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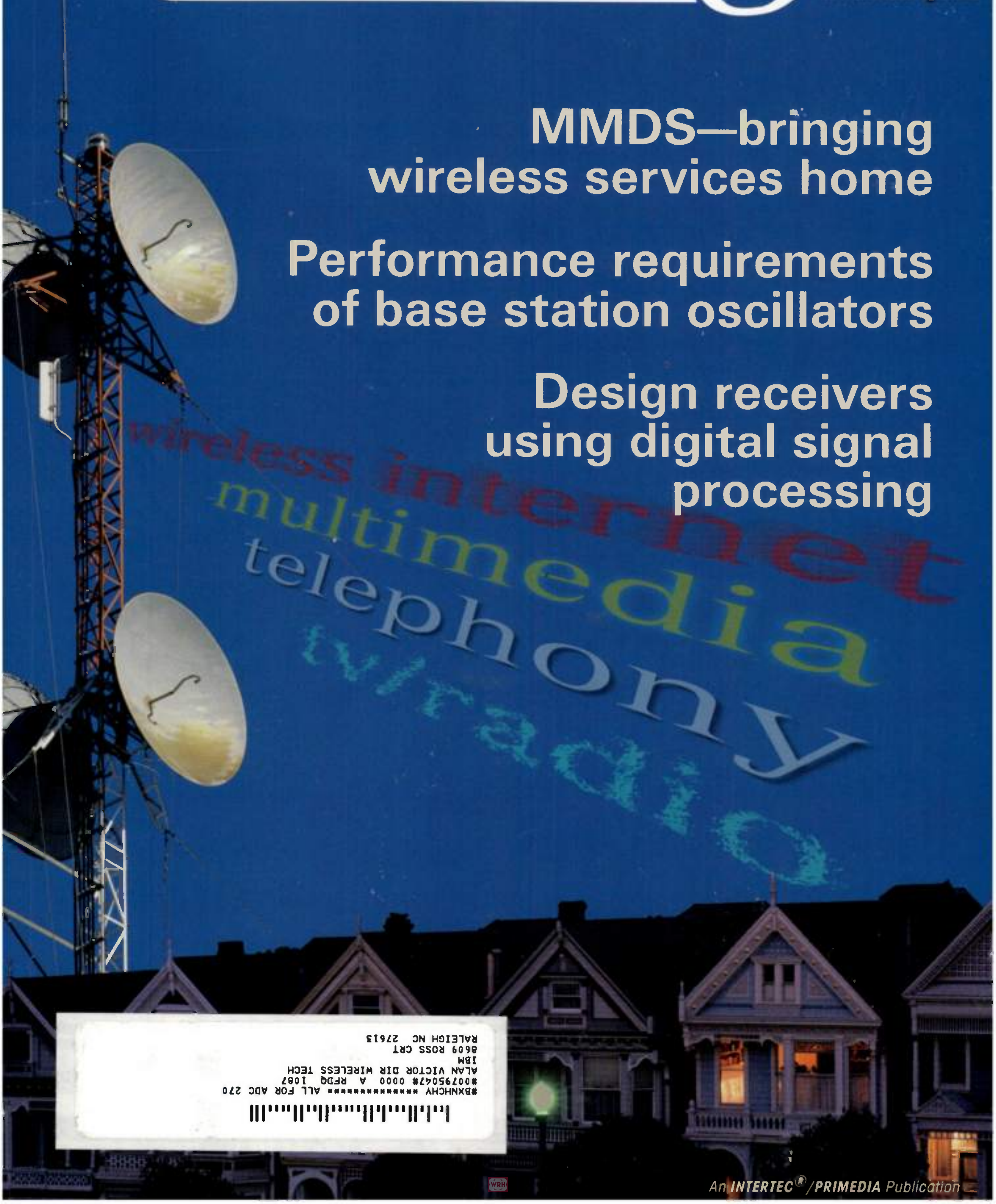

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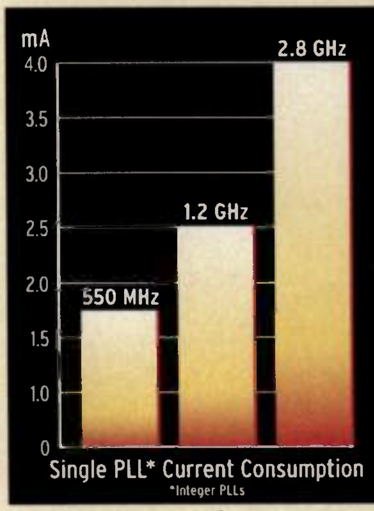
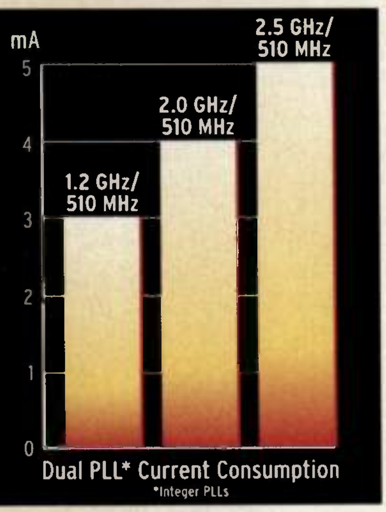
INFO/CARD 1

Part Number	RF Input (Main & Aux PLLs)	Active I_{CC} (typ @ 3V)	V_{CC} Range	Package
Single PLLs				
LMX2306	550MHz	1.7mA	2.3 to 5.5V	TSSOP16*
LMX2316	1.2GHz	2.5mA	2.3 to 5.5V	TSSOP16*
LMX2326	2.8GHz	4.0mA	2.3 to 5.5V	TSSOP16*
Dual PLLs				
LMX2330L	2.5GHz & 510MHz	5.0mA	2.7 to 5.5V	TSSOP20*
LMX2331L	2.0GHz & 510MHz	4.0mA	2.7 to 5.5V	TSSOP20*
LMX2332L	1.2GHz & 510MHz	3.0mA	2.7 to 5.5V	TSSOP20*
LMX2335L	1.1GHz & 1.1GHz	4.0mA	2.7 to 5.5V	TSSOP16/SO16*
LMX2336L	2.0GHz & 1.1GHz	5.0mA	2.7 to 5.5V	TSSOP20*
LMX1600	2.0GHz & 500MHz	5.0mA	2.7 to 3.6V	TSSOP16*
Frac-N Dual PLLs				
LMX2350	2.5GHz/550MHz	7mA	2.7 to 5.5V	TSSOP24*
LMX2352	1.2GHz/500MHz	5.5mA	2.7 to 5.5V	TSSOP24*

*CSP package option also available.





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INFO/CARD 2

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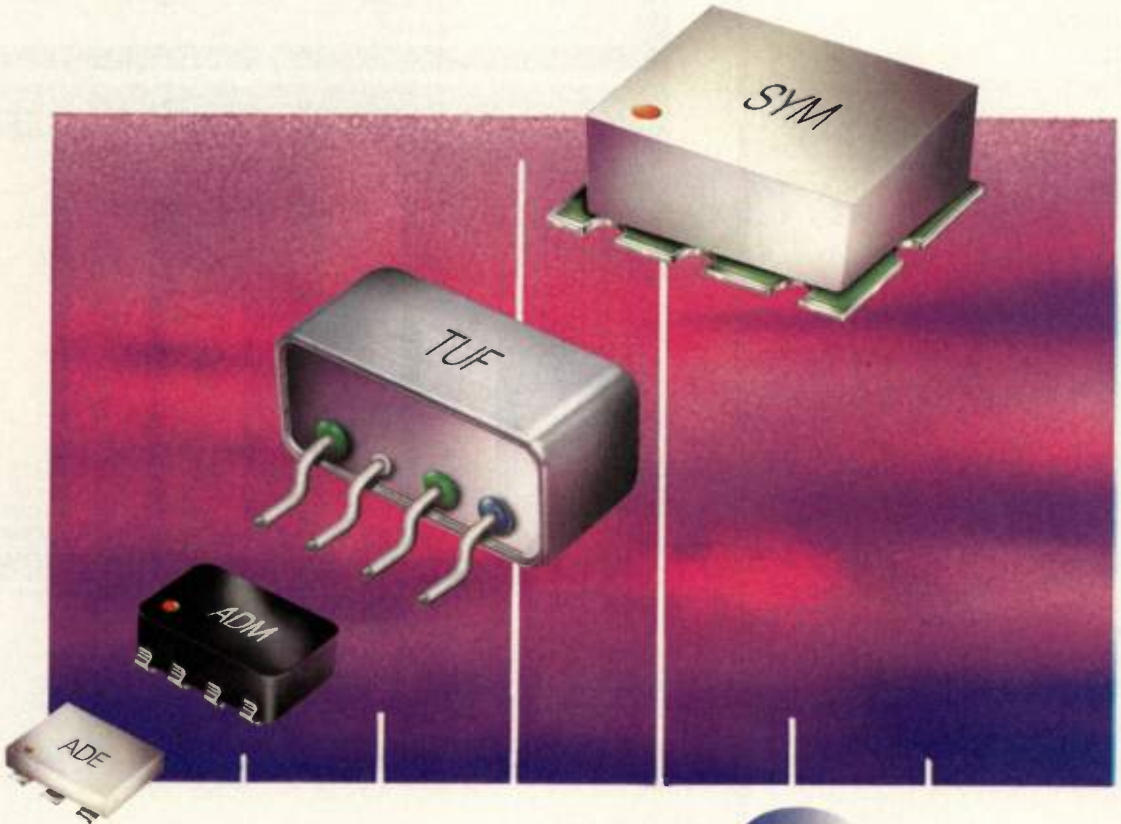
suppress noisy intermods



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*ADE-12H	500-1200	28	34	28	6.7	8.95**
SYM-18H	5-1800	30	45	40	5.75	17.95
SYM-10DH	800-1000	31	45	29	7.6	18.95
SYM-22H	1500-2200	30	33	38	5.6	19.95
•TUF-18DHSM	100-1800	27	41	33	7.3	21.95
*ADM-10DH	800-1000	30	35	37	6.0	15.95

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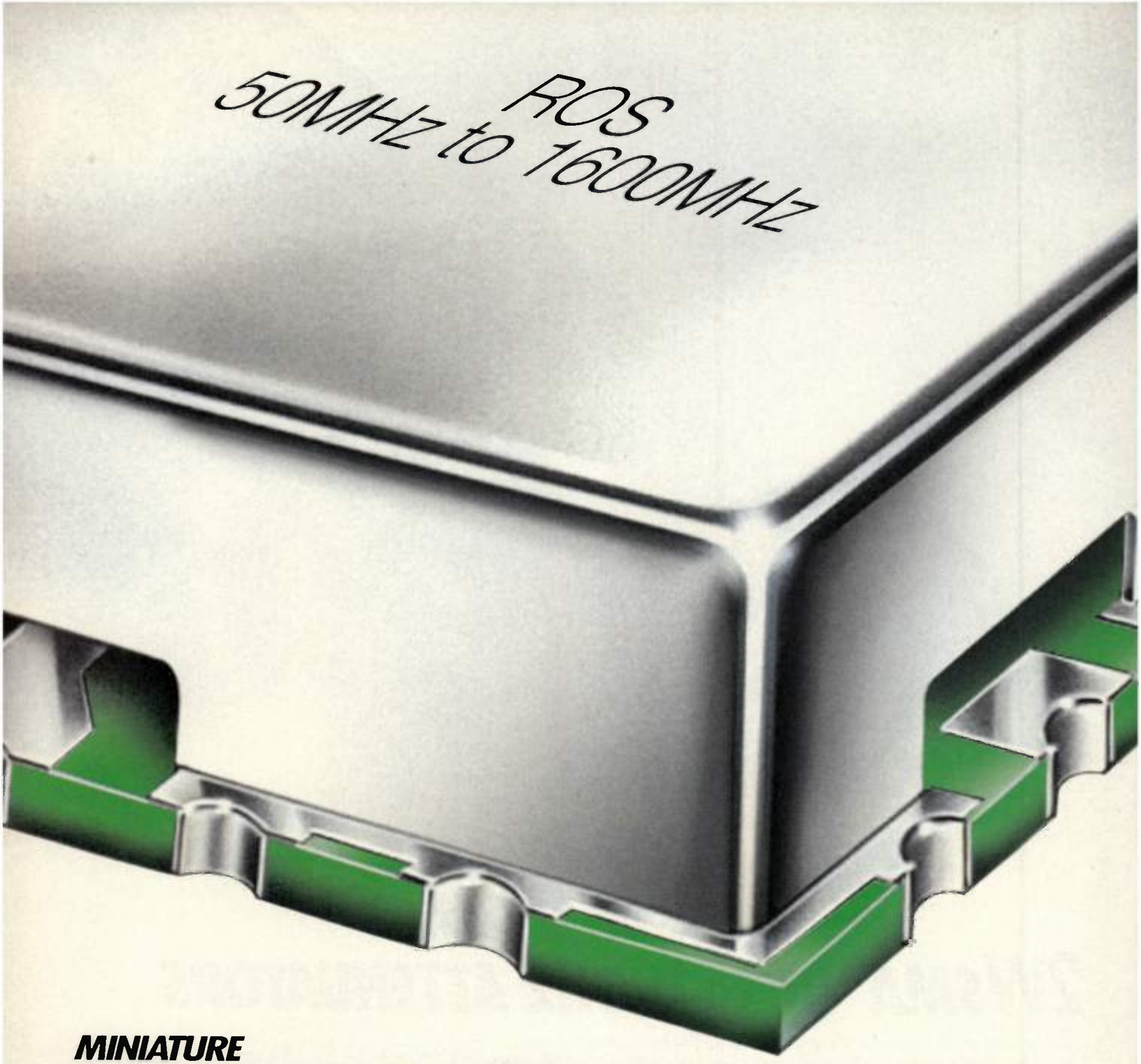

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ROS SPECIFICATIONS:

Model	Freq. Range (MHz)	V_{tune} (V) Max.	Phase Noise* Typ.	Harmonics** (dBc) Typ.	Voltage V	Current (mA) Max.	Price $ea. (5-49)
ROS-285PV	245-285	5	-100	-20	5	20	17.95
ROS-900PV	810-900	5	-102	-25	4.5	12	19.95
ROS-960PV	890-960	5	-102	-27	5	12	19.95
ROS-1000PV	900-1000	5	-104	-33	5	22	19.95
ROS-1600PV	1520-1600	5	-100	-26	5	25	18.95
ROS-100	50-100	17	-105	-30	12	20	12.95
ROS-150	75-150	18	-103	-23	12	20	12.95
ROS-200	100-200	17	-105	-30	12	20	12.95
ROS-300	150-280	16	-102	-28	12	20	14.95
ROS-400	200-380	17	-100	-24	12	20	14.95
ROS-535	300-525	17	-98	-20	12	20	14.95
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in this issue


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DEPARTMENTS

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GET LINKED — RF Design Online now has three ways to link to companies mentioned in this issue: *advertiser links*, *product directory* and *editorial links*. See page 66 for more information.

High-tech manufacturing. Who said it was easy?

By Don Bishop
Editorial Director

Our friends from Sunnyvale, CA-based Spectrian came by the office to talk about engineering power amplifiers (PAs) for base stations.

First, the statistics. Easy now. Just a few.

Did you know that 4.2% of the cost of a base station is for the power amplifier? And that a third of the market for the amplifiers, $1 billion worth, is not "captive"?—meaning, for that portion, the original equipment manufacturers (OEMs) of the base station transmitters do not make their own power amplifiers. And that the PA is the most expensive single component?

"The key is cost, cost, cost," said Peter R. McIntyre from corporate communications.

Engineering and manufacturing for minimum cost to meet a standard defines many commercial projects. But wait. What if the standard hasn't yet been issued? Actually, a PA supplier can't wait, as McIntyre explained. Because the OEM can't wait.

Spectrian has to engineer a design and offer prototypes to OEMs well before a standard is set. If not, OEMs do the same to make sure they can be among the first to market with base stations for carriers.

"We have to break the make/buy decisions," McIntyre said.

Early engineering, a delivery track record and financial strength combine to convince OEMs not to make their own PAs but to buy them from suppliers.

John Pelose, vice president and general manager of the company's Multicarrier Business Unit added that third- and fourth-generation PAs are approaching commodity status. They are moving from small, high-tech manufacturing to high-volume production where manufacturing techniques make big cost differences and where off-shore production is indicated to meet performance and yield gates.

"PAs are the No. 1 user of DC power at base stations," Pelose said. "They generate the most heat, and they are among the largest components."

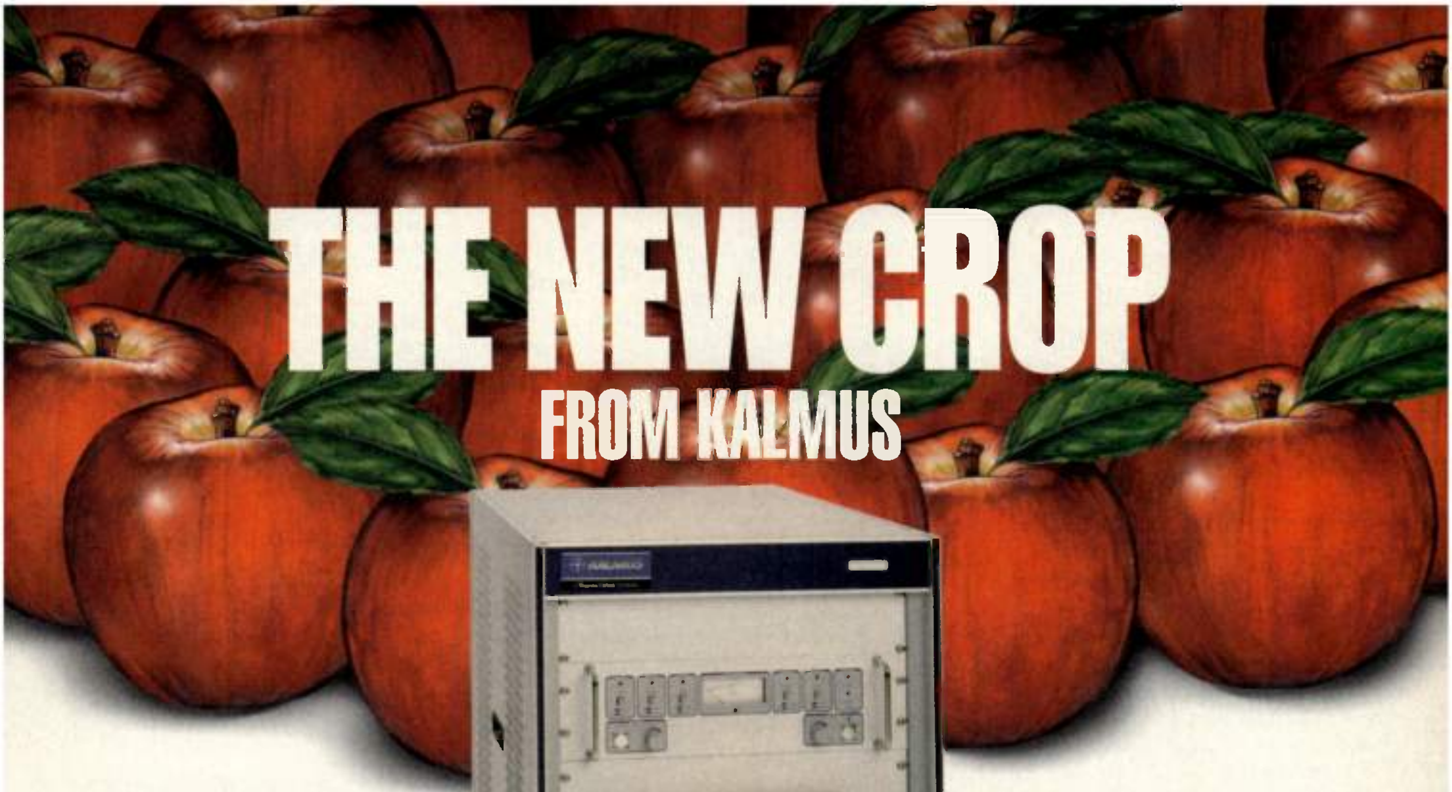
These characteristics raise network operating costs. Improved PA efficiency that reduces power consumption, heat generation and size gives a supplier a selling advantage. Upgrading a site with such amplifiers boosts network capacity without changing operating costs. Some sales turn on this factor. One reason for Spectrian's visit was to give us information to pass to you about products with such improvements.

By Spectrian's count, four or five companies compete to supply PAs to OEMs. Some specialize in commercial applications, others in military. And in Spectrian's opinion, the market has to have competitors because OEMs won't risk sole-source vendor relationships. Without competiton, OEMs now using suppliers might return to making their own PAs. Only two companies are large competitors for the OEM base station PA business.

There's a dilemma. If Spectrian somehow were to achieve market domination, that achievement could undermine itself. Someone once said, "Competition is good, but market domination is better." Might have been someone in my own organization, come to think of it. Anyway, maybe it wouldn't be better for a PA supplier.

Joe Veni, executive vice president and general manager of the company's Single Carrier Business Unit explained the market fluctuations that lifted and plunged Spectrian and other wireless equipment makers in 1997. That's a story for another time.

Our thanks to Spectrian for the visit, and to Jane Bryant of McQuerter Group for the arrangements. *RF*



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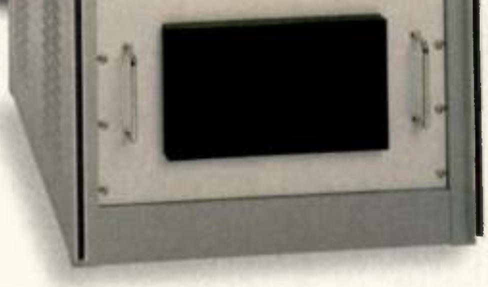

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INFO CARD 6

Editorial Forum

By Emily Reid, Associate Editor

Three cheers for paper

In recent months, *RF Design* has made several improvements to its Web site (**www.rfdesign.com**), with more to come. You can now find links to advertisers and editorial as well as a product directory. Does that mean that you can just forget about your hands-on paper copy of the magazine? I don't think so.

In this age of constantly evolving technology, people are talking about paper publications becoming obsolete. Personally, I'm not worried. First of all, reading on a computer screen is difficult. Researchers have performed studies on reader's speed and comprehension reading from a computer screen as compared to printed copy. So far, the results favor the old standby. I don't know how many times I've found something interesting on the net and still had to print it to be able to read it.

Beyond eye strain, paper is more portable. Is anyone going to drag their laptop out to the beach to read the latest bestselling novel off of **"www.booksthateveryonereads.com"** (which by the way, will charge you an access fee) while they hang out by the ocean? I doubt it. What about the Sunday paper? You can't exactly kick back on the couch with any ease, to read the "computer" paper.

When it comes to trade publications, while having articles posted on a Web site for future reference is a value added (which, by the way, *RF Design* will be offering in the near future), having that printed copy offers you the ability to look at back issues for that one product manufacturer or advertiser you may need to contact. You'll find most companies have a Web address listed and now it's time to get on the computer.

I think it's safe to say that paper is here to stay. The Internet is a great tool, but use it as a supplement to the great (paper) publications that are out there. You can relax knowing that your paper copy of *RF Design* will be around for the long haul. **RF**

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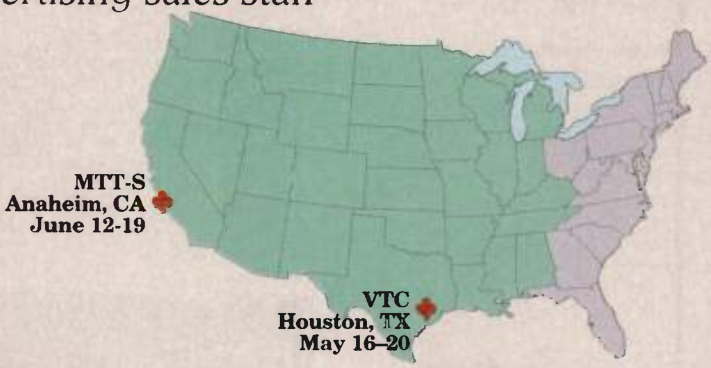

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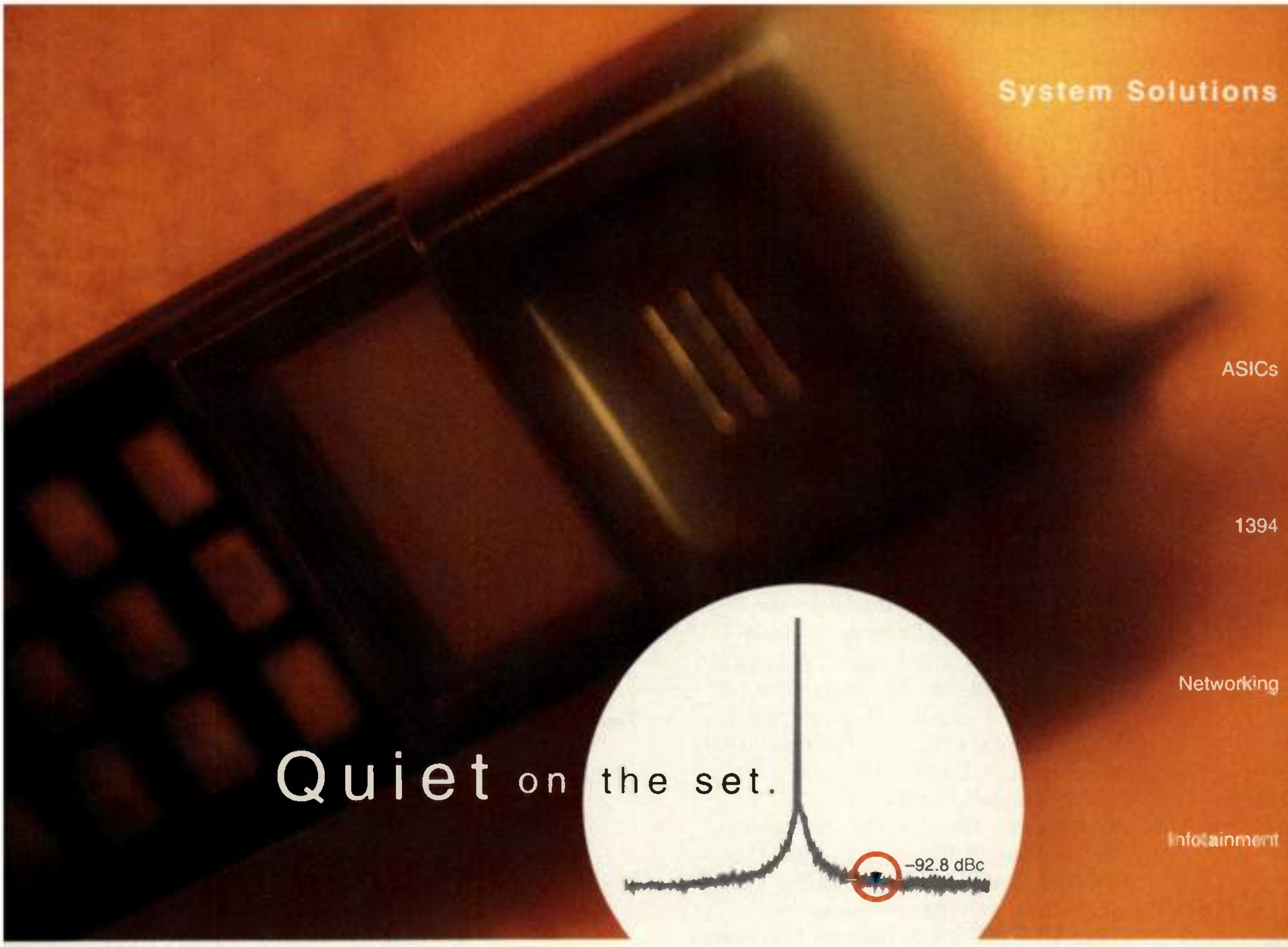

Spurious Noise

RF calendar

May 24–26 **Markets and Applications for High Frequency Magnetic Materials '99**—*Santa Clara, CA*. Information: Karen Zacharias, Conference Coordinator, Gorham/Intertech Conferences, 411 US Route One, Portland, ME 04105. Tel 207-781-9800.

24–26 **49th Electronic Components and Technology Conference**—*San Diego*. Information: Electronic Components, Assemblies, Equipment & Supplies Association. 2500 Wilson Boulevard, Arlington, VA 22201-3834. Tel. 703-907-7536; Web site **www.eia.org**.

June 2–4 **1999 Virginia Tech Symposium on Wireless Personal Communications**—*Blacksburg, VA*. Information: William H. Tranter, MPRG-Bradley Department of Electrical & Computer Engingeering, Virginia Tech, 432 NEB, Mail Code 0350, Blacksburg, VA 24061. Web site **www.mprg.ee.vt.edu**.

6–10 **Supercomm '99**—*Atlanta*. Information: Supercomm, 549 West Randolph St, Suite 600, Chicago. Tel. 800-278-7372. Web site **www.super-comm.com**.

12–19 **1999 IEEE MTTS International Microwave Symposium**—*Anaheim, CA*. Information: Dr. Robert Eisenhart, Microwave Symposium–MTT '99, Eisenhart & Associates, 5982 Ellenview Ave., Woodland Hills, CA 91367; Tel 818-716-1995; Fax 818-713-1161.

August 2–6 **IEEE 1999 International EMC Symposium**—*Seattle, WA*. Information: Ghery Pettil, Intel. Tel 253-371-5515; Fax 253-371-5690; e-mail *g.pettit@ieee.org* Web site **www.seattleemc99.org**.

25–27 **21st Piezoelectric Devices Conference and Exhibition**—*Reno, NV*. Information: Pete Walsh, Electronic Industries Alliance, 2500 Wilson Blvd., Arlington, VA 22201-3834. Tel. 703-907-7547; Web site **www.eia.org**.

September 21–24 **IEEE Wireless Communications and Networking Conference 99**—*New Orleans*—Information: IEEE Communications Society, 305 East 47th Street, New York, NY 10017-2303. Tel. 212-705-8900; Fax 212-705-8999; Web site **www.comcos.org**.

27–29 **32nd International Connector and**

Interconnection Show—*Anaheim, CA.* Information: Pete Walsh, Electronic Industries Alliance. Tel. 703-907-7547.

October 17–20 **IEEE GaAs IC Symposium**—*Monterey, CA*—Information: Harry Kuemmerle, VIP Meeting and Conventions, 1515 Palisades, Suite I, Pacific Palisades, CA 90272-2113. Tel. 310-459-4692; Fax 310-459-0605; Web site **www.gaasic.org**.

Oct 31–Nov 3 **MILCOM '99**—*Atlantic City*—Information: Gerald Wl. Lazaroff, Vice President Corporate Development, Lucent Technolgies, 9305-D Gerwig Lane, Columbia, MD 21045. Tel. 410-309-7032; e-mail *Lazaroff@lucent.com*.

December 5–9 **IEEE Global Communications Converence**—*Rio de Janeiro*—Information: Roberto de Marca Cetuc-Puc/Rio, Rua Marques de Sao Vicente 225, Rio De Janerio, RJ, 22453, Brazil. Tel +55.21.512.2091; Fax +55.21.294.5748; e-mail *jrbm@equitell.ecetuc.puc-rio.br;* Web site **www.globecom99mhw.com.br**

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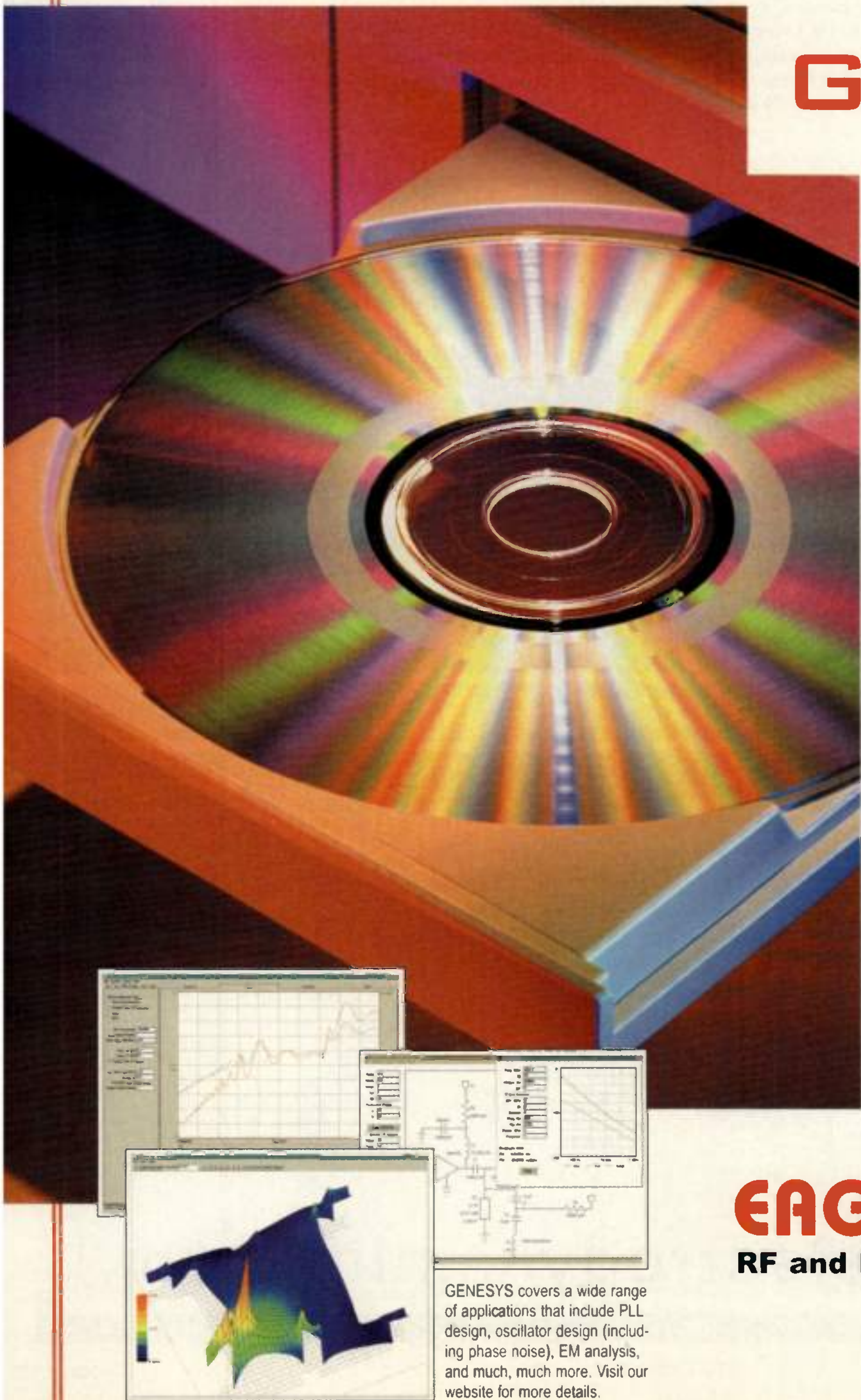

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UCLA Extension— *Using Design Patterns, Frameworks and Corba to Develop Object-Oriented Communications Systems*—Jun 2–4; *Communications Networking: Local, Metropolitan and Wide-Area Networks*—May 24–28, Los Angeles. Information: UCLA Extension, Department of Engineering, Information Systems and Technical Management, Short Courses, 10995 Le Conte Ave., Suite 542, Los Angeles, CA 90024-2883. Tel. 310-825-3858; Fax 310-206-2815; e-mail *tlawrenc@unex.ucle.edu*.

University of Missouri-Rolla— *Grounding and Shielding Electronic Systems–How to Diagnose and Solve Electrical Noise Problems*—Jun 1–3, Toronto; Jun 8–10, Ottawa; *Circuit Board Layout to Reduce Noise Emission and Susceptibility*— Jun 1–3, Toronto; Jun 8–10, Ottawa. Information: UMR Continuing Education, Tel 573-341-4132/4200; Fax 573-341-4992.

University of Oxford— *High Speed Digital Design*—Jun 7–8; *Digital Signal Processing*—Jun 7–9 ; *Digital Transceiver Design*—Jun 21–23; *MMIC Design (RF to mm-wave)*—Jul 1–2; *Digital Communications: an Introduction*—Jul 5–6; *CDMA for 2nd and 3rd Generation Communication Systems*—Nov 22–23, University of Oxford, UK. Information: OUSEP (rfdes), CPD Centre, University of Oxford, Department of Continuing Education, 67 St. Giles, Oxford, OXI 3LU. Tel. 44 (0) 1865.288170; e-mail *dee.broquard@conted.ox.ac.uk*.

Georgia Institute of Technology—*CMOS Analog Integrated Circuits*—Jun 14–18, Santa Clara, CA. Information: Distance Learning, Continuing Education and Outreach, Georgia Institute of Technology, Atlanta, GA 30332-0385. Tel 404-894-2547.

California State University, Northridge—*Far-Field, Near-Field, Compact Ranges and Anechoic Chambers*—Jun 8–11, Northridge, CA. Information: Shirley Lang, College of Engineering and Computer Science, California State University, Northridge, Northridge, CA 91330-8295. Tel. 818-677-2146; Fax 818-677-5982; e-mail *shirley.lang@csun.edu*.

Northeast Consortium for Engineering Education—*Antennas: Principles, Design and Measurements*—Aug 16–19, Colorado Springs. Information: Kelly Brown, NCEE, 1101 Massachusetts Ave., St. Cloud, FL 34769. Tel. 407-892-6146; Fax 407-892-0406; Web site **www.usit.com/antenna**.

University of Colorado at Denver—*Basic Principles of RF and Microwave Network Analysis*—Online course. Information: Kim Penoyer, University of Colorado at Denver Continuing Engineering Education, Campus Box 104, P.O. Box 173364, Denver, CO 80127-3364. Tel. 303-556-4907; Fax 303-556-2511; e-mail *kpenoyer@castle.cudenver.edu;* Web site **www.cudenver.edu/public/engineer.**

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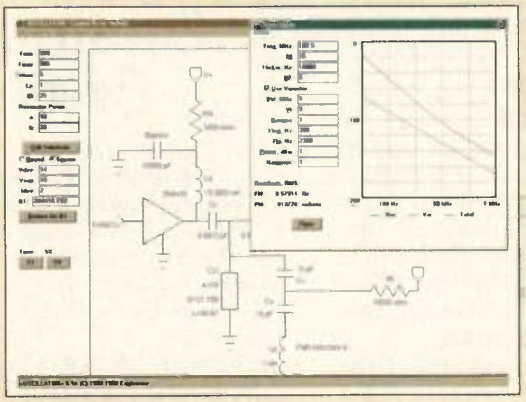

=OSCILLATOR=
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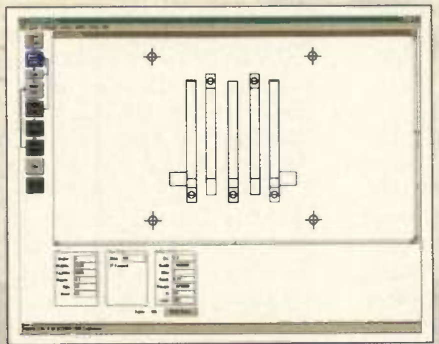
- Dielectric resonator
- SAW hybrid, MOSFET, BJT
- Cavity bipolar & hybrid
- T-line and L-C VCO
- Crystal Pierce, Colpitts, Driscoll
- Butler overtone
- VCO with transformer

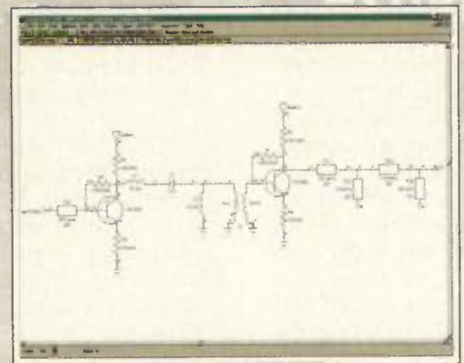


=M/FILTER=
- Interdigital
- Edge Coupled
- Hairpin
- Combline
- End Coupled
- Stepped-Z
- Elliptic Lowpass
- Stub Lowpass
- Elliptic Bandpass
- Stub Bandpass
- Stub Bandstop
- Edge Bandstop

Microstrip, Stripline, Slabline and Coaxial

=FILTER=
- All-pole and elliptic
- Top-C and -L coupled
- Shunt-C coupled
- Tubular
- Blinchikoff flat delay
- Zig-Zag
- Eagleware Symmetrical
- 6 Group Delay Equalizers

=A/FILTER=
- GIC transform
- Single & Multiple feedback
- State variable (bi-quad)
- VCVS
- Dual amplifier
- Low Sensitivity
- 3 Group Delay Equalizers



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- T-line single/double stub
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Digital think tank formed at MIT

Motorola, Phoenix, AZ, has donated $5 million to the Massachusetts Institute of Technology (MIT) to establish the DigitalDNA Laboratory at the MIT Media Lab in Cambridge, MA.The Laboratory will focus on actually linking "smart" products such as set-top boxes, automobiles, household appliances, personal digital assistants and wireless communications systems.

The Motorola grant is intended to combine major business and education resources in an effort to develop leading edge embedded systems, software, architecture and applications.

RFID market to reach $1.6 billion by 2002

An analysis from Venture Development Corporation (VDC), Natick, MA, "*Global Markets and Applications for Radio Frequency Identification Equipment,*" finds that worldwide shipments of RF identification (RFID) systems reached $655 million in 1988 and are expected to increase as much as 25% annually, to reach $1.6 billion by 2002.

The report finds that while market infrastructure issues still plague the industry (including standards development, channel training and end-user education), the RFID market is expected to provide strong near term growth. While the majority of current RFID shipments are directed to security/access control applications, VDC finds the greatest long-term opportunity may be the supply chain, such as cradle-to-grave tracking, closed loop logistics management and high value asset management.

VDC sees one of the reasons for RFID growth will be the operational advantages RFID offers over competing technologies. These advantages include non-line-of-site requirements, real-time updatability of (read/write) tags, high multiple simultaneous tag read rates (with latest generation anti-collision) and the ability of tags to sustain harsh environments.

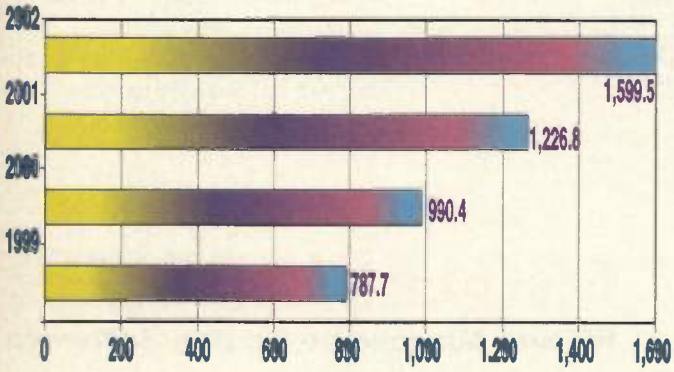
TRW/JPL set high frequency record

TRW, Redondo Beach, CA and the National Air and Space Administration's (NASA's) Jet Propulsion Laboratory (JPL), Pasadena, CA, has produced and demonstrated a new indium phosphide microchip that operates at 190 GHz. According to TRW, this is the highest frequency of any known solid state monolithic microwave integrated circuit (MMIC).

The new circuit is a low-noise amplifier (LNA) that can amplify signals at high frequency with low power consumption.The two-stage LNA chip was designed and fabricated by TRW using its patented indium phosphide high electron mobility transistor (HEMT) MMIC process.

In testing conducted by JPL, the LNA achieved a peak gain of 9.6 dB at 190 GHz and 8 dB gain from 160–190 GHz. TRW notes that the circuit design is unique in that it allows multiple LNA chips to be linked together, or "cascaded" to create an amplifier with 20–30 dB of gain at 190 GHz.

While the initial use of the new LNA targets NASA's environmental and weather satellites, Dwight Stireit, manager of the microelectron department at TRW's electronics and technology division, notes that the technology has other potential. "For wireless communications, this LNA has the most payoff for Ka band (18 –38 GHz) and point-to-multipoint," Stireit said. "Noteworthy, the technology offers an ultra low-power consumption by reducing power requirements by 30 %."



Global Shipments of RFID Systems (millions of dollars)

Patent awarded for multiple band amplifier

Anadigics, Warren, NJ, has been awarded a patent for a single chain multiple band amplifier. The patent was granted to Aharon Adar, Anadigics advanced gallium arsenide (GaAs) design manager. "Traditional dual

Business Briefs

TAS joins HP channel partner program— Telecom Analysis Systems (TAS), Eatontown, NJ, will partner with Hewlett-Packard (HP), Santa Rosa, CA, to provide advanced code-division, multiple-access (CDMA) test solutions. Through HP's channel partner program, TAS's CDMA test solutions will be combined with HP test equipment to address CDMA handset test requirements.

MITEQ appoints new UK and Canadian representatives— MITEQ, Hauppauge, NY, has appointed UKRF Ltd (UK), to exclusively represent its full line of RF/microwave components and satellite communication equipment in the United Kingdom. MITEQ has also appointed Giga-Tron Associates (Canada) to represent its product line in Canada.

IFR Systems to represent Giga-tronics—IFR System, Wichita, KS, has entered into an agreement to market microwave synthesizers and power measurement instruments manufactured by Giga-tronics, San Ramon, CA.

TriQunit and GHz Circuit Design form alliance—TriQuint Semiconductor, Hillsboro, OR, and GHz Circuit Design, Newberryport, MA, have joined forces to offer turnkey gallium arsenide (GaAs) integrated circuit (IC) services. Under terms of the agreement, TriQuint will be supported by GHz Circuit Design's radio frequency integrated circuit (RFIC) design team. TriQuint will provide wafer manufacturing.

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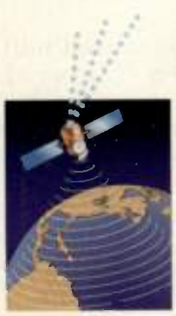

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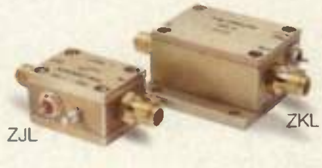
SPECIFICATIONS

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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band phones require a separate power amplifier for each individual band," Adar said. "This solution offers the functionality of two power amplifers in one."

The patent covers a high efficiency single chain GaAs metal semiconductor field effect transistor (MESFET) monolithic microwave integrated circuit (MMIC) dual-band power amplifier for wireless communications. The amplifier can be used for the advanced mobile phone system (AMPS) 800 MHz, global system for mobile communications (GSM) 900 MHz or personal communications service (PCS) 1900 MHz.

3G intellectual property rights issue resolved

Ericsson, Norway, and Qualcomm, San Diego, CA, have entered into a series of definitive agreements that resolve the two companies' disputes concerning intellectual property rights (IPR) issues that plagued the International Telecommunications Union (ITU) efforts to establish a standard, or family of standards, for third-generation (3G) technologies. Both companies will jointly support a single code-division multiple-access (CDMA) standard with three optional modes.

The agreements allow the cross licenses for their respective patent portfolios and to settle existing litigation. As part of the agreement, Ericsson will purchase Qualcomm's terrestrial CDMA wireless infrastructure.

Contracts

Celeritek receives $3.3 million in orders from Motorola—Celeritek, Santa Clara, CA, has received purchase orders for $3.3 million from Motorola, Cambridge, MA, for 3.0 V RFIC power amplifier products. The amplifers are expected to be used in Motorola's code-division, multiple-access (CDMA) personal communications services (PCS) Star Tac phone.

KDI/triangle wins AT&T contract—KDI/triangle, Whippany, NJ, has signed a contract with AT&T for multicoupler assemblies for use in cellular base stations. The multicoupler has six inputs and 12 channel outputs and operates from 824–894 MHz.

Advantages of SiGe for RF front-ends

Components manufactured using a SiGe bipolar process exhibit lower noise, better linearity and lower current consumption than their pure, bipolar-only process counterparts.

By Richard Lodge

The requirements of portable telecommunications equipment are becoming more demanding in terms of integration levels and performance. Achieving high receiver sensitivity requires low noise from the front-end amplifiers and mixers. Low current consumption for improved battery life necessitates the use of high-speed processes to reduce bias currents in transistors.

One of the main noise generation mechanisms in bipolar transistors is the Johnson noise generated by r_{bb}, or the parasitic resistance within the base region of the npn transistor. Reducing r_{bb} improves the noise performance of the transistor, and it can be achieved by shrinking the emitter width (i.e., shortening the base length) or by increasing the doping within the base. Another option is to use an emitter-base heterojunction. This can be done by adding germanium doping within the base, thus reducing r_{bb} for a given emitter width.

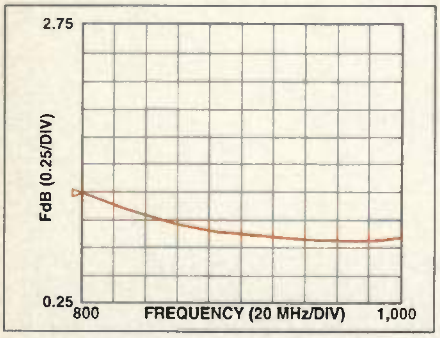


Figure 1. Measured LNA noise figure.

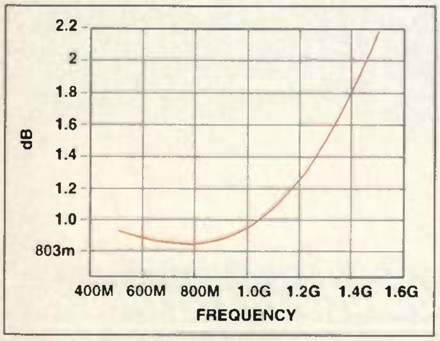


Figure 2. Simulated LNA noise figure.

Adding germanium into the p silicon base creates a bandgap reduction of about 80–100 mV within the base, creating a strong electric field. Electrons diffuse into the base and are then swept across the base-collector junction by this electric field. This causes a reduction in the transit time, t_b, taken for carriers to cross the base [1]. Reducing t_b provides an increase in f_T with all other factors remaining constant. In addition to improvements to r_{bb} and f_T, silicon germanium (SiGe) transistors offer improvements in beta and *early voltage* (which improves the output resistance of devices) owing to reduced base-width modulation. An increase in beta also helps to reduce base-current shot noise, further improving the low noise performance of SiGe.

One form of a SiGe process, a deep trench-isolated bipolar process, uses three layers of gold metalization to provide the following advantages:

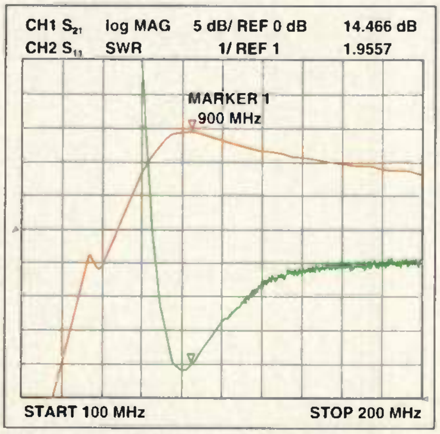


Figure 3. Measured S11 and S21 data for LNA.

- better electron migration properties compared to aluminium (Al)-based metalization.
- lower sheet resistivity to improve inductor Q and lower resistive drops in gain blocks to reduce Johnson noise generated in the resistance of metal tracks.

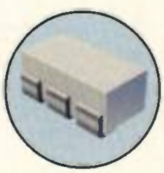
By adding a fourth layer of gold metal, the process can also offer high Q inductors used at the main cellular frequencies at around 900 MHz, 1.8 and 1.9 GHz. These can be used for source/load impedance matching and within on-chip resonators for voltage controlled oscillators (VCOs).

LNAs

Demands on low-noise amplifier (LNA) performance are increasing as handheld digital cellular terminals require higher sensitivity. As explained previously, a SiGe process yields lower base shot noise and Johnson noise generated within the parasitic base resistance r_{bb}. Furthermore, the higher f_T improves high-frequency noise performance because beta roll-off occurs at a higher frequency. These effects combine to provide significant improvements.

Furthermore, the output impedance properties of the SiGe transistor provide benefits in improving intermodulation distortion. This is because the C_{bc} of the device is less voltage-dependent in a SiGe process than in pure bipolar. Figure 1 shows the noise figure measurements on a SiGe LNA optimized for 900 MHz applications over frequency. It shows that the noise figure is around 0.8 dB between 900 MHz to 1 GHz. This reduces to 0.6 dB at –40°C . Figure 2 shows the simulated noise figure and demonstrates a close correlation between modeled and measured characteristics. Parts are packaged in a SOT23-6 pin plastic package.

Figure 3 shows s21 and s11 plotted over frequency giving a mid-band for-



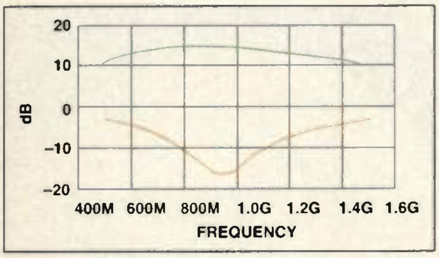


Figure 4. Simulated S11 and S12 LNA performance.

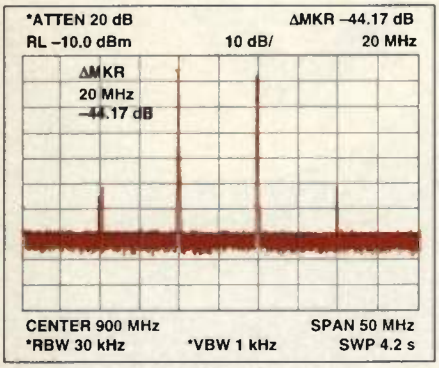


Figure 5. IM3 distortion in LNA.

ward gain at 900 MHz of around 14.5 dB. Figure 4 shows the close agreement with simulated behavior. Figure 5 shows the third-order intermodulation (IM3) distortion of the amplifier giving an input referred third-order intercept (IP3) point of −9.3 dBm. Current consumption is just 3.3 mA. By comparison, a silicon-based amplifer at 900 MHz would have a noise figure at least 0.5 dB higher, with the same current consumption and IIP3. This demonstrates the important benefits of the lower r_{bb}, higher f_T and higher beta.

These results illustrate what is possible for 900 MHz applications—a typical noise figure well below 1 dB with an IIP3 better than −10 dBm and current consumption of less than 4 mA. For 1.8 GHz, a noise figure well below 1.5 dB using less than 5 mA is clearly achievable.

Mixers

Figures 6, 7 and 8 show a comparison of single sideband (SSB) noise figure, conversion gain and IIP3 for three devices. At 900 MHz, SSB noise figure is around 6 dB. Comparison with a comparable silicon mixer at 900 MHz shows a 4 dB improvement in IIP3, with a 2 dB better noise figure with both devices consuming 9 mA at room temperature off a single 3V supply. Furthermore, SiGe's higher f_T will permit designs at much higher frequencies than previously possible to include 3.5 GHz applications (such as radio-local-loop) and beyond.

VCOs

Integrated circuit (IC)-based VCO products are starting to become commonplace in many RF systems. For instance, a VCO with noise performance is shown in Figure 6. With 9 mA of current, a phase noise of −120 dBc/Hz at 100 kHz can be achieved. A planned SiGe derivative part is expected to show an improvement in close phase noise of a few dB with the same circuit configuration and current consumption.

Conclusion

SiGe provides significant advantages over a pure bipolar process in terms of

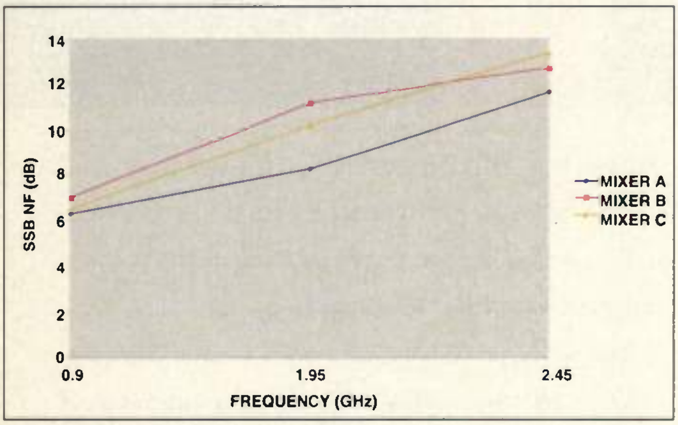


Figure 6. SiGe mixer NF over frequency.

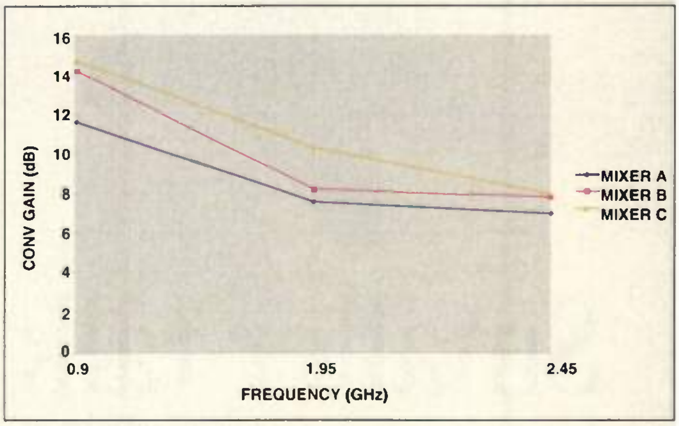


Figure 7. SiGe mixer conversion gain.

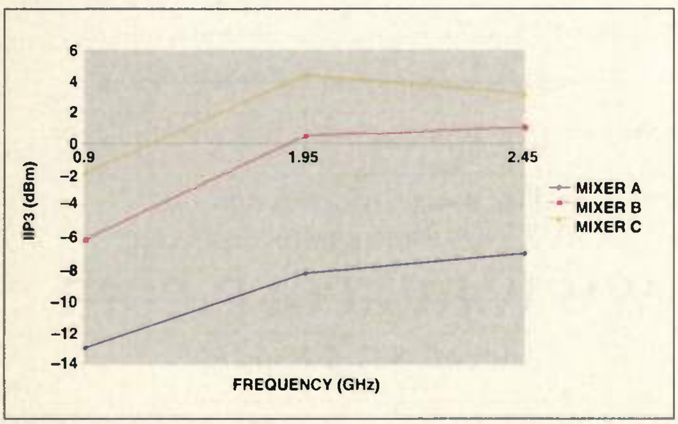


Figure 8. SiGe mixer IIP3 vs. frequency.

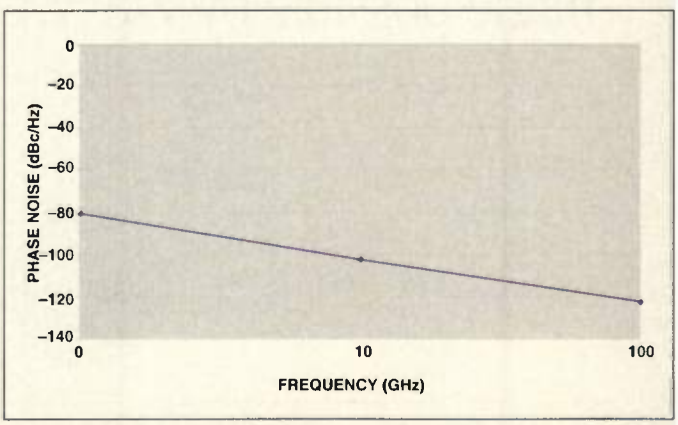


Figure 9. Pure bipolar VCO phase noise.

f_T, early voltage, beta and lower current consumption for a given f_T and reduced voltage dependence of C_{bc}. These combine to enable LNAs, mixers and oscillators to be built. An LNA at 900 MHz with a typical noise figure of 0.8 dB with over 14 dB of gain, 3.3 mA current consumption and an IIP3 of –9.3 dBm has been shown. A 1,900 MHz LNA consuming 3.2 mA has has also been measured and yields a 1.25 dB noise figure, 14.7 dB forward gain and –6.0 dBm IIP3. These noise, IIP3 and current consumption characteristics are considerably better in SiGe technology than are possible using the pure bipolar process upon which it is based. Comparable benefits are possible for mixer and VCO products. *RF*

References

1. Harame and Cressler, Transactions on Electron Devices, Vol. 42, No. 3, March 1995, pp. 455-468.

About the author

Richard Lodge received his Bachelor of Science in Applied Physics and Electronics in 1985, and his Masters of Science in Microelectronics in 1987 from the University of Durham, UK. He was previously an ASIC applications manager for Maxim Integrated Products, Reading, UK, responsible for assisting cutsomers to develop custom products on high-frequency bipolar, SiGe and BiCMOS process technologies. For information regarding this article, contact Walter Lau at 408-737-7600 Ext. 6986 or by e-mail at *walter_lau@ccmail.mxim.com*. The parts described in this article are the MAX2641 LNA and the MAX2680 mixer available from Maxim Integrated Products.

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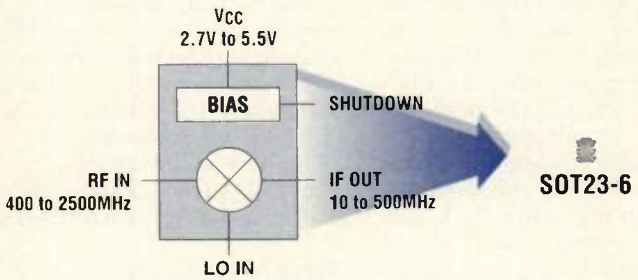
TECHNOLOGY		PART	Icc (mA)	IIP3* (dBm)	NF* (dB)	CONV. GAIN* (dB)
SiGe	⇒	**MAX2681**	**9**	**-6**	**7**	**14.2**
GaAs	⇒	HP IAM91563	9	-6	7	11
Si Bipolar	⇒	NEC UPC8112T	9	-10	9	15

- Higher Conversion Gain vs. GaAs
- Higher IIP3 and Lower NF vs. Si Bipolar



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MAX2680	5	400 to 2500	-13	6.3	11.6
MAX2681	9	400 to 2500	-6	7.0	14.2
MAX2682	15	400 to 2500	-2	6.5	14.7

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Performance requirements of communication base station time standards

Modern communication systems demand high reliability time standards. Understanding the environmental conditions will help in selecting the right oscillator.

By John A. Kusters
and Charles A. Adams

Modern communication networks are complex. They can involve one or more central offices, controlling toll offices, mobile switching offices, land and submarine cable, television network transmission and the familiar home telephone. As a wired network, they are connected in one form or another with copper wire or coax cable. There is also the wireless network, involving microwave repeater links, cable television (CATV), satellite links, cell sites and all forms of wireless voice and data communication.

The wireless network depends on base stations, or cell sites that handle the two-way wireless communication as well as providing links to the wired network. Usually, the cell sites are housed in small buildings at the base of an antenna structure. The future will see micro-cells, a collection of electronics in a sealed box hanging on a telephone pole. Micro-cells are unattended communication cell sites without any form of environmental control. This forces the cell site time standard to operate over wide temperature ranges. These operating temperatures can range from –40° to +85° C, humidity from 0–100% (condensing), and pressure change equivalent to a 10,000-foot elevation change.

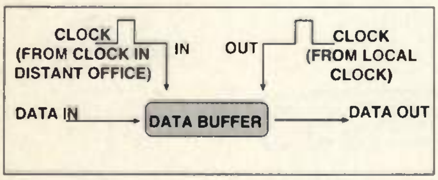

Figure 1. Data buffers for wired communication networks.

Even with loss of the external reference, the time standard must continue to operate with only limited change in performance, which is called holdover. Under holdover conditions, the time standard is not locked to the reference and the cell site accumulates timing errors. System requirements may be as tight as "less than seven microseconds accumulated timing error, 24 hours after loss of the reference, under all environmental conditions" [1]. Acceptance testing involves cycling the environment over the full range while the time standard is in holdover.

Synchronization

Communication in any network depends on time synchronization between all of the stations and cell sites involved. Loss of synchronization in the wired network can cause many problems. For voice messages, the consequence may be as small as a slight click. For TV signals, video may be lost for as long as six seconds, resulting in a "freeze frame." For secure data communication, a synchronization error will abort the transmission and break the communication link. In the wired network, data buffers are used to couple data between two sites. In the example shown in Figure 1, a clock signal derived from synchronous signals in the incoming data clocks the data into a buffer at the receiving site. The local clock of the receiving site clocks the data out of the buffer. As long as the two clocks are essentially synchronized, data is clocked into the buffer at about the same rate as it is clocked out. If the clocks differ significantly in frequency, the buffer either overflows (data lost) or underflows (null data clocked out).

For the wireless network, the problem is more severe because cell phone mobility depends on the use of a variety of cell sites. Propagation delays complicate the use of clocking signals derived from the incoming data. Commonly, the system requires that all cell sites share the common reference. The more sophisticated systems use Navstar global positioning system (GPS) as the common reference [2].

Recent advances

The Navstar GPS system offers a globally distributed timing system based on a network of satellites that are continuously monitored and controlled. A timing signal that is ultimately referenced to Coordinated Universal Time (UTC) is available as an output from GPS receivers. The timing specification for the GPS system is ±340 ns at the 95% confidence level (170 ns root mean squared—RMS) when receiving signals from four satellites.

Current GPS timing engines using eight or more channels simultaneously can reduce this to about 40 ns RMS, or an overall timing uncertainty of about 200 ns peak-to-peak.

Using the GPS timing as a reference, technology reduces this further to about 16 ns RMS or about 80 ns peak-to-peak [2].

Customer requirements

A typical customer may expect a timing source to meet its specifications over temperature ranges from –40°C to +85°C, humidity from 0–100% (condensing), pressure changes equivalent to 10,000-feet elevation change, and have 100,000 hours mean time between failure (MTBF) at a low price.

The customer also expects that after


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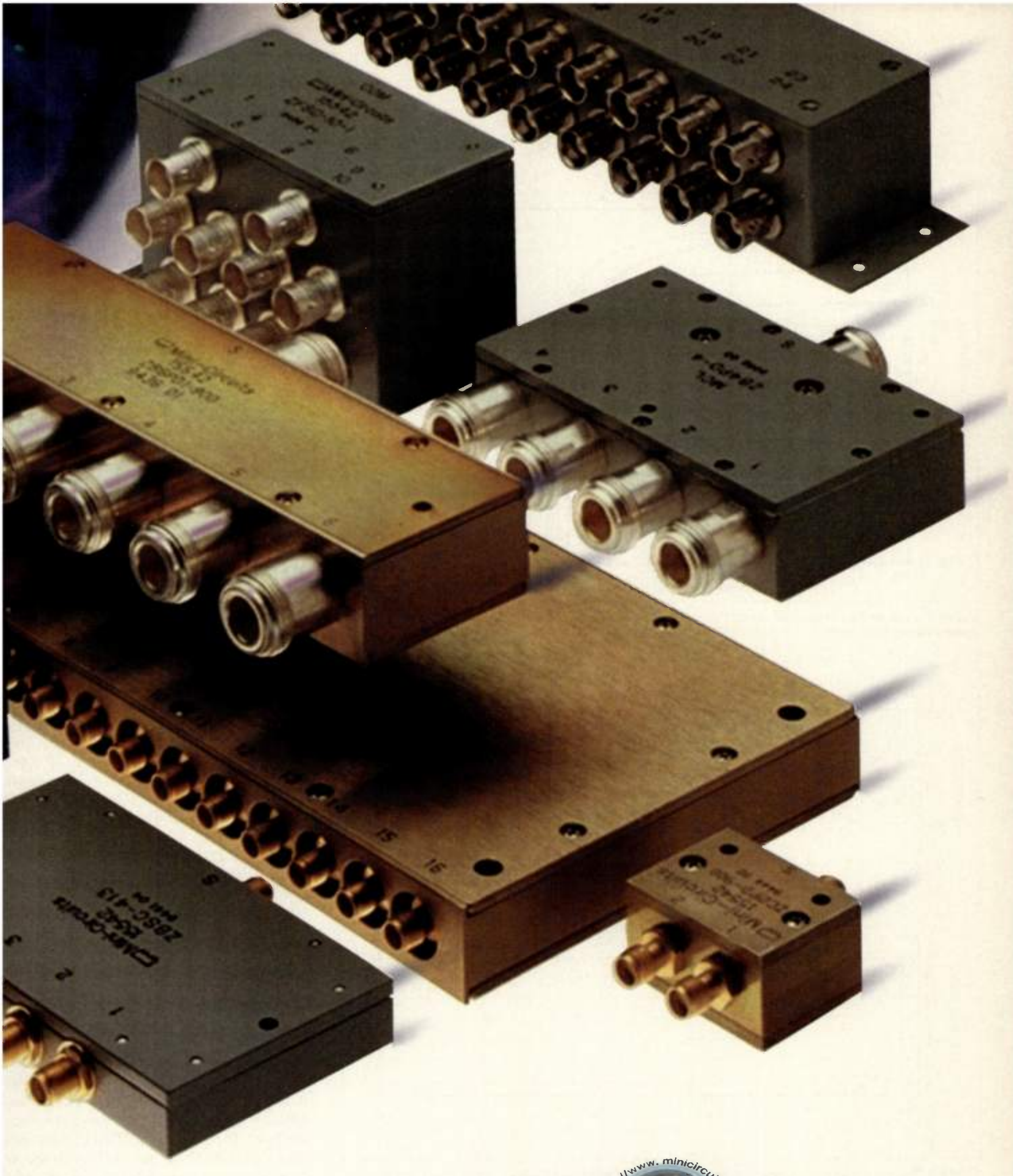

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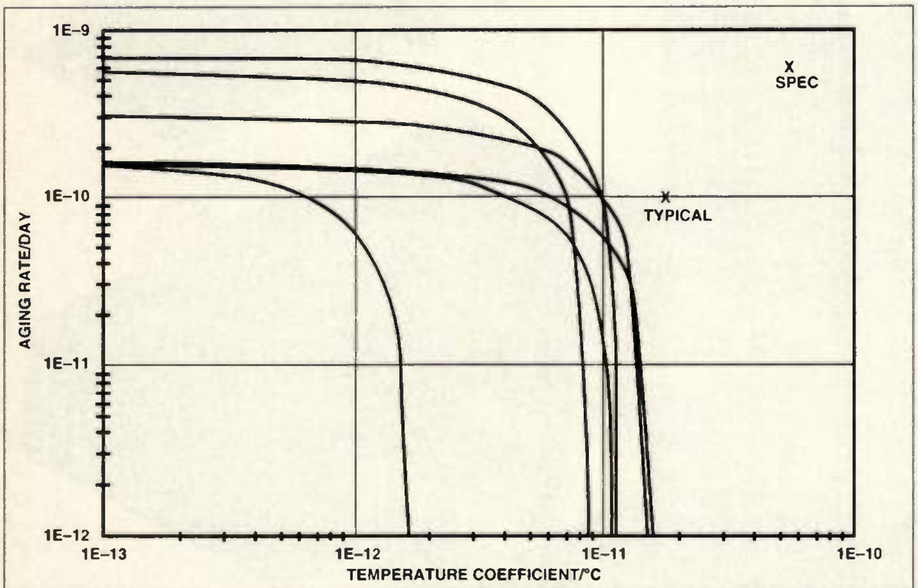

Figure 2. Each of the six lines represents the locus of linear aging rate and temperature coefficient that exactly meets the minimum customer holdover requirements.

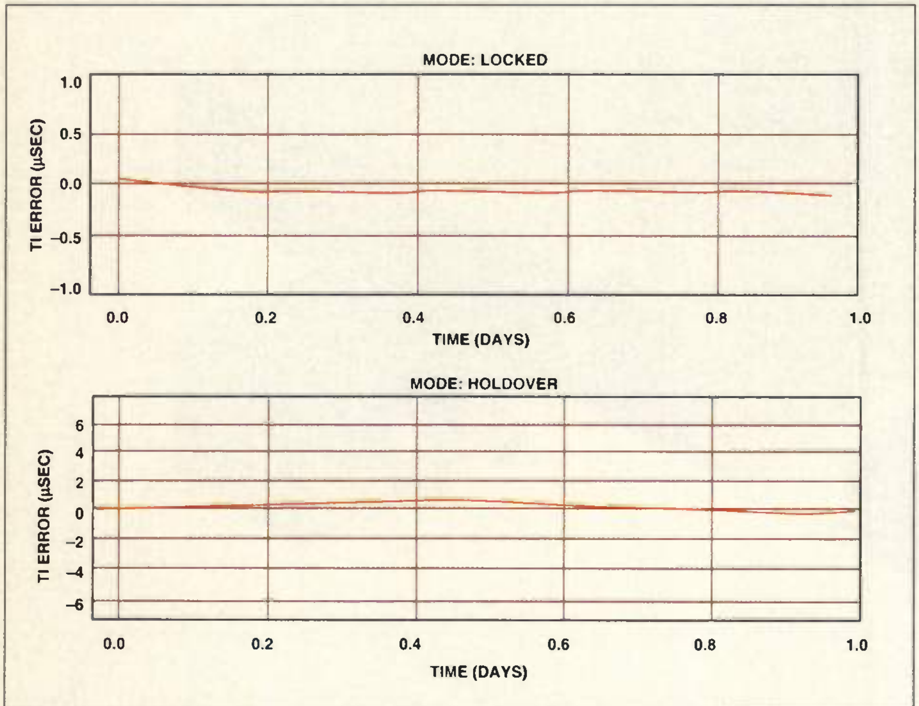

Figure 3. The top graph shows time interval error over a 24-hour stabilization period. The bottom curve shows the holdover results using the aging and temperature data learned during stabilization. Unit passes test even with a small frequency jump.

24 hours of operation locked to the external reference, that the timing unit will continue to operate without the external reference. After 24 hours of unlocked operation, the total accumulated timing error has to be less than 7 µs. This is equivalent to an average frequency offset of 8.1 × 10^{-11}. Operation not locked to the external reference is termed holdover and is the major challenge to any oscillator provider.

The oscillator problem

The total timing error of a clock in terms of its variables can be expressed as

$$x = x_0 + y_0 t + \frac{1}{2}At^2 + \int_0^t E(T,P,M,H,G)dt + \varepsilon(t) \quad (1)$$

where:

x_0 = the starting time offset or synchronization error

y_0 = the starting frequency offset or syntonization error

A = a linear aging of the oscillator, the integral represents all of the environmental factors

ε = the effect of system noise and frequency jumps

In general, all of the environmental factors can be minimized, except perhaps temperature, by sealing the oscillator and using adequate shock and vibration isolation. Synchronization and syntonization errors may also be eliminated through careful calibration and algorithmic designs.

However, the effects of aging or of unpredictable events such as frequency jumps cannot be eliminated. In any practical case, the effects of temperature cannot be eliminated, either. The best quartz oscillator in production still has a temperature coefficient of 4.4 × 10^{-13} per °C [3]. To further complicate the situation, aging is seldom linear over any significant period of time.

Figure 2 is a plot of the assumed linear aging rate and temperature coefficient that exactly meets the customer holdover requirements. In this plot, requirements for six cases are shown. Even the typical performance does not meet any of the customer requirements.

Figure 2 assumes that there is no synchronization error, no syntonization error, no linear aging, no environmental effects beyond temperature and that there are no frequency jumps or other perturbations to the oscillator frequency. Even with these assumptions, it is apparent that a typical quartz oscillator will not meet the requirements without further help. The figure further assumes that there is no retrace or hysteresis in the oscillator and that the aging in the 24-hour stabilization period is linear and stable.

In a new family of timing standards, the difference is the use of algorithms that learn the oscillator aging characteristics and its temperature performance while locked to the external reference. In holdover, the learned characteristics are used to keep the oscillator on frequency by compensating

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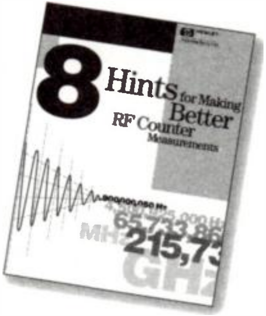

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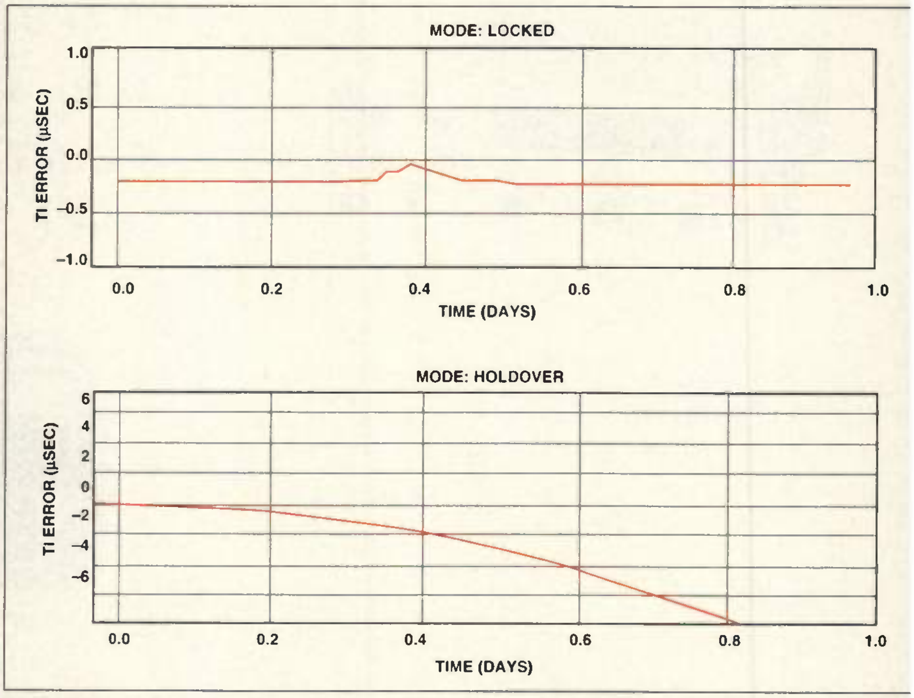

Figure 4. The top graph shows time interval error over a 24-hour stabilization period. The bottom curve shows the holdover results using the aging and temperature data learned during stabilization. Unit fails holdover specification because of a frequency jump during the learning process.

for aging and temperature changes. Obviously, what is needed is an oscillator that has the sum of all environmental effects below 1×10^{-11}, never jumps, never needs calibration, has no retrace or hysteresis and costs less than $100.

Reality

Partial solutions do exist. The oscillator can be hermetically sealed. Multiple ovens or other radical designs can be used to reduce the temperature coefficient below 2×10^{-13} per °C over a 50°C range. Extensive pre-aging, intelligent aging and compensation systems can be used. Oscillators can be selected by doing extensive holdover testing over the required environmental ranges.

With partial solutions, one gets partial results. None of the conventional oscillator testing used anywhere in the industry will guarantee that the final unit will pass customer testing. Current processes require multiple holdover testing at the factory. A single fail ends the test—a "test until failure" philosophy. Total yield is below expectations; the major problems are retrace and frequency jumps. Figures 3 and 4 illustrate the problem.

From the clock equation given previously, a synchronization error results in a static offset in the holdover response. A syntonization error results in a linear time interval error. A linear aging error results in a second-order time interval error. In actual performance, all three exist. Further, in most practical cases, the time dependence of aging is not linear. Temperature coefficients may be a function of both time and temperature. Retrace or hysteresis may give a false estimate of linear aging during the first 24 hours of stabilization. The three figures are examples of actual production testing.

Figure 3 shows a slight time synchronization error that carries over to the holdover mode. Of significance in the holdover mode response is that the slope changes at about day 0.4. The holdover results show a break after 0.4 days of holdover corresponding to a frequency jump of 3.5×10^{-11}. Even with the frequency jump, this unit passes the holdover requirement of ±7 µs over 24 hours.

Figure 4 shows a disturbance at about day 0.4 in the locked mode caused by a frequency jump. Because of the servo nature of the locked mode, the frequency offset or syntonization of the oscillator is adjusted until there is no longer an apparent time interval error. The problem is that plotted in the frequency domain, we would see at least two distinct frequencies for the

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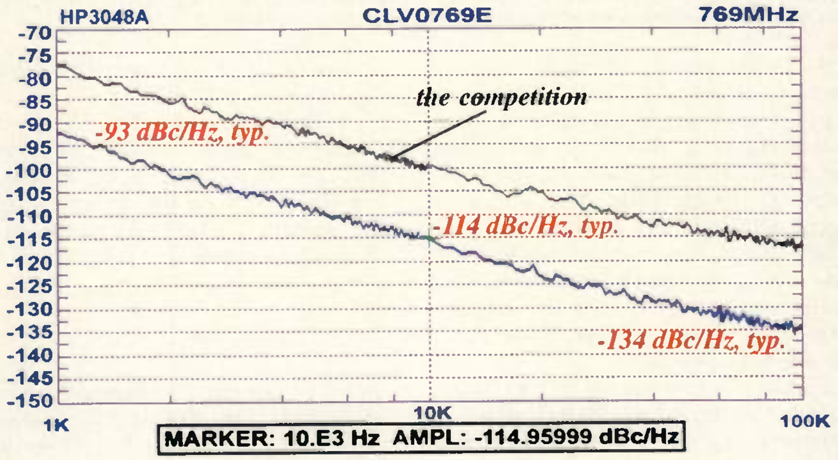

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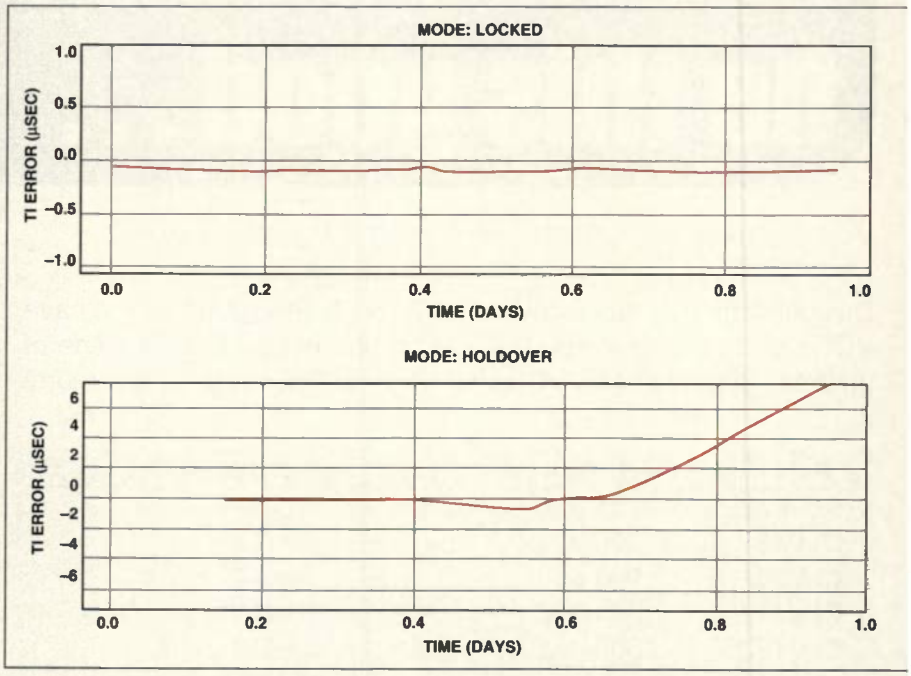

Figure 5. The top graph shows time interval error over a 24-hour stabilization period. The bottom curve shows the holdover results using the aging and temperature data learned during stabilization. The unit fails holdover specification because of a frequency jump during holdover.

locked data over the first 24 hours. A linear fit through this data would be seriously in error. The consequence of this is shown in the locked data. Here we reach the test limit at about 0.8 days. This unit fails. The apparent aging error is 2.7×10^{-10} per day. Another test run would probably pass this oscillator, but the confidence that the customer would also see satisfactory performance is lower. This unit is considered a reject.

Figure 5 shows good performance during the locked mode, but although unlocked, the unit shows a significant change in frequency at about day 0.7. The change in slope amounts to a frequency change of about 3.4×10^{-10}.

Conclusion

Modern communication requirements need quartz oscillators that may be beyond the current state of the art. Retrace and frequency jumps are the worst offenders. Careful design backed up with extensive testing is the only way to meet the exacting requirements of modern communication systems. *RF*

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Advances in broadcast technology—MMDS's rocky past and promising future

MMDS, aka wireless cable, has been around for several years now. Recent advances in both distribution technology and infrastructure will open new avenues of opportunities for the RF industry.

By Ernest Worthman,
Contributing Editor

In the first of a two-part series about local multipoint distribution service (LMDS) and multichannel multipoint distribution service (MMDS), this article will look at the broadband wireless cable broadcast technology, MMDS. LMDS will be featured as the cover story in the August issue of RF Design.

MMDS is a Federal Communications Commission (FCC)-regulated wireless cable system for the delivery of multiple video signals via point-to-multipoint microwave transmission. MMDS is a derivative of multipoint distribution service (MDS). In 1963, the FCC allocated a portion of the commercial spectrum for distributing television signals. The problem was that it consisted of only one or two channels. This obviously could not compete in the cable market so these channels were used for alternatives such as adult shows and other unique programming. Realizing the problem, the FCC bumped the frequencies up, allowing for more channels to be carried, and it also hoped to produce some competition in the cable market. This expansion created instructional television fixed service (ITFS) and operations fixed service (OFS). OFS was created to allow the government as many as three channels for training. LTFS allowed schools and colleges to broadcast educational programming. By the 1980s, this spectrum was being underused and MDS developed into MMDS.

Its place in the sun

Presently, all wireless cable services (MMDS, LMDS and direct broadcast satellite (DBS)) account for less than 10% of the broadcast cable television (CATV) market. MMDS has about 2% of the United States market. Deployment outside of the United States is somewhat better because of the lack of the wired infrastructure that exists in the United States.

Third-world countries, almost all of which have no wired infrastructure, prefer MMDS to DBS because content can be previewed and edited, which is not possible with DBS. Some experts predict MMDS and related wireless broadcast services could eventually have as much as 30% of the broadcast television market outside of the United States.

Seen as a competitor to DBS and traditional CATV, MMDS (also called multichannel multipoint distribution systems) has a number of advantages, as well as some disadvantages, over its competition.

On the plus side, like all wireless services, MMDS eliminates the need for premise and interconnect wiring. It also requires a smaller receiving dish than DBS systems (18″ compared with 36″). It can provide service to locations where direct cable installation is impractcial because of distance or location and can be viewed within that premise by using the homes that are pre-wired cable or copper.

From the provider's side, MMDS is less expensive to roll out, and the infrastructure payback is immediate because the system is open-ended. Additionally, today's MMDS is (or will be shortly) digital-based and has more flexibility in adapting new technologies and integrating new services (such as interactive services and wireless Internet). Finally, personal experience has shown that reception quality is better and more reliable than that of cable.

Although its detriments are few, MMDS has some major obstacles. MMDS's significant advantage is also its significant disadvantage. MMDS is line-of-site, so topography is the major deployment consideration. Technologies available such as "beam benders" (low-power

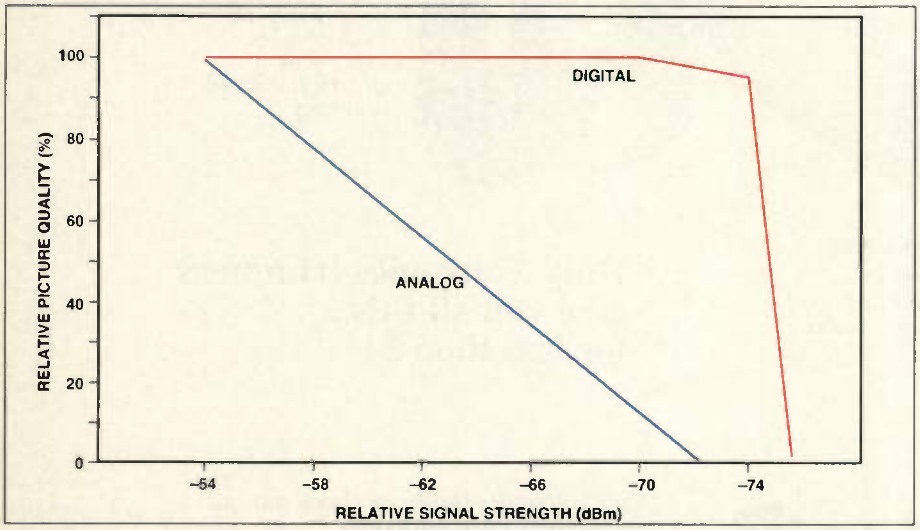
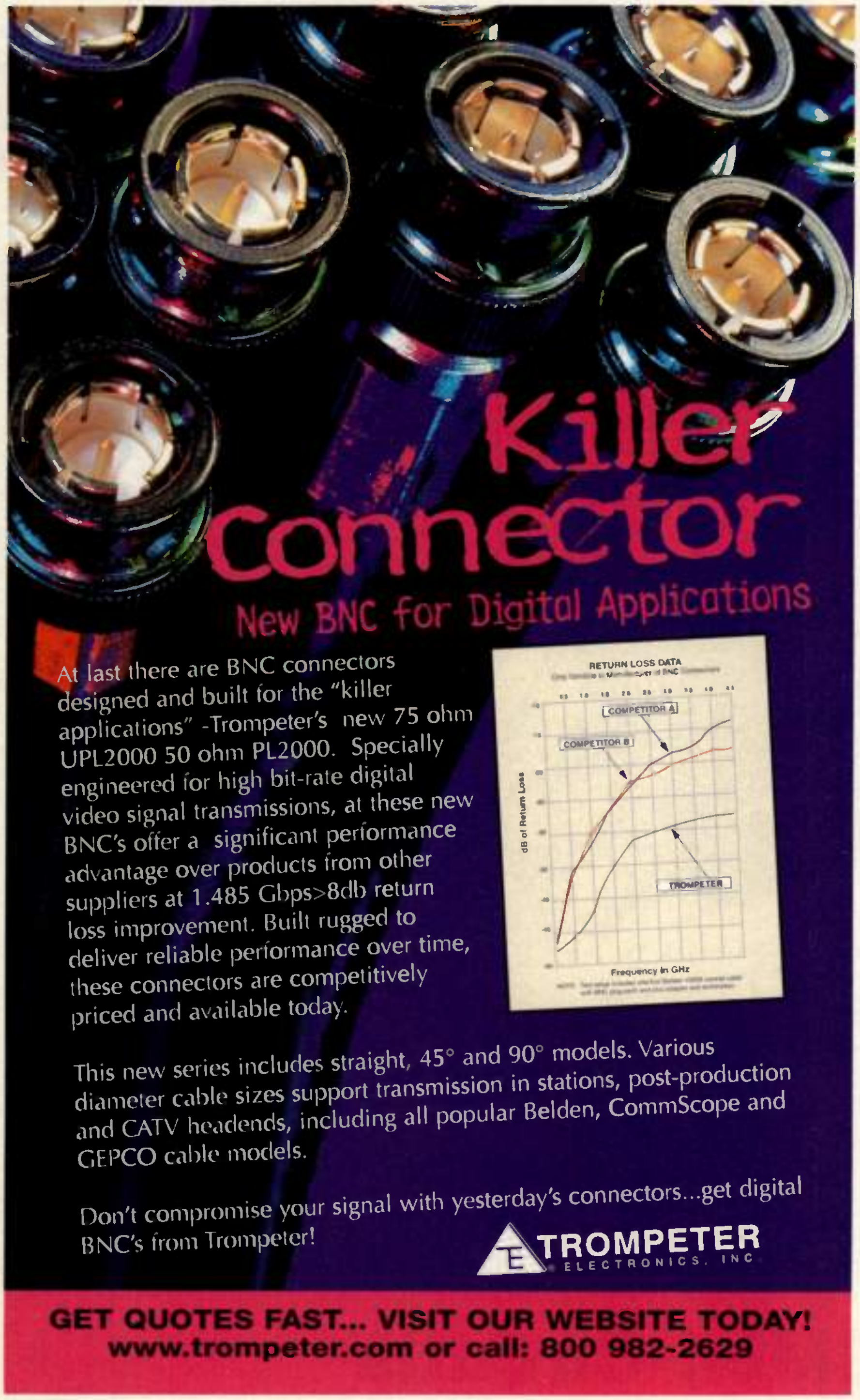


Figure 1. Digital signals retain their quality until they reach a point that the signal is so weak that the receiver looses the picture. Analog, on the other hand, gets progressively worse as signal strength weakens.

Frequency Range	Type of Service	Channel Groups	Number of Channels
2.150–2.162 GHz	MDS	1, 2, 2(A)	2
2.500–2.596 GHz	ITFS	A, B, C, D	16
2.596–2.644 GHz*	MMDS	E, F	8
2.644–2.686 GH**	ITFS	G	4
2.644–2.686 GHz**	MMDS	H	3
2.686–2.689875 GHz	MMDS	Response channels	31

Table 1. Breakdown of current offerings and what type of service is in each band. Some of the frequencies are MMDS only*, while others still share with ITFS channels**.



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directional repeaters) can help alleviate some of the problems, but basically, if you can't see the antenna, you can't get the picture. Some future services, such as interactive capabilities, require a wireless return path, which has not yet been approved by the FCC.

Second, weather affects signal quality. Because heavy rain and fog tend to absorb or reflect microwave signals, picture quality is affected under such conditions. If the broadcast signal is analog, the picture will deteriorate linearly with the loss of signal strength. With digitally broadcasted signals, the curve is a bit different. Digital signals retain most of their quality until they reach a point that the signal is so weak that the receiver looses lock and the picture gets "muddy" (see Figure 1). (Note: The figure's numbers are used as a reasonable approximation only.)

Its makeup

MMDS is deployed at frequencies in the super high frequency (SHF) band. Table 1 is a breakdown of the current offerings and the type of service available in each band. Because some MMDS and ITFS share the same band, MMDS can't broadcast on all of the channels all of the time. However, this is a dynamic relationship, and once the FCC-required ITFS educational broadcast hours are met, MMDS operators can use the ITFS channels if the ITFS licensee grants permission.

Additionally, the last row of channels is response channels only with a 125 kHz bandwidth. Response channels (also called talk-back channels) were originally designed to allow interactivity on the ITFS channels. There was one response channel for each broadcast channel. In effect, the instructors could get live feedback during the classes.

These voice channels are broadcasted back to the source via standard FM techniques with FM's 25 kHz deviation, at about 100 mW. Today, in MMDS broadcasts, these channels are used for data and overhead rather than voice. They can also be used to send program material, but their bandwidth limits their application.

Assuming future two-way communications, the distribution system's building blocks consist of a microwave antenna, a central office (CO) and the customer premise equipment (CPE). Figure 2 is a simplified block diagram of a system.

Its technology

MMDS broadcast systems are usually low power (compared to major broadcast networks) with small coverage areas. Although the maximum effective isotropic

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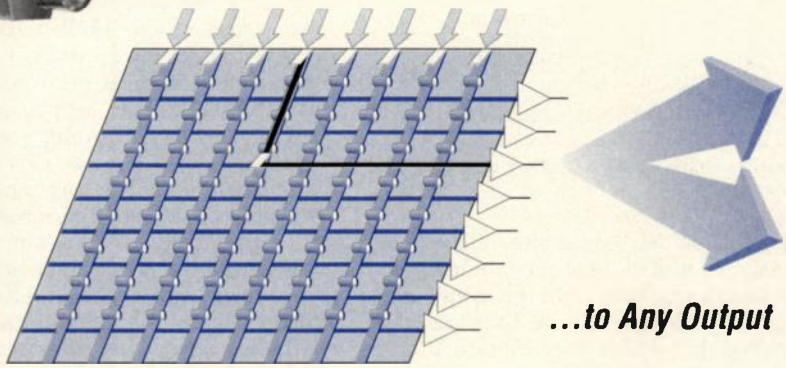

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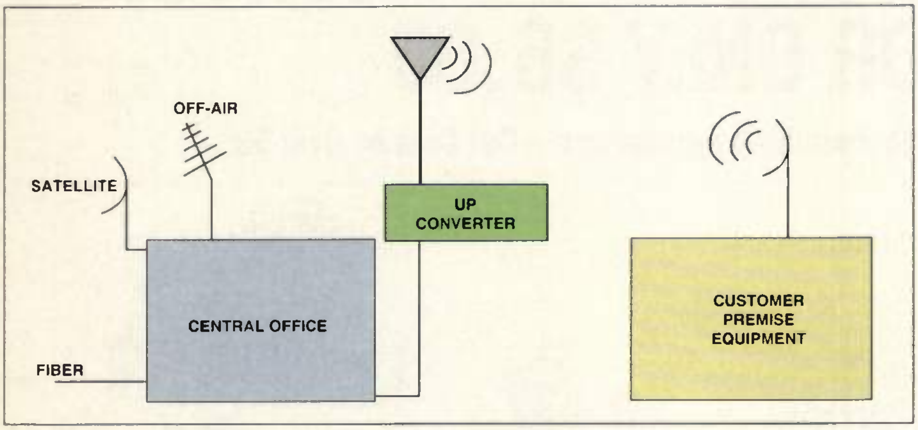

Figure 2. MMDS's receive signals at a head-end from satellites, fiber cables and off-air broadcasts and rebroadcast them from microwave sites within their service area.

radiated power (EIRP) allowed is 2 kW, most systems use 10–50 W transmitters with gain antennas (it saves money). Systems typically use a +13 dB gain antenna and, taking a 3 dB return loss into account, produces systems radiating 100–500 W at the antenna.

MMDS's receive signals at a head-end, from satellites, fiber cables, off-air broadcasts, as well as local programming, and rebroadcast them from microwave sites within their service area. Broadcast technology presently uses Motion Picture Experts Group MPEG-2 compression technology, which allows excellent picture quality in the limited 6 MHz bandwidth.

However, only 33 analog channels are allocated to MMDS. No self-respecting broadcast service can expect to compete with DBS and cable services, capable of offering 100 plus channels. Therefore, wireless cable technology was a prime market for digital conversion.

What has come to the aid of wireless cable services (including other services mentioned further on), is the rapid development and proliferation of very large scale integration (VLSI) technology, application specific integrated circuits (ASICs), and most significantly, fast, powerful digital signal processors (DSPs). This technology warrants a quick overview because it is likely to be the fundamental coding scheme for future digital wireless broadcasting.

Currently, quadrature amplitude modulation (QAM) seems to have emerged as the coding scheme yielding the best cost-benefit relationship. Essentially, QAM is a technique that combines amplitude and phase modulation. Modulation techniques used in MMDS include QAM-16 and QAM-64. QAM can be implemented

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HDTV and in-station coaxial transmission lines

High definition television (HDTV) is bringing significant changes to the broadcast market, especially the coax wireline that connects the station equipment (tape players, downlink feeds, and cameras right through the switches, routers, editors, patch equipment, and monitors) together to process the broadcast signals.

One of the factors driving the bandwidth requirements is the pixel count. On plain old television service (POTVS), the matrix is 525 × 487 for 256k points of address. Stepping up to one of the several versions of digital definition (480 × 640) produces a matrix of 307k address points, but the screen ratio is still 4 × 3 (x to y axis). Assuming that the industry settles on full digital HDTV (screen ratio of 16 × 9) and something like 1080i as the standard, the matrix count is now as high as 2,074k discrete address points, an increase of 8× today's standard. Even with compression, this requires significantly more bandwidth capacity than current coaxial wireless can transmit without unacceptable loss or signal degradation.

One good solution is using high frequency wave forms, which allows more discrete data points (changing states) per unit of time. However, high frequency RF transmission lines engage entirely new issues in physics that a designer needs to consider and provide for (such as reflection).

The technical issues that make a wireline into a transmission line include insertion loss and reflection. And related to reflection is the voltage standing wave ratio (VSWR). In elementary terms, it's enough to know that electromagnetic effects can degrade signal strength and interfere with the primary signal, causing a breakdown in clarity, even where only ones and zeros are at stake. Further, the concept of reflection is important to issues of signal meaning since, at high frequency, wave forms are additive. Adding a strong plus wave to a strong reflected negative wave (180° out of phase) creates a null or standing wave that is "seen" by the system as no signal at all. This is potentially fairly serious. High frequency waves used in HDTV transport sufficiently well in coax since there is usually no discontinuity or difference in physical construction, dielectric or spacing in the cable. Once the cable is terminated into a connector, a considerable potential for discontinuity exists, creating reflection of the signal energy.

What frequency?

Assuming 1080i uncompressed signals (a data rate of 1.485 Gbps), the use of alternate mark inversion coding technology (translates into a basic "clock" rate of 750 MHz) and use of the third harmonic to achieve the square waveform (Fourier transform technology), the maximum frequency needed is 2.25 GHz. There is some question regarding the need for upside "headroom" in frequency because of assumptions about the use of compression technology. Obviously, the more compressed a signal, the less bandwidth is needed to transport it. On the other hand, it seems to be the case that as soon as some plateau of bandwidth use is about to be reached, a new application or add-on is found that requires more. In the course of a few short years, the Internet advanced from "text only" to graphics to photos to streaming audio and video. It seams reasonable to assume that the broadcast industry will follow suit.

The key products that comprise the in-station transmission line are the cable wireline itself, the patchjacks and connectors (including equipment jacks, distribution panel jacks, and cable terminating plugs). Let's take these one at a time.

The coax cable used in transporting the HDTV digital signal within a facility is quite good. However, existing cable still needs to be replaced since it was designed for lower frequency and higher insertion loss conditions. The innovation of major manufacturers is resulting in cable products with better and better insertion loss performance. Use of low loss dielectric materials and lower dielectric constant materials is growing. Typical values on some new cable types today are less than 1 dB loss for 100 meters of length. (Note that the key technical issue for cable selection is insertion loss over distance.) Further, the tradeoff of overall cable diameter, cable weight and cost are being attended.

Digital video patchjacks are used to insert new signal content into a signal stream that is in place. For that reason, patchjacks are usually specified as "normal through," meaning that the "back end" (or BNC jack side) is wired to pass the energy through the jack, and onward if nothing is in the "front panel" or patch side. The interior of the jack itself is a tough engineering assignment because the switching function must coexist with multiple signal paths, all of which need shielding and dielectric controls for optimum signal processing. The key test is how it performs in normal through mode as well as how it does with front side patching in progress. It is important to test for make/break sureness of contact. Comprehensive testing is the only sure way to successfully select the right hardware for the life cycle of your station. Also needed is a monitor plug that can be inserted into the front side of the patch-jack to sample the normal through signal going through, without degrading that signal significantly.

Another key element of the transmission line is the coax cable connector. The North American broadcast market has traditionally used BNC connector technology for this assignment and will continue doing so with HDTV. Until recently it was not uncommon for stations to use 50 Ω connectors on 75 Ω cable. In any case, an upgrade is strongly recommended with HDTV, since many low-end BNC connectors are not capable beyond 1 GHz.

—Dale Reed, Trompeter Electronics

CHARACTERISTIC	POTVS	HDTV
Frequency	45 MHz	1.5 GHz
Conductor	full cross section	surface only or "skin"
Dielectric	voltage barrier	constant media, tight tolerance, low loss
Electromagnetic Field	weak, not noticeable	significant source of signal degradation
Ground	return path	boundary condition for field
Connectors	insertion loss resistance (heat)	reflection (VSWR) signal canceling
Losses	conductors (heat)	dielectric (radiation)

POTVS differs significantly from HDTV technology.

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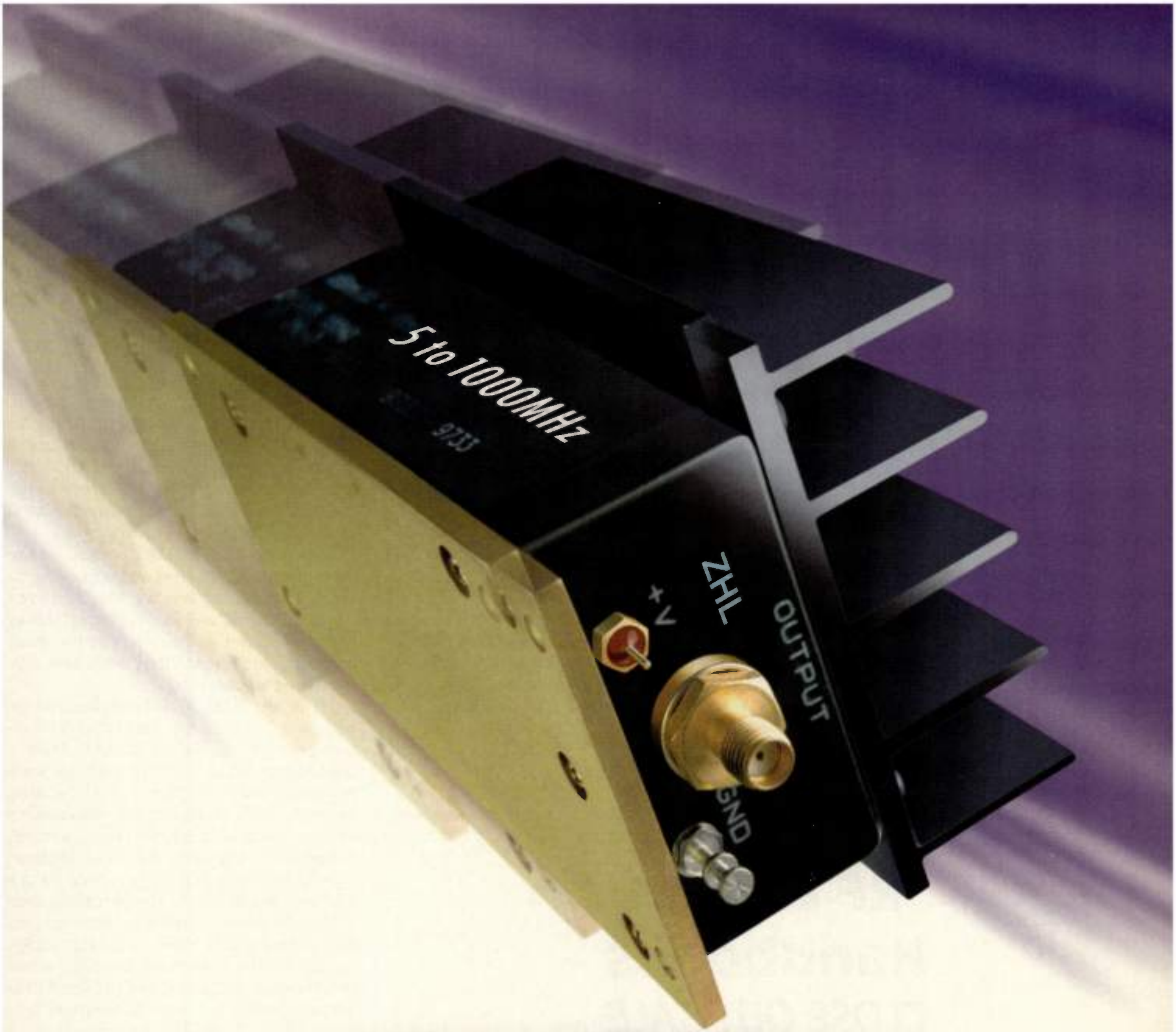

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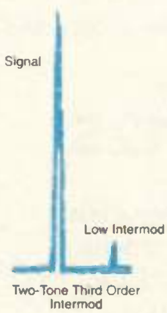

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■ ZHL-1010-75	50-1000	9.5	+26	525	+47	149.95
△ ZHL-1010	50-1000	9.5	+26	525	+46	149.95
△ ZHL-2010	50-1000	20	+26	900	+46	169.95
△ ZHL-3010	50-1000	30	+26	1000	+46	179.95

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Modulation	Bits/Hertz	Data rate within the 6 MHz band (Mbps)	+/- S/N for 10-6 bit error rate.1
BPSK	1	5	11
QPSK	2	10	14
QAM-16	4	20	21
QAM-64	6	30	27
QAM-256	8	40	33

Table 2. Increased data rates result in increased S/N.

from quadrature phase shift keying (QPSK or QAM-4) to QAM-256. Basically this is a bit-coding scheme in binary as high as 8 b/Hz.

QAM in-phase (I) and quadrature (Q) outputs are derived by combining two separate binary phase shift keying (BPSK) channels transmitted in the same band in quadrature to each other. This makes one of the outputs I and the other Q to it, relative to the carrier. The major advantage of applying QAM is that, once the carrier is suppressed, two signals are occupying the same bandwidth, with no increase in S/N—not bad!

Increasing the bit-per-hertz rate results in increased throughput. As the bit-per-hertz rate is increased, i.e. increasing from QAM-4 to QAM 256, the accuracy of the sample is increased by sampling the waveform more frequently. However, there are trade-offs. Increased sampling improves on data rates and increases spectral efficiency, but at the cost of S/N (see Table 2).

However, even fundamental digitization requires significant digital signal processing resources. The higher the modulation rate, the faster and more complex the processors need to be. Today's DSPs have reached speed and processing levels that make them reasonably adaptable and cost effective to QAM schemes as high as 8 b/Hz. When choosing QAM schemes, the only real limiting factor is the tolerable S/N of the channel.

Its future

How much of the market can wireless cable garner? Early on, MMDS as a ubiquitous, pervasive broadcast technology showed promise, but several attempts to deploy large systems did not fare well, especially those that were undertaken by the Regional Bell Operating Companies (RBOCs).

Competition from sources such as DBS and wired cable has been gaining ground. They, too, have been moving to the digital domain. Cable modems promise a number of interactive applications, and DBS services are becoming more affordable as the payback period for early up-front costs is dropping out of the equation.

It is likely that MMDS, because of the attractive benefits that are appealing to developing countries as well as other first-world countries, will fare better outside of the Untied States. To reiterate, the most promising are regions that don't have any real wired infrastructure.

However, MMDS's future seems to be with wireless Internet, and other interactive services. 6 MHz channels offer a tremendous bandwidth for features such as home office voice and data, local area network (LAN) interconnect, videoconferencing, telemedicine, distance learning, residential multimedia and a host of other, mostly two-way services, especially for business installations. The overall success of this, however, depends on both up and downstream data rates. And currently, upstream (return) doesn't have the same transmission paths or speeds as the downstream path. There is a movement to allow 6 MHz channels in both directions.

So, the frequencies are there, the technology is there, and the opportunity is there. Although MMDS has had a turbulent past, there is a quiet stirring and jockeying for position from some of the players. This is sure to offer new opportunities for the RF industry.

Finally, just to put a fly in the ointment, the jury is still out on what role low earth orbit (LEO) satellites will play in broadcast technology over the next few years. If the projects come off as ambitious as has been touted by the LEO players, we could have a whole new ball game. RF

Acknowledgment

The author thanks John Saul, vice president at EMCEE Broadcast Products (www.emceebrd.com), for his input into preparing this article.

Reference

1. 10^{-6} BER is generally recognized as the minimum standard for acceptable data transmission errors.

Automated RF path characterization in mobile phone test systems

An automated application can make the process of RF path characterization easier and more accurate.

By Dennis Thiers

Today's mobile phone test systems make accurate RF level measurements. To ensure accuracy, offsets in RF levels caused by cabling, instrumentation or active components in the RF path must be considered. Methods used for characterizing and compensating for these offsets include the use of power meters and signal sources, as well as calibrated mobile radios. The problems in identifying RF paths in the system and associating path offsets by frequency with a given path are also part of the process that is used to correct measurements. Using a Visual Basic application, a test engineer can quickly define the RF paths in a test system, produce a table of offsets for each path and store these for use by the mobile phone test system.

RF paths

An RF path in a mobile phone test system is comprised of a series of components through which the radio signal is transmitted or received by the phone under test. The most obvious component is usually a coaxial cable and its connectors that lead from the phone, or a fixture carrying the phone, to RF instrumentation. Other common components of the path are RF relays, attenuators and amplifiers. A fixture is often used to contain the phone under test, and this fixture may have RF connectors and cabling that are also components of the path.

Experience has shown that this collection of components can be crucial to making accurate measurements of RF power levels transmitted and received by the phone. Variations in the RF power offsets caused by minor changes in the path can introduce significant error into these measurements. A method for capturing, storing and compensating for these offsets can improve the accuracy of power level measurements.

RF measurements

A straightforward method for measuring path offsets is to connect the path between an RF signal generator and an RF power meter. The signal generator is programmed to a known frequency and power level, without modulation. The RF power level at the signal generator output is then compared to the power measured at the power meter input. The difference is the RF offset for that particular frequency. Offsets are usually measured for the range of frequencies used in testing the phone. These frequencies correspond to the forward and reverse cellular or personal communications service (PCS) channel frequencies. However, disconnecting and reconnecting an RF path can influence the offset measurements by as much as 0.5 dB.

When an RF mobile station test set is connected to the path in normal testing use, it is possible to avoid disconnecting the RF path during path characterization. The RF mobile test station can act as a programmable source of RF power and can also make RF power level measurements at the appropriate channel frequencies. In this case, the phone end of the RF path is connected to a power meter. The test set is programmed to output a known frequency signal and power level, and the power meter reading is compared to the known level. The result is the RF offset including any inaccuracies in the RF test set. The RF path offset has thus been extended to include any offset introduced by the RF test set.

Another process for measuring RF offsets caused by RF path components in mobile phone test systems is the *Golden Phone* method. This idea is to use a calibrated phone and the RF test-set to source and measure all of the RF signals. In this way, it is possible to avoid disconnecting the RF path at either end. The calibrated phone is programmed to transmit at known levels on various channels, and those levels are then measured with the RF test set. The calculated offsets are stored and used exactly as those obtained by the other characterization methods. This method has the advantage of minimizing error caused by changing connections, but it has the limitations of accuracy and programmability imposed by the phone and the RF test set.

RF offsets

As an example, when characterizing an RF path that is part of a test system for advanced mobile phone ser-

AMPS Channel	Applied Frequency (Hz)	Measured RF Power (dBm)	Offset RF Power (dBm)	Value (dB)
1	869040000	0	–0.2	–0.2
71	871140000	0	–0.3	–0.3
141	873240000	0	–0.3	–0.3
211	875340000	0	–0.4	–0.4
281	877740000	0	–0.4	–0.4
351	879540000	0	–0.3	–0.3
421	881640000	0	–0.3	–0.3
491	883740000	0	–0.2	–0.2
561	885840000	0	–0.3	–0.3
631	887940000	0	–0.2	–0.2
701	890040000	0	–0.2	–0.2
771	892140000	0	–0.1	–0.1

Table 1. RF path offsets by AMPS channel.

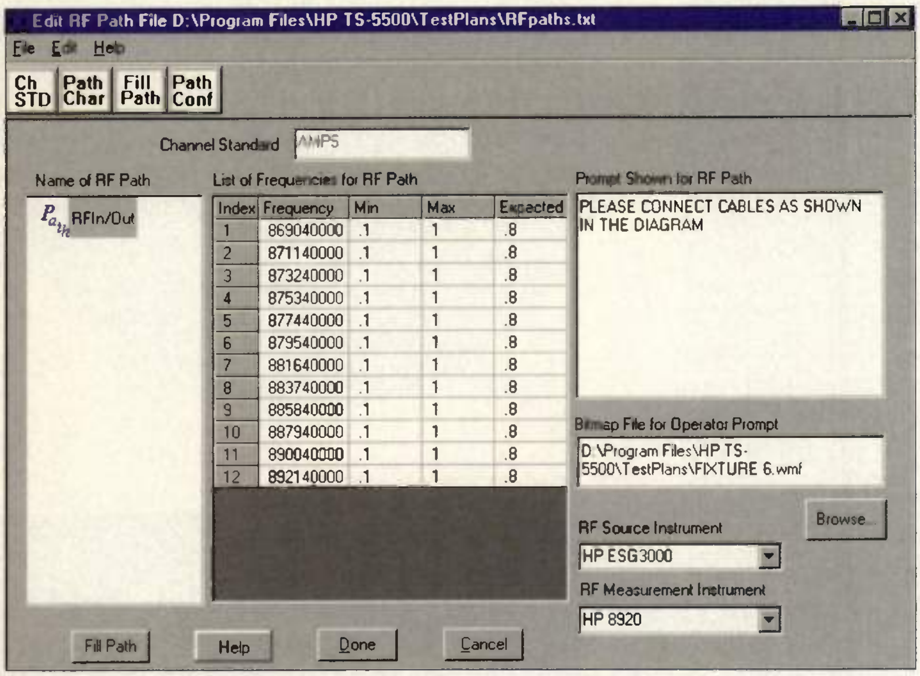

Figure 1. RF Path Characterization screen.

vice (AMPS) devices, several channels throughout the forward (base station transmitting) frequency range might be selected and 0 dBm signals applied to the RF path at those frequencies using an RF signal generator. Assume that the results, measured at the other end of the RF path using a power meter, are as listed in Table 1.

These offsets can now be stored and used to adjust the measured values or signal levels applied during the testing of phones connected to the above RF path. Assume that the required power level at the phone under test is –50 dBm and the channel used for the test is 211. The proper programmed setting of the RF test set is

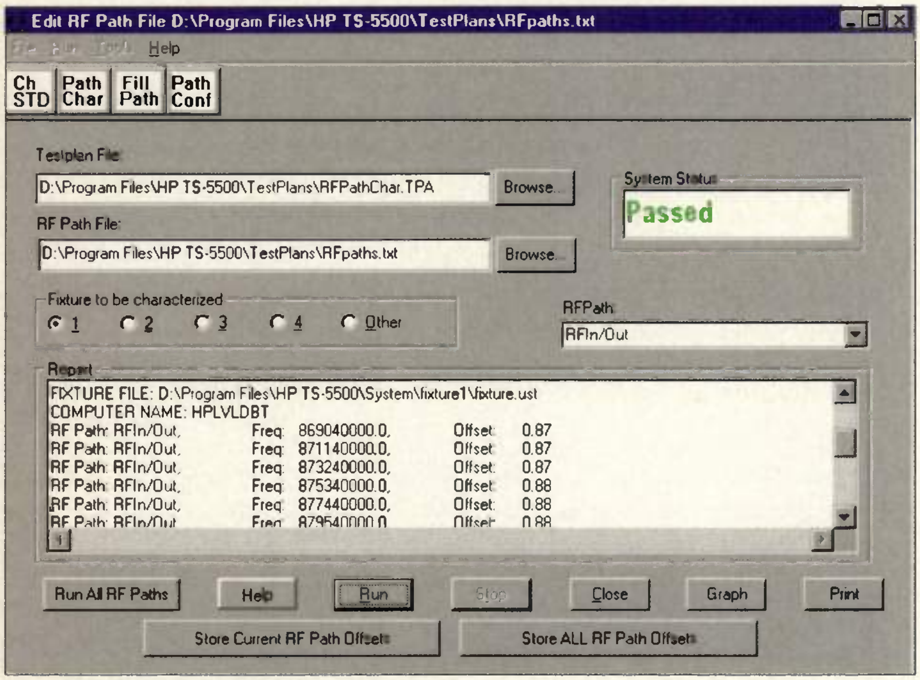

Figure 2. RF Path Characterization screen.

computed as

–50 dBm ⇒ Forward trasmit power level (at phone)

– –0.4 dB ⇒ RF path offset

–49.6 dBm ⇒ Programmed power level (at RF test set)

Tools for defining RF paths and characterization data

Test software provides for the use of tables of offsets for selected channel frequencies that are accessible for compensating all RF measurements and RF source settings. The RF offset tables are stored in a file that is loaded at runtime into the environment of the test executive program. The test executive makes the offsets available to tests and measurements contained in the phone test plan so that RF power levels can be adjusted as needed.

Because RF path offsets tend to vary with time, temperature and mechanical changes to the test system, it is necessary to periodically update the offset tables. A Visual Basic application has been developed that allows for automatic updates, once the RF channels and several other options have been selected. Some operator intervention is required to make any necessary connections to instruments.

The test engineer must decide what RF paths in the system are to be characterized. In most systems, only one RF path for each phone under test is needed. This RF path will connect the phone to the RF test set for both transmitting and receiving. In some cases, a separate path will carry the forward (base station transmitting) and reverse (mobile phone transmitting) signals. In more complex instances, paths to peripheral RF instrumentation will need to be characterized.

The test engineer must also choose which channels (frequencies) are to be measured, as well as operator or technician instructions to ensure that the proper connections have been made. Consider a simple case where there is one path. Figure 1 shows the *RF Path Configuration* screen of the path characterization program.

The test engineer first chooses a channel standard such as AMPS, PCS, global system for mobile communications (GSM) or digital communications system (DCS)-1800 that determines the forward and reverse channels and frequencies. The next step is to choose a set of channels from which the RF path offset measurements will be made. It is desirable to

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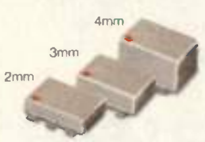

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ADE-1ASK	3	2-600	+7	5.3	50••	16	3.95
ADE-2ASK	3	1-1000	+7	5.4	45••	12	4.25
ADE-12	2	50-1000	+7	7.0	35	17	2.95
ADE-14	2	800-1000	+7	7.4	32	17	3.25
ADE-901	3	800-1000	+7	5.9	32	13	2.95
ADE-5	3	5-1500	+7	6.6	40••	15	3.45
ADE-13	2	50-1600	+7	8.1	40••	11	3.10
ADE-20	3	1500-2000	+7	5.4	31	14	4.95
ADE-18	3	1700-2500	+7	4.9	27	10	3.45
ADE-3GL	2	2100-2600	+7	6.0	34	17	4.95
ADE-3G	3	2300-2700	+7	5.6	36	13	3.45
ADE-30	3	200-3000	+7	4.5	35	14	6.95
ADE-35	3	1600-3500	+7	6.3	25	11	4.95
ADE-18W	3	1750-3500	+7	5.4	33	11	3.95
ADE-30W	3	300-4000	+7	6.8	35	12	8.95
ADE-1MH	3	2-500	+13	5.2	50••	17	5.95
ADE-12MH	3	10-1200	+13	6.3	45••	22	6.45
ADE-25MH	3	5-2500	+13	6.9	34••	18	6.95
ADE-35MH	3	5-3500	+13	6.9	33••	18	9.95
ADE-42MH	3	5-4200	+13	7.5	29••	17	14.95
ADE-10H	3	400-1000	+17	7.0	39	30	7.95
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have expected offset values, so that the measuring instruments can be set to the correct range, as well as maximum and minimum values, so the test operator can be informed if erroneous RF path offset values are measured.

Instructions to the test operator may also be entered in the appropriate field as text. There is a field that can be used to select a picture file of any standard format, such as .bmp, .wmf or .jpg. The picture file may contain a drawing or a photograph of the test system and any cable connections that may need to be made by the operator.

The program also associates a source instrument and a measurement instrument to be used in the measurement of all of the offsets for each RF path.

The previous data is entered for each RF path to be characterized. All of the path data is then stored into a file that is used when the RF path characterization test plan is run.

Measuring and storing offsets

Figure 2 shows the *RF Path Characterization* screen of the RF path characterization program. The test operator or technician runs the RF path characterization test plan generating tables of RF path offsets. As these offsets are computed, they are compared to the minimum and maximum values, and an error is raised if these limits are exceeded. The operator has the option of graphing the offsets vs. frequency along with the minimum, maximum and expected values.

If no errors exist, the operator or technician may store the offset values into configuration files that are used in the manufacturing test of mobile phones. Once these values are stored in the configuration files, they are automatically used in every measurement and source setting.

Conclusion

This system is flexible enough to allow for multiple RF paths, different channel standards, various types of source and measuring instruments, as well as RF paths that are a composite of different channel standards. At the same time, it is easy to use, and it allows for rapid configuration of RF path offset measurements and rapid updating and accessing of these important test system parameters. *RF*

About the author

Dennis B. Thiers received his B.S. in physics from the University of Illinois and his B.S. in computer science from Colorado State University. He has worked for Hewlett-Packard (HP) for 14 years, nine of those years as a software development engineer. He can be contacted at 970-679-2022 or by e-mail at *thiers@lvld.hp.com*. The RF path characterization program described in this article is the HP TS-5500 RF path characterization and measurement software program.

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An (almost) all-digital HF communications receiver

CMOS monolithic digital downconverters permit the construction of low-cost receivers using digital signal processing.

By Peter Traneus Anderson

Communications receivers for the high-frequency (HF) band from 3–30 MHz are asked to perform under difficult conditions, extracting weak signals on frequencies close to the frequencies of unwanted strong signals. These receivers use analog circuitry in the signal path, with basic designs descended from Armstrong's original superheterodyne design [1].

Over the past few years, monolithic analog-to-digital converters (ADCs) and digital downconverters (DDCs) have appeared on the commercial market. These devices permit the construction of inexpensive HF receivers using a signal path that is almost entirely digital.

This article considers HF communications receivers used primarily for aural reception of single-sideband (SSB) amplitude-modulated voice signals and on-off keyed (OOK) continuous-wave (CW) Morse-code signals.

Receiver Type	Minimum Discernible Signal (MDS)	Blocking Dynamic Range (BDR)	Intermod Dynamic Range (IMDDR)
Analog	–128 dBm	142 dB	97 dB
ADC	–113 dBm	111 dB	80 dB

Table 1. Analog receiver vs. ADC performance at 14 MHz with 500 Hz bandwidth.

Architecture of digital HF receiver

The block diagram of a basic digital receiver for aural reception is shown in Figure 1 [2][3]. The signal from the antenna passes through a lowpass filter (LPF), a low-gain broadband amplifier and a second LPF to the input of the ADC.

The ADC digital output goes to the input of the DDC. The DDC is set to output a real signal, rather than the usual in-phase/quadrature (I/Q) complex signal. When operating in real mode, the DDC uses Weaver's method of SSB demodulation [4] to shift the desired signal frequency down to the audio frequency range and to bandpass-filter the signal. In Weaver's method, the incoming HF signal is downconverted to a complex baseband lowpass signal and then upconverted to a real bandpass audio signal.

The DDC also decimates the samples, reducing the high-input sample rate to a rate appropriate for the audio-frequency output. The output of the DDC drives one input of a scaling multiplier. The other input of the multiplier is a gain parameter. The gain parameter is adjusted to compensate for varying signal strengths, to keep the audio output at a desired level.

The output of the multiplier drives a digital-to-analog converter (DAC). The DAC's output passes through an LPF to remove aliases, giving the desired analog audio signal. The audio signal is amplified and sent to the loudspeaker.

In the receiver described in [3], the LPFs pass frequencies below 22 MHz and have unity gain in the passband. The preamp has a gain of 10 dB. The ADC is 12-bit, capable of operating as high as 65 MSPS (megasamples per second), with a fullscale input (from 50 ohms through a 2:1 step-up transformer considered as part of the ADC) of –2 dBm. The DDC can operate as high as 52 MSPS.

Both the ADC and the DDC operate at 50 MSPS in this receiver. The 50 MSPS sample rate limits the frequency coverage to frequencies below 22 MHz.

Dynamic range of digital vs. analog receivers

The dynamic range of a digital receiver is limited primarily by the ADC linearity and noise level. Table 1 compares the specified performance of the ADC with the reported measured performance of a high-performance commercial analog receiver, the receiver portion of an amateur-radio transceiver [7].

The transceiver's data in Table 1 comes directly from a product review by Lindquist and Swanson [8]. The ADC data is calculated from specifications in a data sheet [5]. Both receivers are operating at a signal frequency of 14 MHz with a bandwidth of 500 Hz. The transceiver is operating with its RF preamp turned off. The ADC has a 2:1 step-up transformer at its input, and is operating at 50 MSPS.

The blocking dynamic range (BDR) is taken as the signal-to-noise ratio (SNR) in dB at the ADC output of a signal 1 dB down from full-scale, increased by the SNR process gain in dB incurred in the DDC (where the signal bandwidth is reduced from 25

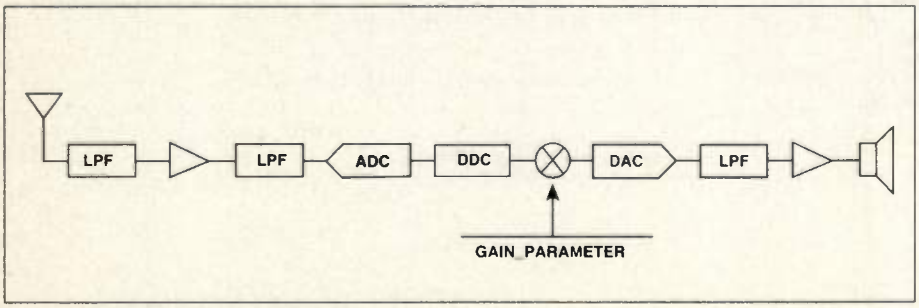

Figure 1. Block diagram of digital receiver for aural reception.

MHz to 500 Hz). The minimum discernible signal (MDS) is taken as the full-scale signal in dBm minus the BDR. The third-order intermodulation-distortion dynamic range (IMDDR) is taken directly from the ADC's data sheet.

The ADC is one of the best currently available, and its performance is clearly not as good as that of the transceiver. The ADC's IMD dynamic range is 17 dB worse than that of the transceiver. According to the ADC's data sheet, dither (out-of passband noise) can be applied to the ADC to improve its IMD performance by 10 dB, giving a spurious-free dynamic range (SFDR) of 90 dB. This is just 7 dB poorer than the performance of the transceiver.

The ADC's MDS can easily be improved in a receiver by providing some gain in a preamplifier ahead of the ADC. The receiver described in [3] uses 10 dB of gain for this reason. The preamplifier can, of course, degrade the intermodulation distortion (IMD) performance of the ADC.

The ADC's BDR is determined by SNR in the ADC's data output. Improving the BDR requires improving the SNR. Improving the SNR requires increasing the number of bits in the ADC data word. This requires the least-significant bit (LSB) becoming smaller, the fullscale signal becoming larger, or both.

The ADC's SNR is 67 dB, good for a 12-bit converter. To equal the transceiver's performance, the ADC's SNR must increase by 31 dB, implying an increase in the word length of 5 bits (at 6 dB per bit). This would give a word length of 17 bits and an SNR of 98 dB.

A longer word implies a smaller LSB or a larger fullscale or both. In a sampling ADC, the LSB cannot be made much smaller than the value in the ADC because of the analog noise floor set by wideband analog noise being aliased into the ADC passband by the sampler in the ADC.

The Johnson noise of a 50 Ω room-temperature signal source is about –138 dBm for a noise bandwidth of 500 Hz. Thus the ADC's noise floor, –113 dBm for a noise bandwidth of 500 Hz, is only 25 dB above the Johnson noise level.

For the overall receiver to have a noise floor limited by Johnson noise of the 50 Ω input signal source, there must be some gain and filtering between the receiver input and the ADC analog input, so the bandlimited amplified input noise will be large compared to the ADC internal noise.

Reducing the noise floor by 11 dB might help. This leaves 20 dB to be gained by increasing the fullscale input by a factor of 10. The ADC has a full-scale input at the chip of 1 V peak-to-peak. Increasing the full-scale input to 10 V peak-to-peak is difficult in modern mixed-signal chips, as the trend is to supply rails of 5 V or less.

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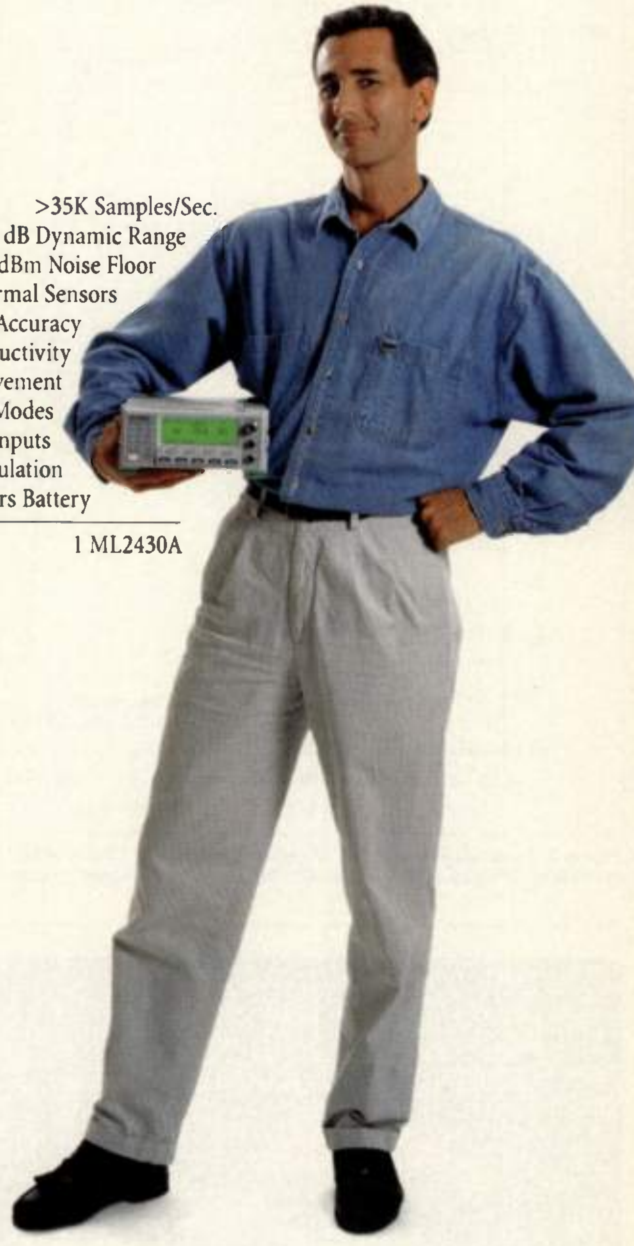

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pling, or deltasigma, ADC. This type of ADC has built-in antialiasing because of the high sample rates used, so the in-band LSB noise can be pushed down to the Johnson-noise floor. Deltasigma ADCs are well-known for potential high SNR and linearity.

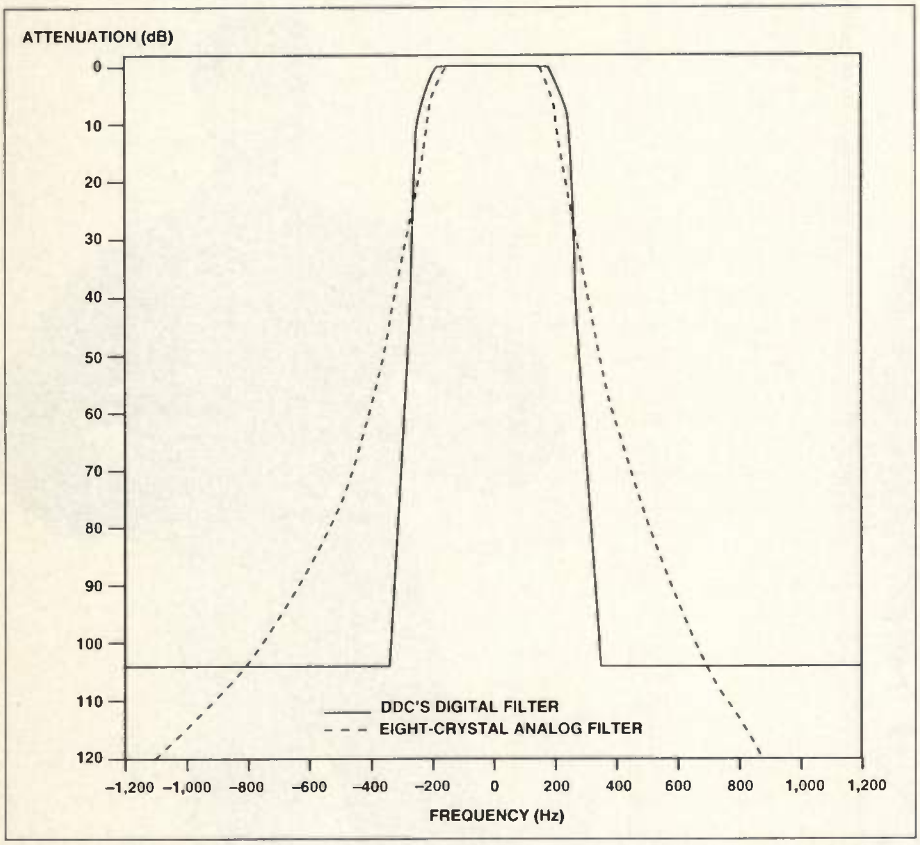

Figure 2. Frequency responses of eight-crystal analog filter (dashed line) and the DDC's digital filter (solid line). The digital filter attenuation floor is actually ragged, always below the straight lines shown.

Adams, et. al., describes an audio deltasigma ADC with 100 dB of SNR available at an oversampling ratio of 64 [9][10]. Recent experiments have demonstrated the potential of deltasigma ADCs at HF signal frequencies. Gao, et. al., describes a registered comparator intended for use in deltasigma ADCs at a clock speed of 5 GHz [11]. With an oversampling ratio of 64, the signal frequency range would be DC to 5 GHz/128 = 39 MHz. Jensen, et. al., describes a working deltasigma ADC running with a clock speed of 3.2 GHz and an oversampling ratio of 32 [12]. This gives a signal frequency range of DC to 50 MHz. This ADC has an SFDR of 72 dB and an SNR of 55 dB using a second-order design. Higher orders and higher oversampling ratios will lead to improved performance.

Oscillator phase noise and tuning steps

A superheterodyne analog receiver must have at least one variable-frequency oscillator (VFO) to permit tuning to the desired input frequency. This oscillator is always a difficult part of analog receiver design. Mechanically-tuned VFOs are diffi-

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cult to control digitally, and are difficult to set to precise frequencies. Phase-locked-loop (PLL) frequency synthesizers have difficult trade-offs between phase noise and tuning step size. Direct digital synthesizers (DDSs) have no problem with small tuning steps, but are limited by the noise and nonlinearities in the DAC used to convert the digital sinewave to analog. The DDC sidesteps all these problems by using a DDS without a DAC.

Characteristics of digital vs. analog filters

Every HF communications receiver exhibits a narrow passband, set by lowpass or bandpass filters. The narrowest filters are used for CW reception. Figure 2 compares the frequency responses of analog and digital CW filters. The dashed line shows the calculated frequency response of an analog bandpass filter using eight quartz crystals, having a –3 dB bandwidth of 400 Hz. The filter consists of two identical four-crystal sections cascaded with an isolating buffer between the sections. Each four-crystal section is a Cohn filter [13][14]. The measured attenuation in dB of one section, was doubled to give the calculated attenuation of two sections cascaded. The solid line shows the specified bandpass response of the DDC operating in real mode. The DDC's filter is set for a –3 dB bandwidth of 427 Hz.

The digital filter shows an attenuation floor at –104 dB not present in the analog filter. The floor is actually ragged, always below the straight lines shown. The floor is caused by the design of the finite impulse response (FIR) filter and to the finite-precision integer arithmetic used to implement the filter. The level of the floor in the digital filter is set by economic tradeoffs (a lower floor requires a more complex chip), rather than by physical feasibility. The digital filter response is wider in the passband and narrower in the stopband, exhibiting the narrow skirts common in digital filters.

Improvements needed in DDC's for HF receivers

Once excellent ADCs, with dynamic ranges as good as or better than those of analog receivers, are available, the DDC performance will have to be improved. The dynamic range must be improved, and the real-mode audio passband must be made shiftable for receiving various signals.

Dynamic range

From Table 1, the analog receiver BDR is at least 142 dB for a receiver bandwidth of 500 Hz. Some applications use much smaller bandwidths. Coherent CW uses time-quantized transmitter keying and synchronous (hence the name coherent) receiver baseband sampling to communicate by Morse code at 12 words per minute using a noise bandwidth of 9 Hz [15]. The narrower bandwidth increases the SNR process gain by 18 dB, giving an analog receiver BDR of 160 dB. A good DDC must have an SFDR greater than the intended receiver BDR, as DDC spurious outputs appear after the process gain in SNR that comes with narrowband filtering in the DDC. Thus, a good DDC for HF radios must have an SFDR of 160 dB or better. The DDC is the best currently available, with an SFDR of 102 dB [6]. On-air listening tests of the receiver in reference [2] showed that this is insufficient: the DDC exhibits a center-of-passband spurious tone 102 dB down from the fullscale signal (note that this is within the DDC's specification limits), which interferes with weak-signal reception.

The spurious tone is caused by nonexact calculations in the DDC. Fortunately, when the DDC's decimation ratio is set to exactly a power of two, the offending tone is absent. With the tone absent, the DDC exhibits output SNR equal to that expected from the ADC's SNR and the bandwidth-reduction SNR process gain. The DDC is useable in an HF receiver because, when used carefully, it exhibits SNR greater than its SFDR.

Fortunately, the restriction on the decimation ratio permits the bandwidths needed for SSB and CW reception. An improved DDC with high SFDR, will permit wider choice of bandwidths, as the DDC's SFDR will be greater than the receiver's SNR at any bandwidth.

Shiftable audio passband

Recall that the DDC down converts the incoming HF signal to a complex baseband lowpass signal, and then

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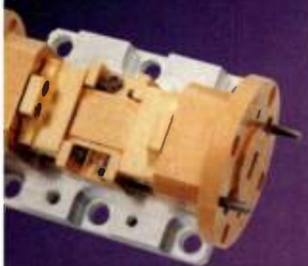
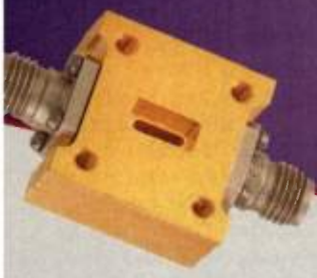


AMPLIFIERS

Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	I/O VSWR (Max.)	Output Power at 1dB Comp.* (dBm, Typ.)
JSW4-18002600-18-5A	18-26	28	1.0	1.8	2.0:1/2.0:1	5
JSW4-26004000-25-5A	26-40	25	2.5	2.5	2.0:1/2.0:1	5
JSW4-18004000-32-8A	18-40	21	2.0	3.2	2.0:1/2.5:1	8
JSW4-30005000-45-5A	30-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW4-40006000-65-0A	40-60	16	2.5	6.5	2.5:1/2.5:1	0

* Higher output power options available



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	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	20	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	20	45
ARE3436LC1	34-36	15.5-16.5	2.7-3.3	25	4	20	60
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20

MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, min.)	Output Power* (dBm, min.)	Fundamental Feed Through Level (dBc, min.)	DC current @+15VDC (mA, nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	12	18	160
MAX2M200380	10-19	20-38	6	14	18	200
MAX2M300500	15-25	30-50	10	8	18	160
MAX4M400480	10-12	40-48	10	8	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	8	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

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Signal Type	Passband Width	Passband Center	Passband Range
CW	214 Hz	191 Hz	84–298 Hz
CW	427 Hz	382 Hz	168–595 Hz
CW	854 Hz	763 Hz	336–1,190 Hz
CW/SSB	1,709 Hz	1,526 Hz	671–2,380 Hz
NONE	3,418 Hz	3,052 Hz	1,343–4,761 Hz

Table 2. Audio passbands available from DDC at 50 MHz clock.

upconverts the baseband signal to a real bandpass audio signal. In the DDC, the ratio of the center frequency of the real passband to the bandwidth, is fixed. This ratio needs to be made variable, so the center frequency can be varied without changing the passband. Table 2 shows the audio passbands of the receiver in reference [2] for various bandwidths used for SSB voice and CW Morse reception. The 427 Hz and 214 Hz bandwidths should have their passbands moved higher in frequency, so the passband is entirely in the audible range, and so that the passband center is independent of filter bandwidth.

CW passband center frequencies should be adjustable, as different operators prefer to listen to different tone frequencies. Also, the CW center frequency should be independent of bandwidth, so the tone does not change as bandwidth changes. The 1,709 Hz bandwidth, passing frequencies from 671–2,380 Hz, when used for SSB voice reception, is narrower than usually desired. The passband includes barely enough low frequencies and high frequencies for intelligibility [2].

The next wider bandwidth useable with the DDC, is twice 1,709 Hz or 3,418 Hz. This bandwidth doubles the low-frequency band edge to 1,343 Hz. This is too high for voice intelligibility, rendering the wider bandwidth useless. If the passband could be lowered by 1,000 Hz, giving a 344–3,760 Hz passband providing excellent voice reception.

Subjective performance

Because this receiver is intended primarily for aural reception, the subjective response of listeners is significant. Overall, the subjective performance is excellent. Receiver noise levels are below the noise level coming from the antenna. The audio exhibits negligible distortion. The SSB passband, though audibly narrow, is clearly intelligible for both male and female voices. The filter edges are sharp, with no hint of ringing, giving clear response to the on-off keying of CW signals. Mallet [16] reports excellent tuning stability and filter response in listening to CW signals on a similar receiver.

Conclusion

Digital HF receivers are now capable of excellent operation at low cost if the signal environment does not exceed the limited dynamic range and frequency range of the digital receiver. Expected improvements in ADCs and DDCs will soon permit the construction of digital HF receivers with better performance than that obtained in analog receivers. *RF*

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About the author

Peter Traneus Anderson is a senior electronics engineer with Visualization Technology. He has been building HF receivers for 40 years and is working on his Ph.D. thesis (on improved loop antennas) in the department of Electrical and Computer Engineering, University of Vermont. He can be contacted at 978-933-1009 or by e-mail at *peteand@vitech.com*.

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INFO/CARD 139

EMC protector reduces effects of radiation

The EMCxxF-LC series is a combination lowpass inductor-capacitor (LC) filter and transient voltage protector. The device provides electromagnetic compatibility (EMC) network interface protection by reducing the harmful effects of electromagnetic/radio frequency interference (EMI/RFI) as well as providing complete transient immunity. The device incorporates four low-capacitance diode clamp and EMI/FRI filter networks into a standard SO-16 surface-mount package. Although the device is designed for 500 MHz circuit applications, filter elements are changeable for –3 dB roll-off from 50–1,000 MHz. The roll-off is also adjustable by changing from a Bessel to a Butterforth type filter. Specific circuit applications can be matched by interchanging LC elements with resistive-capacitive (RC) elements. The low-capacitance series offers as many as four lines of protection and is available in voltages ranging from 3.3–15 V. The device is designed for 50 Ω interface circuit terminations. Suitable for the reduction of noise reflections and ringing associated with high-speed data line circuits, the device is used at board level in wireless communications, graphics, video cards and notebook computers.
Protek Devices
INFO/CARD 140

Test system develops current waveform

The IEC 1000-4-10 magnetic field damped sine immunity test system develops the damped sinusoid current waveform in the uniform area of the loop. The system can generate as much as 100 A/m peak in a one-meter loop for the 100 kHz or 1 MHz waveforms. The output waveform can be monitored with a broadband magnetic field sensor or a current probe. The generator output level, and either a single pulse or the specified burst of pulses, can be selected manually from the front panel or from a PC using control software. The system includes a digital oscilloscope to capture the waveform.
Fischer Custom Communications
INFO/CARD 141

Plastic covers shield selected portions

The Cho-ver Shield electromagnetic interference (EMI) shielding covers are designed for cellular handsets, personal communications service (PCS) and other small packages. The covers combine a slim-profile, metallized plastic with a low-closure force conductive elastomer gasket. They can be used to shield selected portions of a printed circuit boards (PCBs), eliminating the need to shield a device's outer housing. Custom-shaped covers replace the use of solder-mounted metal cans over board components. They are easily removed for PCB access during assembly or after testing. The covers provide 100 dB of shielding effectiveness at 500 MHz. Pins, holes and other locating features can be designed in for fast, precise installation. The covers feature plastic with nickel/copper plating on interior surfaces. The plastic can be compartmentalized to provide shielding against component cross-talk. The integral EMI gaskets are made from overmolded Cho-seal 1310 silver-plated, glass-filled conductive elastomer.
Chomerics
INFO/CARD 142

EMI shielding products offer lightweight designs

A full range of electromagnetic interference (EMI) shielding products are designed to make EMI shielding easier. The products feature thin, lightweight, resilient designs that can conform to a variety of mating surfaces and are simple to install. They meet such diverse applications as leak reduction in computer and telecommunication shielded enclosures; grounding around I/O ports; notebook and portable equipment shielding and distributed grounding for high-frequency RF devices.
APM
INFO/CARD 143

EMI gasketing offers more packaging space

The Electroform series 8558 compounds are single-component silicone-based compounds that provide more packaging space for board-level components and smaller package dimensions. The compounds reduce raw material, labor and assembly requirements for substrates, enclosure panels and shielding and grounding metal and plastic housings. Filled with proprietary conductive particles, they provide shielding effectiveness of greater than 120 dB at 1 GHz. Because they do not have to be mixed, the compounds shorten production cycles and reduce waste. The compounds cure quickly at normal room temperature and humidity, eliminating the need for heat curing systems and permitting the use of inexpensive plastic or metal substrates. They provide adhesion to a variety of materials, including aluminum and other cast alloys, stainless steel, nickel-copper plating over plastics, and copper-, silver- and nickel-filled paint on plastics. Their low compression force accommodates mating surfaces that lack mechanical stiffness.

Programmable location and dispensing equipment applies the compounds onto intricate multicompartment parts with accuracy and consistency, providing a secure bond to the substrate.
Instrument Specialties
INFO/CARD 144

Absorptive microwave attenuator

The EMC Thermopad is an absorptive microwave attenuator—a revolutionary approach to amplifier temperature compensation. The thermopad replaces elaborate active multicomponent schemes with a single, passive component. It offer high reliability, produces no distortion and takes up less circuit board space. The EMC Technology Thermopad Evaluation kit includes samples of both planar chips plus triple wrapped terminations chips. Each kit also includes the new Thermopad Selection Software Tool, which can be used to select the Thermopad that optimizes amplified gain over temperature.
Avnet RF
INFO/CARD 145

IEC inlet filter similar to chassis-mount units

The FN9246 IEC inlet filter combines a small form factor with high attenuation characteristics. The noise suppression performance is more typical of a chassis-mount unit. Designed primarily for applications involving fast-switching semiconductors, the filter is a suitable electromagnetic interference (EMI) suppression product for use when space is at a premium. Typical applications include switch-mode power supplies and small- and medium-sized uninterruptible power supplies. The filters are available with a choice of eight current ratings, spanning 1–20 A. The 16 A and 20 A versions measure 35 × 75 mm, and the lower current models are smaller at 30 × 47 mm. The filters have high inductance and X capacitor values to ensure high attenuation of differential and common-mode noise. As a typical example, the 3 A model provides some 40 dB asymmetric attenuation at 100 kHz, rising to 50 dB from 200 kHz to 30 MHz.
Schaffner
INFO/CARD 146

RF/EMI shielding line protects components

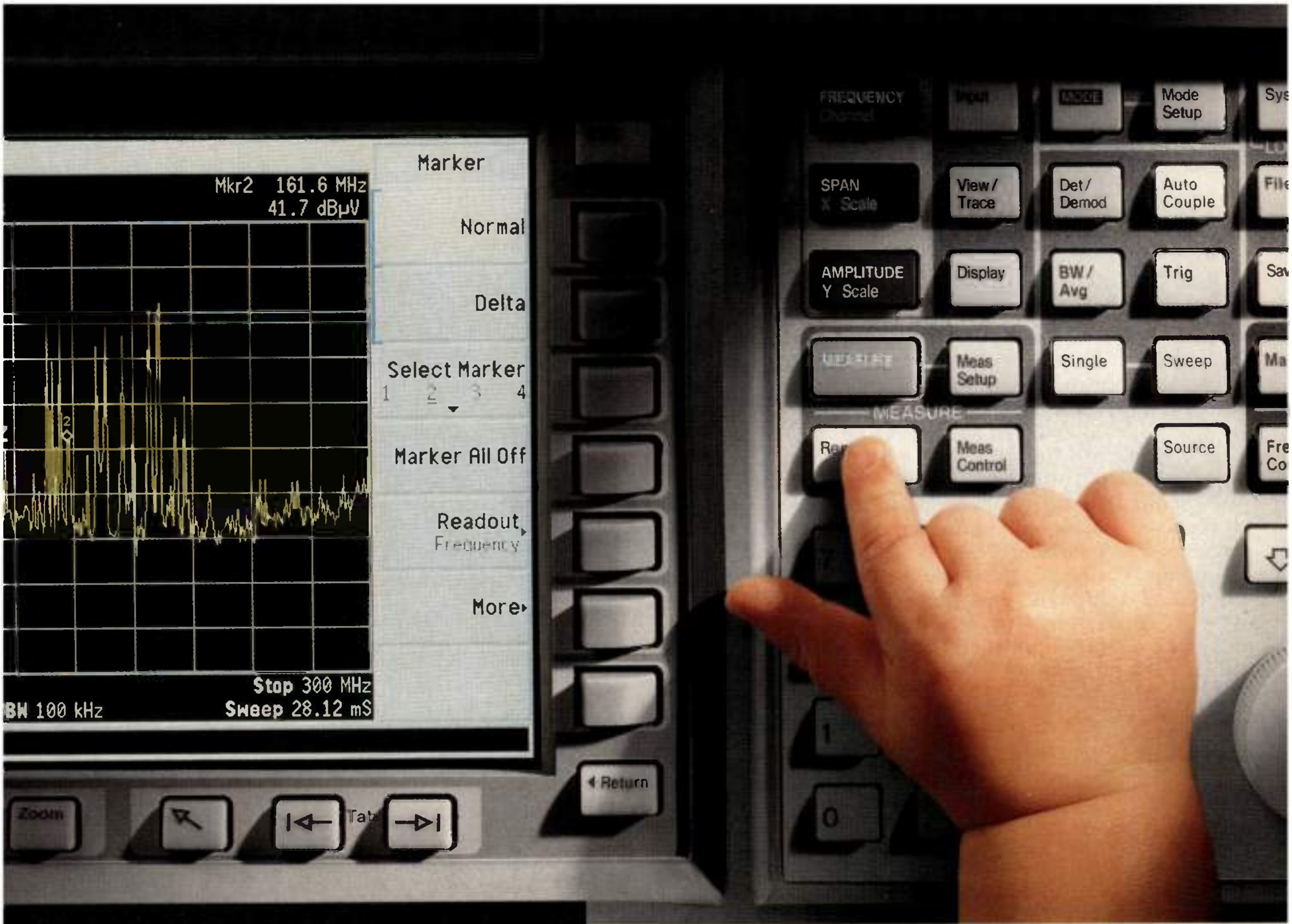
A line of photochemically etched radio frequency/electromagnetic interference (RF/EMI) shielding and filter screen is designed to protect components from RF/EMI and environmental hazards and to provide electrical grounding. RF/EMI shields are hand-formed and can be custom-designed to meet stringent customer requirements. Custom bend lines, logos, soldered or welded corners and RF cans with removable top covers are also offered.
Photofabrication Engineering
INFO/CARD 147

Filtered terminal blocks

The EMPac series of filtered terminal blocks are engineered to accommodate customer-specific requirements such as high power handling, enhanced filtering and custom mechanical configurations. EMPac's mechanical design eliminates capacitor failures from over- torquing screws, provides capacitance as high as 10,000 pF, and can incorporate integrated transient suppression. EMPac filtered terminal blocks are available with any number of terminals and standard or custom dimensions.
EMP Connectors
INFO/CARD 148

Low-profile turntables

Model 2088 EuroPro turntable family is designed for today's electromagnetic compatibility (EMC) test applications where height is a concern and installation options may be limited. All three low profile turntables in this series are metal topped, have variable speed operation and feature a ground plane interface system to simplify installation.
EMC Test Systems (ETS)
INFO/CARD 149



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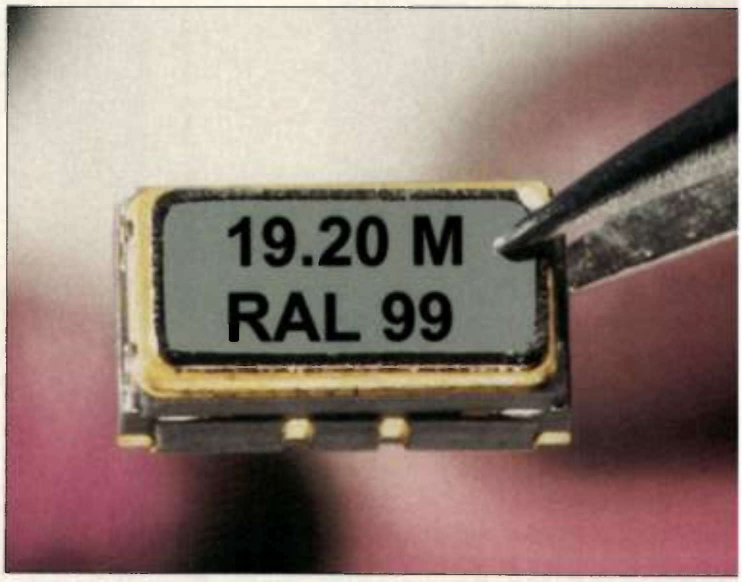
INFO/CARD 43

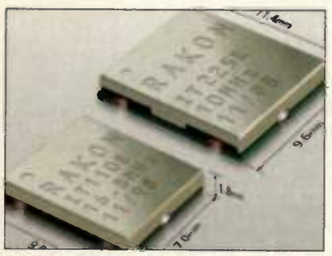
Surface-mount TCXO uses custom IC to slash size, cost

The RTVY-174 temperature compensated-crystal oscillator (TCXO) incorporates a custom integrated circuit (IC) chip to reduce size and improve efficiency. Designed for use in pagers, cell phones, two-way radios and other wireless systems worldwide, the RTVY-174 has a footprint of 6 x 3.5 mm. The device offers ±2.5 ppm stability over the –30°C to 80°C temperature range as a standard feature. Other features include an output voltage of 0.9V p-p minimum clipped sinewave, current drain of 2 mA maximum and is powered by a single 3.0 V supply. The unit is available in standard frequencies from 12.6–19.8 MHz. Stability variation with aging is better than ±1 ppm per year. The RTVY-174 is priced at less than $5.95 each in quantities of 10,000.
Raltron
INFO/CARD 150



Crystal oscillators

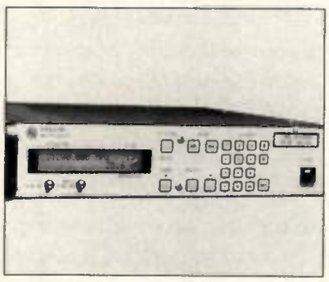
A range of crystal oscillators features an analog integrated circuit (IC) for oscillator and temperature compensation. The IT100 and IT200 series are capable of achieving a frequency stability of ±1 ppm over a temperature range of –40°C to 85°C. Other features include a phase noise of –105dBc/Hz



at a 100 Hz offset, a regulated power supply that allows the unit to operate anywhere from 2.7–5.5 V, a typical energy consumption of 1.2 mA and a unit weight of 0.172 g for the IT100 series. Frequency slope and perturbation specifications can be customized to suit application requirements.
Rakon
INFO/CARD 151

Synthesized converters

This series of Ka-band converters offers upconverters in the 27.5–31.0 GHz frequency bands and down-



converters in the 17.7–21.2 GHz bands, not only for existing Ka band satellites, but also for satellites currently being planned. Frequency tuning is in 125 kHz minimum step size. Both frequency and level control is available via the front panel keypad or by the remote interface. Phase noise is data quality.
MITEQ
INFO/CARD 152

VHF TV channel bandpass filter

Model 11990N bandpass filter isolates a VHF channel while maintaining a low loss of 0.5 dB maximum at the final output of the transmitter. It can be custom tuned to any VHF high-band frequency and is available for different channel formats. Features include a video-audio separation of 6.5 MHz, a passband loss of 0.5 dB maximum and voltage standing wave ratio (VSWR) of 1.3:1 maximum. Rejection is 20 dB ± 12.5 MHz from the

center frequency. The unit handles 500 W of power and measures approximately 18.25″ × 16.30″ × 5.0″.
Microwave Filter
INFO/CARD 153

Environmental coaxial cable

The Enviroflex family of fluorine-free coaxial cables enables users to switch from cables containing fluorine to

halogen-free alternatives for RG 316D, 142, 400 and 393. Compatible with all standard connector types, they possess equivalent mechanical and electrical performance to fluorine-containing counterparts. An extended temperature range and increased flexibility allow them to be used in broader applications over conventional PE cables. It is less expensive than teflon cable and does not require special disposal.
Huber + Suhner
INFO/CARD 154

NEW PRODUCTS

NO.58

RF/IF MICROWAVE COMPONENTS

2W PRECISION ATTENUATORS FOR DC TO 18GHz BAND

New BW-S30W2 fixed attenuators from Mini-Circuits provide precision 30dB nominal attenuation with ±0.85dB accuracy (add 0.5dB typ above 12.4GHz) over the wide DC to 18GHz frequency band. These low cost 50 ohm units are built tough to handle 2W average with 125W peak power and exhibit high temperature stability, outstanding phase linearity, and excellent VSWR. They're miniature in size measuring only .99" long and .312" across hex flats, and are ideal for impedance matching and test set-up. Maximum operating temperature range is -55°C to +100°C.

it™ 2WAY SPLITTER/COMBINER FOR 0.5 TO 400MHz BAND

Mini-Circuits introduced the ADP-2-1, a 2way-0° power splitter/combiner for the 0.5MHz to 400MHz band. Uniquely engineered in a 0.155" low profile water washable package, this device exhibits low 0.3dB insertion loss (above 3.0dB), excellent 0.10dB amplitude unbalance and very good 0.5 degree phase unbalance (all typ). Ideal for 50 ohm instrumentation use. Patent pending.

5 TO 450MHz HIGH IP2 AND IP3 AMPLIFIERS

Engineers working in the high traffic 5 to 450MHz band can choose Mini-Circuits new ZHL-450-75 connectorized amplifiers typically providing high 48dBm IP3 and 88dBm IP2 to help suppress noisy intermodulation products. These broad band 75 ohm amplifiers also display very low 3.5dB (typ) noise figure and 11.4dB typical gain (±0.7dB max. flat) for CATV and instrumentation applications. Equipped with BNC-Female connectors and available off-the-shelf.

100 TO 1800MHz MIXERS IN PLUG-IN AND SM VERSIONS

Mini-Circuits new plug-in TUF-18DH and TUF-18DHSM, its surface mount counterpart, are level 17 (LO power) microwave mixers intended for PCS, PCN, cellular, and airphone applications in the broad 100 to 1800MHz band. Typically, both feature low 7.3dB conversion loss, excellent 41dB L-R isolation, and 27dBm IP3 at center band. These mixers are built tough to operate within a maximum -55°C to +100°C temperature range and come with a 5 year Ultra-Rel® guarantee.

180° VOLTAGE VARIABLE PHASE SHIFTER FOR 100 TO 150MHz

The JSPHS-150 from Mini-Circuits is a 180° (min.) voltage variable phase shifter used in aircraft communications and delay for feed-forward amplifiers covering the 100 to 150MHz VHF band. Important characteristics of this surface mount unit include 0 to 12V control voltage with a control bandwidth range from DC to 30kHz typical and low 1.2dB (typ) insertion loss. VSWR is good at 1.2:1 typical. Solder plated J leads provide superior mechanical integrity over temperature.

LOW PROFILE 75 OHM DIRECTIONAL COUPLERS FOR CATV

Mini-Circuits announces off-the-shelf availability of their new 5MHz to 1000MHz ADC-16-4-75 directional couplers. These wide band 1W (max.) units free engineers from the expensive task of compensating by providing a nominal 16.2dB±0.5dB coupling value and excellent ±0.1dB (typ) flatness for CATV applications. Water washable and only 0.108" tall, these 75 ohm couplers typically exhibit low 0.7dB insertion loss and high 30dB midband directivity. Patent pending.

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TEST EQUIPMENT

Spectrum analyzer for wireless testing

The V9054 programmable spectrum analyzer is designed for use in VXI cellular production test systems. The 0.5 ppm frequency accuracy is accomplished by digital tuning that locks the synthesizer to the reference oscillator at each point in a sweep. Independent point markers simultaneously provide the absolute amplitude and frequency value of two points. A constant display of the delta values of these two points provides the user with an easy method of measuring power amplifier intermodulation distortion (IMD) and other in-band and out-of-band characteristics of miscellaneous cellular RF components and assemblies. The synthesizer's step time of less than 120 µs results in a fast measurement speed that has a direct effect on production throughput. The 1.6 GHz analyzer has an amplitude range of –120 dBm to +20 dBm with an absolute level accuracy of ±0.5 dB. The unit also offers a complete overlay drawing capability so that the user can set up limits for any of the cellular protocol spectral standards such as code-division, multiple access (CDMA), time-division, multiple access (TDMA) or global system for mobile communications (GSM).
Morrow Technologies
INFO/CARD 155

Sockets feature extended temperature range

The elevator Vertisockets for elevating displays and switch devices are available with bifurcated or collet contacts. The bifurcated elevator sockets are available in pin counts of 14–16 pins on 0.3″ centers, and with 18 pins on 0.6″ centers. The bifurcated contact material is Grade A spring-tempered phosphor bronze per QQ-B-750 and is offered in either 90/10 tin/lead (200m) or gold (10m) plating over nickel (50m). The body material is UL-94V-0 glass-filled 4/6 nylon. The collet elevator Vertisockets are available in pin counts of 6–10 pins on 0.2″ centers, 6–40 pins on 0.3″ centers and 6–48 pins on 0.6″ centers. The collet contact material is beryllium copper alloy per UNS C17200 and is offered in gold (30m) over nickel (50m) plating. The body is UL 94V-0 glass-filled 4/6 nylon.
Aries Electronics
INFO/CARD 156

SEMICONDUCTORS

Silicon IQ demodulator IC supports digital receivers

The UPC3205GR silicon radio frequency integrated circuit (RFIC) in-phase and quadrature (IQ) demodulator from NEC is designed for digital communications systems. It features an on-chip quadrature (90°) phase shifter

INFO/CARD 81

INFO/CARD 78

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Temperature Range -55°C to 125°C
+3.3 Volt Option (HCMOS)
Enable / Disable Option
Through Hole and SMD Configurations

VCXO'S

Frequency Range to 2.48 GHz
Tolerance and Stability to ± 10 PPM
Temperature Range -55°C to 125°C
+3.3 Volt Option (HCMOS)
Enable / Disable Option
Through Hole and SMD Configurations

TCXO'S

Frequency Range to 160 MHz and Higher
Stability to ± 0.3 PPM
Wide Temperature Range
Low Phase Noise
Through Hole and SMD Configurations

OCXO'S

Frequency Range to 100 MHz
Frequency Stability to ± 1.0 PPB
Temperature Range -40°C to 85°C
Excellent Short and Long Term Stability
Enable / Disable Option
Through Hole and Surface Mount

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and can achieve ±2° phase balance at an input frequency of 479.5 MHz. Suitable for high-density surface-mount designs, the demodulator also integrates an automatic gain control (AGC) amplifier, double balanced mixers, oscillator, plus I and Q output buffer amps—all in a miniature 20-pin SSOP package. Performance features include an RF input bandwidth of 440–520 MHz and an IF output bandwidth of 0.3–30 MHz. The IM3 distortion is a typical 56 dBc and the supply voltage is 5 V.
California Eastern Laboratories
INFO/CARD 157

Receiver offers low-power consumption

The AWR8004 is an 800–1,000 MHz receiver for use in cellular telephones, cordless telephones and wireless local area networks (WLANs). Designed for 3 V operation, the gallium arsenide (GaAs) receiver features low-power consumption, a small footprint and is integrated, allowing wireless systems manufacturers to lower component counts. The receiver features typical conversion gain of 17 dB. This wireless receiver is able to detect low-power signals because it is sensitive, featuring a maximum noise figure of 3.5 dB.
Anadigics
INFO/CARD 158

AMPLIFIERS

Amplifiers drive large output swings

The KH560 and KH561 wideband hybrid driver amplifiers are designed specifically for output/drive amplifier applications. The amplifiers drive large output swings and capacitive loads. They provide low distortion at high drive levels and high frequencies and maintain high bandwidths at large gain settings. They offer user-definable output impedances (50 Ω, 125 Ω) and provide short-circuit protection. The amplifiers offer customizable frequency response characteristics. The amplifiers are protected against shorts to ground and can be configured to withstand shorts to the supplies with the addition of one external resistor. Their outputs are internally limited to 250 mA, so driving high capacitive loads is simple. Their output impedance is set using a two-resistor external feedback network, so no backmatching resistor is needed. Both amplifiers are constructed using in-house thin-film resistor/bipolar transistor technology.
Kota Microcircuits
INFO/CARD 159

High-power amplifier for large object testing

The 2000W1000A amplifier offers 2,000 W CW from 80–1,000 MHz. It is designed for applications requiring the high power and broad bandwidth needed to generate fields at a distance. Pop-

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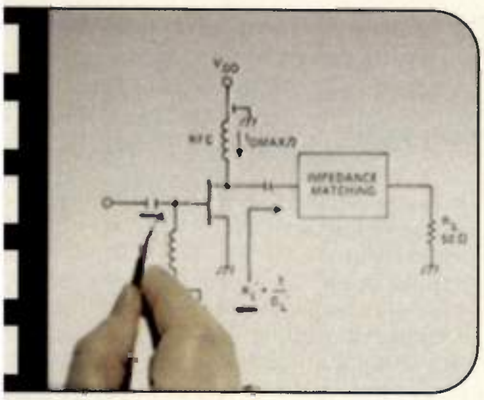
VIDEO COURSES

RF Circuit Fundamentals
Instructor: Les Besser

This is the first part of the best one-two punch in basic RF circuit design instruction. It's an ideal introduction to high-frequency analog design for new engineers, or for engineers from digital or low-frequency specialties. Topics covered include — RF Concepts, Lumped-Element Component Methods • Resonant Circuit and Filters • Transmission Line Fundamentals • The Smith Chart and its Applications • Small-Signal Amplifier Design with S-Parameters. The course includes six one-hour tapes, class notes, and the book *RF Circuit Design* by Chris Bowick. This class offers thorough coverage of all the essential basic concepts specific to RF engineering.

NP-16. . . . . $595.00



RF/Microwave Transistor Amplifier Design
Instructor: Les Besser

Amplifier matching, stability and noise techniques are a cornerstone of RF and microwave engineering. This course is an outstanding way to learn classical amplifier techniques — Review of Circuit Fundamentals • Introduction to CAD • Amplifier Design Methods and Comparisons • Impedance Matching • Lossless Transformations • Applying Negative Feedback. Amplifier design is covered completely, including CAD and Smith Chart methods, gain and stability analysis, low noise techniques and layout. Real-life examples are used throughout the course. Six two-hour tapes (12 hours total) and the book *Microwave Transistor Amplifiers* by G. Gonzales.

NP-14. . . . . $1195.00

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RF Circuit Fundamentals II
Instructor: Les Besser

Instruction continues from the above course, adding the topics — Microstrip Transmission Lines • Power Combiners and Dividers • Broadband Matching Networks • PIN Diode Circuits • Broadband Amplifiers • Large-Signal Amplifiers. The course includes six one-hour tapes, notes, and the book *Transmission Line Transformers* by Jerry Sevick.

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Filter and Matching Networks
Instructor: Randall W. Rhea

Complete, well-presented information on practical filters and matching networks that you will actually build, not just theory and equations with no application. Topics — Fundamentals • CAE Techniques • Real-World Effects • Matching • Bandpass Filter Symmetry • Group Delay • Direct-Coupled Microwave Filters • Field-Coupled Microwave Filters. Nine one-hour tapes and complete notes.

NP-12. . . . . $895.00

Microwave Filters, Couplers and Matching Networks
Instructor: Robert Wenzel

Detailed instruction on distributed structures — Filter Responses and Basic Calculations • Realization of Practical Filters • Filter Design • Directional Couplers • Distributed Element Matching Networks. Six two-hour tapes plus complete class notes.

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Oscillator Design Principles
Instructor: Randall W. Rhea

No other course gives you as much insight into oscillator design. All common resonator types are discussed — LC, coaxial, microstrip, crystal, SAW; and many active devices — bipolar, FET, MMIC amplifier. Noise performance, oscillator starting, VCOs and more. Six-hours with extensive notes.

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Instructor: Steven L. March

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ular applications include the radiation of large objects and whole vehicles.
Amplifier Research
INFO/CARD 160

Amplifier offers 21 dBm output power

The JCA218-407 2–18 GHz amplifiers can provide +21 dBm output power while accommodating wideband needs. Gain is 30 dB minimum, with a noise figure of 5.0 maximum. The current is 500 mA nominal. The amplifiers incorporate reliability and performance. All units are tested and guaranteed.
JCA Technology
INFO/CARD 162

Amplifiers feature GaAs technology

The RF2333, RF2334, RF2335, RF2336, RF2337 and RF2338 amplifiers are general-purpose broadband amplifiers that combine low cost, small size and gallium arsenide heterojunction bipolar transistor (GaAs HBT) process technology for use in intermediate frequency (IF) and RF wireless voice and data communications. Typical applications for the amplifiers include use as broadband, low-noise gain blocks, as IF or RF buffer amplifiers, as a driver stage for power amplifiers and as the final power amplifier (PA) for low-power products. The RF2333, for example, is designed as an easily cascadable 50 Ω gain block with an operating range of DC to 6,000 MHz. The component is offered in a small industry-standard SOT-23 five-lead surface-mount package.
RF Micro Devices
INFO/CARD 161

SUBSYSTEMS

Desktop power supply for portable equipment

The DT series of lightweight, low-profile external power supplies includes a large range of adapter-style power supplies, offering three-wire or Class II (with two-pin wall plug) double insulated inputs and is available with a variety of output cables and connectors, making it suitable for powering most lightweight, portable equipment. Available in 10 package sizes starting from 1″ in height, the power supplies offer output voltages from 5–24 V, including dual and triple outputs. All models are protected against accidental short circuit, and most are in compliance with EN61000-4 specifications for lightning, surge and electrical static discharge (ESD) protection.
Lambda Electronics
INFO/CARD 163

Portable antenna shorter than standard

The SX antenna can be as much as 20% shorter at the same frequency as industry-standard injection molded antennas. The industry-standard antennas with a frequency bandwidth of 150–161 MHz measures 6.5″ long. The SXB 155 MX, in the same bandwidth, is an inch shorter at 5.5″. The antenna features capless sheath construction, which enhances ruggedness while retaining flexibility. The patented sheath design also features a dimple at the tip of the antenna, a sleek finish and a profile that matches newer radio designs. Industry performance standards are exceeded in the SX series, with a voltage standing wave ratio (VSWR) rating at less than 1.5:1 at resonance frequency.
Centurion International
INFO/CARD 164

RFID tagging ICs feature advanced anticollision circuitry

The MCRF355 and MCRF360 13.56 MHz radio frequency identification (RFID) tagging devices have advanced anticollision circuitry for reading multiple tags in the same reader field, a "cloaking" feature that minimizes the detuning effect of adjacent tags, low-power consumption for extended read range and 154 bits of user memory. Both devices are contact-programmable and are designed for write once read many (WORM) applications. The MCRF355 allows the user to externally tune a resonance capacitor, while the MCRF360 contains an on-chip 100 pF resonance capacitor. The RFID tags can read through objects, such as parcels or inventory items, and can eliminate inaccurate or missed reads from damaged, dirty or obstructed barcodes. These tags can be

used in harsh environments and remain resistant to heat, moisture, abrasion, dirt and paint.
Microchip Technology
INFO/CARD 165

Modem, amplifier for license-free operation

The model 2400 frequency hopping spread-spectrum radio modem and the model AMP2440 pole-mounted bi-directional amplifier for license-free operation in the 2.4 GHz band feature ranges of more than 50 miles line-of-sight when used with 24 dB gain grid dish antennas. The radio modem has an RS-232 interface and operates point-to-point or point-to-multipoint at speeds as high as 115.2 kbps asynchronous. It can also be configured to operate at 64 kbps synchronous for point-to-point wireless data links. The modem can be used without the amplifier for short-range links (of several hundred feet or less) using small whip antennas and several miles using outdoor gain antennas. The amplifier consists of a low-noise receiver preamplifier and a transmit power amplifier. The remote mounting feature allows the amplifier to be mounted next to the antenna, which places the full transmit power where it is most effective.
Young Design
INFO/CARD 166

Transmitter shielded in protective enclosure

The Stingray transmitter is a self-contained laboratory instrument housed in an electromagnetic/radio frequency interference (EMI/RFI) protective enclosure. The components of this stimulus transmitter are a built-in frequency synthesizer, dynamically controlled power amplifier and the ability to remotely control all of the transmitters' parameters via a PC. Remote adjustments include the power level, channel and frequency assignment and transmit on and off.
Berkeley Varitronics Systems
INFO/CARD 167

SIGNAL PROCESSING COMPONENTS

High bandwidth and high frequency switch

The 50S-1035 single-pole, quadruple throw (1P4T) switch covers all cellular and some satellite bands. The switch features a 20–4,000 MHz frequency band with insertion loss of 2.0 dB maximum at 20–1,000 MHz and 4.0 dB maximum at 1,000–4,000 MHz. The isolation is 80 dB minimum at 20–1,000 MHz, 70 dB minimum at 1,000–2,000 MHz and 60 dB minimum at 2,000–4,000 MHz. The switch is available with a sub-miniature A (SMA) female connector and an N female connector.
JFW Industries
INFO/CARD 168

Diplexer screens PCS signals

The model W1805D intermodulation distortion (IMD)-free diplexer screens personal communications service (PCS) signals. A low-cost miniature cavity diplexer, it features two standard +40 dBm signals that produce less than –30 dBm of IMD. The diplexer covers full PCS bands with less than 1.2 dB of insertion loss. The Rx/Tx isolation is greater than 90 dB. The Rloss is greater than –16 dB, and power capability is greater than 50 W. It takes SMA connectors or type N. The device measures 2″ × 2″ × 9″.
Wireless Technologies
INFO/CARD 169

Isohybrid provides 52 dB of interchannel isolation

The 0184IMN4 isohybrids are designed to provide 52 dB interchannel isolation with a low insertion loss of 3.4 dB, including the loss caused by the 3 dB hybrid coupler. These isohybrids provide 23 dB of isolation from output to input at 1,805–1,880 MHz frequency bandwidth and can process several 100 W of power with RF leakage less than –50 dBc. These units have a voltage standing wave ratio (VSWR) match of 1.2:1 on all ports over the specified frequency bandwidth and temperature range of –10°C to +85°C. Isohybrids at other frequency bandwidths are available in a similar package.
Nova Microwave
INFO/CARD 170

Splitter/combiner offers low insertion loss

Tuned to cover the wide 1.7–9 GHz frequency range, the two-way 0°

ZN2PD-9G power splitter/combiner offers low 0.5 dB typical insertion loss, good 22 dB (typical) isolation and 0.6 dB amplitude, 4.0° phase unbalance (maximum) bandwidth. This 50 Ω unit is equipped with SMA connectors and has a maximum power input of 1 W (as splitter) when used in the –55°C to +100°C temperature range (maximum). Uses include radar and satellite communication.
Mini-Circuits
INFO/CARD 171

CDMA combiner can be mechanically tuned

The model WSC2-00011 is a personal communications service (PCS) band, mechanically tunable code-division, multiple access (CDMA) transmit combiner. It offers 1.5 dB maximum (1.0 dB typical) passband insertion loss and 30-dB minimum (greater than 40 dB typical) passband-to-passband isolation with a 1 CDMA carrier to carrier separation. The combiner can be tuned to any CDMA carrier assignment within the PCS base station transceiver (BTS) transmit frequency range of 1,930–1,990 MHz. The combiner also provide 23 dB minimum antenna to transmit input isolation, 20 dB minimum transmit input port return loss, 14 dB minimum port return loss, 100 ns maximum channel group delay, and is specified to –75 dBm maximum intermodulation products with two +44 dBm transmit carriers applied. The combiner measures 9.5″ × 6.0″ × 2.7″, excluding type N-F connectors. Operating temperature range is 0 to 55°C.
K&L Microwave
INFO/CARD 174

Circulator for HDTV, digital applications

The low-loss 1 kW UHF circulator, CT-1510-S, operates over channels 26–44 for use in digital and high-definition TV applications. Typical loss is 0.12 dB over the operating band. Three units span the domestic channels 14–69. Another covers the channel 69–78 range. Isolation is greater than 20 dB and 1.20 maximum voltage standing wave ratio (VSWR). Connectors are 7/8 EIA with a type N load port. DIN 7/16 or N connector models are also available.
Ute Microwave
INFO/CARD 173

Fractional-N synthesizers lead to 3.7 GHz device

The next generation 7-family of fractional-N synthesizers builds on the new 6-family of the synthesizers (SA8026, SA8016, SA7026, SA7016). They are manufactured with QUBiC3 BiCMOS process technology and support applications as high as 3.7 GHz. The fractional-N synthesizers provide low close-in phase noise, fast switching and high comparison frequencies without decreased resolution. By simultaneously delivering low phase noise and fast acquisition time, the 6-family meets the requirement for services like high-speed circuit-switched data (HCSD) and general packet radio service (GPRS) of the global system for mobile communications (GSM) standard.
Philips Semiconductors
INFO/CARD 172

Balun eliminates custom fitting task

The Xinger balun is designed to be surface-mounted by automatic assembly equipment onto a printed circuit board (PCB), eliminating the task of custom fitting coaxial baluns. The balun is smaller than a conventional printed microstrip balun. The balun takes an unbalanced input signal and splits it into a balanced output signal that is then fed into a push-pull transistor pair. This allows the transistors to work in parallel, efficiently and with low impedance. The balun can be attached to the same ground plane for both input and output, ensuring common ground. This design allows for the dissipation of heat, making the balun

suitable for high-power applications.
Anaren Microwave
INFO/CARD 175

SIGNAL SOURCES

Surface mount VCXO has high-frequency capabilities

The VSM series surface-mount voltage-controlled crystal oscillator (VCXO) has high-frequency capabilities as high as 100 MHz. Available in four- and six-pin models, the VSM series operates at 5 Vdc or 3.3 V with frequency stabilities of 620, 625 and 650 ppm over a temperature range as wide as –40°C to 85°C and deviations as high as 6,100 ppm over a control voltage range of 0.5–4.5 VDC. All models are hermetically sealed in a compact 9 × 14 mm ceramic package with a grounded metal case in LCC or solder-dipped J-leaded designs. The VSM series also features low-jitter as well as low-phase noise performance caused by the use of fundamental mode crystals in the design.
Connor-Winfield
INFO/CARD 178

VCXOs feature wide frequency range

The K1528C series of voltage-controlled crystal oscillators (VCXOs) offers a tri-state disable option in frequency stabilities as low as ±25 ppm (typical) over an operating temperature range of 0–70°C. The VCXOs feature a wide frequency range of 35–125 MHz in TTL/CMOS compatible output. An optional temperature range of –40°C to +85°C is available. The device provides a variety of deviation sensitivities and a control voltage range of 0.5–4.5 V. Using a sealed crystal resonator package will also provide optional tight aging characteristics for this K1528C series, making it suitable for telecom infrastructure and data networking apparatus.
Champion Technologies
INFO/CARD 179

CABLES & CONNECTORS

RF coaxial cable assemblies

A line of custom cable assemblies feature flexible and semi-rigid RF coaxial cables in lengths as long as 150 feet, which can be equipped with a wide variety of connectors to eliminate the need for adapters. Manufactured to specification, the cables can range from 0.11–1.20″ O.D. and include 7/16, C, EIA, HN, LC/LT, QDL, QDS, SC and other types of connectors. The assemblies allow customers to solve equipment compatibility problems, smooth out cable runs and deal with space constraints by incorporating straight-thru or right-angle cable designs. The assemblies can be rated at 50–75 V from 0–18 GHz. Connectors can be made from brass, bronze alloys, BeCu and other materials with insulations, gaskets and finishes to military and commercial specifications.
Tru-Connector
INFO/CARD 177

Fire-retardant coaxial cable rated CATVR

The LMR-FR line of low-loss coaxial cable for in-building fire retardant applications is rated CATVR by Underwriters Laboratories. In accordance with the National Electric Code, LMR-FR can be run anywhere within a building, except in return air handling plenums (e.g. suspended ceilings). LMR-FR can be considered for all indoor applications where fire retardancy, low-smoke generation and zero-halogen is required. Unlike PVC jacketed cables, LMR-FR does not generate lethal toxic fumes when exposed to fire. The coax is available in all standard LMR sizes from 0.2–1.67″ in diameter. It is size compatible with standard LMR and accepts all LMR connectors and hardware accessories.
Times Microwave Systems
INFO/CARD 176

RF software

First substrate modeling, noise analysis solution

Snaketech's Layin 2.0 is the first substrate modeling and noise analysis solution targeted at RF, analog and mixed-signal integrated circuit (IC) design. The software allows designers to model and analyze substrate noise coupling effect in ICs before fabrication. Layin takes its information from process doping profiles and builds a three-dimensional model of the substrate. It also concentrates on modeling local effects.

Snaketech
INFO/CARD 115

Test software improved with VRM capability

Powerwin, from Eltest, has been updated to include voltage-regulated module (VRM) and AC/DC power supply testing. Previous versions supported testing of DC/DC power supplies. The software controls Eltest's EL-467 power supply measurement boards that contain a 14-bit, 1 MSPS sampling A/D.

Eltest
INFO/CARD 116

Design software adds EDIT/SDF support

Tanner EDA's L-Edit-Pro integrated circuit (IC) design software has been upgraded with the ability to read electronic design interchange format (EDIT) 2000 netlist files and write standard delay format (SDF) files. The standard cell place and route module in L-Edit-Pro, L-Edit/SPR, translates graphical and electrical information from EDIF netlist created in S-Edit.

Tanner EDA
INFO/CARD 117

Circuit analysis program offers RF design tools

The Linc2 RF and microwave circuit analysis program, from Applied Computational Sciences, now includes integrated schematic capture and a suite of RF design tools. The software combines an RF/MW simulation engine with a set of design tools that are task oriented. Circuit development can proceed from automated synthesis to performance analysis rather that the reverse process of design by repeated cut and try simulation. Interactive tuning provides immediate insight into circuit behavior while any one of 18 circuit responses are updated in real time as component values are adjusted.

Applied Computational Sciences
INFO/CARD 118

Load pull data module for HP software

Maury Microwave offers a load pull data module (model MT993Q1) software that allows device characterization data from Maury's automated tuner system to be imported into Hewlett-Packard (HP) EEsof advanced design system (ADS). The data can be used for design simulation and analysis of circuits and systems. The module automatically translates ATS data files into ADS data sets.

Maury Microwave
INFO/CARD 119

Schematic software offers new functions

WinDraft Schematics, Version 3.0, by Ivex Design International, has been updated with 20 major user suggestions. Improvements include a module footprint browser to allow designers to scan WinBoard PCB software for the desired footprint packages and assign it to the selected schematic part. Part editing has been expanded to use all the edit characteristics of a part on a schematic, such as pin type and pin shape.

Ivex Design International
INFO/CARD 120

Software on the Web

Web site offers drivers and tools

Anritsu offers Labview and Lab windows drivers to support automated test equipment (ATE) as well as downloadable tools for its Sitemaster and Powermeter product lines. The downloads are executable zip files.

Anritsu Company
INFO/CARD 121

To access this Web site and other Web sites offering downloadable software or online programs, check out **RF Design Online** for direct links. You can also access any company whose product release is mentioned in this month's Software section.

RF literature

Products for RF distribution systems

Renaissance Electronics offers a four-page product catalog of customized base station products for multichannel multipoint distribution service (MMDS), specialized mobile radio (SMR), cellular, personal communications service (PCS) and other markets. Included are receiver multicouplers with eight primary and two expansion outputs, duplexers and multichannel transmitter combiners that combine in nine different configurations.
Renaissance Electronics
INFO/CARD 122

Data book details frequency products

The *1999 Crystal Product Data Book,* from C-MAC Frequency Products (CFP), provides detailed specifications on standard frequency products, plus information on a range of custom design services available from CFP. The 344-page catalog includes products from IQD (UK), C-MAC quartz crystals, CEPE (France) and Greenray.
C-MAC Frequency Products
INFO/CARD 123

Data sheets detail tunable bandpass, band reject filters

K&L's full color data sheets describe the company's tunable bandpass and band reject filters. The filters include octave range tuning designed to replace the need for several fixed tuned filters. The data sheets include product description, performance data and product photos.
K&L
INFO/CARD 124

MMIC die products featured in new catalog

Hittite Microwave's latest catalog features as many as 75 monolithic microwave integrated circuit (MMIC) die, ceramic packaged die and plastic packaged die covering DC to 40 GHz. ten new products are featured including 5 mm wave MMIC up/downconverter and amplifier die as well as attenuators, mixers and modulators for wireless applications.
Hittite Microwave
INFO/CARD 125

Catalog describes EMI/RFI shielding tapes

Venture Tape offers a new catalog for design engineers requiring electromagnetic interference (EMI) or radio frequency interference (RFI) shielding tapes. The catalog features super conductive foils, fabrics and adhesive tapes, each categorized by their specific EMI/RFI application.
Venture Tape
INFO/CARD 126

Catalog offers test and measurement products

IFR's 312-page 1999/2000 test and measurement catalog features detailed

Online

Goodfellow offers online metals and materials catalog—Goodfellow's catalog of up to 48,000 metal and material products is available on the company's Web site. Products include metals and materials for research or prototype development and feature pure metals, alloys, polymers, ceramics and composites. Goodfellow's Web can be found at **www.goodfellow.com**
Goodfellow
INFO/CARD 133

MMC develops new Web site—Microelectronic Modules Corporation (MMC) offers a new Web site detailing the company's microelectronic packaging capabilities, as well as its lines of standard and custom components and subsystems. The site offers users online review and downloadable product data sheets and applications notes for MMC's DC/DC converters and other products. Access the site at **www.mmccorp.com.**
MMC
INFO/CARD 134

Interconnect Devices offers online ordering—Interconnect Devices introduces its new online ordering system for spring contact probes. The new capability allows users to manually key in the part number, or the part number can be built by selecting the links for the desired tip style, spring force or placing. The contact probes are designed for use in automated test equipment. Interconnect Devices' Web site is at **http://ecom.idinet.com**.
Interconnect Devices
INFO/CARD 135

National Instruments offers e-mail newsletter—National Instruments, *"NI news,"* is a free e-mail publication providing computer-based measurement and automation news, tips and techniques. Subscribers can get information about the company's LabView, data acquisition, test and measurement and other information. National Instruments' Web site is at **www.natinst.com/news**.
National Instruments
INFO/CARD 136

Trompeter adds E-commerce capability—Trompeter Electronics has upgraded its Web site to include electronic commerce (E-commerce) capabilities such as online quotations and direct order placement. Trompeter manufactures RF coaxial, triaxial and twinaxial interconnects and other products. Trompeter's Web site is at **www.trompeter.com**
Trompeter Electronics
INFO/CARD 137

AVX offers online capacitor purchasing—AVX's new capacitor part number generator and parser allows engineers to enter the description of the capacitors they need and arrive at AVX capacitor part numbers that correspond with their specifications. The Web address is **www.avxcorp.com**
AVX
INFO/CARD 138

RF Design Online

For direct access to those companies offering information through their Web sites, go to **www.rfdesign.com**.

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descriptions of the company's expanded product line. Products include commercial and wireless test sets, signal sources and analyzers, counters and power meters, avionics, spectrum analyzers, microwave, telecommunications, automated test equipment (ATE) and other capabilities.
IFR Systems
INFO/CARD 127

Sourcebook details crystals and oscillators

Ecliptek's 1999 International Sourcebook features the company's frequency control devices. The 64-page catalog includes a product selection guide and detailed technical specifications. Also included are as many as 40 surface-mount and through-hole quartz crystals, crystal oscillators, voltage controlled crystal oscillators (VCXOs) and temperature compensated crystal oscillators (TCXOs). Each product data sheet contains a part numbering guide and mechanical dimensions.
Ecliptek
INFO/CARD 128

Selection guide features single processing products

Signal Processing Technologies (SPT) offers its 1999 product selection guide for data conversion and signal processing integrated circuits (ICs). The catalog features an overview of SPT's analog-to-digital converters (ADCs), digital-to-analog converters (DACs), video DACs, comparators and track-and-hold amplifiers.
Signal Processing Technologies
INFO/CARD 129

Catalog details passive components

Venkel has updated its catalog of passive components. The catalog features information on ceramic and tantalum chip capacitors, thick and thin film chip resistors, melf chip resistors, high meg chip resistors (as high as 1000 G Ω), chip inductors, chip resistor arrays, thick and thin surface mount device (SMD) resistor networks and engineering kits.
Venkel
INFO/CARD 130

Guide offers insight into phase noise

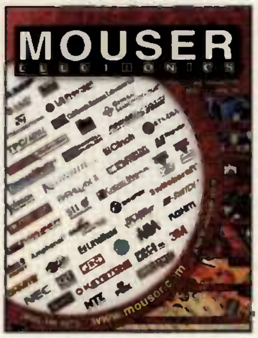
Connor-Winfield offers a phase noise guide to assist designers in understanding the problem of phase noise when selecting oscillator designs for timing circuits. The guide includes a technical explanation of phase noise along with the random processes in electronic systems that contribute to phase noise occurrence.
Connor-Winfield
INFO/CARD 131

Catalog features microwave cable assemblies

Micro-Coax's 24-page catalog describes its Utiflex flexible microwave cable assemblies that are constructed using a low or ultra-low density PTFE dielectric. The catalog includes a selection guide for cables, connectors and armors, as well as a description of a typical cable construction. Charts detail the mechanical, electrical and environmental attributes of the cables.
Micro-Coax
INFO/CARD 132

RF Literature/Product Showcase

ELECTRONICS PURCHASING MANUAL



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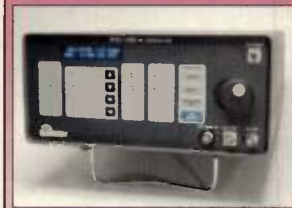

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INFO/CARD 214

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RF design

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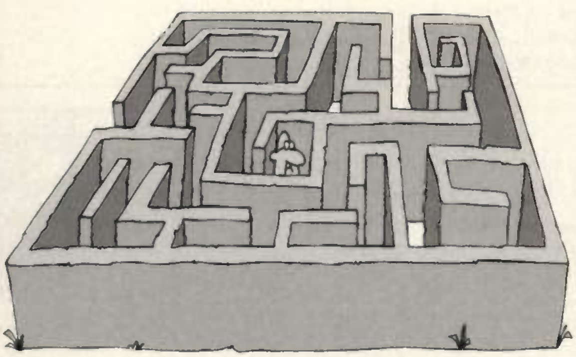

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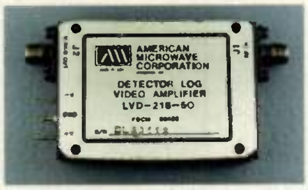
• SWITCHES

•• MODEL MSN-10DR/DT-05
FREQUENCY: 0.5 to 18.0 GHz
INSERTION LOSS: -4.5 dB
ISOLATION: 70 dB
VSWR: 2.0:1
SPEED DELAY ON: 75 nS Typ.
DELAY OFF: 75 nS Typ.
SIZE: 5.00" x 1.50" x 0.40"

• ATTENUATORS (Mulitoctave & Octave Bands / Digital, Analog, or Current Controlled)

•• MODEL DVAN-2040-60-8 L
FREQUENCY: 2.0 to 4.0 GHz
ATTENUATION RANGE: 60 dB
INSERTION LOSS: -2.0 dB
VSWR: 2.0:1
FLATNESS: @ 10 dB ±0.4 dB
@ 20 dB ±0.8 dB
@ 40 dB ±1.5 dB
@ 60 dB ±1.6 dB
ACCURACY: 0 to 30 dB ±0.5 dB
30 to 50 dB ±1.0 dB
50 to 60 dB ±1.5 dB
SWITCHING SPEED: < 500 nS
SIZE: 2.00" x 1.80" x 0.50"

• DETECTOR LOG VIDEO AMPS



•• MODEL LVD-218-50
FREQUENCY: 2 to 18 GHz
FREQUENCY FLATNESS ± 1.0 dB
DYNAMIC RANGE: -40 to +5 dBm
LOG LINEARITY ERROR: ±0.5 dB
PULSE RESPONSE: 50 nS to CW
RISE TIME: 20 nS
SETTLING TIME: 45 nS
RECOVERY TIME: 150 nS TYP.
TSS: -42 dBm
VSWR: 3.0:1
MAXIMUM RF INPUT: +15 dBm
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Platform independence...maybe, but RF sure looks like a major player

by Ernest Worthman

OK, I've been saying it for years. And I have been hearing from futurists for years as well. Pretty soon, they say, it won't make any difference whether or not we have to understand how it's done. End-to-end connectivity is the "pièce de résistance"—the final frontier of communications. It won't matter if it's a computer, mobile phone, a locator device (such as global positioning system (GPS) or automatic vehicle location (AVL)), a pager, an office, a home, a person, a vehicle...or even the microwave!

There will be that "magic channel" that will connect everything, whether it's wireline, wireless, telepathic, interdimensional, intuitive or artificially intelligent. Well, that's nice for that "end user" but for those of us that have to make this "channel" technology work, it will be a challenge. Especially with so many platforms needing integration.

Knowing what I know about technology, I have this funny feeling that much of this "channel" will be wireless-based. Simply because it may be practical to build the copper, fiber, infrared (IR), ultrasonic, or other cheaper communications ability into future devices and buildings, it generally isn't cost-effective to retrofit the existing infrastructure.

We pretty much have the installations and the RF technology part down pat. Therefore, I believe one of the biggest challenges the RF industry will face, in the next few years, will be the interface.

Because I'm limited to how many words this column can contain, I chose to take a look at one of the hotter topics in intelligent communications—the smart house—and see what some of these challenges might be.

We have to assume a couple of things. First, each device has some sort of intelligent interface. On one end may be a computer, or at least a full-blown central processing unit (CPU), much like today's X86-based technology, or more likely a reduced instruction set computer (RISC).

The second assumption is the opposite end will contain a simple RF identification (RFID) code that is merely unidirectional (off or on state). One alternative is that others may contain an application specific integrated circuit (ASIC) that is distinctly designed for the device. Depending on the level of intelligence, the device could be capable of remotely setting multiple on-times, off-times and cycle-times, as well as status, feedback and real time on-the-fly instructions.

Within this home, I see a low-power RF-based network. Every device on the system would have an RF interface. The transmission system would be digital spread spectrum, probably at GHz frequencies. Even as it connects to the outside world, it could also be low-power RF with a transceiver and a tiny antenna in the attic or on the roof. On every block there is a central controller with solar power and battery backup. This central controller connects to the "worldwide network" (WWN), to which all controllers are linked via, most likely, a fiber cable or perhaps a microwave link. Or it could talk to the low earth orbit satellites (LEOs) and bypass terrestrial communication links altogether.

There wouldn't be much of a problem within the house. Since it would be a local "cell." The major issue here is between the digital mode of the devices and the RF transmitter (or transceiver, in the more sophisticated devices). As the RF and digital world are already finding each other, this should be relatively easy to implement.

The more complex issues will be the interface between the RF devices and those that use other communications mediums (those mentioned earlier). There might also be some issues with the premise exit interface as well. Does it connect to fiber, copper, satellite, microwave, etc.? Although these technologies have been pretty well integrated with RF already, it may be that a ubiquitous interface is needed—remember, platform independence.

So, now it seems a matter of getting the related industries together to pow-wow before, as other industries have proven, it turns into a free-for-all. There is a tremendous opportunity for all these industries (as well as many others too numerous to mention) to form partnerships, share technology, and develop devices, interfaces and a channel that is reliable, dependable and...works (which is more than I can say for today's cellular infrastructure).

OK, I'm going to take a break now and interconnect my TTIM (Transcendental Telepathic Interbrain RF Modulator), and will my microwave to heat up the bagels.

Ernest Worthman is RF Design's contributing editor. He is a fellow of the Radio Club of America and a member of the IEEE. He holds a B.S. in electronics engineering technology and teaches college courses in electronics and computers. Ernest is easily recognizeable at conferences by the coffee cup surgically attached to his hand. You can contact Ernest by e-mail at ernest_worthman@ieee.org.

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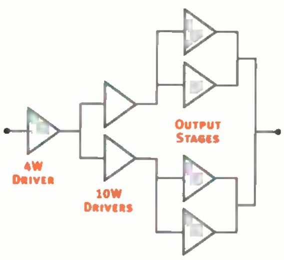

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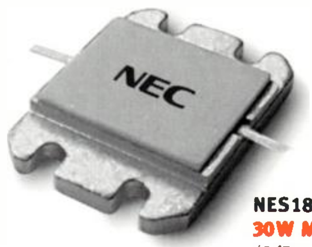

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