. Typical ESR for the SK series is in the milliohm range at 1 MHz. The SK series feature high RMS and surge current capabilities and a wide operating temperature range of –55° to +125°C for NPO/X7R and +10° to +85°C for Z5U. Prices: 50¢ to $1.80 (1000) for the SK series and 60¢ to $1.87 (10,000) for the SV series (depending on size). Delivery: stock to 10 weeks (SK series); stock to eight weeks (SV series).

AVX Corp.,
Myrtle Beach, SC (843) 946-0414.

Circle No. 217

Miniature Coaxial Coupler



The model 50-AC-FFA-10 miniature coaxial coupler offers a compact, cost-effective and quality solution to UHF and cellular applications. The unit has a frequency range of 0.5 to 1.0 GHz and is available with a 10, 20 or 30 dB coupling factor. Other specifications include an SWR of 1.15 (max, primary and secondary line); reflected power of 5 W (avg), 3 kW (peak); and frequency sensitivity of ±0.75 dB (max). Size: 3.61" × 0.86" × 0.42". Weight: 1.3 oz.

BCP (Bird Component Products),
Largo, FL (727) 547-8826.

Circle No. 218

Integrated Circulator and High Power Termination Assembly

The model IR360 integrated circulator and high power termination assembly is a WR-28 waveguide isolator rated at 200 W CW forward power into any output load impedance (including a short circuit). Typical specifications over the operating bandwidth include an isolation of 23 dB, SWR of 1.15 and insertion loss of 0.25 dB. Cooling is achieved through both conduction and forced air (convection).

Channel Microwave Corp.,
Camarillo, CA (805) 482-7280.

Circle No. 219

Sub-band PCS Duplexers

The models WSD-00132/00133/00134 high performance, compact, sub-band PCS duplexers are offered in 20 MHz A&D, B&E and F&C-band models with exceptional isolation and low insertion loss. The duplexers are configured with receive passbands of 1850 to 1870 MHz for the WSD-00132, 1870 to 1890 MHz for the WSD-00133 and 1890 to 1910 MHz for the WSD-00134. The transmit passbands are 1930 to 1950 MHz, 1950 to 1970 MHz and 1970 to 1990 MHz, respectively. Insertion losses within the passbands are specified at 1.5 dB (max) for the receive and 0.9 dB (max) for the transmit, with passband return loss specified at 14 dB (min). Transmit passband power handling is rated at 10 W CW and 100 W peak instantaneous power (PIP). Operating temperature range is 0° to +50°C. Size: 4.2" × 2.5" × 1.5", excluding connectors.

K&L Microwave Inc.,
Salisbury, MD (410) 749-2424.

Circle No. 223

Toroidal Inductors

The low cost HCT series toroidal inductors are designed for high current, low voltage applications, particularly the latest generation of low voltage microprocessors.

The toroid core offers a compact size with minimal external magnetic fields. The series has an operating temperature range of –40° to +85°C with high shock and vibration resistance. The 1.5 µH inductors can be provided in either a vertical or horizontal mounting style; custom versions are also available. Price: 65¢ (10,000). Delivery: stock.

Coilcraft, Cary, IL (847) 639-6400.

Circle No. 220

Wideband Terminations

This complete series of SMA, 3.5 mm and K connector-compatible wideband terminations offers 1 W power handling in a low profile package. The full DC to 18 GHz performance allows for multiband coverage or permits the user to procure one part type for many applications. Use part number 12-008 for applications where an SMA male low power termination is required.

Florida RF Labs,
Stuart, FL (800) 544-5594
or (561) 286-9300.

Circle No. 221

Wideband, Solid-state, Programmable Attenuator

The model 50P-1391 solid-state programmable attenuator covers the frequency range of 800 to 3000 MHz with an attenuation range of 0 to 63 dB in 1 dB steps. The unit features a 5 microsecond switching speed with an accuracy of ±3 percent of programmed attenuation at 3000 MHz, third-order intercept of +40 dBm and input power of +20 dBm. The unit has built-in TTL drivers and is available with SMA female RF connectors.

JFW Industries,
Indianapolis, IN (317) 885-3247.

Circle No. 222

[Continued on page 172]

NEW PRODUCTS

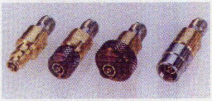
GaAs SPDT Switches

These GaAs SPDT switches are available in low cost, small SOT plastic packages and cover the DC to 3 GHz frequency range. The model SW-437 MMIC SPDT reflective switch is available in the ultraminiature SOT-363 package; the model SW-442 SPDT terminated switch is available in the SOT-26 package. Both switches are suitable for use in applications requiring low insertion loss, good isolation and small package size, and are particularly well suited for use in portable, dual-band telephones where switching between small-signal components is required. The units also can be used for general-purpose switching in applications up to 0.25 W. Key attributes include positive or negative control voltages (2.5 to 8 V), good device-to-device consistency and low insertion loss for CDMA, TDMA, GSM and wideband CDMA applications.
M/A-COM, Lowell, MA (800) 366-2266.
Circle No. 224

Combline Filters

The MMFM-FGBC series combline filters allow very wide stopband rejection in very small enclosures without the appearance of re-entrant spurious passbands. The units require no tuning once incorporated in a circuit, which makes them very cost effective, especially in high volume production. The temperature range is from –55° to +125°C with inherently low EM emissions and the ability to handle low to medium power. The filters can be designed with center frequencies from 500 MHz to 40 GHz and employ the company's patent-pending Multi-Mix™ multilayer manufacturing process. Size: 0.75" × 0.53" × 0.04".
Merrimac Industries Inc.,
West Caldwell, NJ (888) 434-6636.
Circle No. 226

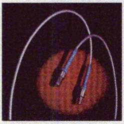
3.5 mm Adapters



The Quick Test QT3.5mm™ 8006 adapters are push on/pull off 3.5 mm adapters designed for long life and excellent repeatability. The in-series adapters adapt from standard 3.5 mm to one of four optional QT3.5mm connector configurations: the "no nut" design, the 3/8" nut design, the 9/16" nut design and the guide sleeve design. The new, patent-pending design is specifically developed for rugged, long-term use. The maximum mating cycles of the 8006 series will meet or exceed conventional thread-on 3.5 mm connectors without any significant degradation in repeatability.
Maury Microwave Corp.,
Ontario, CA (909) 987-4715.
Circle No. 225

Low Loss Cable Assemblies

The UFA series UTiFLEX® low loss cable assemblies feature outstanding mechanical integrity without sacrificing insertion loss, phase stability or SWR. Maximum insertion loss ranges from 0.11 dB/ft at 1 GHz to 1.21 dB/ft at 50 GHz, depending on the cable assemblies. Phase stability is as low as 2° at 10 and 18 GHz. All five assemblies in the series have 50 Ω impedance. Frequency ranges are DC to 26.5 GHz for the models UFA147B, UFA210A and UFA210B; DC to 40 GHz for the model UFA147A; and DC to 50 GHz for the model UFA125A. The units also have a patented connector attachment that provides high reliability and can withstand heavy stress. The connector body, dielectric and center contact are completely captivated.

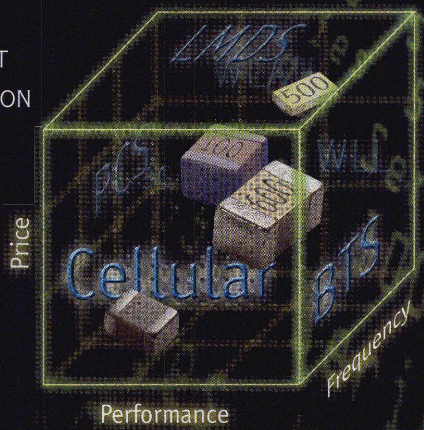


MICRO-COAX,
Collegeville, PA (800) 223-2629.
Circle No. 227

MOSFET Quad Mixer

The model PE4120 high linearity MOSFET quad mixer is a passive, broadband device that performs functions ranging from frequency conversion to phase detection at up to 2.5 GHz. A conversion loss of only 6 dB across its entire operating frequency range makes the unit ideal for such applications as cellular/PCS telephone network base stations and cable modems. The chip

[Continued on page 174]



LMDS
500
100
600
WLL
Price
Cellular
BTS
Frequency
Performance

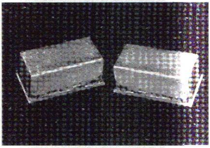
NEW PRODUCTS

offers both cost and performance advantages over other devices of its kind. Operating across a frequency range from 500 MHz to 2.5 GHz, the PE4120 mixes a received RF signal with the output of an LO to produce an IF. For transmission, it mixes IF and LO signals to produce an RF output. Power loss during the conversion is only 6 dB at any frequency with a 20 dBm LO drive. The linearity of the chip is 28 dBm, LO-IF isolation is 36 dB and LO-RF isolation is 34 dB. Operating temperature range is –40° to +85°C. Price: $1 (10,000).

Peregrine Semiconductor Corp., San Diego, CA (858) 455-0660.

Circle No. 229

■ LC Filters

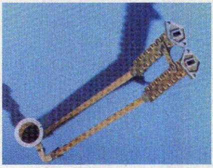


The 8600 series LC filters for the Customer Premise Equipment transceiver element of the LMDS/MMDS wireless network are packaged as hermetically sealed true SMT devices that will completely support full automated assembly operations. The transmit path filters feature center frequencies in the 450 to 650 MHz range, and the receive path filters feature center frequencies in the 1200 to 1500 MHz range. The 1 dB passband responses are generally 75 and 375 MHz for the transmit and receive paths, respectively. Both filters exhibit excellent stopband rejection characteristics and operate within a temperature range of –40° to +85°C. The filters are available on tape and reel and can be customized. Delivery: eight to 10 weeks (ARO).

Piezo Technology Inc. (PTI), Orlando, FL (407) 298-2000.

Circle No. 231

■ Precision Microwave Feed Assembly



The precision waveguide 22 (WR28) assembly makes possible the deployment of the latest communication technology for high density data transfer. This precision microwave feed assembly uses the company's MM casting process to minimize the number of parts required in the assembly. Castings are used for complex microwave filters, intricate waveguide bends and orthomode transducers. These cast parts are brought together using specially developed bonding methods, which enable rapid assembly while still retaining microwave integrity and mechanical strength. This process is ideally suited for production of small, high precision alloy components that have thin walls and require superior finish and minimal porosity.

Micro Metalsmiths Ltd., Pickering, N. Yorks, UK +44 (0) 1751 475058.

Circle No. 228

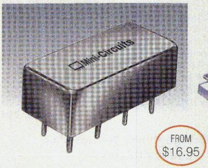
■ 25 W RF Filter

This RF frequency-agile filter using microelectromechanical system (MEMS) relays supplied by Cronos Integrated Microsystems Inc. matches or exceeds several performance criteria of traditional RF filters, but in a much smaller assembly using fewer parts. The 25 W tunable power RF bandpass filter is for potential use in a variety of military and commercial telecommunications applications in which compact size and high efficiency are needed. By employing MEMS relays in the tuning process, the board area and volume of the RF filter tuning components can be reduced by more than 50 percent compared with RF filters using PIN diode switches for tuning. This MEMS-based filter is tunable to four separate sub-bands in the VHF spectrum ranging from 44 to 56 MHz

[Continued on page 176]

NEW PRODUCTS NO.71

RF/IF MICROWAVE COMPONENTS



SHIELDED VCO PROVIDES 400 TO 800MHz OCTAVE BAND TUNING

The POS-800W is Mini-Circuits new shielded, laser sealed voltage controlled oscillator for UHF/VHF receiver applications within the 400 to 800MHz band. Low SSB phase noise is typically -93dBc/Hz at 10kHz offset, and output power is flat at 8dBm typical while drawing a maximum 25mA current from a 10V power supply. Typically, pulling is low at 3.0MHz (pk-pk at 12dBr) and pushing is 0.5MHz/V. Additional features include linear tuning and value price.

0.07" MIXERS PERFORM IN HIGHER FREQUENCY DESIGNS

Mini-Circuits patented family of Blue Cell™ mixers deliver a unique combination of low conversion loss, superb temperature stability, thin profile, and low cost to higher frequency designs. This level 7 (LO) MBA-671 model spans 2400MHz to 6700MHz with 36dB L-R, 26dB L-I isolation and low 6.5dB midband conversion loss (all typ). Operating temperature is -40°C to +85°C (max.) and applications include satellite, ISM, and PCMCIA. Available off-the-shelf.

3WAY SPLITTER/COMBINER IS HIGH POWER CELLULAR SOLUTION

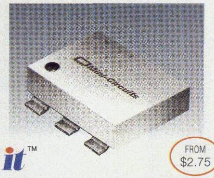
The ZB3CS-920-15W power splitter/combiner from Mini-Circuits is a connectorized solution for 3way-0° cellular requirements in the 825MHz to 920MHz band. With typically high 27dB isolation, low 0.2dB insertion loss (above 4.8dB), and 0.1dB amplitude, 1.7 degrees phase unbalance, this 50 ohm unit can handle up to 15 watts input power and is a low cost price/performance value. Equipped with SMA connectors and immediately available from stock.

13dB COUPLER INTRODUCES VERSATILE BROAD BAND FAMILY

Mini-Circuits 50 ohm TCD-13-4 is a broad band 5 to 1000MHz directional coupler offering a 13.0dB±0.5dB nominal coupling value with ±0.6dB maximum flatness. Mainline loss is low at 0.7dB (typ) and directivity is 18dB typical at midband. This rugged plastic surface mount device is equipped with solder plated leads for excellent solderability, and is from a family of low cost 9 to 20dB directional couplers in 50 and 75 ohm versions. Applications include cellular and CATV.

6 WAY SPLITTER/COMBINER IDEAL FOR VHF-TV

Mini-Circuits has introduced the AD6PS-1, a 6way-0° power splitter/combiner covering the 2MHz to 250MHz band. Uniquely engineered in a 0.210" low profile water washable package, this 50 ohm device exhibits high 30dB typical isolation, low 0.2dB insertion loss (typ. above 7.8dB), and less than 0.4dB amplitude, 6 degrees phase unbalance at midband. VSWR port matching is good with 1.20:1 input and 1.10:1 output typical. Patent pending.



VERY BROAD BAND RF CHOKE BIASES AMPLIFIERS TO 8GHz

Mini-Circuits low cost ADCH-80A is a very broad band 50MHz to 8000MHz RF choke housed in an ultra-low profile 0.108" package. Typically, the unit displays low 0.3dB insertion loss when added in parallel to an RF circuit, 1.1:1 VSWR, and 1.8μH inductance at 50mA DC current. Parasitic capacitance is low at 0.1pF typical and the effective parallel resistance is 800 ohms (typ). This patent pending circuit provides high RF impedance over a very broad frequency range.

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NEW PRODUCTS

with total insertion loss of 0.8 to 1.0 dB. (The MEMS relays contribute a total of 0.1 to 2.0 dB of that loss.)
Raytheon Co.,
Fort Wayne, IN (219) 429-5547.
Circle No. 232

Miniature High Voltage Connector

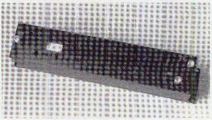
These miniature high voltage (MHV) connectors provide shielded disconnects where high

voltages are present and the BNC-type interface is required. Center contacts are recessed within lengthened dielectric material to provide protection against electrical shock when handling unmated connectors. These non-constant-impedance MHV connectors feature nickel-plated, machined-brass bodies; gold-plated pins and contacts; and Teflon insulation for enhanced performance. They are designed to be used in applications with frequencies of DC to 300 MHz and a test voltage up to 5 kV RMS in mated pairs.
RF Connectors,
San Diego, CA (800) 233-1728
or (858) 549-6340.
Circle No. 233

Surface-mount SAW Filter and Resonator

This surface acoustic wave (SAW) filter at 868.35 MHz and 868.95 MHz with an accompanying 10.7 MHz LO resonator is intended for use in the European Telecommunications Standards Institute's newly released 868 to 870 MHz frequency band. The model RF1336B filter is a surface-mount, metal lid, ceramic base package with an 8.71 × 6.04 mm footprint; the model R02164A resonator is a surface-mount, ceramic lid, ceramic base package with a 5.97 × 3.94 mm footprint.
RF Monolithics Inc. (RFM),
Dallas, TX (800) 704-6079
or (972) 448-3700.
Circle No. 234

High Power and Standard Cellular Duplexers



These cellular duplexers provide both high isolation and low insertion loss. The absence of magnetic materials together with strict attention to structure result in low intermodulation. Both high power and standard models are supplied in a 2U rack-mount package. Power ratings assume an operating altitude of 10,000 feet, a base plate temperature of +50°C and an antenna SWR of 2. Return loss is 14 dB and impedance is 50 Ω.
RLC Electronics Inc.,
Mt. Kisco, NY (914) 241-1334.
Circle No. 235

SATCOM Waveguide Switch

The model WS8189 waveguide switch is the first in a family of waveguide switches being designed for use in SATCOM ground-based applications. The switch includes manual override and Form 3C inhibit contacts and is available in WR 75 and WR 62. The switch time is 100 ms and the actuator current is 0.9 A in all conditions. Typical values at room temperature are 60 ms and 0.7 A, respectively. The entire switch (including the actuator) is weatherized and suitable for outdoor applications.

Sivers Lab AB,
Kista, Sweden +46 (8) 477 68 00
or e-mail: wgswitch@siverslab.se.
Circle No. 236

[Continued on page 179]

NEW PRODUCTS

■ Cable Assemblies

The 94 series cable assemblies offer stable electrical performance in a rugged package. Consistent performance over multiple flexures (< 0.1°/GHz at 2.50" radius) makes these units an ideal choice for vector network analyzer test applications through 26.5 GHz. The solid construction is demonstrated by a connector retention of > 60 lb and compressive strength of > 200 lb/inch. The cable is also available with soft or hard armoring for when additional compression resistance is needed and flexibility is not as critical.
Storm Products-RF/Microwave,
Hinsdale, IL (888) 347-8676 or (630) 323-9121.

Circle No. 237

■ I&Q Modulator/Demodulator

The models VMS 935 and VMS 1710 I&Q modulator/demodulator have high dynamic range in a miniature package that measures 0.5" × 0.5" × 0.22". The VMS-935 has 27 dB carrier and 30 dB single sideband (SSB) rejection. Typical amplitude unbalance is 0.2 dB and phase unbalance is 1°. The VMS-1710 has an excellent carrier and SSB rejection of 25 dB and 27 dB, respectively, with typical amplitude and phase unbalance of 0.4 dB and 2°, respectively.

Synergy Microwave Corp.,
Paterson, NJ (973) 881-8800.

Circle No. 238

■ High Density PIN Interface Blocks

The VG series interface blocks (VGRCB) feature one model with triple capacity for signal, power and high frequency transmission, and a second model with a standard ribbon cable interface. Four configurations provide for 170, 136, 110 or 40 test signals per connector block. The new 136-pin count version is designed to use standard ribbon cable headers. Size: 2.345" × 1.115" with 100-mil grid pin spacing.
TTI Testron, a division of Everett Charles Technologies,
Pomona, CA (909) 625-9332.

Circle No. 239

■ 100 dB High Isolation Switch

The model SWM-6000-1DTU-ECL-GB is a 100 dB high isolation, 20 ns ultra-high speed, balanced, low video transient, nonreflective, SPST solid-state switch. Between 10 MHz and 2 GHz, the insertion loss is 3 dB and the SWR is 2 (max). The switch operates from ±5 V DC at ±100 mA (max). Control logic is ECL, but TTL is also available. Size: 1.5" × 1.5" × 0.4", with removable SMA connectors. Miniature sizes are available.

American Microwave Corp. (AMC),
Frederick, MD (301) 662-4700.

Circle No. 289

■ Variable Capacitors

The 1500 series Eco-Trim® variable capacitors are low cost, high performance air capacitors for applications where high Q and cost are design criteria. The devices are suitable for use in impedance matching, filter tuning, interstage coupling and antenna tuning with a capacitance range of 1 to 10 pF, a rated voltage of 250 V DC and an operating temperature range of –65° to +125°C. Five mounting styles are available for PC and surface-mount applications. Price: $1.95 (2500). Delivery: four to six weeks.

Johanson, Boonton, NJ (973) 334-2676.

Circle No. 291

■ Bandpass Filter

The model 13010 bandpass filter is part of a family of waveguide filters used in microwave radio applications to isolate, transmit and receive frequencies. It has a passband of 50 MHz in the 27.5 to 29.5 GHz frequency range, maximum insertion loss of 2.0 dB, return loss of 15 dB (typ) and rejection of 30 dB (min) at ±150 MHz from the center frequency. The unit is supplied with WR-28 flanges and has a maximum length of 1.75".

Microwave Filter Company (MFC),
East Syracuse, NY (800) 488-1666 or (315) 438-4700.

Circle No. 292

■ Phase-invariant Attenator

The model A3P-64-0AE digitally controlled PIN diode phase-invariant attenuator offers virtually phase-free operation over a dynamic range of 45 dB in the 3:1 bandwidth of 6 through 18 GHz. At any attenuation up to 20 dB, the unit has a flatness vs. attenuation of less than ±0.9 dB and a delta phase of less than ±5°. The attenuator demonstrates monotonic performance with eight bits of TTL-compatible binary logic and has an SWR of less than 2 with a total switching speed under 350 ns.
G.T. Microwave Inc., Randolph, NJ (973) 361-5700.

Circle No. 290

■ RF Relays

The company's expanded RF relay product offering includes magnetic latching, high repeatability, bypass and attenuation models. With enhanced bandwidth performance up to 4 GHz, the units all have excellent RF signal response over their entire bandwidth. In addition, each device includes a metal enclosure for electromagnetic interference shielding, a ground pin option to improve case grounding, high isolation between control and RF signal paths, and a higher resistance to ESD.
Teledyne Relays, Hawthorne, CA (323) 777-0077.

Circle No. 263

[Continued on page 181]

Get Connected
with Richardson Electronics and SDP Components
SDP Components and Richardson Electronics work hand-in-hand to provide substantial savings on a wide range of RF and Microwave coaxial connectors.
The alliance between SDP and Richardson ensures your connector needs are satisfied with on-time delivery on low cost, high quality components.
Richardson Electronics offers SDP's SMA, N, BNC, TNC, 7/16, MCX/MMCX, SMB/SMC, UHF/Mini UHF and F Series connectors. Custom designs are also offered at the same low prices as the standard designs.
SDP also offers full design support by the provision of free samples and technical assistance during prototyping, while Richardson's engineering team is available to support your current designs and future applications.
SDP and Richardson Electronics — your connection is only a phone call away.
Richardson Electronics
Engineered Solutions
SDP
Components Inc.
RELL Online
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Catalog
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More than 60 locations worldwide to serve you. E-mail: ssc@rell.com, Internet: www.rfpowernet.com, Toll Free: 800-RF Power or 800-737-6937 (U.S. & Canada), Australia: Castle Hill, ACN 069 808 108, +61 (2) 9894-7288, Bayswater, ACN 069 808 108, +61 (3) 9738-0733, Brazil: São Paulo, +55 (11) 820-6199, China: Shanghai, +86 (21) 6440-0807, Colombia: Sante Fe de Bogota, DC, (57-1) 636-1028, France: Colombes Cedex, +33 (1) 55.66.00.30, Germany: Puchheim, +49 (89) 890 214-0, Hamburg, +49 (40) 555 88 410, Italy: Sesto Fiorentino (FI), +39 (055) 420831, Agrate Brianza (MI), +39 (039) 653145, Roma, +39 (06) 41.73.37.51, Japan: Osaka, +81 (6) 6314-5557, Tokyo, +81 (3) 5215-1577, Korea: Seoul, +82 (2) 539-4731, Mexico: Mexico City, +52 (5) 674-2228, Guadalajara, +52 (3) 645-4641, Netherlands: Amsterdam, +31 (20) 446 7070, Philippines: 63-2-633-9480, Singapore: +65 487-5995, Spain: Madrid, +34 (91) 528 3700, Barcelona, +34 (93) 415 8303, Sweden: Stockholm, +46 8 564 705 90, Taiwan: Taipei, +886 (2) 86915238, Thailand: Bangkok, +66 (2) 749-4402, Turkey: Içlevent Istanbul, +90 212 264 3721, United Kingdom: Lincoln, +44 (1522) 542631, Slough, +44 (1753) 733010, Vietnam: Ho Chi Minh City, +84 8.811.1919. For other international inquiries call Corporate Headquarters: LaFox, IL (630) 208-2200, Fax (630) 208-2550. MK0585 ©2000 Richardson Electronics, Ltd.
1-800-RF-POWER • www.rfpowernet.com • ssc@rell.com

NEW PRODUCTS

■ Microwave Assembly

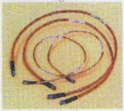
The model MP4269 highly integrated subassembly is designed for a military airborne requirement. This switched filter bank integrates seven switched bandpass filters operating over the input frequency range of 0.45 to 20.10 GHz and a passband range of 0.45 to 8.05 GHz. The passband insertion loss is 5.5 dB (max), passband-to-passband variation is 1.5 dB (max) and differential group delay is 10 ns. Channel-to-channel isolation is 60 dB (min) and SWR (all ports) is 1.8. The operating temperature range for the assembly is 0° to +70°C with power supply voltages of +5 and –15 V. Logic is CMOS compatible. Size: 5.0" × 4.0" × 0.5", excluding SMA connectors, which are field replaceable.

Robinson Laboratories Inc., Nashua, NH (603) 880-7880.

Circle No. 294

■ Low Loss Flexible Cables and Cable Assemblies

The Coaxi-Flex™ high performance, low loss, flexible cables and cable assemblies designed for use in microwave and video applications. The innovative primary shield design features a silver-plated, flat copper strip instead of conventional round wire, significantly reducing attenuation. Coaxi-Flex performance capabilities are further enhanced by the precise engineering of prime material into the center conductor, dielectric, second and third shields, and sturdy jacket. The cables operate up to 26 GHz and are available in 0.195" and 0.120" diameters. Cable assemblies in lengths of 18", 24", 30" and 36" are available standard from stock with SMA connectors.



Precision Tube, Salisbury, MD (410) 546-3911.

Circle No. 293

■ Thin- and Thick-film Chip Resistors

The models RM0502, RM0402 and RM0603 high reliability, thin-and thick-film chip resistors are qualified to MIL-PRF-55342 (revision G, amendment 3). They are used in mission-critical applications, such as manned space flight, life support systems, human-implantable medical devices and satellite communications. The resistors have power ratings of up to 70 mW and TCRs from 25 to 300 PPM. Maximum voltage ratings are 25 V (RM0402), 40 V (RM0502) and 50 V (RM0603), and the units are available with tolerances as low as 0.1 percent and have an operating temperature range of –55° to +125°C. Sizes: 0.05" × 0.02" × 0.01" (RM0502), 0.04" × 0.02" × 0.01" (RM0402) and 0.06" × 0.03" × 0.01" (RM0603).

State of the Art Inc. (SOTA), State College, PA (800) 458-3401.

Circle No. 295

■ Low Profile EL Choke Coils

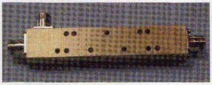
The D31FU series surface-mount fixed inductors are low profile, unshielded inductors designed for use as EL inverter IC choke coils. The coils are available in 0.10 to 1.2 mH inductance values and have a 3.3 × 3.3 mm footprint with a low profile of only 1.7 mm (max). They are packaged on tape and reel in 3000-piece quantities.

Toko America Inc., Mount Prospect, IL (847) 297-0070.

Circle No. 264

■ High Power Directional Coupler

The model FC0813 directional coupler operates over the 280 to 560 MHz frequency range and offers typical insertion loss of 0.2 dB, SWR of 1.29 (max) and directivity of 20 dB (min). Coupling is 10 ±1 dB, flatness is ±0.3 dB and power handling is 350 W (avg). Typical applications include TX power monitoring in telecommunications base stations. Size: 6.26" × 1.16" × 1.16" with standard type-N female connectors. Connectors and coupler configuration variants are available upon request.

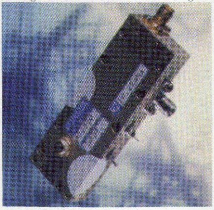


Sage Laboratories Inc., Natick, MA (508) 653-0844.

Circle No. 308

■ Microwave Frequency Converters

The new AFC series miniature frequency converters have a frequency coverage from 6 to 16 GHz and are designed for use in terrestrial microwave links. Each unit has a dielectric resonator oscillator that uses a GaAs FET as the active device. The frequency converters can be mechanically tuned over ±30 MHz and maintain a stability of frequency within ±120 ppm over a temperature range of –10° to +60°C. Conversion loss from RF to IF is typically 7 dB and is flat over the DC to 4 GHz IF range to within 1 dB. Size: 2.5" × 1.0" × 0.55".



Atlantic Microwave Ltd., Braintree, Essex, UK 01376 550220.

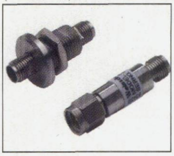
Circle No. 278

[Continued on page 183]

NEW PRODUCTS

■ 26.5 GHz Fixed Attenuators

These 3.5 mm, fixed attenuators are available in a bulkhead version (model 83) and a standard round body configuration (model 56). The units are available in decibel values of 1 to 10, 20 and 30 with a 2 W power rating and 1.10 to 1.25 SWR (max). Operating temperature range is –55° to +85°C with ±0.50 dB deviation (max). Nominal impedance is 50 Ω.

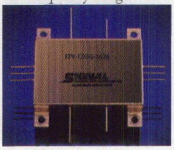


Weinschel Corp.,
Frederick, MD (800) 638-2048
or (301) 846-9222.

Circle No. 309

■ I/Q Vector Demodulator

The model FPX-CDBQ-1076 I/Q vector demodulator operates over an RF frequency range of 2.5 ±0.25 GHz. It has an input power of –1 ±3 dBm, with an RF to video conversion loss of less than 14 dB and total ripple of less then 0.75 dB at either I or Q output. Quadrature accuracy is ±3° (max), and I/Q video output power balance is ±0.25 dB (max) into a 1.25 SWR. Price: $750 (5–9).



Signal Technology Corp.,
Beverly, MA (978) 524-7211.

Circle No. 282

AMPLIFIERS

■ 800 W C-band, Solid-state Power Amplifier

The 800 W C-band, solid-state power amplifier and 3200 W phase-combined system are built for satellite communications. The single 10.5-inch-high rack design offers 800 W SSPA in C band, 600 W in X band and 250 W in Ku band. Phase-combined, multi-unit packages produce 3200 W of power in C band with an equivalent performance of 10 kW traveling-wave tube (TWT)/klystron amplifiers, 2400 W in X band and 1000 in Ku band. These amplifiers are low maintenance with no costly tubes to replace, and power consumption and heat generation are low.
Advantech, Advanced Microwave Technologies Inc.,
Montreal, Quebec, Canada (514) 420-0045.

Circle No. 240

■ 2.25 kW C-band TWT Amplifier

The model VZC-6967B4 C-band TWT amplifier has been refined to provide an improved user interface and CE certification for European safety requirements. It works seamlessly with earlier models and with fixed-satellite service applications such as video transmission and high volume international data and telephony.

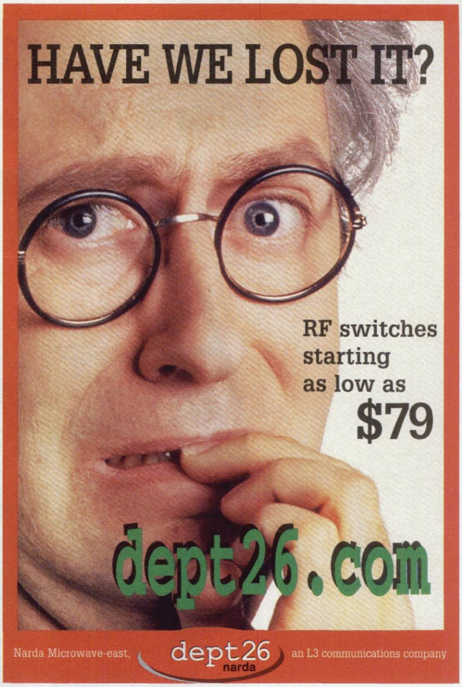
Communications
& Power Industries (CPI),
Satcom Division,
Palo Alto, CA
(650) 846-3700.

Circle No. 241

■ Octave- and Ka-band Amplifiers

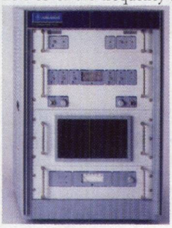
The model JCA1826-300 GaAs FET amplifier covers the frequency range of 18 to 26 GHz with a gain of 15 dB. Noise figure is 4.0 dB (max), minimum power output is +10 dBm and SWR is 2.0. Drop-in-style packages are available. The model JCA2730-K01 Ka-band amplifier for LMDS covers a frequency of 27.5 to 30.0 GHz with a minimum gain of 31 dB and maximum gain flatness of ±1.0 dB. Typical noise figure is 6.5 dB and power output is +15 dBm at P1 dB. The SWR is 2.0 (max) and includes optional drop-in-style packages, alternate gains and temperature compensation.
JCA Technology Inc., Camarillo, CA (805) 445-9888.

Circle No. 243



■ Wideband Amplifiers

The models 7200LC (200 W linear) and 7400LC (400 W linear) amplifiers cover the frequency range of 20 to 1000 MHz in a single band, making them ideal for a variety of broadband applications including high power RF immunity testing. No band switching, tuning or adjustments are required to operate the system. Both units are linear class A amplifiers designed to be driven from 1 mW (0 dBm) sources and feature low harmonics and spurious outputs, infinite SWR tolerance and remote control.

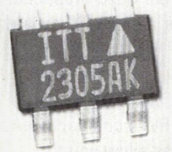


Kalmus,
Bothell, WA
(425) 485-9000.

Circle No. 244

■ Power Amplifier

The model ITT2305AK single positive supply power amplifier is designed for use as a boost-er for high power Bluetooth devices. It features 20 dB of gain that dramatically increases the range of low power devices. It can operate over a wide range of supply voltages and has easily controlled output power via varying input power or the analog control voltage. The typical draw is 60 mA and the amplifier can operate at 100 percent duty cycle. Housed in an extremely small six-pin SOT plastic package, it is suitable for pick-and-place automated component insertion and can be supplied either on tape and reel or in cans.



GaAsTEK, Roanoke, VA (888) 563-3949 or (540) 563-3949.

Circle No. 242

[Continued on page 185]

NEW PRODUCTS

■ 6–18 GHz Switched Amplifier

The model A222011-1 switched amplifier is a broadband integrated microwave assembly that includes a four-stage amplifier section that can be internally bypassed by a pair of SP2T switches integrated at the input and output of the assembly. Also integrated at the output is a 20 dB directional coupler that provides a second sample RF output from the device. The unit operates from ±12 V DC supplies and requires a single TTL-level signal to control its RF state. When switched to the amplifier state, the insertion gain is +21 ±1.5 dB with high linearity (+38 dBm typical TOI). When switched to the bypass state, the insertion gain is –4 ±1.5 dB, with similar high linearity. In addition, the amplifier's +12 V bias current is reduced to less than 35 percent of its value in the amplifier state, thereby reducing the device's overall power dissipation.
Microwave Concepts Inc. (Micro-Con),
Fairfield, NJ (973) 244-1040.

Circle No. 245

■ Power Amplifier Module

The model PA3100™ power amplifier (PA) module is the first in a family of PA modules that will, in conjunction with the MSM3100™ Mobile Station Modem baseband processing chip, RFT3100™ transmit and RFR3100™ receive chips, and PM1000™ power management chip, work to form a very complete and highly integrated CDMA chipset solution. Together, the PA3100 module and the RFT3100 chip compose the entire radio portion of the transmit chain for I-95B-compliant handsets. The module delivers 28 dBm linear output power with 25 dB linear gain and 34 percent linear efficiency in CDMA mode and 50 percent efficiency in AMPS mode.

QUALCOMM Inc., San Diego, CA (858) 587-1121.

Circle No. 246

■ 80 dB Ultra-high Dynamic Range SDLVA Chip

The model SDLVAC-0120-80 is a 300 MHz to 2 GHz, –75 to +5 dBm dynamic range succes-sive detection logarithmic video amplifier chip (SDLVA chip) with a log scope of 25 mV/dB (10 to 50 mV/dB available). The log linearity is ±1.0 dB from the best fit straight line over the dynamic range and an additional ±1.0 dB over the operating temperature range of –40° to +85°C (typ). The chip provides 20 MHz video bandwidth and a limited IF output of –20 dBm (min). It operates from +5 V DC at +80 mA and –5 V DC at –135 mA (typ). Size: 0.50" × 0.35" × 0.09".
Planar Monolithics Industries Inc. (PMI),
Frederick, MD (301) 662-4700.

Circle No. 247

■ CDMA/FM Low Noise Amplifier/Mixer 900 MHz Downconverter

The model RF2461 complete receiver front end provides excellent noise figure and linearity performance for dual-mode CDMA/FM cellular applications. This component is the first introduced using the company's advanced silicon germanium process technology. It meets all front-end requirements at an economic price and minimizes board area in its 4 × 4 mm leadless package. The RF2461 offers a stepped gain control range as it amplifies and downconverts RF signals. Along with digitally controlled LNA gain, mixer gain and a power-down mode, the component features an adjustable IIP3 of the LNA and mixer bias current using an off-chip current-setting resistor. Price: $1.87 (10,000).
RF Micro Devices Inc., Greensboro, NC (336) 664-1233.

Circle No. 248

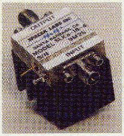
■ 18–31 GHz Low Noise Amplifier

The model CHA2069 18 to 31 GHz three-stage, self-biased, wideband monolithic low noise amplifier is manufactured with a standard pHEMT process: 0.25 μm gate length. It provides a 2.5 dB noise figure with 22 dB gain and ±1 dB gain flatness within the defined band. The 20 dBm output third-order intercept point provides a better dynamic range while offering low DC power consumption at 55 mA. Delivery: stock.
United Monolithic Semiconductors,
Orsay, France +33 1 69 33 03 35.

Circle No. 251

■ K- and Ka-band Low Noise Amplifiers

The models SLK-18-3 and SLKa-18-4 low noise amplifiers operate from 18 to 26.5 and 26.5 to 40 GHz, respectively. Typical maximum noise figures are 2.5 dB (3.0 dB in K band) and 3.5 dB (4.0 dB) in Ka band. Gain for both models can range from 10 to 30 dB. A variety of moderate-bandwidth amplifiers can be built to customer specifications. Bias is +8 to +15 V at 75 mA. Input/output connectors can be either K-connector or waveguide.



Spacek Labs Inc.,
Santa Barbara, CA
(805) 564-4404.

Circle No. 249

■ GaAs HBT MMIC Power Amplifier

The model TG2013F PA is ideal for applications in 1.9 GHz PCS and CDMA systems. It offers high output power of 29 dBm, a single power supply of 3.6 V, high gain of 24 dB, efficiency to 30 percent and SWR of < 3. The low SWR allows the unit to transmit more power than it reflects, making it much more efficient. The device provides even better linearity than a silicon device while the high output power and high gain boost the signal for transmission. Size: 5.3 × 6.4 mm. Price: $4.50 (1000).
Toshiba America Electronic Components Inc.,
Irvine, CA (800) 879-4963, ext. 209.

Circle No. 250

■ 6–12 GHz Microwave Amplifier

The model AML612P4401 6 to 12 GHz, 1 W microwave amplifier provides 44 dB gain and flatness of ±2 dB. The maximum noise figure is 2.5 dB and input/output SWR is 1.8. DC current consumption is 700 mA (nom) from a 12 to 15 V DC supply. Connectors are removable SMA. Size: 2.0" × 0.8" × 0.35".
AML Communications Inc., Camarillo, CA (805) 388-1345.

Circle No. 298

NEW PRODUCTS

Surface-mount Power Amplifier

The model ASMA-301 surface-mount power amplifier covers the 1 to 1000 MHz frequency range for RF and microwave applications and is an excellent choice for such broadband applications as digital radios, wireless communications base stations and repeaters. The device is also an excellent solution for 2.0 GHz PCS, MMDS and INMARSAT applications. Nominal power gain is 10.5 dB and output power is +28 dBm (typ) at 1 dB compression. The cascadable, broadband amplifier is a stable 50 Ω gain block that features good linearity, internal biasing and single positive supply operation. It is provided in a ceramic power package and is available in tape and reel.

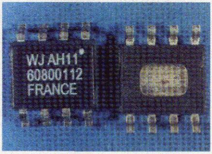
Avnet, Microwave Technical Solutions (Avnet MTS),
San Jose, CA (408) 360-4000.
Circle No. 296

Linear Amplifiers

These lightweight, high power, linear amplifiers use LDMOS FETs for pulsed avionics applications. Using proprietary device and circuit technology, the amplifiers operate reliably at elevated DC voltages and exhibit ultralinear class AB performance. They are also specifically optimized to provide undistorted, open-loop amplification of the new, complex, high data rate avionics modulations.

Zeta, an Integrated Defense Technologies company,
San Jose, CA (408) 434-3602.
Circle No. 253

Ultra-high Dynamic Range GaAs Amplifier



The model AH11 GaAs amplifier extends the linear efficiency advantages of previous models to higher power levels. It can deliver over +17 dBm of linear output power with an output IP3 greater than 50 dBm, operating from a 5 V supply in a push-pull configuration. The unit also exhibits a 3.7 dB noise figure at a P1dB of +27 dBm. The device is available in an SOIC-8 package and is 100 percent RF and DC tested. Price: < $6.75 (10,000).

Watkins-Johnson Co.,
Munich, Germany (800) 951-4401 (US) or +44 125 266 1761 (Europe).
Circle No. 252

Solid-state RF Amplifier

The model SSPA2.2-2.6-80 high power, solid-state RF amplifier is designed for use in commercial or military systems. It offers greater than 30 dB of gain from 2.2 to 2.6 GHz and has a 1 dB compression point of 49 dBm (min). The unit operates from 12 V DC with an input/output SWR of less than 1.5 (typ) and a noise figure of less than 6 dB. Power-added efficiency is greater than 30 percent. Size: 4" × 8" × 1". Input and output connectors are SMA female standard.

Aethercomm Inc.,
San Marcos, CA (760) 598-4340.
Circle No. 297

Dual-band, High Power Amplifiers

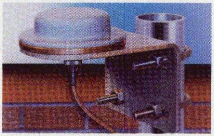
These flexible dual-band, high power amplifiers allow easy utilization of both Ku- and DBS-band frequency ranges in one compact unit making them ideal for mobile applications. The amplifiers are available in either single-thread or configurations, with three models available for power levels of 100, 300 and 500 W.

Xicom Technology,
Sunnyvale, CA (408) 481-3002, ext. 114.
Circle No. 299

[Continued on page 188]

NEW PRODUCTS
ANTENNAS

GPS Antenna

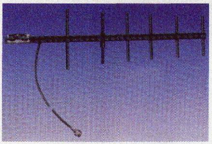


This fixed-mount GPS antenna enables the capture and deployment of synchronized time signals for timing applications in cellular, paging, PCS operations and other industries. It permits GPS signals to be used at fixed locations in establishing precise time/space reference measurements. In addition, the antenna can be used to geographically locate signal sources and is designed for operation under harsh conditions. Gain is 3.5 dB with an LNA gain of 26 dB, and the unit operates at a frequency of 1575 MHz ±4.0. SWR is < 2.0 and impedance is 50 Ω. Price: starts at $275. Delivery: four to six weeks.

Hirschmann,
Pine Brook, NJ (973) 830-2000.

Circle No. 254

Broadband Yagi Antennas



The models ASP-998 and ASPG998 Yagi antennas provide broadband coverage for the 806 to 894 and 890 to 960 MHz frequency ranges, respectively, eliminating field tuning. These lightweight, durable, water-resistent antennas are ideal for quick and easy deployment in point-to-point systems, wireless local loop, spread spectrum and select area coverage applications. The two antennas have 8 dBd (10 dBi) gain with an SWR of 1.5. Both are wind rated at 120 mph, have black DURACOAT™ aluminum elements, include completely encapsulated feed assemblies, are vertically polarized and have a 125 W power rating. Weight: 1.2 lb (0.55 kg). Length: 23.2 inches (58.9 cm).

Antenna Specialists, an Allen Telecom company, Cleveland, OH (440) 349-8400.

Circle No. 300

2.4 GHz ISM-MPR Parabolic Reflector Antennas

The models MPR24020, 24022 and 24024 parabolic reflector antennas are designed for the 2400 to 2483.5 MHz frequency band. They can be used as a bridge antenna between two networks or for point-to-point communications. The nominal impedance is 50 Ω. Wind survival is 110 mph with 1/2-inch of ice. The units feature a narrow beamwidth and have rugged mounts with a 20° fine-adjustment feature for horizontal and vertical planes.

MAXRAD,
Hanover Park, IL (800) 323-9122.

Circle No. 255

Embedded Antenna

The industry's smallest Bluetooth embedded antenna is currrently available for Bluetooth adopters. The 2.4 GHz model for notebook computers provides reliable, easy-to-use, adjustment-free antenna technology. This antenna features spherical coverage and is so small it can be mounted onto a board as if it were a component without sacrificing performance. In addition, the unit provides both vertical and horizontal polarization when installed on a horizontal plane, making it ideal for notebook computing devices.

Rangestar Wireless,
Aptos, CA (888) 647-7100
or (831) 661-4200.

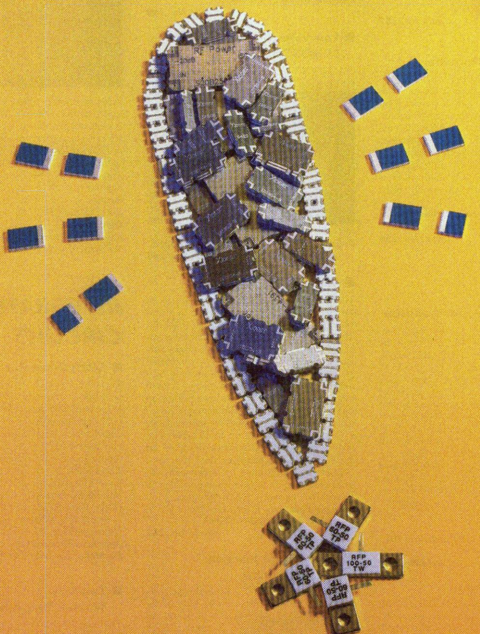
Circle No. 256

In-band Transverter/Antenna

The model MTR2000 MMDS transverter and antenna has been designed to operate in the MMDS band exclusively. It features 126 MHz of downstream and 12 MHz of upstream bandwidth. The pre-LNA filter and internal diplex-

[Continued on page 190]

What's next?



Anaren is proud to announce the acquisition of RF Power Components, Inc., to complement our current microwave component manufacturing and design capabilities. We welcome RF Power's management, engineers, employees, and customers to the Anaren family and look forward to providing our joint clients worldwide with new opportunities and ideas.

www.anaren.com

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NEW PRODUCTS

er provide excellent immunity to interfering PCS, military and weather radar signals. A single crystal oscillator provides the reference frequency for two phase-locked local oscillators. Optional antennas with gains of 15 or 18 dBi are also available.

REMEC Magnum Inc.,
San Jose, CA (408) 432-9898.

Circle No. 257

■ Dual-polarized Diagonal Horn Antenna

The model 9911-800 dual-polarized broadband diagonal horn antenna is designed for very low sidelobes and near-constant beamwidths. It was originally intended for use in radiometry data gathering, but may be used in any application requiring low sidelobes and/or near-constant beamwidth. The frequency range is 4.5 to 7.0 GHz with 21.0 dBil gain. SWR is 1.7, isolation is 20 dB (min) and cross polarization is 25 dB (min). The unit weighs approximately 17.5 lb.

Seavey Engineering Associates Inc.,
Pembroke, MA (781) 829-4740.

Circle No. 258

DEVICES

■ 860–960 MHz Power Transistor

The model PTF10160 power transistor features a flat power gain of 16 ±0.2 dB over the 869 to 894 MHz and 921 to 960 MHz ranges, while efficiency is 53 percent (typ). The 85 W device is supplied in a 20248 package, which offers a footprint of 34 × 19 mm, including flanges. Designed to operate from a standard 26 V power supply, the unit offers a drain-source breakdown voltage of 65 V. At 25 W peak envelope power, the third-order class AB two-tone intermodular distortion figure is a low –43 dBc. The transistor employs full gold metallization to ensure good device lifetime and reliability. To meet quality control procedures, 100 percent lot traceablity is standard.

Ericsson Microelectronics,
RF Power Products,
Newcastle-under-Lyme, Staffordshire, UK
+46 8 757 4700.

Circle No. 259

■ RF LDMOS Devices

The models MRF21125 and MRF21180 RF LDMOS devices are designed for use in 3G base station applications. The MRF21125 is a high power, single-ended device (125 W), and the MRF21180 is a high power, push-pull device (160 W) available in the 2.2 GHz band for wideband CDMA applications. The new devices are fully characterized, individually tuned to operate in the 2.1 to 2.2 GHz frequency range and suitable for all linear transmitter formats. The complete characterization of the devices makes them easier to use in applications where matched device performance is important. The MRF21125 is a single-ended, 125 W device with 20 W average power operating at 2170 MHz. For applications requiring higher peak and average power, the MRF21180 is an internal impedance-matched push-pull transistor that provides 160 W peak power and 24 W average power while meeting the wideband CDMA mask. Both devices are available in package styles with and without the flange and are designed for class AB wideband CDMA applications. Prices (10,000): $216 (MRF21125); $312 (MRF21180).

Motorola, Semiconductor Products Sector,
Phoenix, AZ (480) 413-5383.

Circle No. 260

■ Low Voltage RF Power LDMOS Transistor

This 7.5 V, 6 W surface-mount transistor exhibits 10 dB gain at 500 MHz. It is not internally matched and will perform well down to DC. The unit is designed for both narrow and wideband data/voice communication applications. Data sheets, Spice models and S-parameters are available at www.polyfet.com.

Polyfet RF, Camarillo, CA (805) 484-4210.

Circle No. 261

■ Varactor Tuning Diodes

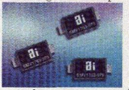
The models GVD60100 and GVD60200 silicon varactor tuning diodes are offered in a new surface-mount monolithic package (SMMP). This new package design approaches the size of a diode chip yet can be handled using surface-mount technology. It employs photolithographic methods at wafer fabrications to connect to the diode. Since this technique is more exact than wire bonding, it makes it possible to tightly control the parasitic package inductance. Operation is optimized at approximately 2 GHz and is possible up to 10 GHz. The 60100 has a C-V characteristic designed for low voltage VCO applications; the 60200 has a characteristic well suited for wide-bandwidth VCO designs. Both of the models have high Q. Price: $7.75. Delivery: eight to 10 weeks.

Sprague-Goodman Electronics Inc.,
Westbury, NY (516) 334-8700.

Circle No. 262

■ Hyperabrupt Junction Tuning Varactor

The model SMV1763-079 hyperabrupt junction tuning varactor is specifically designed for 3 V platforms and features a high capacitance ratio at low reverse voltage, making it ideal for low phase noise VCOs in wireless systems up to and beyond 2.5 GHz. The unit is designed for high volume, low cost battery applications, including low noise wideband UHF and VHF VCO for W-CDMA, GSM, PCS and analog phones. It is manufactured in the ultra-small SC-79 package and is available in tape and reel.



Alpha Industries,
Woburn, MA (781) 935-5150.

Circle No. 301

HARDWARE

■ Low Closure Force EMI Gaskets

This new line of SOFT-SHIELD® 5000 electromagnetic interference (EMI) gaskets are compliant with 94V-0 flammability requirements and are designed to meet the shielding and mechanical performance requirements for today's commercial electronic enclosures. Consisting of an electrically conductive fabric jacket over soft urethane foam, the gaskets require less than 1 lb/inch (0.175 N/mm) closure force to achieve 40 percent deflection. They are self-terminating and provide greater than 90 dB of EMI shielding from 30 MHz to 1 GHz, and more than 75 dB at 10 GHz. All gaskets are available with a pressure-sensitive adhesive tape for easy attachment. Profiles include rectangular, D- and P-shaped profiles, and C-folds. Price: $1/foot (500 ft) for standard lengths.

Chomerics,
a division of Parker Hannifin Corp.,
Woburn, MA (781) 939-4163.

Circle No. 302

INTEGRATED CIRCUITS

■ Clock Generator

The model FS6261-01 single-chip motherboard clock generator IC is designed for 133 MHz front-side bus motherboards and offers nonlinear, spread spectrum modulation for reduced system electromagnetic interference. It also delivers low cycle to cycle CPU clock jitter (under 150 ps p-p) for improved time margins. The FS6261-01 provides four CPU clocks at up to 133 MHz, two CPU/2 clocks, seven PCI bus clocks, four AGP clocks, three IOAPIC clocks, two REF clocks and one USB clock. It is available in a 56-pin, 0.3-inch shrink small outline package. Price: $2.18 (10,000).

American Microsystems Inc. (AMI),
Pocatello, ID (208) 233-4690.

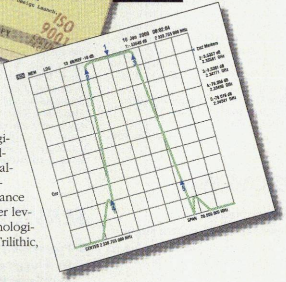
Circle No. 311

■ Two-way Wireless Transceiver

The model PT800 multipurpose RF (MuRF) transceiver enables two-way radio communication in personal wireless connectivity applications operating in the 220 to 870 MHz and 902 to 928 MHz industrial, scientific and medical bands. The unit halves the number of components normally required for two-way radio transmission, which reduces power consumption by up to 100 percent and cost by up to 50 percent. The frequency-locked active filter design enhances gain, sensitivity and selectivity while minimizing battery power consumption. The peak power consumption for the receiver section is less than 8 mW, which is a reduction of 40 to 100 percent. The transceiver powers

[Continued on page 192]

At Trilithic, our engineers are thinking all the time. One of the things we've been thinking about lately is how to utilize recent advances in ceramic technology and its significant power handling capabilities. We thought it might be interesting to apply this technology to our advanced filter product line. Offering superior insertion loss and suppression performance, the Trilithic dielectric resonator filter configuration offers a variety of advantages. RF design engineers will now enjoy greater flexibility in meeting demanding spectral purity and interference requirements for specialized wireless communication systems. The result is an outstanding filter implementation, offering cryogenic performance for insertion loss and signal suppression during high power levels – at room temperatures (patent applied for). This technological creativity may seem alien to some. But then again, at Trilithic, we see the world a little differently.



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Philsar Semiconductor Inc., Nepean, Ontario, Canada (800) 551-2319 or (613) 274-0922.

Circle No. 230

Low Drift RF Detector/Controller

The model AD8314 RF detector/controller enables precise, temperature-stable power amplifier control and supports all current and emerging cellular standards. It replaces discrete diode detectors and offers wireless designers a single-package IC solution. Operating at up to a 2500 MHz frequency range with 45 dB dynamic range, the unit handles a wide signal range with ±0.5 dB accuracy. Designers no longer have to adjust for temperature variability during manufacturing, and design time is reduced. The detector/controller also minimizes board area due to its eight-pin microSOIC packaging, which reduces required space by as much as 50 percent. Price: $3.95 (1000).
Analog Devices Inc., Wilmington, MA (800) 262-5643.

Circle No. 303

MATERIAL

Urethane Liquid Foam System

The ECCOSTOCK®FPH high temperature rigid foam in place urethane series gives users a two-part liquid foam system for filling cavities populated with sensitive electronics to provide lightweight, low dielectric loss, thermal insulation and vibration-damping properties. The series is available in kits with densities of 2, 4, 6 and 10 pound/ft³. Kits are available in 2-, 10- and 70-pound sizes.
Emerson & Cuming Microwave Products, Randolph, MA (800) 650-5740 or (781) 961-9600.

Circle No. 304

PACKAGING

Hermetic Headers, Connectors and Feedthroughs

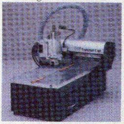
This new line of hermetic headers, connectors and feedthroughs uses pins made of Alumel, Chromel or copper. It is possible to use these materials in glass-to-metal seals with a variety of body materials due to a newly developed sealing glass and the company's proprietary Tek-Seal™ sealing process. The pin materials are especially suited to the temperature-sensing industry or any application in which low electrical resistance is required.
Tekna Seal Inc., a division of Maxwell Technologies, Minneapolis, MN (612) 574-1613.

Circle No. 267

PROCESSING EQUIPMENT

Circuit Board Plotters

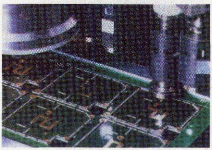
The ProtoMat C series circuit board plotters are designed based on a 75 mm cast aluminum base plate framework, ensuring high resistance to torsion and vibration absorption without excessive weight. Dimensional accuracy is achieved and maintained by precise milling and integration of patented roller guides under the machine table. The y-axis of the series is constructed of a solid cast aluminum frame with a V profile cross section and patented integrated guides. The ProtoMat technology has thus been improved such that even with the smaller model, structures finer than 0.1 mm can be produced when milling printed circuit boards.



LPKF Laser & Electronics AG, Garbsen, Germany +49 (0)5131-7095-0.

Circle No. 268

EMI Gasket Installation System



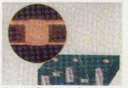
The GORE-SHIELD ALLEGRO™ semi-automatic assembly machine rapidly and accurately installs GORE-SHIELD® EMI gaskets that are narrower than 1 mm and at throughputs consistently faster than other smaller machines. It is ideal for medium to high volume production of shielding components used in hand-held portable devices, such as cellular telephones. The system is designed for low maintenance operation, long service life and maximum throughput.
W.L. Gore & Associates Inc., Newark, DE (800) 445-4673.

Circle No. 305

SERVICE

Prototyping Service for Plugging High Density Multilayer PC Boards

This service utilizes microvia technology, which eliminates the need for through-hole plating and results in highly miniaturized PC boards with blind, buried and throughhole vias. The technology is ideal for the production of most compact electronic systems and equipment and is intended to "boot strap" the process of getting potential users started with microvia-equipped PC boards by showing both designers and manufacturers how the process works and demonstrating what types of benefits it offers.



Methode Development Co., a subsidiary of Methode Electronics Inc., Chicago, IL (800) 323-6858.

Circle No. 269

SOFTWARE

High Frequency Circuit and System Design Software

Serenade Version 8.5 is the latest version of the company's high frequency circuit and system design software, which adds powerful new capabilities for demanding RFIC, MMIC and wireless circuit and system designs. Features such as compiled user-defined models and Matlab cosimulation provide engineers with customizable models necessary for advanced device simulation found in today's telecommunication systems. These benefits provide a significant increase in the flexibility of both the linear and nonlinear circuit and system design suites. New layout capabilities enhance features such as parameterized footprints and support of an arbitrary number of layers.
Ansoft Corp., Pittsburgh, PA (412) 261-3200.

Circle No. 270

Calibration Software

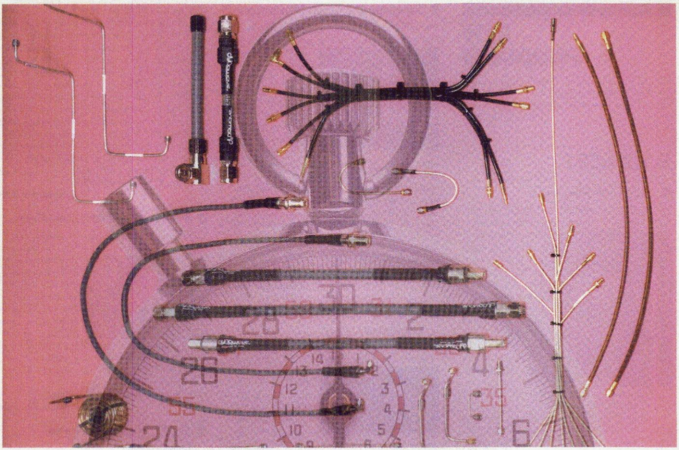
This newest version of MET/CAL® Plus calibration software now extends workload coverage to include RF and microwave instruments like signal generators. The software also meets new international standards for calculating and reporting measurement uncertainties, and adds synchronization and Web server options. This capability further enhances the software's usability and accessibility in remote and network applications. Price: $3800 (upgrade from previous version, $1000).
Fluke Corp., Everett, WA (888) 492-7554.

Circle No. 271

Electronic Design Automation Products

GoldenGate/Sim™ and GoldenGate/NN-Model Compiler™ software dramatically accelerates design cycles for RF and wireless communication. The products are targeted to designers developing products for existing 2G and rapidly evolving 3G and Bluetooth communication standards. GoldenGate/Sim is a comprehensive RF circuit- and subsystem-level simulation and analysis tool that offers advanced, robust and accurate linear RF, harmonic balance and envelope circuit simulation tools with unique linear and nonlinear stability and phase noise analysis capabilities. GoldenGate/NN-Model Compiler is an innovative behavioral modeling tool based on neural network technology that enables designers to accelerate RF circuit and subsystem simulation while maintaining circuit-level simulation accuracy. It significantly increases productivity of wireless system designers and enables them to handle complex designs. Prices: GoldenGate/Sim is $55,000 for Unix platforms, $10,000 to 40,000 for Windows™ platforms; GoldenGate/NN-

[Continued on page 194]



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To be more efficient and more competitive, call a company that's more efficient and competitive. Dynawave. For over ten years, we've been designing and manufacturing low cost, superior quality cable assemblies, delay lines, and harnesses for the wireless and military markets. Our on-demand and just-in-time delivery systems can satisfy the most stringent procurement requirements. And we can deliver prototypes, short runs, and high volume production with the same efficiency.

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NEW PRODUCTS

Model Compiler is $75,000 for both platforms.
Xpedion Design Systems Inc.,
Santa Clara, CA (408) 987-0615.
Circle No. 266

SOURCES

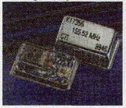
■ 925–1650 MHz VCO

The model V585ME20 VCO has been engineered for the cable modem market and offers linear, broadband tuning and single-sideband phase noise performance. The unit generates frequencies from 925 to 1650 MHz within 3 to 21 V DC of control voltage and covers the frequency range with an average tuning sensitivity of 57 MHz/V. The VCO also exhibits good spectral purity of –102 dBc/Hz (typ) at 10 kHz from the carrier while drawing 16 mA of current from an 11.5 V DC supply. The unit offers 7 ±2.5 dBm of output power into a 50 Ω load and is designed for tough outdoor applications since it is specified to operate over the extended commercial temperature range of –40° to +85°C. In addition, the device can optimize any cable modem phase-locked loop with its 1.1:1 linearity over frequency and temperature. The VCO also pulls less than 20 MHz with a 14 dB return loss, any phase, and has a pushing specification of less than 2 MHz/V within a five percent change in the supply voltage. The unit is supplied in an industry-standard, low profile, miniature SMT package measuring 0.50" × 0.50" × 0.22". Price: $15.95 (5). Delivery: stock to six weeks.

Z-Communications Inc.,
San Diego, CA (858) 621-2700.
Circle No. 277

■ PECL VCXOs

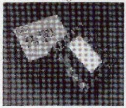
The models K17255 and K17355 positive emitter-coupled logic (PECL) complementary output voltage-controlled-crystal oscillators (VCXO) are configured to operate at 155.52 MHz and provide a total frequency stability of ±30 ppm at 0° to 70°C and ±50 ppm at –40° to +85°C. The K17255 operates from a 5.0 V supply voltage and the K17355 operates from a 3.3 V supply voltage. The devices are ideal for low jitter performance (5 ps, typ) as jitter performance is maintained while the VCXOs exhibit waveform rise and fall times of less than 450 p. The crystal is hermetically sealed for predictable long-term aging and reliability.



Champion Technologies Inc.,
Franklin Park, IL (800) 888-1499.
Circle No. 272

■ Synchronous Clock Generators

The SCG series synchronous clock generators has been engineered to replace discrete designed phase-locked loops (PLL). The generators will accept an input reference signal at one frequency and the output will be a jitter-reduced, phase-coherent signal at a higher frequency. The SCG devices are miniature timing subsystems that dramatically reduce design time in a complete single-packaged PLL. When used with a timing module the user has a complete packaged telecom timing system and can be assured the maximum, tight-tolerance performance.



Connor-Winfield Corp.,
Aurora, IL (630) 851-4722.
Circle No. 306

■ SAW-based, Voltage-controlled Oscillator

The model VS-500 SAW stabilized, voltage-controlled oscillator operates at the fundamental frequency of the internal SAW filter. It is a high stability, high Q quartz device that enables the circuit to achieve low phase jitter performance over a wide operating temperature range: 3 pS rms (typ) for 622.080 MHz and 6 pS rms (typ) for 155 MHz. The VS-500 has output frequencies from 155 MHz to 1 GHz with 10 K ECL, PECL logic levels and fast transition times. The unit is ideal for clock smoothing and frequency transition in clock and data retiming applications. It is housed in a low profile, surface-mount package that is the smallest available at 622.080 MHz.

Vectron International,
Norwalk, CT (888) 328-7661.
Circle No. 307

■ Ceramic Resonator

The CSTS-MG series resonator is a drop-in replacement for the company's CST-MGW, downsized 10 percent in width and 20 percent in thickness. It has a shorter standard lead length than the current CST-MGW (3.5 vs. 5.0 mm) with excellent temperature and secular characteristics. In addition, the resonator has improved mounting reliability due to round leads and is available on tape.
MuRata, Smyrna, GA (770) 436-1300.
Circle No. 274

SUBSYSTEMS

■ Integrated Modular Assemblies

Designed for microwave, RF, video and audio test applications in the DC to 18 GHz range, these integrated modular assemblies provide a good interface between test equipment and complex, sophisticated systems with multiple inputs and outputs that need to be tested. The company's switch matrix technology provides the basis of the integrated assemblies. A variety of passive components are added, depending on the schematic, to provide customization and increased functionality to testing processes. The units' modular design adds flexibility by allowing the removal of sections from the complex assembly for easy maintenance and service. The switches range from SPST to SP6T, transfers, T-switches and a family of waveguide designs as well as waveguide blocks, matrices and integrated assemblies.

Dow-Key Microwave Corp.,
Ventura, CA (805) 650-0260.
Circle No. 279

■ Pre-approved RF Transceiver

The model TR-916-SC-PA RF module can be integrated into products without further certification from the FCC, which saves customers thousands of dollars and untold delays in bringing their products to market. The unit operates in the 900 MHz band and is capable of transferring analog or digital content bidirectionally. Price: $34.70.

Linx Technologies,
Grants Pass, OR (541) 471-6256.
Circle No. 281

■ C-, X-, Ku- and K-band Linearizers

The WAFL series predistortion linearizers can give TWTAs an effective 4× power increase with multicarrier traffic. The frequency ranges are 5850 to 6650 MHz, 7900 to 8400 MHz, 13,750 to 14,500 MHz and 17,300 to 18,400 MHz, respectively. The input/output SWR is less than 1.35. Input power is 120/220 V AC, less then 20 W. The units are easy to tune with full uplink bandwidths.
Linearizer Technology Inc.,
Hamilton, NJ (609) 584-8424.
Circle No. 280

TEST EQUIPMENT

■ Digital Power Meter

The model 5000 THRULINE® digital power meter is the industry's first hand-held directional RF power meter combining a digital display with the ability to accurately measure power in both analog and digital RF systems. Its rugged construction and rechargeable NiMH battery make it ideal for use in the field. The operation is fast and easy with a backlit digital display, simple menu commands and five dedicated speed keys. The device provides average, true average or peak measurements of 0.1 to 10,000 W with ±5 percent accuracy and automatically calculates SWR, return loss and match efficiency. Operating range is 0.45 to 3600 MHz.

Bird Electronic Corp.,
Cleveland, OH (440) 248-1200, ext. 2226.
Circle No. 284

[Continued on page 196]

a Wide Range of

Quality Attenuators

Step-Rotary / Continuously Variable / Fixed Coaxial

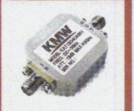
Designed by KMW for consistency and stability, these Attenuators will be your first choice for building wireless communication system applications

KAT2DO4SA000
KAT1DO4SA002

Step-Rotary Attenuators

Product Code No.	KAT2DO4SA000	KAT1DO4SA002
Operating Type	Make-Before-Break	
Frequency Range	DC ~ 3GHz	DC ~ 3GHz
Insertion Loss (Max.)	0.2dB	0.2dB
VSWR (Max.)	1.15:1	1.15:1
Incremental Attenuation Range (dB)	0 ~ 1	0 ~ 10
Attenuation Step (dB)	0.2	1
Nominal Impedance	50 ohm	
I/O Port Connector	SMA(F) / Right Angle SMA(F)	
Average Power Handling	1W @ 2GHz	
Temperature Range	-30°C ~ +80°C	
Dimension (inch)	1.925*1.567*2.224	

KAT13O4CA000



KAT13O4CA001

Continuously Variable Attenuators

Product Code No.	A type : KAT13O4CA000 B type : KAT13O4CA001		
Frequency Range	DC ~ 1GHz	1 ~ 2GHz	2 ~ 3GHz
Insertion Loss (Max.)	0.15dB	0.3dB	0.35dB
VSWR (Max.)	1.25:1	1.25:1	1.25:1
Attenuation Range (Min.)	13dB @ 2GHz		
Nominal Impedance	50 ohm		
I/O Port Connector	SMA(F) / SMA(F)		
Average Power Handling	2W @ 2GHz / 25°C, without Heat-Sink		
Temperature Range	-55°C ~ +85°C		
Dimension (inch)	A type : 1.496*1.102*0.457 B type : 1.224*1.102*0.457		

Fixed Coaxial Attenuators are available

N-type, SMA-type Connectors

13131 East 166th Street, Cerritos, CA 90703-2202
1-800-8320-KMW • www.kmwinc.com
tel: 562.926.2033 • fax: 562.926.6133

KMW

NEW PRODUCTS

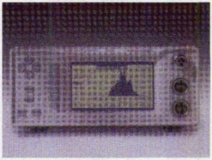
Noise Generator

The VXI9000 series programmable noise generator is able to switch between two noise bands within one instrument, providing dual-frequency capabilities. Available options include a signal and noise combiner, 0.1 dB precision attenuation steps for both the signal and the noise path, and custom noise filtering. Frequency ranges are available from 10 Hz to 40 GHz.

Noise Com,
Paramus, NJ (201) 261-8797.

Circle No. 286

Universal Power Meters



The 8650A series universal power meters have added significant new features such as histograms, CDF/CCDF and strip chart capabilities. They are available in single- and dual-channel configurations and have extensive measurement capabilities and features required to measure the peak and average power of TDMA, GSM and CDMA (IS-95 and third-generation) signals. They can also measure CW and pulse modulated signals with NIST-traceable accuracy from 10 MHz to 40 GHz over a –70 to +47 dBm range. The new histogram, CDF/CCDF and strip chart measurement features join crest factor standard deviation and mean power to provide statistical analysis modes for evaluating

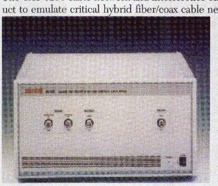
[Continued on page 198]

NEW PRODUCTS

modulated signals over a selected time interval. Prices: $3310 (single channel), $4870 (dual channel). Delivery: 30 days.
Giga-tronics Inc.,
San Ramon, CA (800) 726-4442.

Circle No. 285

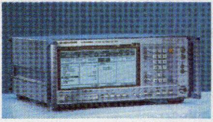
Cable Network and Interference Emulator



The TAS 8250 cable network and interference emulator is the first product to emulate critical hybrid fiber/coax cable network impairments in a controllable laboratory instrument. It is an ideal tool for evaluating the transmission performance of cable modems, cable modem termination systems, set-top boxes, HDTV equipment and Internet protocol products. It emulates both upstream (5 to 42 MHz) and downstream (50 to 860 MHz) HFC channel characteristics in a single, integrated instrument. A built-in diplex filter conveniently combines the upstream and downstream channels from the CMTS (or headend) into a single interface, allowing single or multiple subscriber devices to be tested.
Telecom Analysis Systems Inc. (TAS),
Eatontown, NJ (732) 544-8700.

Circle No. 287

TV Test Transmitters

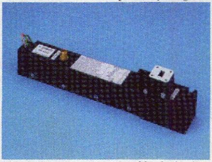


The new DVB-T SFQ-TV test transmitter features bandwidths of 6, 7 and 8 MHz as well as hierarchial coding in 2k and 8k COFDM mode. The ATSC model complies with the DTV standard and has 8 VSB and 16 VSB capability.
Rohde & Schwarz GmbH & Co. KG,
Munich, Germany +49 89 4129-3779.

Circle No. 276

TUBES

Miniature Traveling-wave Tube



The TH 4030 traveling-wave tube is part of a new range of conduction-cooled mini tubes that is specifically designed for satellite uplink and local multiple distribution system (LMDS) applications. Operating in a bandwidth of 25.5 GHz to 31.5 GHz it covers all frequencies used by these applications. Developing 40 W CW, the unit also accommodates most of the power requirements for satellite uplink and LMDS. The dual- stage collector enables high efficiency driving power consumption down to 140 W (max). It has a gain of 45 dB (min). Size: 180 × 30 × 40 mm.
Thomson Tubes Electroniques,
Velizy, France +3 (1) 30 70 36 40.

Circle No. 288

NEW LITERATURE

PRODUCT CATALOG

This 132-page catalog offers information and specifications on the company's full line of RF inductors, power inductors, EMI/RFI suppressors, transformers and other specialty products. Industry-standard, circuit solution and application-specific components are detailed as well as a number of new products.
API Delevan Inc.,
East Aurora, NY (716) 652-3600.
Circle No. 200

RF PRODUCT DATA SHEET

This two-page data sheet describes a variety of RF products, including adapters, connectors, cable assemblies, attenators, circulators, splitters, loads and custom assemblies. A "build your own coax cable" fax form is included.
Delaire USA,
Manasquan, NJ (732) 528-4520.
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RF CONNECTOR CATALOG

This 176-page catalog contains drawings and specifications for the company's 25 standard connector series, which range from subminiature types to large, high power connectors. Full cable assembly instructions and mounting dimensions are included as well as a section outlining many of the company's production technologies. A CD-ROM version is also available.
Delta Electronics Manufacturing Co.,
Beverly, MA (978) 927-1060.
Circle No. 202

OVEN-CONTROLLED CRYSTAL OSCILLATOR DATA SHEET

This two-page data sheet describes the model FE-2260A temperature-stable, oven-controlled crystal oscillator. This unit features warm-up to stabilized frequency in less than two minutes and temperature stability of 5×10^{-8} (–55° to +85°C). Full specifications and technical highlights are listed.
Frequency Electronics Inc.,
Mitchel Field, NY (516) 794-4500.
Circle No. 203

ELECTRONIC PACKAGING PRODUCT CATALOG

This 38-page catalog describes a variety of connecting, heat dissipation and shielding solutions. It focuses on elastomeric connectors where space is most limited, offering up to 500 conductors per inch, thermal management components, shielding and custom silicone rubber extrusions.
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COAXIAL PROBE SUPPLEMENTARY CATALOG

This supplementary catalog details some of the company's most successful custom coaxial probe designs, expanding on the nine offerings in the current catalog and sourcebook. The probes feature true rated characteristic impedance through their entire length and are available in both 50 and 75 Ω versions.
Interconnect Devices Inc. (IDI),
Kansas City, KS (913) 342-5544.
Circle No. 205

RF PERSONAL MONITOR DATA SHEET

This data sheet describes the 8846 and 8848 series RF personal monitors, which offer 300 kHz to 45 GHz detection in one unit. The monitors' patented "shaped" frequency response is designed to conform to Federal Communications Commission, Safety Code 6, ICNIRP and NRPB standards and guidelines. Specifications and photographs are provided.
Narda, an L-3 Communications company,
Hauppauge, NY (631) 231-1700.
Circle No. 206

CABLE ASSEMBLY AND ADAPTER CATALOG

This 60-page catalog features an extensive line of standard flexible and semirigid cable assemblies and coaxial adapters. Also included are descriptions of RF/microwave components, such as isolators, circulators, detectors, limiters, attenuators, terminations, and phase-adjustable adapters and connectors.
Microwave Distributors Company (MDC),
Islandia, NY (800) 637-4353.
Circle No. 207

DC-TO-DC CONVERTER REFERENCE GUIDE

This eight-page reference guide (*Power Page*™ 41) is designed to aid engineers in improving performance in systems using DC-to-DC converters. It includes discussions of the key safety, thermal and mechanical considerations that are applied to the use of these converters as well as details on the input and output connections and sense circuits required for optimum system performance.
Powercube,
Chatsworth, CA (800) 866-3590.
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TRIMMER CAPACITOR BULLETIN

This 12-page bulletin describes the company's complete line of ceramic dielectric trimmer capacitors. It contains product data for surface mount, lead-through-hole and hybrid application models. Features, specifications, outline drawings and application notes are also included.
Sprague-Goodman Electronics Inc.,
Westbury, NY (516) 334-8700.
Circle No. 210

SINGLE-ENDED ALUMINUM ELECTROLYTIC CAPACITOR DATA BOOK

This 172-page data book provides a chart for viewing new and existing single-ended aluminum electrolytic capacitors at a glance. A company overview, list of applications and complete set of data sheets are also included.
EPCOS Inc. (formerly Siemens),
Iselin, NJ (800) 888-7729.
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TEST SOLUTION CATALOG

This 152-page catalog (*EMC Test Solutions*) describes the company's complete line of electromagnetic compatibility (EMC) instrumentation systems and services, with primary coverage given to EMC test solutions for the industrial, commercial, telecom and automotive industries.
Schaffner EMC Inc.,
Edison, NJ (732) 225-9533.
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CIRCLE 162 ON READER SERVICE CARD

Flip Chip Technologies

John H. Lau
McGraw-Hill
565 pages; $89
ISBN: 0-07-036609-8

Of the three popular chip-level connection technologies, flip chip provides the highest packaging density and performance, and the lowest packaging profile. Unfortunately, it is also the least understood. This book deals with classical solder-bumped flip chip technologies, the next-generation flip chip technologies and known-good-die (KGD) testing for multi-chip module (MCM) applications.

> *"...flip chip provides the highest packaging density and performance, and the lowest packaging profile."*

Solder-bumped flip chip technology is described, including a new fluxless process called plasma-assisted dry soldering. Important aspects of the electrical and thermal performance of solder-bumped flip chip assemblies are discussed as well as a methodology to develop accelerated test strategies. Some test results of the thermal management, manufacturability and reliability of very large and high I/O flip chip technologies are examined. The design, development and optimization of manufacturing processes for cost-effective, large-volume assembly of flip chip are presented.

Polymer flip chip technology is overviewed along with design, process, electrical and mechanical reliability data. Polymer bump formation and metallization, assembly/rework processes, and fabrication costs are discussed. Applications of anisotropic conductive film (ACF) and adhesive (ASA) paste are described. The principle of ACF interconnects and the role of conducting particles dispersed in ACF are presented, along with the application of ACA and ACF materials to flip chip on glass technology.

Face-down wired flip chip technologies are covered along with an area array tape-automated bonding type of flip chip. Metallurgy-bumped flip chip technology is discussed as well as bumping processes and characteristics for Au, AuSn and NiAu metallurgies, and Au stud and solder-stud bumps. The final section deals with the application of flip chip technology to MCM packaging. KGD definition and standards are presented and the principles of burn in for flip chip ICs are explained.

This book is particularly aimed at individuals active in research and development of flip chip technologies, and is useful to those engineers who have encountered problems with the technology or must choose a high performance, robust and cost-effective packaging technique for their product.

To order this book, contact: McGraw-Hill Publishing Co., New York, NY (800) 262-4729.

Radio Propagation in Cellular Networks

Nathan Blaunstein
Artech House Inc.
386 pages; $89, £61
ISBN: 1-58053-067-2

This book examines the different situations of wireless communication in an urban environment and various propagation phenomena that influence the line-of-sight (LOS) and non-line-of-sight (NLOS) obstructive transmission of radio signals through urban communication channels. The various phenomena described include free-space propagation above regular and irregular terrain, reflection and diffraction by various obstacles regularly or randomly distributed on the terrain, and effects of scattering from such obstructions and from the ground surface. The behavior of waves at UHF and L-band frequencies is emphasized.

The book is segmented into four parts. Part one describes how to differentiate between various urban environments by using different kinds of terrain surfaces and antenna positions. Applied aspects of electromagnetism and wave propagation are discussed.

Part two describes the propagation phenomena in open and rural areas. Radio wave propagation over flat and curved smooth terrain is then discussed and propagation in rough and hilly terrain for LOS and NLOS conditions is depicted.

> *"This book examines the different situations of wireless communication in an urban environment..."*

Part three describes propagation phenomena in built-up areas. Evaluation by means of a multi-slit street waveguide model is introduced to describe wave propagation characteristics along straight, rectangular streets in cases where both antennas, receiver and transmitter, are directly visible at lower than rooftop levels or with NLOS conditions. Irregular built-up terrain is considered and existing empirical and semi-empirical models are presented for describing propagation characteristics above rough terrain with many obstacles randomly distributed.

Part four considers special aspects of cellular map construction. The main characteristics of cellular areas are described and a useful technique for predicting the dimensions and geometry of contours of cellular maps using the propagation characteristics for each cellular channel is presented.

To order this book, contact: Artech House Inc., 685 Canton St., Norwood, MA 02062 (781) 769-9750, ext. 4002; or 46 Gillingham St., London SW1V 1HH, UK +44 (0)20 7596-8750.

Frank Bashore

Frank Bashore is a member of the Microwave Journal *staff.*

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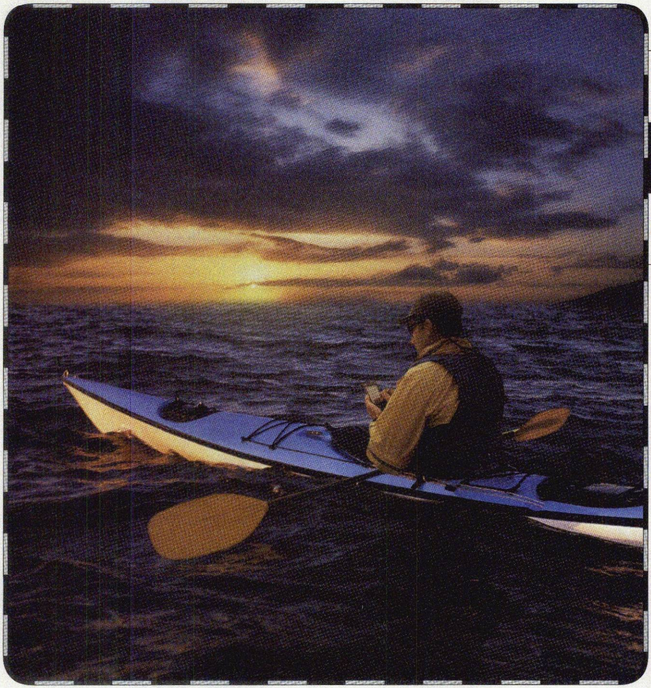
He just placed a market order.
But got bread and milk instead. Isn't 3G great?



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